EPFL

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

A Portfolio Allocation Framework
for Algorithmic Trading Strategies

Master Project

In cooperation with **NAFORA SA**

Realized by:
ALESSANDRO DANIELE FORLONI

Supervised by:
YILIN HU and SEMYON MALAMUD

Academic Year
2017/2018

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2 Introduction

In this thesis we address the challenge of portfolio allocation applied to a set of trading algorithms. The aim here is to allocate risk to many algorithmic trading strategies on a weekly basis. The problem is to be solved in two seprate parts: firstly address at any moment in time which strategies out of the many available to put into production and at last assign proper risk weights to these strategies. We will see that both the steps are to be addressed with care as none of these problem if solved alone can achieve satisfactory results. All the results will be compared with a proper benchmark that mimics the current non systematic allocation strategy.

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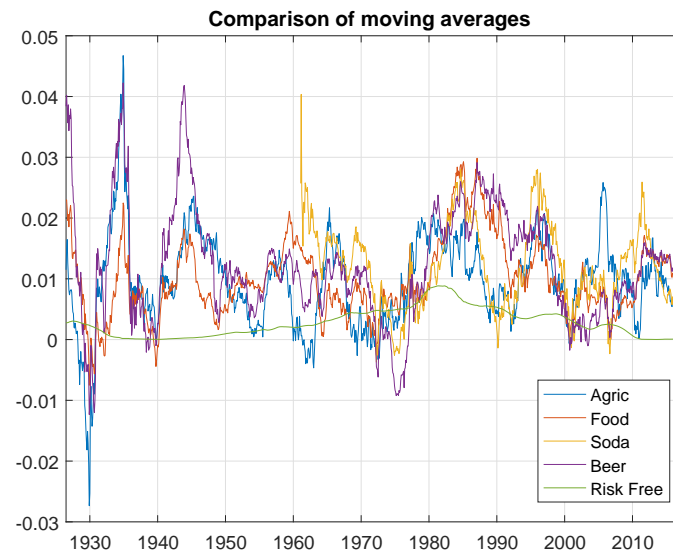Figure 1: Rolling average of the returns for 4 industries and Rf
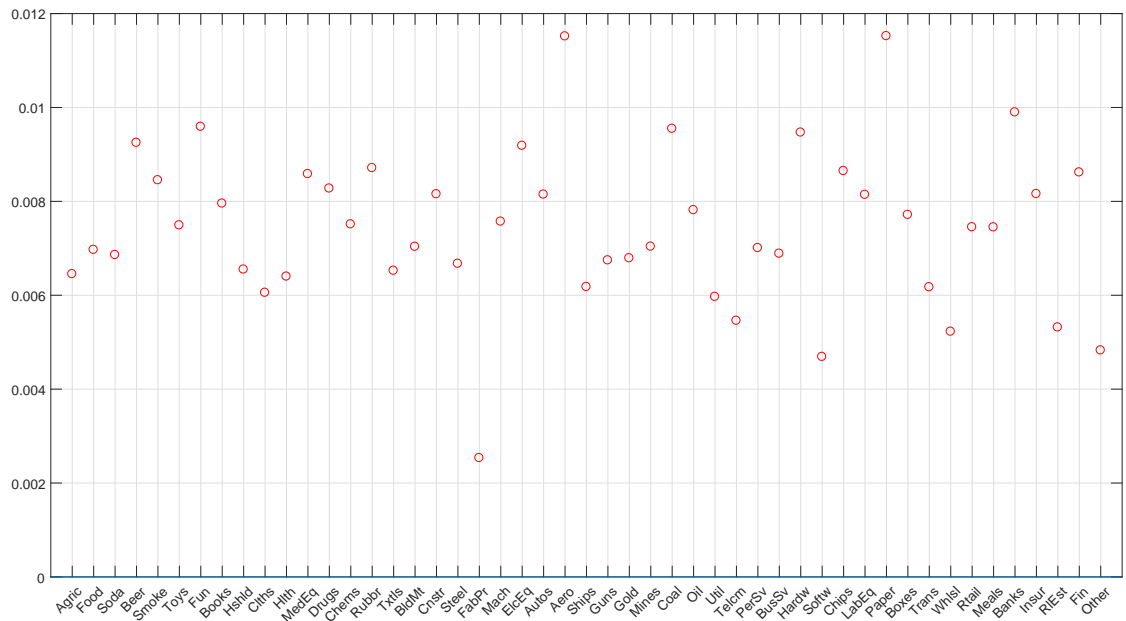
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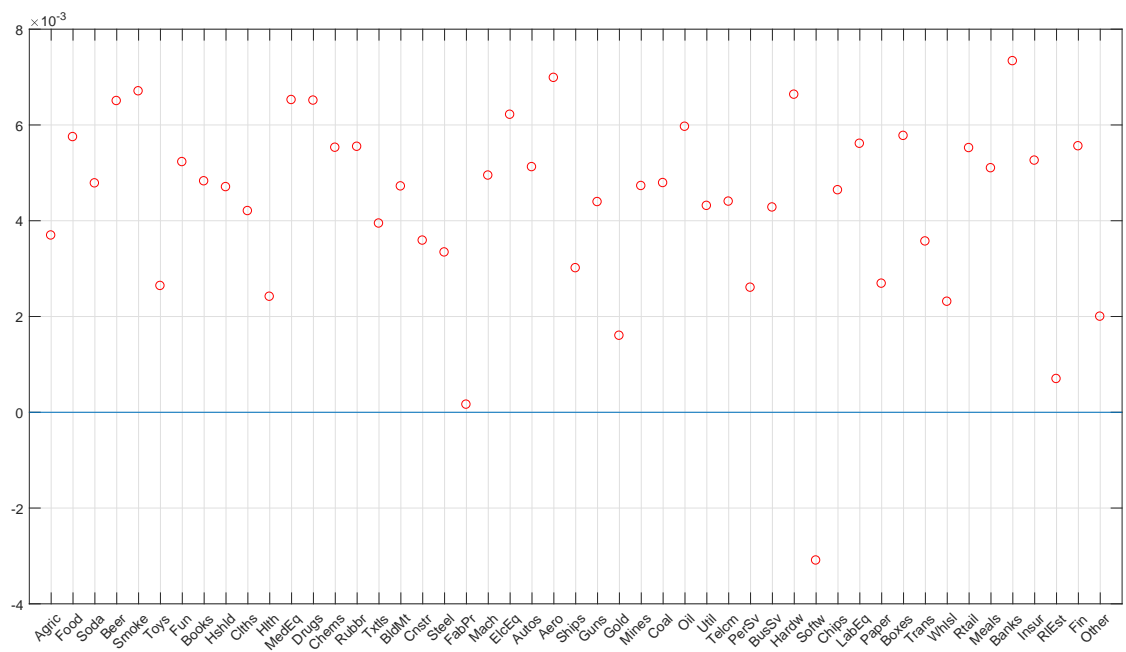
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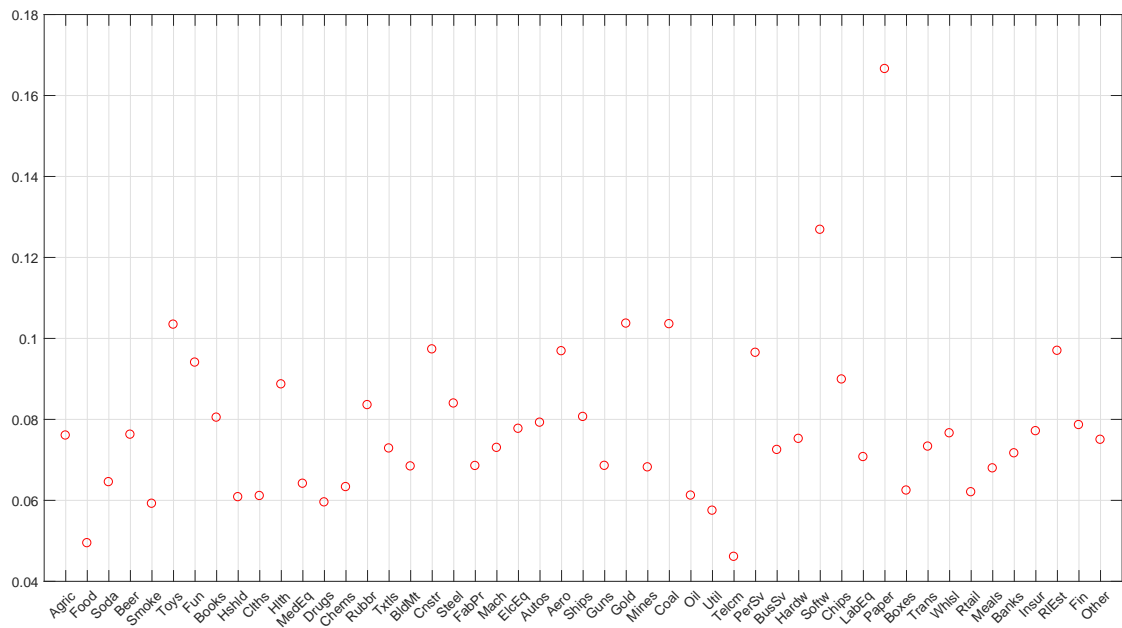
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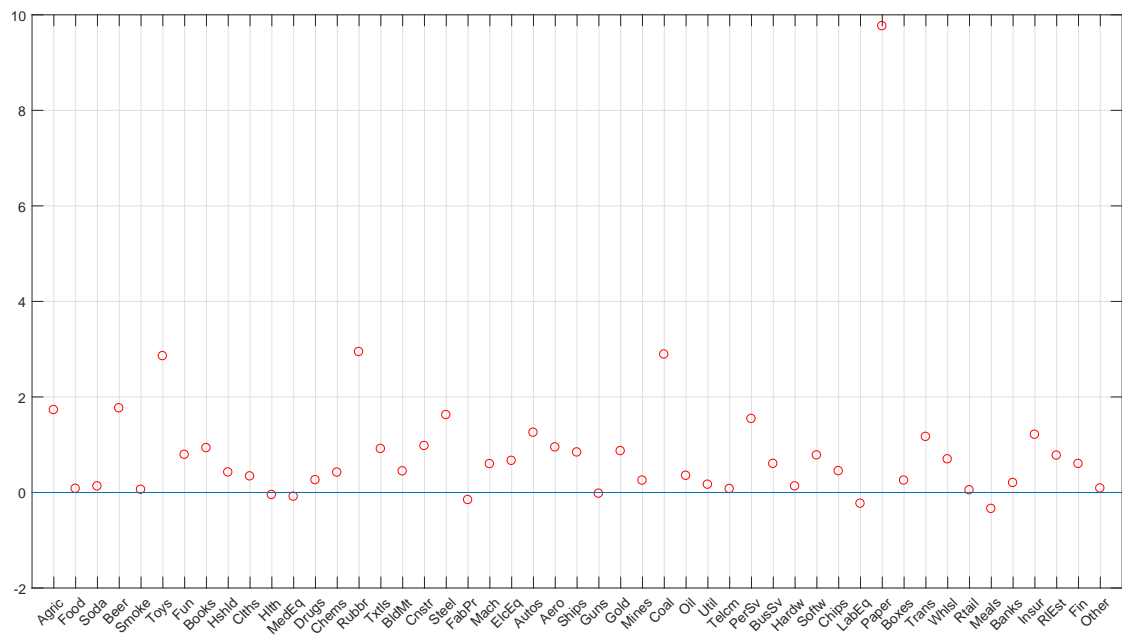
