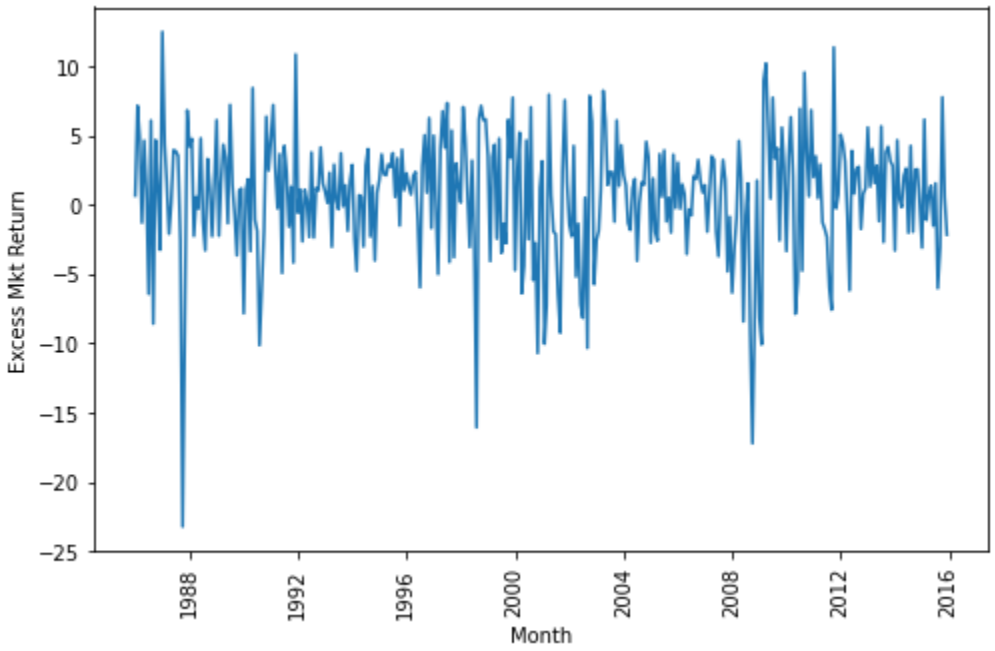
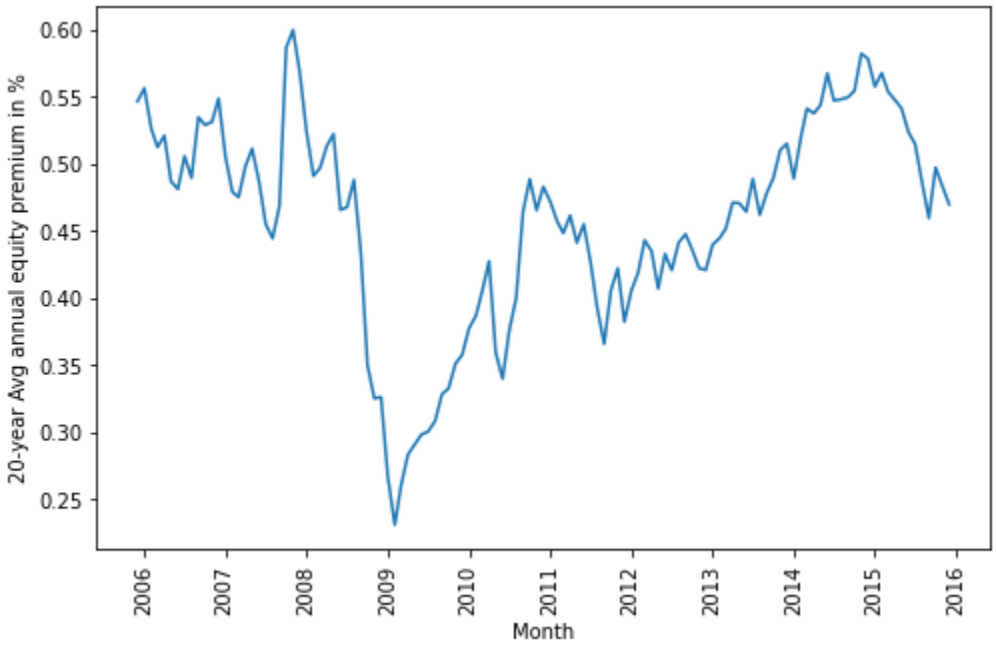
Q1.1

The excess market return by months from 1986 to 2016 is plotted as below:



The 20-year average annual equity premium per month is plotted below. The Effective Annual Returns of the equity premium is calculated using geometric mean since it is for historical returns.