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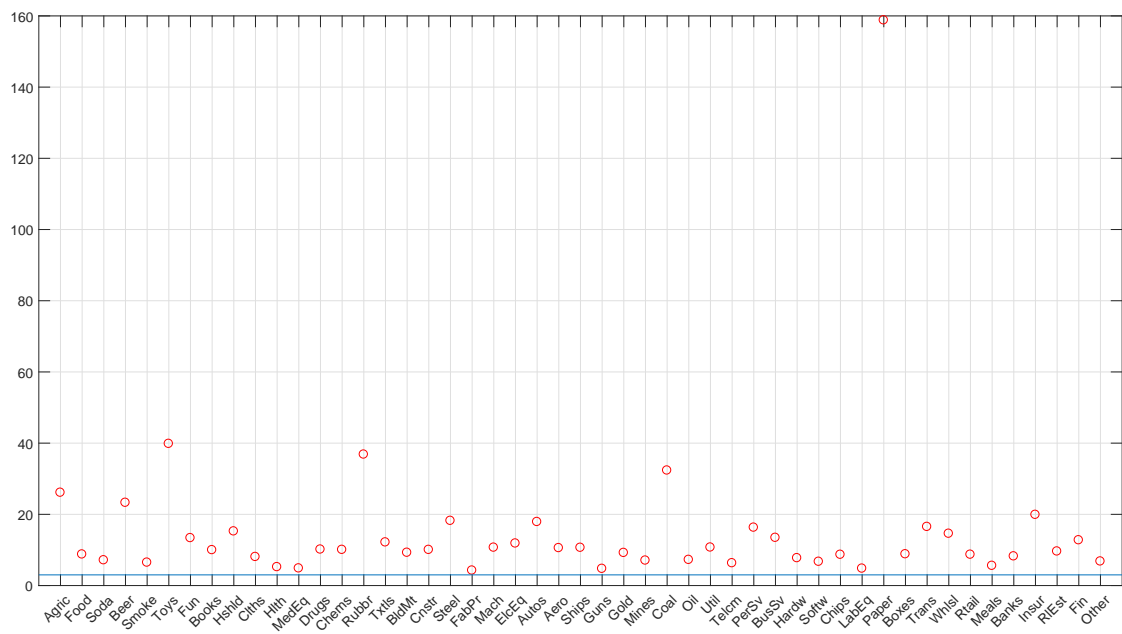
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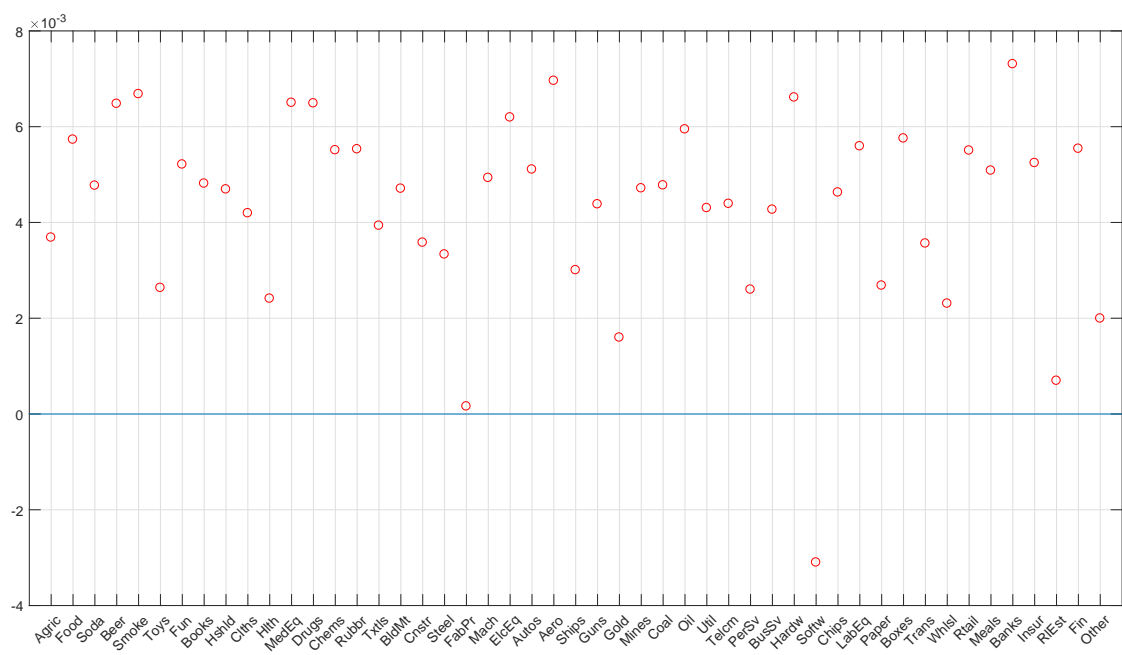
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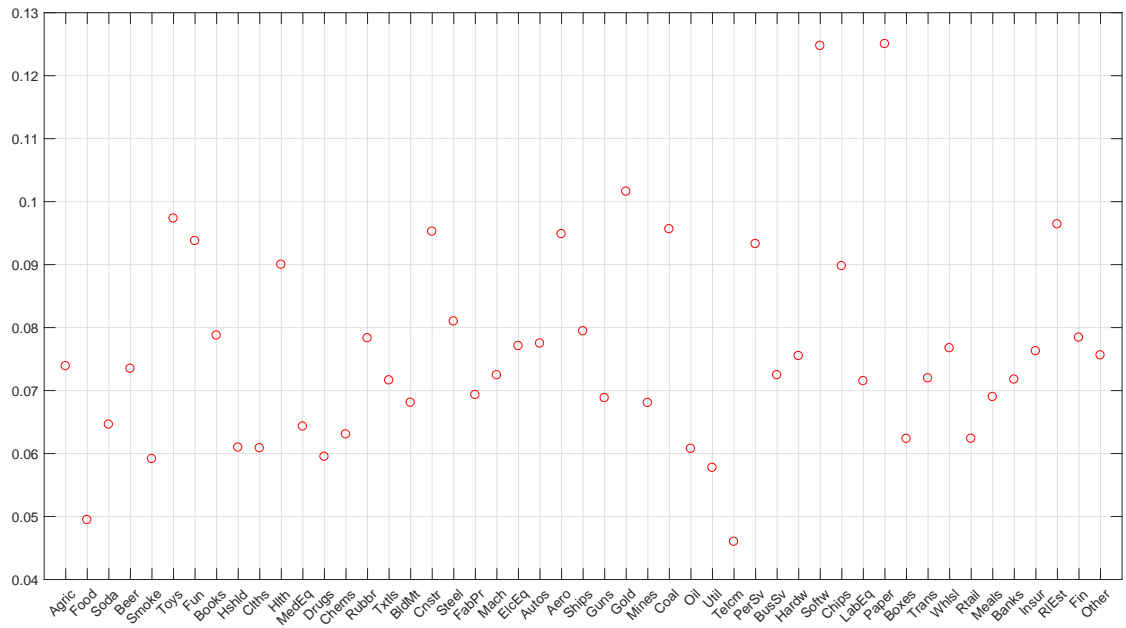
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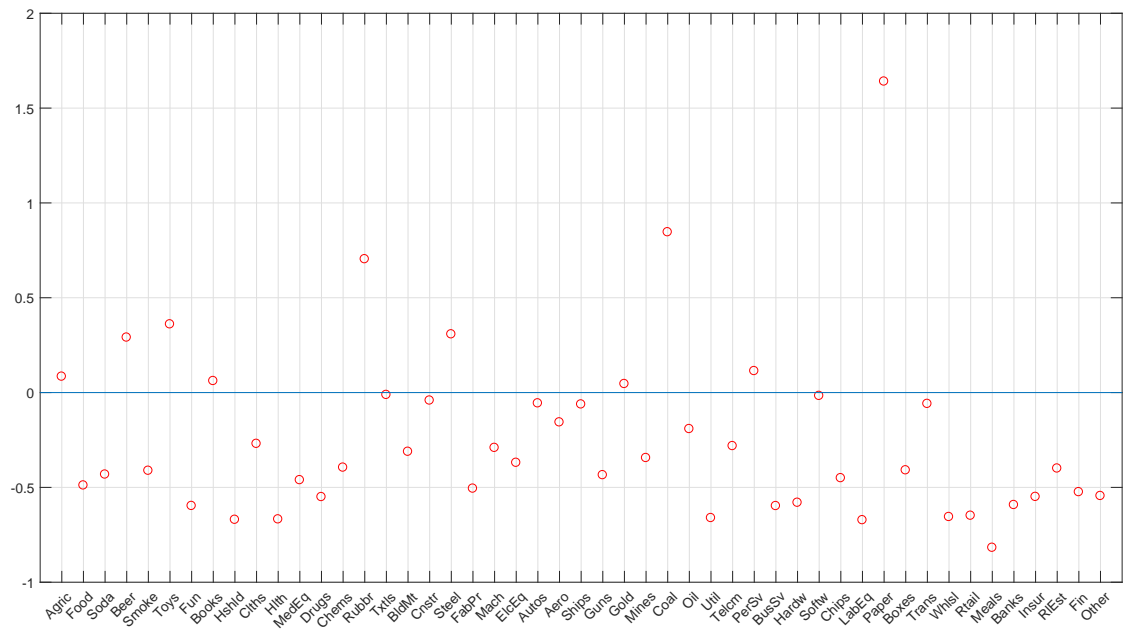
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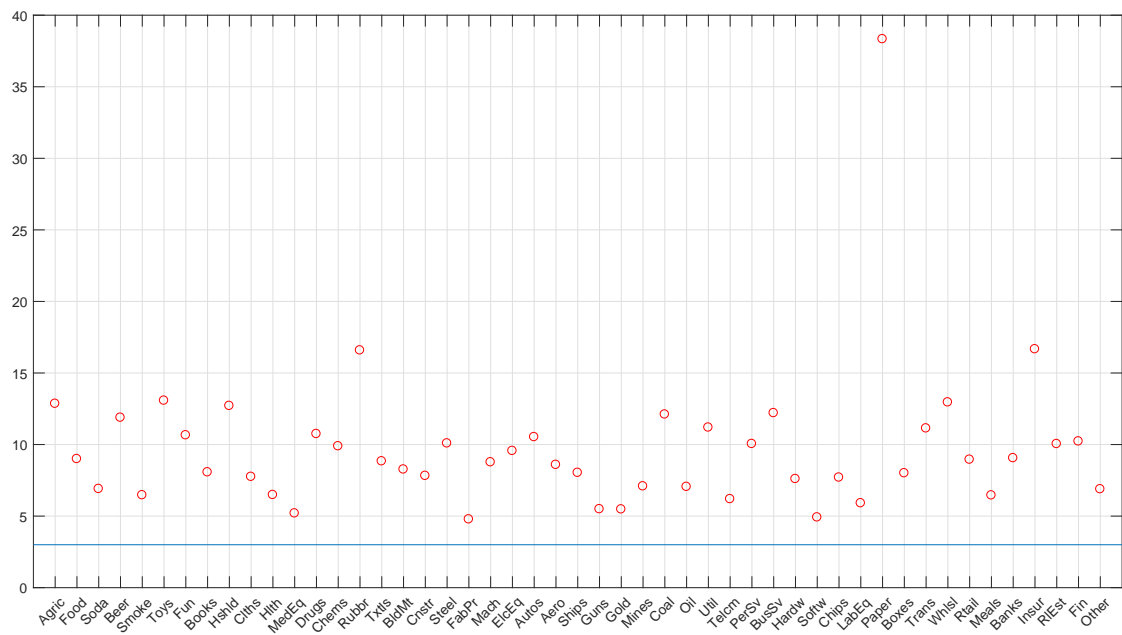
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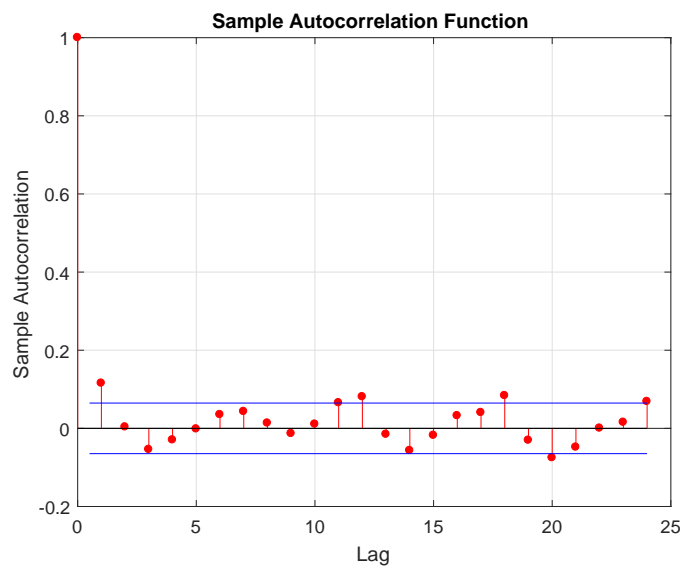
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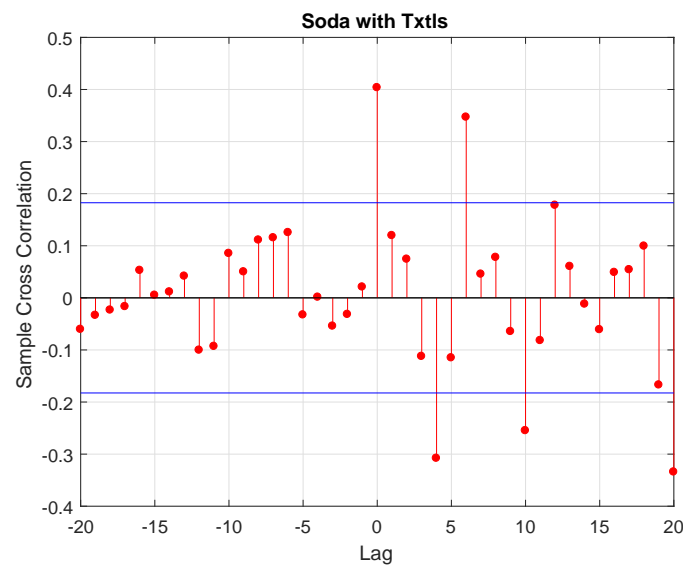
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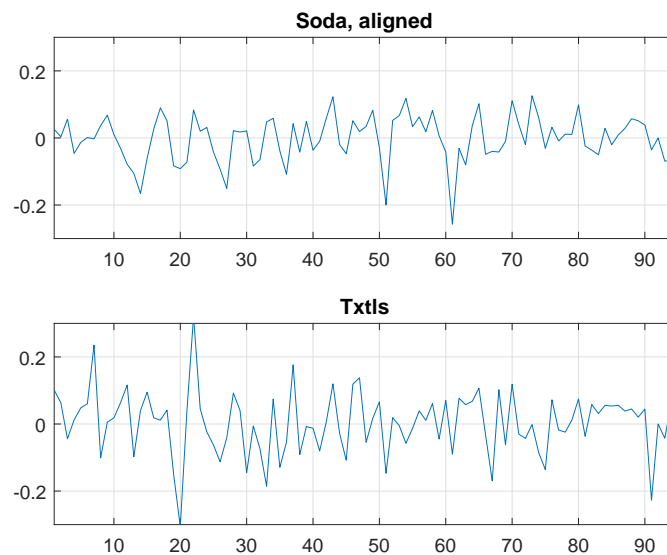