Q2.1

The expected excess return of the 48 industry portfolios is shown in below table:

Industry	**Agric**	**Food**	**Soda**	**Beer**	**Smoke**	**Toys**	**Fun**	**Books**	**Hshld**	**Clths**
Expected Return	0.7009	0.8368	0.8995	0.9919	1.2543	0.5310	0.9407	0.4801	0.6680	0.8228
Industry	**Hlth**	**MedEq**	**Drugs**	**Chems**	**Rubbr**	**Txtls**	**BldMt**	**Cnstr**	**Steel**	**FabPr**
Expected Return	0.5797	0.8469	0.9343	0.7717	0.8034	0.7998	0.7674	0.6789	0.4294	0.2926
Industry	**Mach**	**ElcEq**	**Autos**	**Aero**	**Ships**	**Guns**	**Gold**	**Mines**	**Coal**	**Oil**
Expected Return	0.7297	0.9097	0.5680	0.8122	0.7045	0.8735	0.2489	0.8009	0.5289	0.6915
Industry	**Util**	**Telcm**	**PerSv**	**BusSv**	**Comps**	**Chips**	**LabEq**	**Paper**	**Boxes**	**Trans**
Expected Return	0.5757	0.6013	0.3988	0.8788	0.6350	0.8376	0.7519	0.6621	0.7940	0.6746
Industry	**Whlsl**	**Rtail**	**Meals**	**Banks**	**Insur**	**RlEst**	**Fin**	**Other**		
Expected Return	0.5588	0.8327	0.7899	0.6834	0.7041	0.1913	0.8416	0.2849		

Q2.2

Based on program result, the weight vector for the 3 constructed portfolio is as below:
EWP Weight:

```
[0.02083333 0.02083333 0.02083333 0.02083333 0.02083333 0.02083333
 0.02083333 0.02083333 0.02083333 0.02083333 0.02083333 0.02083333
 0.02083333 0.02083333 0.02083333 0.02083333 0.02083333 0.02083333
 0.02083333 0.02083333 0.02083333 0.02083333 0.02083333 0.02083333
 0.02083333 0.02083333 0.02083333 0.02083333 0.02083333 0.02083333
 0.02083333 0.02083333 0.02083333 0.02083333 0.02083333 0.02083333
 0.02083333 0.02083333 0.02083333 0.02083333 0.02083333 0.02083333]
```

TAN Weight:

```
[-0.09435441  0.1530272   0.08662343  0.1104785   0.2995244  -0.38133487
  0.18638871 -0.18630205 -0.31210067  0.11605872 -0.00342404  0.47532814
  0.33062431 -0.13150861  0.43435952  0.17164913 -0.0262847  -0.02106621
 -0.37409459 -0.05767593 -0.07967925  0.25821426  0.07855709 -0.0811106
 -0.04940718  0.38047381 -0.05453656  0.36913954 -0.1225659   0.34867112
  0.42150699 -0.38450713 -0.46762073  0.553589   -0.43643119  0.40769319
 -0.00819824  0.21278509 -0.06161164  0.34724601 -0.63145548  0.08938611
```

0.02751928 -0.0846205 -0.20425472 -0.32846163 0.307658   -0.5838947]

GMV Weight:
[0.07111003 0.09457994 -0.00801643 0.00550252 -0.03883012 -0.04575143
 -0.02797509 0.04433541 0.22697491 -0.04033657 -0.02949257 0.07423983
  0.00444643 -0.15673505 -0.06460357 -0.03619626 -0.06297209 -0.13817986
 -0.07137401 0.06785085 -0.01704981 -0.12036106 -0.04121485 -0.12470509
 -0.04117267 0.12137193 0.05469262 0.0218453 -0.0036532   0.12987745
  0.37864979 0.10252557 -0.03843821 -0.05319288 0.09090145 0.03262493
  0.00490531 0.1146428   0.07612637 0.22584111 0.05221575 0.1651965
  0.05852539 -0.0390151 -0.03687624 0.0761373 -0.01767139 -0.04130592]

Q2.3

Below table list down the in-sample expected return, standard deviations, sharpe ratio and betas for the 48 industry portfolios

	mean	**std_dev**	**sharpe**	**beta**
Agric	0.70086111	6.40010755	0.10950771	0.78129415
Food	0.83680556	4.45260827	0.18793604	0.59990055
Soda	0.8995	7.00211494	0.12846119	0.82537766
Beer	0.99188889	5.10706134	0.19421911	0.63929947
Smoke	1.25427778	6.84788392	0.18316283	0.63291577
Toys	0.53102778	6.70647787	0.07918132	1.04432918
Fun	0.94072222	7.59639506	0.12383798	1.3442889
Books	0.48013889	5.72577058	0.08385577	1.03052444
Hshld	0.66797222	4.49921535	0.14846416	0.71660342
Clths	0.82277778	6.57447521	0.12514729	1.08233362
Hlth	0.57969444	6.54812378	0.08852833	0.83713135
MedEq	0.84686111	5.09177981	0.16631927	0.85419291
Drugs	0.93430556	4.87824744	0.19152484	0.74590993
Chems	0.77172222	5.84519271	0.13202682	1.05416082
Rubbr	0.80338889	6.06498055	0.13246356	1.05439781
Txtls	0.79980556	8.0410132	0.09946577	1.19290165

BldMt	0.76741667	6.36101109	0.12064382	1.1376044
Cnstr	0.67888889	7.00606871	0.09690012	1.19558499
Steel	0.42944444	8.12809055	0.0528346	1.43734345
FabPr	0.29263889	7.39812052	0.03955584	1.07186699
Mach	0.72966667	6.69297939	0.10901971	1.26565653
ElcEq	0.90972222	6.47521802	0.14049291	1.24125338
Autos	0.56797222	7.65107865	0.07423427	1.2628331
Aero	0.81216667	6.13680719	0.13234352	1.01210611
Ships	0.70452778	7.62726766	0.09236962	1.07099563
Guns	0.87347222	6.17974122	0.14134447	0.58203607
Gold	0.24886111	10.9979666	0.02262792	0.4053946
Mines	0.80091667	7.9382276	0.10089364	1.09886229
Coal	0.52886111	11.6577733	0.04536553	1.10958513
Oil	0.6915	5.40642478	0.12790338	0.7235385
Util	0.57569444	3.97214621	0.14493284	0.41510252
Telcm	0.60125	5.16091216	0.11650072	0.92880176
PerSv	0.39883333	6.15994707	0.06474623	0.96818748
BusSv	0.87877778	6.55006659	0.13416318	1.27171757
Comps	0.63502778	7.8607473	0.08078466	1.35526866
Chips	0.83761111	8.03385184	0.10426021	1.45650257
LabEq	0.75191667	6.87776118	0.10932579	1.27582556
Paper	0.66208333	5.42578327	0.12202539	0.92656973
Boxes	0.794	6.11018895	0.12994688	0.97795969
Trans	0.67461111	5.34829079	0.12613583	0.93439698
Whlsl	0.55875	4.8762462	0.11458609	0.91521112
Rtail	0.83266667	5.37015804	0.15505441	0.967557
Meals	0.78991667	5.07797393	0.15555745	0.83838302
Banks	0.68344444	6.15967358	0.11095465	1.07276762
Insur	0.70411111	5.39435925	0.13052729	0.92636257

RIEst	0.19133333	7.5613262	0.0253042	1.09351596
Fin	0.84158333	6.75071984	0.12466572	1.32434694
Other	0.28488889	6.64472769	0.04287443	1.10860923

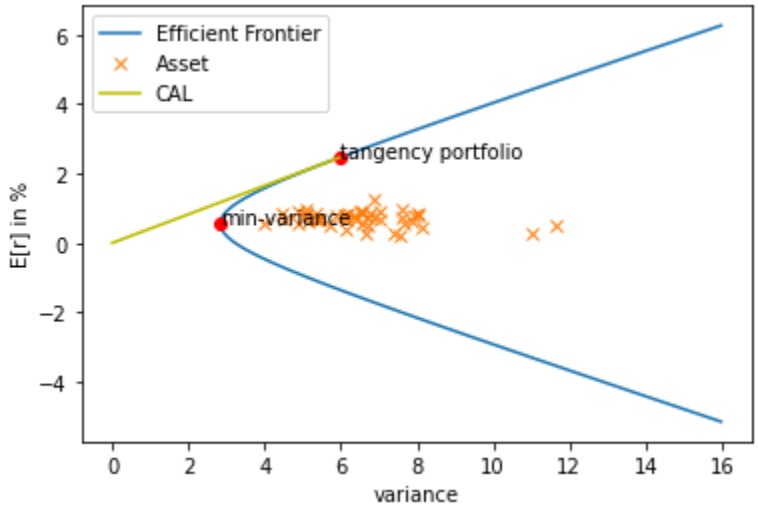
Q2.4

Below table summarize the three in-sample performance metrics of the 4 portfolios

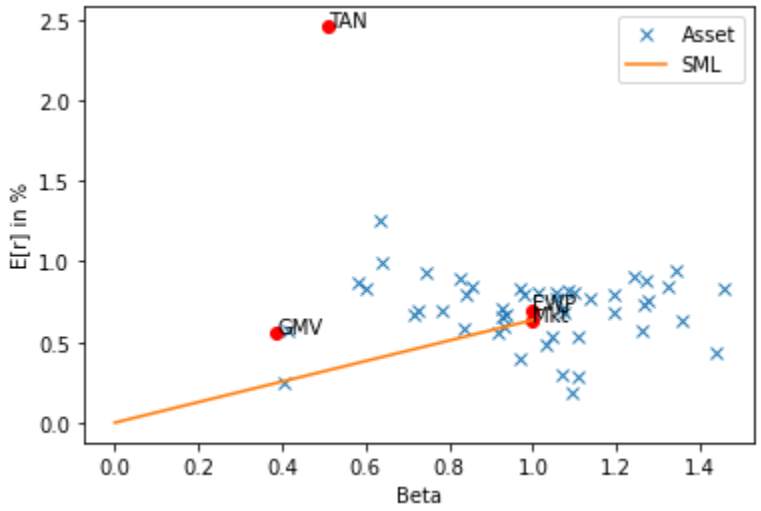
	Return	**std_dev**	**Sharpe**	**beta**
EWP	0.69988137	4.69583912	0.14904288	0.9959856
TAN	2.4563899	5.95895577	0.41221818	0.51141406
GMV	0.55543985	2.83360968	0.19601848	0.38708943
Mkt	0.63636111	4.48452695	0.1419015	1

Q2.5

a) The (ex-post) σ vs. E[r] diagram.



b) The (ex-post) β vs. E[r] diagram



Q3.3.1

First, we calculated the loss (the out-of-sample standard deviation) of GMV_shrink and TAN_shrink when δ equals 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0 in 6-fold cross validation. Then we further find the more precise values of δ in the intervals beside the previous optimal δ.