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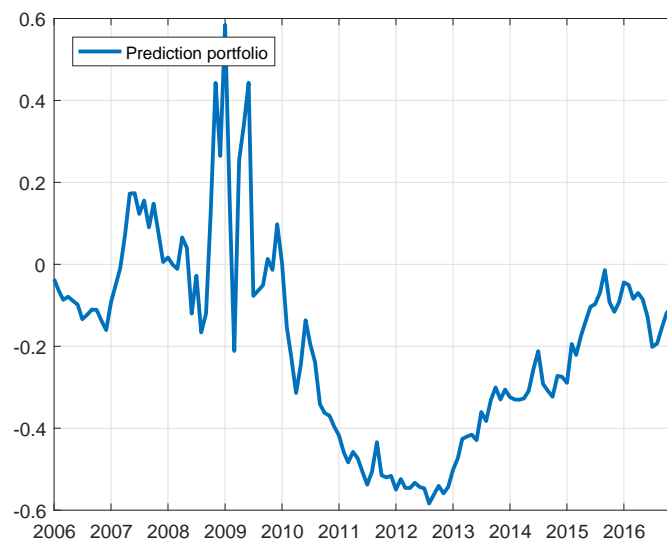
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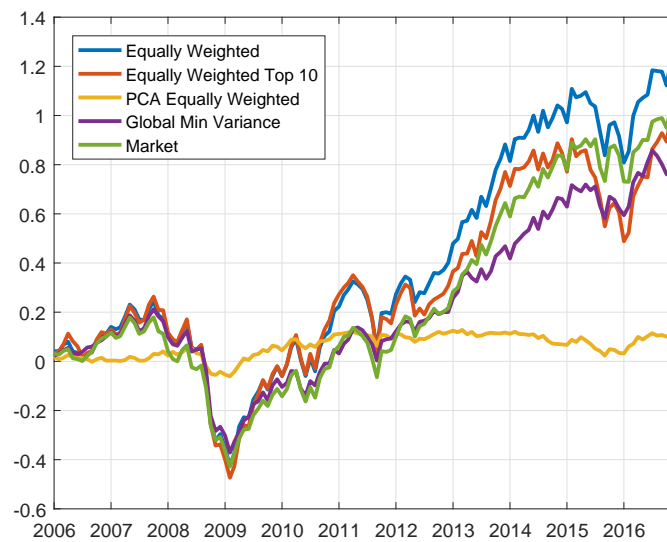
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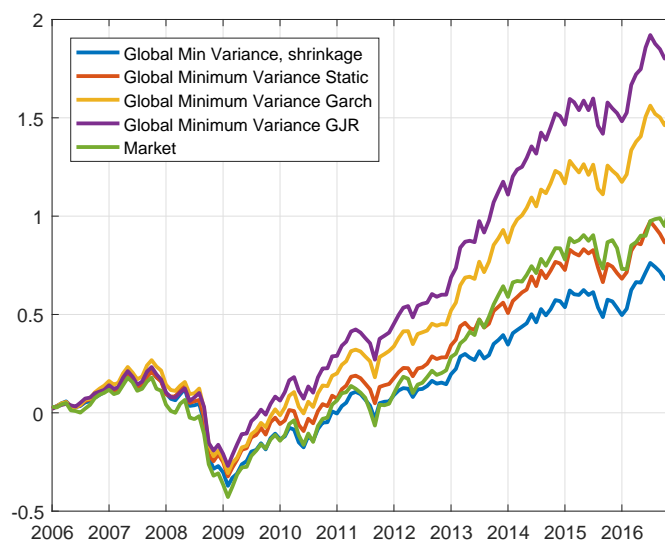
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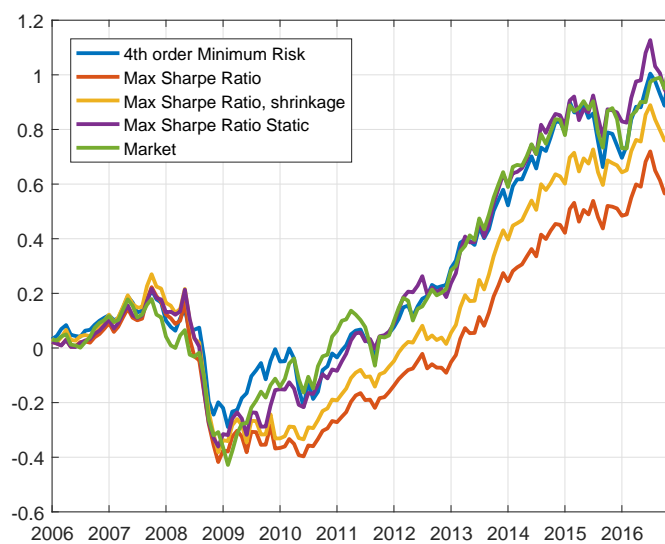
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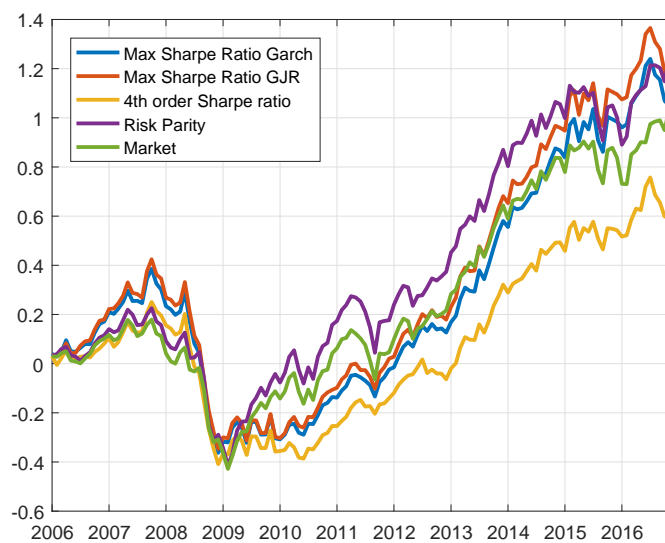
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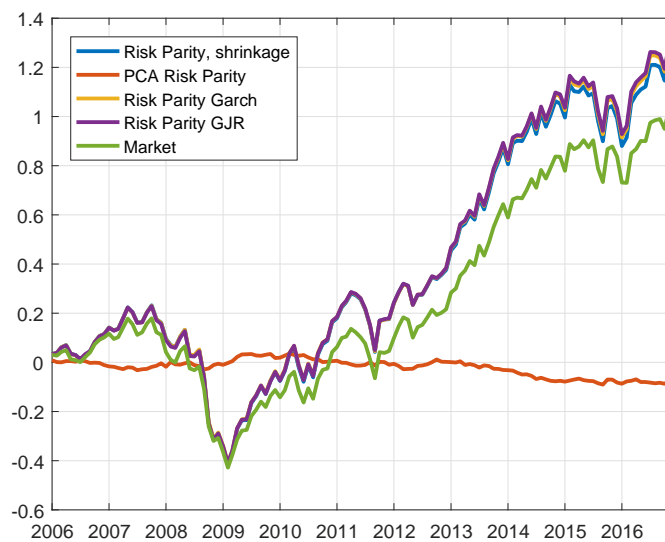
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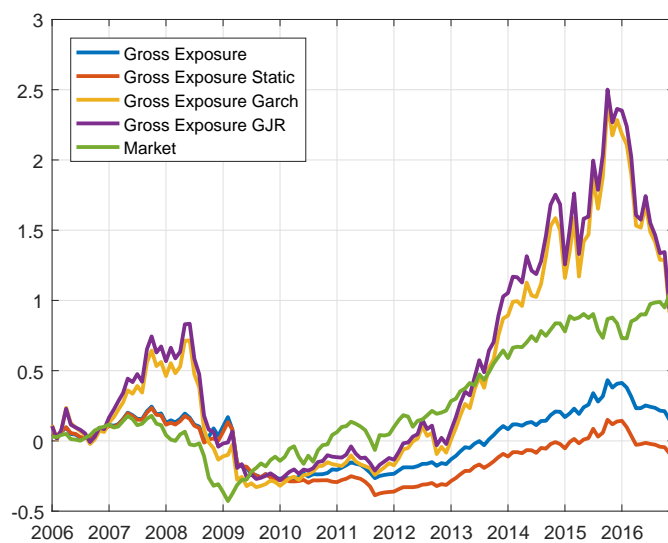
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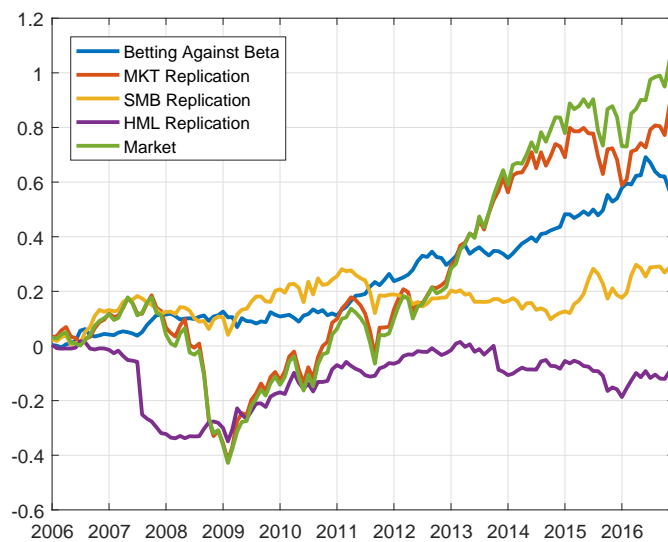
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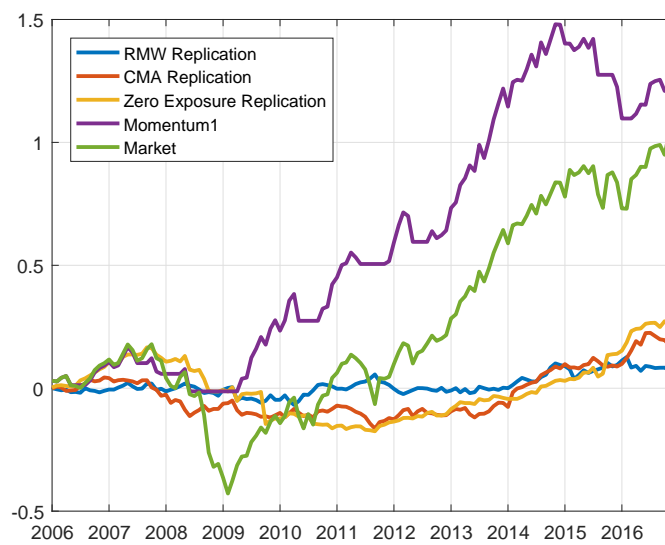
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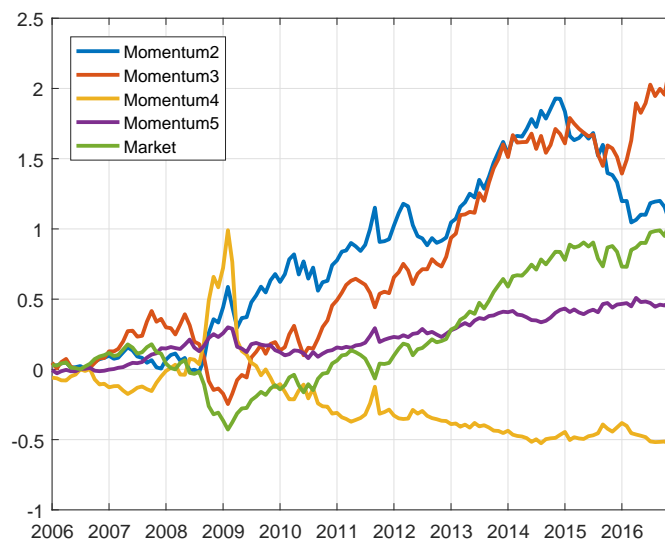
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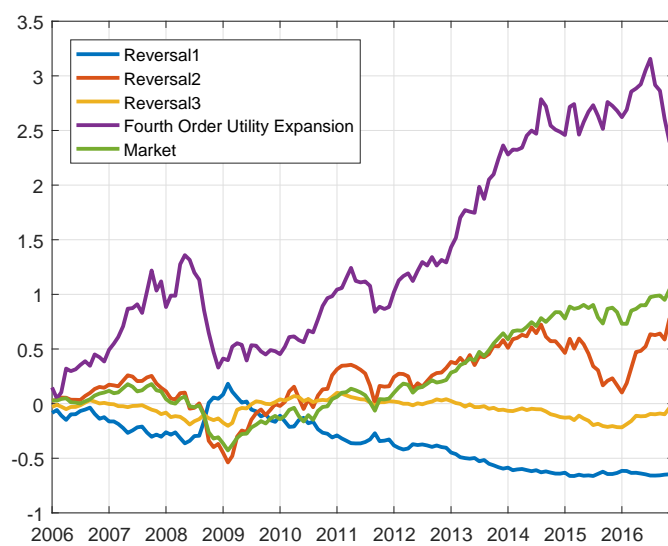
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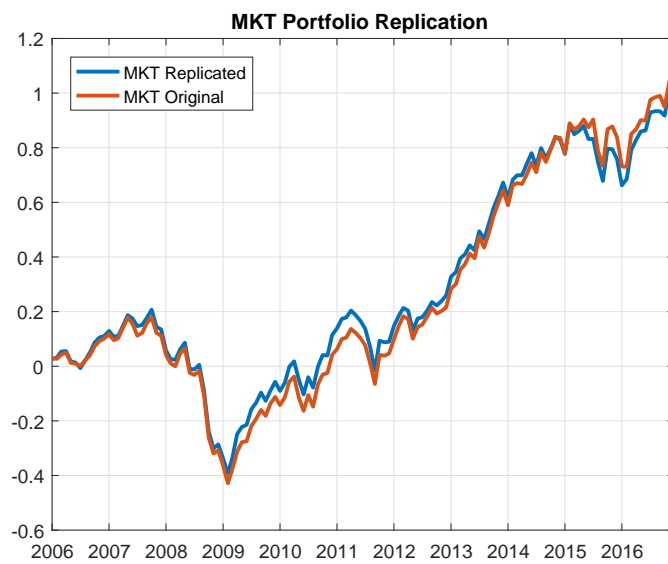
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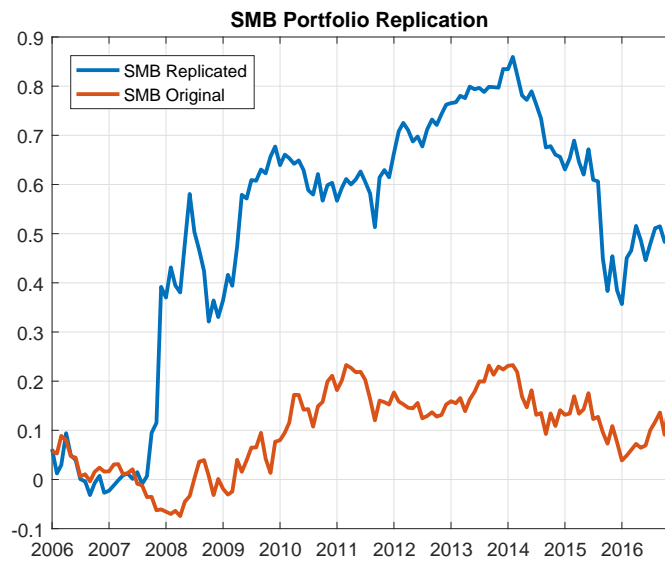
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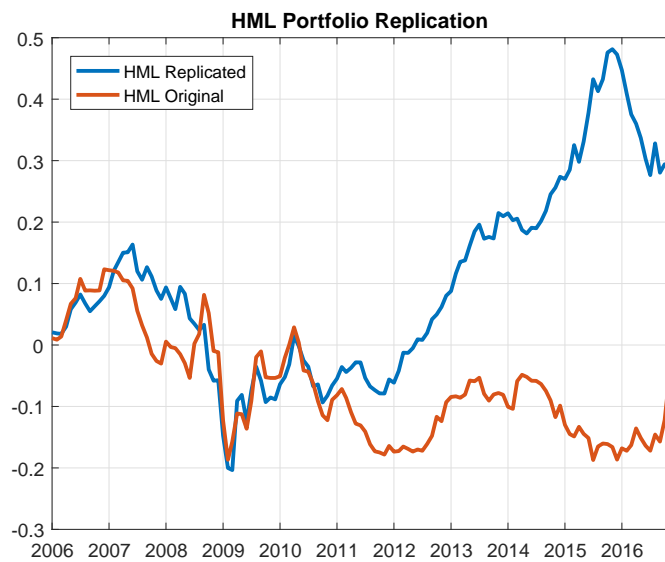
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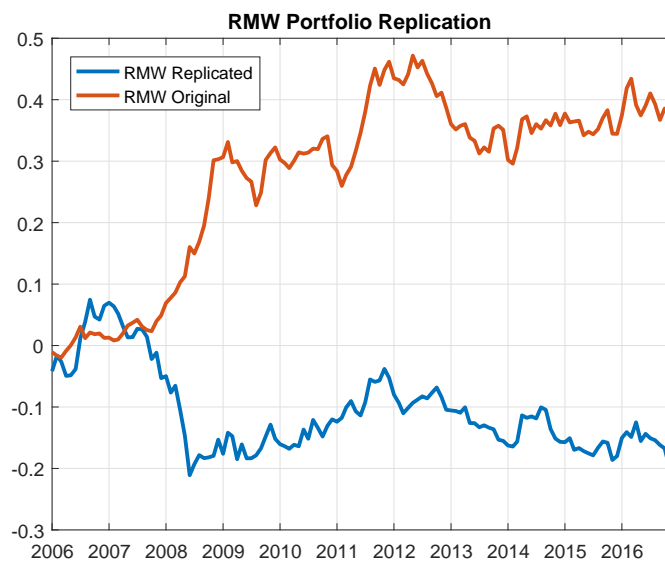
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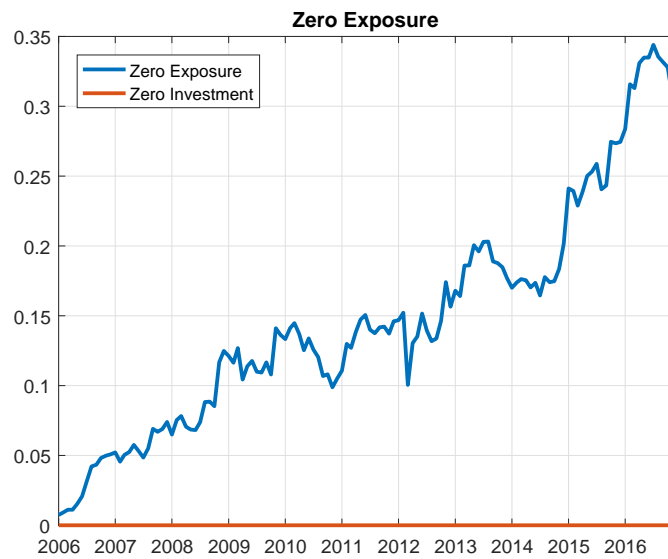
Figure 29: Zero exposure portfolio