As a result, we found the Best δ for TAN_shrink is: 0.03 when the standard deviation is 3.60943. The best δ for GMV_shrink std: 0.003 when the standard deviation is 3.71469.

Q3.3.2

Portfolio	**Expected Return**	**Standard Deviation**	**Sharpe Ratio**
TAN	-0.1414174310862816	8.840333163160826	0.031574051300246625
TAN-shrink	0.637960008	3.60942621019672	0.195768810873164
GMV	0.6191922401304931	3.71470690704912	0.18009985518964464
GMV-shrink	0.6188128973595449	3.714685421248817	0.17995672998259368
MKT	0.6363611111111112	4.403392643707931	0.1662157654616148
EWP	0.6998813657407407	4.5923795516730666	0.17216658953654773

(Best delta for TAN-shrink is 0.03;Best delta for GMV-shrink is 0.003)

The out-of-sample performances above show that portfolio TAN-shrink has the highest sharpe ratio, thus having the best performance.

Q3.3.3

Findings and insights:
In terms of expected return for the risk taken, the in-sample market portfolio performs the worst, so the market portfolio could be considered as a baseline for portfolio choosing and decision making. The out-of-sample and in-sample performance of EWP, MKT, GMV are similar. However, compared to in-sample portfolios, both out-sample EWP and MKT have higher sharpe ratios, while out-sample GMV has a lower one.

The out-of-sample performance of TAN portfolio is much worse than the in-sample performance, and the out-of-sample sharpe is even lower than that of MKT. This may be because the tangency portfolio does not function well in prediction. The excess returns across the test periods are quite different, so the sample estimates of expected return may be too noisy and be of limited value in predicting values in other periods.

It can be seen from the above out-sample result, the TAN-shrink portfolio has better performance metrics than the out-sample tangency portfolio. It has the highest sharpe ratio and it performs more consistently with its in-sample result. This could be partly because of using shrunk V and CAPM implied returns to compute the expected excess returns. It is more robust and has lower sample risk compared without using shrink V, therefore it has a more stable performance when we use it for prediction purposes.

Limitations:

a) We can further use shrinkage parameters for beta to find the most optimal value.
b) The optimal delta we derived is the local optimal, and it's hard to find the global optimal. Also, the delta may be outside the range we defined, which means it may be beyond [0, 1].
c) Selecting delta based on out-of-sample standard deviation may not be the best prediction for future. And simple averaging the k-fold out-of-sample meatrics is not completely reasonable, because the weights of portfolios in each fold are different.

Q4

Based on the results of Q3, our team has decided to adopt the TAN-shrink portfolio to allocate the investment among 48 industries. To estimate the optimised delta value for shrink matrix, we have run 5-fold cross validation on the last 5 years of data available (2011 - 2015), the results of cross validation can be found in Appendix. From the cross validation results, we have identified the delta value 0 that generates the lowest standard deviation for TAN-shrink portfolio (4.214862144221985). In terms of the weightage allocation among the 48 industries, we use the last 1 year (2015)'s in-sample weight allocation of the Tangency shrink portfolio from the 5-fold cross validation results when delta is equal to the most optimal value of 0 and the weight for different assets is attached in

‘GP1_Recommendation_G12.csv’. In terms of investment in the riskless asset, our team decides to not borrow from riskless assets because we are risk averse. The exact percentage invested in the riskless assets will depend on the individual investors’ risk aversion level.

Appendix

The results of cross validation for Q3:

```
0.0 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6410658653532205 TAN_shrink_std
3.611850862851299 TAN_shrink_SR 0.19655770197684627 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6191922401304928 GMV_shrink_std 3.7147069070491217
GMV_shrink_SR 0.18009985518964444
--------------------------------------------------------------------------
0.1 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6312327991607546 TAN_shrink_std
3.624237496431044 TAN_shrink_SR 0.192995147807533 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6074283774971804 GMV_shrink_std 3.735357152967849
GMV_shrink_SR 0.1746100302060811
--------------------------------------------------------------------------
0.2 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6227214742313131 TAN_shrink_std
3.686123840549211 TAN_shrink_SR 0.18758284163760766 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.5972339774227943 GMV_shrink_std 3.7903565596260105
GMV_shrink_SR 0.16842647586185924
--------------------------------------------------------------------------
0.3 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
```

-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6152892979569243 TAN_shrink_std
3.7833342088265596 TAN_shrink_SR 0.1813856627620097 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.5883058842145862 GMV_shrink_std 3.867772514677732
GMV_shrink_SR 0.16231395934962176

0.4 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6087478768001363 TAN_shrink_std
3.904519972897756 TAN_shrink_SR 0.17502404278614905 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.5804150874155948 GMV_shrink_std 3.9590170388789723
GMV_shrink_SR 0.15661592221330908

0.5 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6029490449979867 TAN_shrink_std
4.041063955439713 TAN_shrink_SR 0.16884055772357254 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.5733853235048371 GMV_shrink_std 4.058100238176328
GMV_shrink_SR 0.15144602965536813

0.6 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.5977749234890204 TAN_shrink_std
4.186645555387705 TAN_shrink_SR 0.16301314915943974 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.5670786682403586 GMV_shrink_std 4.160928642934175
GMV_shrink_SR 0.14681025467272404

0.7 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.5931307338451416 TAN_shrink_std
4.336742429836556 TAN_shrink_SR 0.15762091000242925 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.5613856021155529 GMV_shrink_std 4.2647473343700995
GMV_shrink_SR 0.14267039433726134

0.8 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.5889395283118728 TAN_shrink_std
4.488182207976103 TAN_shrink_SR 0.15268432966333742 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.556218012917031 GMV_shrink_std 4.367730459391438
GMV_shrink_SR 0.13897390779578897

0.9 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
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4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
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0.0008191509397513416 TAN_shrink_return: 0.5851382736787655 TAN_shrink_std
4.638779049801287 TAN_shrink_SR 0.14819098982980147 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.5515041719612981 GMV_shrink_std 4.468691944155229
GMV_shrink_SR 0.1356669940821529

1.0 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.862367560264711 TAN_shrink_std
22.739033214092956 TAN_shrink_SR 0.094941045362544 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 1.4584532239843433 GMV_shrink_std 18.146290899655217
GMV_shrink_SR 0.09017491624346753

0.0 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6410658653532205 TAN_shrink_std
3.611850862851299 TAN_shrink_SR 0.19655770197684627 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6191922401304928 GMV_shrink_std 3.7147069070491217
GMV_shrink_SR 0.18009985518964444

0.01 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6400147479695701 TAN_shrink_std
3.6104077004779302 TAN_shrink_SR 0.1963264986207068 GMV_return:

0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6179345760705682 GMV_shrink_std 3.714807012754093
GMV_shrink_SR 0.1796159878408535

0.02 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6389795772288273 TAN_shrink_std
3.609605129639666 TAN_shrink_SR 0.19606293687456636 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6166961133048283 GMV_shrink_std 3.71538783729827
GMV_shrink_SR 0.17911367632430564

0.03 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6379600081338592 TAN_shrink_std
3.609426210196719 TAN_shrink_SR 0.1957688108731638 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6154764008677198 GMV_shrink_std 3.716432141108291
GMV_shrink_SR 0.17859452958212 45

0.04 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6369557051352911 TAN_shrink_std
3.6098540933448695 TAN_shrink_SR 0.1954458741142443 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6142750019296549 GMV_shrink_std 3.7179230913090353
GMV_shrink_SR 0.17806008980828017

0.05 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6359663418216813 TAN_shrink_std
3.610872043434421 TAN_shrink_SR 0.19509583412340017 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6130914932491015 GMV_shrink_std 3.7198442630363178
GMV_shrink_SR 0.17751183113419297

0.06 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:

-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6349916006214971 TAN_shrink_std
3.612463458786022 TAN_shrink_SR 0.19472034804612856 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6119254646497699 GMV_shrink_std 3.7221796400502014
GMV_shrink_SR 0.17695115887116322

-
0.07 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6340311725163463 TAN_shrink_std
3.6146118913843446 TAN_shrink_SR 0.19432101912334865 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6107765185215569 GMV_shrink_std 3.724913614639858
GMV_shrink_SR 0.17637940926358397

0.08 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6330847567649996 TAN_shrink_std
3.617301065355264 TAN_shrink_SR 0.19389939399576825 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6096442693440401 GMV_shrink_std 3.728030986820818
GMV_shrink_SR 0.17579784970513126

0.09 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6321520606377721 TAN_shrink_std
3.6205148941561234 TAN_shrink_SR 0.19345696077424424 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6085283432313295 GMV_shrink_std 3.731516962834523
GMV_shrink_SR 0.1752076793693349

0.1 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6312327991607546 TAN_shrink_std
3.624237496431044 TAN_shrink_SR 0.192995147807533 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6074283774971804 GMV_shrink_std 3.735357152967849
GMV_shrink_SR 0.1746100302060811

0.0 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6410658653532205 TAN_shrink_std
3.611850862851299 TAN_shrink_SR 0.19655770197684627 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6191922401304928 GMV_shrink_std 3.7147069070491217
GMV_shrink_SR 0.18009985518964444

0.001 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6409600259831386 TAN_shrink_std
3.6116772356769737 TAN_shrink_SR 0.19653608964273608 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6190655965124838 GMV_shrink_std 3.7146947855707686
GMV_shrink_SR 0.1800523456473518