|	Means	Geom. means	Std	Skewness	Kurtosis
Agric	0.006451	0.003692	0.076022	1.7264	26.0881
Food	0.0069678	0.0057469	0.04943	0.077403	8.7436
Soda	0.0068588	0.0047807	0.064507	0.12859	7.1141
Beer	0.0092485	0.0065	0.076231	1.7631	23.2572
Smoke	0.0084513	0.0067035	0.05917	0.058214	6.4513
Toys	0.0074909	0.0026382	0.10341	2.8551	39.81
Fun	0.0095897	0.005225	0.094034	0.78908	13.3382
Books	0.0079547	0.0048241	0.080439	0.92906	9.9586
Hshld	0.0065486	0.0047023	0.060793	0.42088	15.2228
Clths	0.0060539	0.0042022	0.061084	0.3378	8.0408
Hlth	0.0063989	0.0024131	0.088659	-0.051356	5.1869
MedEq	0.0085827	0.0065211	0.064113	-0.087466	4.829
Drugs	0.0082751	0.0065093	0.05951	0.25836	10.1244
Chems	0.0075114	0.0055249	0.063286	0.41702	10.0373
Rubbr	0.0087101	0.0055448	0.083538	2.942	36.8028
Txtls	0.0065236	0.0039416	0.072826	0.91155	12.1285
BldMt	0.0070339	0.0047173	0.068393	0.44272	9.2266
Cnstr	0.0081537	0.0035854	0.0973	0.97382	10.0288
Steel	0.0066718	0.0033381	0.083934	1.6211	18.1863
FabPr	0.0025337	0.00015952	0.068503	-0.15752	4.2258
Mach	0.0075694	0.0049435	0.072975	0.59482	10.6562
ElcEq	0.0091851	0.0062135	0.077686	0.66236	11.8235
Autos	0.0081455	0.0051196	0.079195	1.2523	17.8642
Aero	0.011515	0.0069837	0.096852	0.94405	10.5309
Ships	0.0061779	0.0030093	0.080616	0.83866	10.6221
Guns	0.0067447	0.0043901	0.068531	-0.02446	4.7082
Gold	0.00679	0.0015985	0.10367	0.86529	9.1785
Mines	0.007037	0.0047254	0.068158	0.24924	7.0303
Coal	0.0095471	0.0047871	0.10352	2.8884	32.3239
Oil	0.0078142	0.0059628	0.061188	0.35	7.2215
Util	0.005967	0.0043107	0.05746	0.16329	10.6922
Telcm	0.0054578	0.0043998	0.046062	0.072809	6.2862
PerSv	0.0070072	0.0026022	0.096456	1.5402	16.2761
BusSv	0.0068864	0.0042772	0.072464	0.59962	13.4179
Hardw	0.0094668	0.0066327	0.075198	0.12849	7.706
Softw	0.0046885	-0.0030951	0.12684	0.7773	6.6936
Chips	0.0086475	0.0046374	0.08987	0.44638	8.6589
LabEq	0.0081403	0.0056075	0.070703	-0.23438	4.7707
Paper	0.01152	0.002686	0.16655	9.7625	158.7706
Boxes	0.007713	0.0057721	0.062435	0.24969	8.8003
Trans	0.0061721	0.0035677	0.073288	1.1642	16.4832
Whlsl	0.0052253	0.0023087	0.076574	0.69512	14.5684
Rtail	0.0074503	0.0055177	0.062017	0.046815	8.6814
Meals	0.0074474	0.0050969	0.067913	-0.34348	5.5525
Banks	0.0098968	0.0073329	0.071629	0.19938	8.2083
Insur	0.008158	0.0052558	0.077097	1.2091	19.8734
RlEst	0.0053157	0.00069534	0.096949	0.77275	9.5831
Fin	0.0086179	0.0055558	0.078608	0.59824	12.733
Other	0.0048273	0.0019969	0.07497	0.084923	6.7771

Table 1: Descriptive statistics for simple returns

	Means	Std	Skewness	Kurtosis
Agric	0.0036852	0.073884	0.084114	12.8522
Food	0.0057305	0.049454	-0.48958	8.9913
Soda	0.0047693	0.064603	-0.43209	6.9013
Beer	0.006479	0.073475	0.29016	11.8806
Smoke	0.0066812	0.059141	-0.41199	6.4635
Toys	0.0026347	0.097328	0.35994	13.0706
Fun	0.0052114	0.093754	-0.59771	10.6515
Books	0.0048125	0.07875	0.061096	8.0637
Hshld	0.0046913	0.060954	-0.67062	12.7042
Clths	0.0041934	0.060854	-0.2702	7.7474
Hlth	0.0024102	0.089995	-0.66845	6.4791
MedEq	0.0065	0.064299	-0.46166	5.1929
Drugs	0.0064882	0.059498	-0.5508	10.74
Chems	0.0055097	0.063053	-0.39554	9.8841
Rubbr	0.0055294	0.078319	0.7034	16.5828
Txtls	0.0039339	0.07163	-0.012223	8.8332
BldMt	0.0047062	0.068076	-0.31192	8.2602
Cnstr	0.003579	0.095244	-0.041824	7.8152
Steel	0.0033326	0.080992	0.30725	10.0841
FabPr	0.00015951	0.069312	-0.50631	4.776
Mach	0.0049314	0.072444	-0.29147	8.7644
ElcEq	0.0061942	0.07708	-0.37013	9.558
Autos	0.0051066	0.077482	-0.056654	10.5242
Aero	0.0069594	0.094849	-0.15696	8.5837
Ships	0.0030048	0.079424	-0.062392	8.0279
Guns	0.0043805	0.068813	-0.43537	5.4865
Gold	0.0015973	0.10159	0.045328	5.4733
Mines	0.0047143	0.068044	-0.34487	7.0841
Coal	0.0047757	0.095628	0.8456	12.103
Oil	0.0059451	0.060754	-0.1922	7.0472
Util	0.0043015	0.057741	-0.66145	11.1915
Telcm	0.0043901	0.045997	-0.28203	6.1893
PerSv	0.0025988	0.093276	0.11354	10.0438
BusSv	0.0042681	0.072456	-0.59819	12.1992
Hardw	0.0066108	0.075498	-0.58073	7.5959
Softw	-0.0030999	0.12473	-0.017286	4.9122
Chips	0.0046267	0.089773	-0.45116	7.6968
LabEq	0.0055918	0.071499	-0.67273	5.9033
Paper	0.0026824	0.12503	1.6402	38.3289
Boxes	0.0057555	0.062344	-0.40974	7.9998
Trans	0.0035614	0.071956	-0.059484	11.1324
Whlsl	0.0023061	0.076733	-0.65592	12.9507
Rtail	0.0055025	0.062366	-0.64911	8.9466
Meals	0.005084	0.068991	-0.81814	6.4506
Banks	0.0073061	0.071759	-0.59273	9.0526
Insur	0.0052421	0.076259	-0.54993	16.6633
RlEst	0.0006951	0.096406	-0.40021	10.0395
Fin	0.0055404	0.078418	-0.5249	10.2235
Other	0.0019949	0.075601	-0.54514	6.8812

Table 2: Descriptive statistics for log returns

	LBQ test 0011	LBQ test 1111	LBQ test 0111	LBQ test 1011
Agric	0.1104	0.05015	0.13289	0.13328
Food	0.01481	0.016721	0.018068	0.018377
Soda	0.011869	0.0035459	0.0082053	0.0078574
Beer	0.32141	0.27175	0.3593	0.35192
Smoke	0.5661	0.5055	0.54815	0.54554
Toys	0.10762	0.054437	0.099205	0.099504
Fun	0.0074542	0.0083365	0.018912	0.019745
Books	0.011315	0.012094	0.013773	0.013643
Hshld	0.051172	0.08593	0.065976	0.063399
Clths	0.028758	0.10535	0.09996	0.071099
Hlth	0.021069	0.019017	0.031656	0.03014
MedEq	0.073324	0.12766	0.071623	0.071772
Drugs	0.00090201	0.00068743	0.0017368	0.0018741
Chems	0.044676	0.091434	0.025703	0.028461
Rubbr	0.0094089	0.0057572	0.0043939	0.003261
Txtls	7.3601e-05	0.00043061	0.001966	0.0017128
BldMt	0.25476	0.12649	0.15971	0.15153
Cnstr	0.16701	0.25005	0.22858	0.21956
Steel	0.04418	0.046516	0.036244	0.036755
FabPr	0.074945	0.082679	0.10148	0.10085
Mach	0.0092048	0.0070863	0.0082487	0.0081885
ElcEq	0.070028	0.077363	0.23409	0.22434
Autos	0.032043	0.081924	0.068913	0.064514
Aero	0.12977	0.15091	0.12343	0.12278
Ships	0.062563	0.040418	0.060811	0.060735
Guns	0.13036	0.15322	0.11577	0.11364
Gold	0.0034218	0.0087277	0.0038824	0.0031296
Mines	0.095573	0.074076	0.089648	0.089897
Coal	0.045144	0.027249	0.030753	0.027179
Oil	0.070475	0.048442	0.075821	0.077253
Util	0.055193	0.28068	0.05493	0.055056
Telcm	0.028812	0.039995	0.0342	0.035074
PerSv	0.047925	0.041597	0.12499	0.11665
BusSv	0.068838	0.09558	0.096085	0.092729
Hardw	0.013399	0.0042322	0.012516	0.011815
Softw	0.12182	0.10934	0.14279	0.14092
Chips	0.10853	0.06103	0.10781	0.10766
LabEq	0.11618	0.058514	0.16087	0.16317
Paper	0.01778	0.024734	0.01148	0.011961
Boxes	0.3053	0.20869	0.27144	0.27251
Trans	0.24559	0.087564	0.19479	0.18867
Whlsl	0.0011148	0.00043479	0.0016481	0.0017519
Rtail	0.17088	0.11435	0.17956	0.17624
Meals	0.10961	0.051319	0.13571	0.13869
Banks	0.12351	0.064904	0.1789	0.17647
Insur	0.011405	0.021135	0.011148	0.011084
RlEst	0.00023626	0.20714	0.41059	0.12451
Fin	0.11136	0.18689	0.13345	0.13076
Other	0.035945	0.034803	0.03508	0.035272

Table 3: Ljung-Box Q-test results for GARCH(1,1), ARMA(1,1)-GARCH(1,1), MA(1)-GARCH(1,1), AR(1)-GARCH(1,1)

	LBQ test 0011	LBQ test 1111	LBQ test 0111	LBQ test 1011
Agric	0.039421	0.036418	0.042218	0.042313
Food	0.013906	0.010142	0.018223	0.018224
Soda	0.0029027	0.0053743	0.0031421	0.0029456
Beer	0.30174	0.17975	0.31056	0.30718
Smoke	0.51386	0.36286	0.5375	0.53665
Toys	0.054937	0.034883	0.072045	0.072265
Fun	0.0029348	0.0067887	0.0063381	0.0067774
Books	0.0051651	0.0022861	0.0030029	0.0030034
Hshld	0.044545	0.062484	0.025203	0.025087
Clths	0.028546	0.10342	0.11759	0.07888
Hlth	0.018809	0.054102	0.065517	0.062753
MedEq	0.054825	0.1129	0.062177	0.062375
Drugs	0.00031606	0.00034114	0.0010799	0.0011366
Chems	0.024431	0.083776	0.020976	0.0224
Rubbr	0.0080966	0.0024624	0.004583	0.0034302
Txtls	1.2843e-05	0.00067529	0.0006564	0.00036223
BldMt	0.17571	0.10278	0.10649	0.10163
Cnstr	0.15305	0.1604	0.20776	0.19992
Steel	0.034839	0.010547	0.0278	0.028283
FabPr	0.065105	0.035214	0.090309	0.090425
Mach	0.008474	0.0063764	0.0075272	0.0075049
ElcEq	0.035144	0.055132	0.095807	0.091474
Autos	0.030551	0.040942	0.065399	0.061591
Aero	0.1247	0.057056	0.082837	0.083712
Ships	0.046361	0.0314	0.026441	0.026594
Guns	0.12067	0.079138	0.15059	0.14641
Gold	0.0012546	0.0014173	0.0040359	0.0034253
Mines	0.056021	0.050101	0.069849	0.069985
Coal	0.043578	0.012065	0.013729	0.011334
Oil	0.029524	0.014026	0.032061	0.032759
Util	0.055071	0.27409	0.058799	0.058583
Telcm	0.0077346	0.032781	0.0094603	0.0096378
PerSv	0.013701	0.032114	0.032473	0.030597
BusSv	0.050663	0.067719	0.075358	0.073216
Hardw	0.0047234	0.00094676	0.0043712	0.0041121
Softw	0.11393	0.086783	0.13212	0.13024
Chips	0.057183	0.056914	0.065343	0.065176
LabEq	0.060175	0.03502	0.089422	0.091159
Paper	0.0090089	0.0083356	0.015513	0.015264
Boxes	0.20347	0.11359	0.21057	0.21773
Trans	0.13683	0.061348	0.067132	0.064935
Whlsl	0.00044143	1.6568e-05	0.00036033	0.00047552
Rtail	0.12178	0.053225	0.11435	0.11188
Meals	0.035484	0.020994	0.0201	0.021371
Banks	0.10032	0.021809	0.16532	0.16269
Insur	0.0075124	0.00096589	0.0020415	0.0018101
RlEst	0.00013798	0.12245	0.17755	0.071688
Fin	0.0372	0.19895	0.053751	0.051562
Other	0.034206	0.038543	0.040168	0.040301