0.002 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6408543492595898 TAN_shrink_std
3.611510167433524 TAN_shrink_SR 0.19651413730495748 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6189391490791306 GMV_shrink_std 3.714687629565898
GMV_shrink_SR 0.1800046366795874

0.003 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6407488348243537 TAN_shrink_std
3.6113496410906905 TAN_shrink_SR 0.19649184680328569 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6188128973595451 GMV_shrink_std 3.7146854212488165
GMV_shrink_SR 0.17995672998259382

0.004 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6406434823202093 TAN_shrink_std
3.611195639623228 TAN_shrink_SR 0.19646921997461775 GMV_return:

0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.618686840884357 GMV_shrink_std 3.71468814287411
GMV_shrink_SR 0.17990862724631848

0.005 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6405382913909368 TAN_shrink_std
3.6110481460111363 TAN_shrink_SR 0.19644625865289853 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6185609791857053 GMV_shrink_std 3.7146957767366704
GMV_shrink_SR 0.17986033015438488

0.006 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6404332616813141 TAN_shrink_std
3.610907143239897 TAN_shrink_SR 0.19642296466904738 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6184353117972399 GMV_shrink_std 3.714708305171712
GMV_shrink_SR 0.1798118403840697

0.007 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6403283928371132 TAN_shrink_std
3.6107726143006977 TAN_shrink_SR 0.19639933985088334 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6183098382541067 GMV_shrink_std 3.7147257105548115
GMV_shrink_SR 0.1797631596062722

0.008 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6402236845050943 TAN_shrink_std
3.6106445421906863 TAN_shrink_SR 0.19637538602305468 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6181845580929503 GMV_shrink_std 3.714747975301925
GMV_shrink_SR 0.1797142894854946

0.009 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:

```
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6401191363330035 TAN_shrink_std
3.610522909913185 TAN_shrink_SR 0.1963511050069653 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6180594708519007 GMV_shrink_std 3.7147750818694187
GMV_shrink_SR 0.1796652316798124
--------------------------------------------------------------------------
0.01 MKT_return: 0.636361111111111 MKT_std 4.403392643707932 MKT_SR
0.16621576546161473 EWP_return: 0.6998813657407407 EWP_std
4.5923795516730666 EWP_SR 0.17216658953654776 TAN_return:
-0.14141743108628488 TAN_std 7.133933010965649 TAN_SR
0.0008191509397513416 TAN_shrink_return: 0.6400147479695701 TAN_shrink_std
3.6104077004779302 TAN_shrink_SR 0.1963264986207068 GMV_return:
0.6191922401304928 GMV_std 3.7147069070491217 GMV_SR 0.18009985518964444
GMV_shrink_return: 0.6179345760705682 GMV_shrink_std 3.714807012754093
GMV_shrink_SR 0.1796159878408535
--------------------------------------------------------------------------
```

The results of cross validation for Q4:

```
0.0 TAN_shrink_return: 0.5502583379828261 TAN_shrink_std 4.214862144221985
TAN_shrink_SR 0.19300880472956417
weight_TAN_shrink:  [[ 0.05297056  0.06295374 -0.00685701  0.01203884
-0.03243102 -0.02441691
  -0.01570492  0.04358878  0.18135931 -0.02607092 -0.0164331   0.06300746
   0.00343015 -0.07702264 -0.03667591 -0.03096741 -0.03955744 -0.10320433
  -0.0381994   0.04832691 -0.01556003 -0.08810021 -0.03369796 -0.08021052
  -0.04318616  0.08641376  0.04250714  0.00275255  0.00272683  0.09136379
   0.27816855  0.12372526 -0.01752162 -0.00529796  0.07594866  0.03617029
   0.02513508  0.0690744   0.04273541  0.15172488  0.0401416   0.12899743
   0.06106702  0.00578327  0.00402195  0.04919286 -0.01783933 -0.0363717
]]
0.9999999999999999
--------------------------------------------------------------------------
-
0.1 TAN_shrink_return: 0.5780875956372855 TAN_shrink_std 4.325456358434524
TAN_shrink_SR 0.19069654465189242
weight_TAN_shrink:  [[ 0.03256828  0.07481657 -0.02470621  0.00174819
-0.05445611 -0.03160903
  -0.03269193  0.04529377  0.19736532 -0.03405815 -0.03324461  0.09620112
  -0.0102689  -0.04830037 -0.01161802 -0.0498597  -0.02711404 -0.10202081
  -0.04159774  0.0365284   0.03936002 -0.0919377  -0.04170342 -0.07467962
  -0.05557507  0.06980585  0.024242    0.01106496 -0.01598122  0.08999949
   0.29279696  0.12498531 -0.02873123  0.00680589  0.06440005  0.0205123
  -0.00056289  0.07160555  0.03153463  0.15173028  0.12793007  0.12150819
```

```
   0.08233935 -0.00153544  0.00352154  0.04139783 -0.00366406
-0.04414565]]
1.0
--------------------------------------------------------------------------
-
0.2 TAN_shrink_return: 0.6035075984699714 TAN_shrink_std 4.446222070626224
TAN_shrink_SR 0.18777151827586452
weight_TAN_shrink:  [[ 0.01368767  0.08579463 -0.04122416 -0.00777494
-0.07483848 -0.03826473
  -0.04841198  0.0468716   0.21217753 -0.04144966 -0.04880225  0.12691908
  -0.02294622 -0.02172032  0.01157096 -0.06734294 -0.01559872 -0.10092556
  -0.04474262  0.02560987  0.09018393 -0.09548897 -0.04911181 -0.06956125
  -0.06703997  0.05443662  0.00733914  0.0187574  -0.03329394  0.08873694
   0.30633433  0.12615137 -0.03910479  0.01800698  0.05371277  0.00602214
  -0.02434421  0.07394793  0.02116923  0.15173527  0.20917095  0.11457752
   0.10202511 -0.0083083   0.00305845  0.03418418  0.00945397
-0.05133979]]
1.0
--------------------------------------------------------------------------
-
0.3 TAN_shrink_return: 0.6268156226660743 TAN_shrink_std
4.5717892892082705 TAN_shrink_SR 0.18469748067900543
weight_TAN_shrink:  [[-0.00383537  0.09598335 -0.05655442 -0.01661333
-0.0937553  -0.04444187
  -0.06300172  0.04833598  0.22592472 -0.0483097  -0.06324127  0.15542834
  -0.03471201  0.00294857  0.0330926  -0.08356909 -0.00491138 -0.09990906
  -0.04766138  0.01547641  0.13735348 -0.0987849  -0.05598751 -0.06481089
  -0.07768052  0.04017247 -0.00834836  0.02589673 -0.04936184  0.08756518
   0.31889832  0.12723359 -0.04873246  0.0284027   0.04379394 -0.00742614
  -0.04641559  0.07612188  0.01154914  0.1517399   0.28457041  0.10814519
   0.12029541 -0.01459417  0.00262866  0.02748921  0.02162879
-0.05801666]]
1.0
--------------------------------------------------------------------------
-
0.4 TAN_shrink_return: 0.6482622757810228 TAN_shrink_std
4.6987323992770476 TAN_shrink_SR 0.18166423271950738
weight_TAN_shrink:  [[-0.02014219  0.10546489 -0.07082065 -0.02483828
-0.11135917 -0.05019028
  -0.07657883  0.04969872  0.23871775 -0.05469361 -0.07667811  0.18195885
  -0.04566118  0.02590526  0.05312048 -0.09866903  0.00503418 -0.09896311
  -0.05037755  0.00604628  0.18124912 -0.10185207 -0.062386   -0.06039025
  -0.08758253  0.02689836 -0.02294704  0.03254054 -0.06431452  0.08647474
   0.33059029  0.1282407  -0.0576919   0.03807687  0.03456354 -0.01994102
  -0.06695507  0.07814494  0.00259675  0.15174421  0.35473662  0.1021593
   0.13729763 -0.02044376  0.0022287   0.02125892  0.03295858 -0.0642301
]]
```

```
1.0
--------------------------------------------------------------------------
-
0.5 TAN_shrink_return: 0.6680602646116557 TAN_shrink_std 4.824873561331195
TAN_shrink_SR 0.17874849049155003
weight_TAN_shrink:  [[-0.03535516  0.11431042 -0.08412992 -0.0325115
-0.12778218 -0.05555308
  -0.0892452   0.05097005  0.25065263 -0.0606493  -0.08921361  0.20670972
  -0.05587588  0.04732204  0.07180491 -0.11275608  0.01431261 -0.09808061
  -0.05291153 -0.00275128  0.22220028 -0.1047135  -0.06835528 -0.05626614
  -0.09682033  0.01451466 -0.03656645  0.0387387  -0.07826418  0.08545745
   0.34149797  0.12918025 -0.06605035  0.04710211  0.02595232 -0.03161641
  -0.08611677  0.08003229 -0.00575513  0.15174824  0.42019613  0.09657495
   0.15315935 -0.02590096  0.00185557  0.01544655  0.04352838
-0.07002675]]
1.0
--------------------------------------------------------------------------
-
0.6 TAN_shrink_return: 0.6863912654334022 TAN_shrink_std 4.948838755176235
TAN_shrink_SR 0.1759794767809087
weight_TAN_shrink:  [[-0.04958077  0.12258185 -0.09657538 -0.03968672
-0.1431393  -0.06056783
  -0.10108949  0.05215886  0.26181291 -0.06621844 -0.10093554  0.2298542
  -0.06542762  0.06734881  0.08927667 -0.12592884  0.02298884 -0.09725539
  -0.05528104 -0.01097786  0.26049361 -0.10738921 -0.07393713 -0.05240969
  -0.10545857  0.0029347  -0.04930193  0.04453457 -0.09130847  0.08450618
   0.35169771  0.13005883 -0.07386631  0.05554159  0.01789998 -0.04253404
  -0.10403483  0.08179715 -0.01356494  0.151752    0.48140716  0.09135303
   0.1679916  -0.03100397  0.00150666  0.01001142  0.05341218
-0.07544718]]
1.0
--------------------------------------------------------------------------
-
0.7 TAN_shrink_return: 0.7034113576296935 TAN_shrink_std 5.069776972667443
TAN_shrink_SR 0.1733656984179365
weight_TAN_shrink:  [[-0.06291213  0.13033332 -0.10823849 -0.04641088
-0.15753104 -0.06526734
  -0.11218922  0.05327295  0.27227163 -0.07143749 -0.11192059  0.25154376
  -0.07437892  0.08611665  0.10565011 -0.13827354  0.03111966 -0.09648205
  -0.0575016  -0.01868729  0.29637972 -0.10989672 -0.0791681  -0.04879567
  -0.11355379 -0.00791732 -0.06123682  0.04996611 -0.10353277  0.08361472
   0.36125628  0.13088217 -0.08119095  0.06345054  0.01035383 -0.05276536
  -0.12082652  0.08345107 -0.02088382  0.15175552  0.53877031  0.08645938
   0.18189147 -0.0357862   0.00117968  0.00491796  0.06267465
-0.08052687]]
0.9999999999999999
```

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-
0.8 TAN_shrink_return: 0.7192553583397852 TAN_shrink_std 5.187181067546691
TAN_shrink_SR 0.17090626022507036
weight_TAN_shrink:  [[-7.54309813e-02  1.37612367e-01 -1.19190772e-01
-5.27252228e-02
  -1.71045638e-01 -6.96804221e-02 -1.22612455e-01  5.43191331e-02
   2.82092922e-01 -7.63384617e-02 -1.22236143e-01  2.71911407e-01
  -8.27846636e-02  1.03740651e-01  1.21025647e-01 -1.49865858e-01
   3.87549366e-02 -9.57558404e-02 -5.95868300e-02 -2.59268637e-02
   3.30078692e-01 -1.12251404e-01 -8.40802569e-02 -4.54019139e-02
  -1.21155635e-01 -1.81079427e-02 -7.24443244e-02  5.50666062e-02
  -1.15012030e-01  8.27775809e-02  3.70232275e-01  1.31655335e-01
  -8.80691665e-02  7.08774672e-02  3.26759145e-03 -6.23731121e-02
  -1.36594808e-01  8.50041910e-02 -2.77566255e-02  1.51758832e-01
   5.92637365e-01  8.18639764e-02  1.94944179e-01 -4.02769678e-02
   8.72628023e-04  1.34920953e-04  7.13726100e-02 -8.52969754e-02]]
0.9999999999999998
--------------------------------------------------------------------------
-
0.9 TAN_shrink_return: 0.7340403082321487 TAN_shrink_std 5.300771876508174
TAN_shrink_SR 0.16859589180376594
weight_TAN_shrink:  [[-8.72094118e-02  1.44460895e-01 -1.29495286e-01
-5.86661090e-02
  -1.83760926e-01 -7.38324990e-02 -1.32419214e-01  5.53034419e-02
   2.91333339e-01 -8.09495652e-02 -1.31941585e-01  2.91074421e-01
  -9.06932541e-02  1.20322289e-01  1.35491803e-01 -1.60772558e-01
   4.59386266e-02 -9.50725813e-02 -6.15487255e-02 -3.27382531e-02
   3.61784554e-01 -1.14466823e-01 -8.87018867e-02 -4.22088783e-02
  -1.28307870e-01 -2.76958463e-02 -8.29889631e-02  5.98654389e-02
  -1.25812359e-01  8.19899577e-02  3.78677393e-01  1.32382770e-01
  -9.45405788e-02  7.78651321e-02 -3.39953211e-03 -7.14126192e-02
  -1.51430488e-01  8.64654501e-02 -3.42229464e-02  1.51761946e-01
   6.43318477e-01  7.75403674e-02  2.07224894e-01 -4.45021301e-02
   5.83737266e-04 -4.36522400e-03  7.95561308e-02 -8.97849507e-02]]
0.9999999999999999
--------------------------------------------------------------------------
-

1.0 TAN_shrink_return: -4.16196144691749 TAN_shrink_std 25.343510748776502
TAN_shrink_SR -0.10395028344230475
weight_TAN_shrink:  [[-0.59806915  0.19746174 -0.53202655 -0.07172425
-0.50480651  0.14696041
  -0.26553514  0.09574565 -0.44962703  0.12278578  0.83101261  1.20471828
  -0.43369101  0.67246523 -0.7123629  -0.20563015  0.0180584  -0.43727144
   0.01772751 -0.04062411  0.53431211 -0.38724152  0.15923191 -0.00654353
   0.2798297  -0.33349521  0.09735444 -0.33437989 -0.12761928  0.03082885
```

```
   0.75094023 -0.13617567  0.63173185  0.32431725 -0.12213459 -0.42537023
  -0.3218045  -0.1545262  -0.22134085  0.47342343  1.06994715 -0.48294867
   0.20755155  0.08180983  0.03924432  0.15528235  0.21641841
-0.05421059]]
0.9999999999999999
--------------------------------------------------------------------------
-
```