Table 4: Ljung-Box Q-test results for GJR(1,1), ARMA(1,1)-GJR(1,1), MA(1)-GJR(1,1), AR(1)-GJR(1,1)

	Mean	Volatility	Skewness	Kurtosis	VaR
Momentum 1	0.088	0.095	-5.307	52.196	-0.118
Momentum 2	0.088	0.151	-1.110	52.698	-0.265
Momentum 3	0.127	0.166	-2.823	42.091	-0.239
Momentum 4	-0.034	0.229	-3.613	100.078	-0.294
Momentum 5	0.046	0.074	-13.603	91.678	-0.085
Gross Exposure	0.032	0.126	-23.789	164.331	-0.173
Gross Exposure Garch	0.106	0.257	-7.177	50.005	-0.468
Max Sharpe Ratio	0.060	0.149	-9.018	56.654	-0.290
Max Sharpe Ratio Shrinkage	0.072	0.149	-8.888	56.792	-0.298
Max Sharpe Ratio Garch	0.085	0.154	-7.645	51.549	-0.289
Global Min Variance	0.073	0.133	-16.183	97.303	-0.213
Global Min Variance Shrinkage	0.069	0.132	-15.162	90.010	-0.224
Global Min Variance Garch	0.103	0.130	-14.599	82.164	-0.198
PCA Equally Weighted	0.020	0.047	-1.340	46.312	-0.063
PCA Risk Parity	0.007	0.031	1.144	38.164	-0.045
Risk Parity	0.098	0.162	-9.126	70.808	-0.263
Risk Parity Shrinkage	0.098	0.164	-8.850	70.717	-0.265
Risk Parity Garch	0.099	0.161	-9.478	68.721	-0.258
Betting against Beta	0.053	0.048	0.141	39.849	-0.065
FOA	0.062	0.149	-8.922	56.330	-0.292
FOA2	0.137	0.189	1.203	48.945	-0.319
FOA3	0.084	0.148	-9.055	59.563	-0.246
CMA Replication	0.025	0.057	1.246	48.492	-0.093
HML Replication	0.006	0.106	-23.551	219.338	-0.114
MKT Replication	0.079	0.152	-8.537	73.559	-0.232
RMW Replication	0.018	0.047	-9.299	56.523	-0.065
SMB Replication	0.033	0.075	0.495	47.064	-0.101
Zero Exposure	0.034	0.069	-31.316	247.877	-0.109
GE Static	0.011	0.126	-23.790	164.354	-0.177
GMV Static	0.078	0.132	-16.133	98.460	-0.186
MSR Static	0.080	0.144	-8.668	65.150	-0.230
GE GJR	0.108	0.255	-7.378	45.003	-0.466
GMV GJR	0.114	0.126	-14.159	89.829	-0.190
MSR GJR	0.091	0.157	-8.156	50.704	-0.307
Risk Parity GJR	0.100	0.161	-9.596	70.022	-0.260
Reversal 1	-0.073	0.165	13.437	76.102	-0.250
Reversal 2	0.092	0.243	2.680	94.914	-0.334
Reversal 3	0.009	0.088	19.186	125.893	-0.118
Eq. Weighted	0.099	0.174	-7.130	70.906	-0.276
Eq. Weighted Top	0.091	0.192	-4.954	59.304	-0.320

Table 5: Descriptive statistics values for total returns

	Mean	Volatility	Skewness	Kurtosis	VaR
Momentum 1	16	10	14	12	10
Momentum 2	15	24	9	13	28
Momentum 3	2	33	11	3	21
Momentum 4	39	37	12	35	33
Momentum 5	28	7	31	31	5
Gross Exposure	31	14	38	37	12
Gross Exposure Garch	5	40	16	9	40
Max Sharpe Ratio	26	23	25	16	31
Max Sharpe Ratio Shrinkage	23	22	23	17	34
Max Sharpe Ratio Garch	17	26	18	11	30
Global Min Variance	22	18	36	33	17
Global Min Variance Shrinkage	24	17	34	30	18
Global Min Variance Garch	6	15	33	28	16
PCA Equally Weighted	33	3	10	5	2
PCA Risk Parity	37	1	6	1	1
Risk Parity	11	30	27	24	26
Risk Parity Shrinkage	10	31	22	23	27
Risk Parity Garch	8	28	29	21	24
Betting against Beta	27	4	8	2	3
FOA	25	21	24	14	32
FOA2	1	35	5	8	36
FOA3	18	20	26	19	22
CMA Replication	32	5	4	7	6
HML Replication	38	11	37	39	9
MKT Replication	20	25	20	26	20
RMW Replication	34	2	28	15	4
SMB Replication	30	8	7	6	7
Zero Exposure	29	6	40	40	8
GE Static	35	12	39	38	13
GMV Static	21	16	35	34	14
MSR Static	19	19	21	20	19
GE GJR	4	39	17	4	39
GMV GJR	3	13	32	29	15
MSR GJR	14	27	19	10	35
Risk Parity GJR	7	29	30	22	25
Reversal 1	40	32	2	27	23
Reversal 2	12	38	3	32	38
Reversal 3	36	9	1	36	11
Eq. Weighted	9	34	15	25	29
Eq. Weighted Top	13	36	13	18	37

Table 6: Descriptive statistics ranking for total returns

	Mean	Volatility	Skewness	Kurtosis	VaR
Momentum 1	0.078	0.095	-4.961	52.291	-0.129
Momentum 2	0.078	0.151	-0.717	52.605	-0.266
Momentum 3	0.118	0.166	-2.591	42.082	-0.240
Momentum 4	-0.044	0.229	-3.319	100.043	-0.295
Momentum 5	0.037	0.074	-13.021	91.221	-0.086
Gross Exposure	0.022	0.126	-23.708	164.460	-0.174
Gross Exposure Garch	0.097	0.257	-7.154	49.773	-0.468
Max Sharpe Ratio	0.051	0.149	-8.662	56.347	-0.290
Max Sharpe Ratio Shrinkage	0.062	0.149	-8.555	56.467	-0.298
Max Sharpe Ratio Garch	0.076	0.154	-7.387	51.402	-0.290
Global Min Variance	0.064	0.133	-15.749	96.425	-0.214
Global Min Variance Shrinkage	0.060	0.132	-14.742	89.276	-0.225
Global Min Variance Garch	0.094	0.130	-14.152	81.231	-0.203
PCA Equally Weighted	0.011	0.047	-0.351	46.753	-0.063
PCA Risk Parity	-0.002	0.030	2.106	39.284	-0.047
Risk Parity	0.088	0.162	-8.729	70.319	-0.263
Risk Parity Shrinkage	0.089	0.164	-8.461	70.258	-0.265
Risk Parity Garch	0.090	0.161	-9.085	68.211	-0.259
Betting against Beta	0.044	0.048	0.751	38.977	-0.067
FOA	0.052	0.149	-8.571	56.032	-0.293
FOA2	0.127	0.188	0.855	48.323	-0.321
FOA3	0.075	0.148	-8.641	59.082	-0.246
CMA Replication	0.016	0.057	1.909	49.420	-0.098
HML Replication	-0.003	0.107	-23.615	222.416	-0.115
MKT Replication	0.070	0.152	-8.117	73.077	-0.232
RMW Replication	0.008	0.047	-8.381	55.432	-0.066
SMB Replication	0.024	0.075	0.871	47.736	-0.114
Zero Exposure	0.025	0.068	-31.316	251.299	-0.110
GE Static	0.002	0.126	-23.752	164.944	-0.177
GMV Static	0.068	0.132	-15.690	97.621	-0.192
MSR Static	0.070	0.144	-8.255	64.710	-0.231
GE GJR	0.098	0.255	-7.363	44.808	-0.469
GMV GJR	0.104	0.126	-13.650	88.600	-0.193
MSR GJR	0.082	0.156	-7.903	50.554	-0.312
Risk Parity GJR	0.090	0.161	-9.198	69.492	-0.261
Reversal 1	-0.083	0.166	13.522	76.754	-0.250
Reversal 2	0.082	0.243	2.991	95.122	-0.334
Reversal 3	-0.000	0.088	19.548	127.457	-0.119
Eq. Weighted	0.089	0.175	-6.873	70.714	-0.276
Eq. Weighted Top	0.082	0.192	-4.745	59.277	-0.320

Table 7: Descriptive statistics values for excess returns

	Mean	Volatility	Skewness	Kurtosis	VaR
Momentum 1	16	10	14	12	11
Momentum 2	15	24	10	13	28
Momentum 3	2	33	11	3	21
Momentum 4	39	37	12	35	33
Momentum 5	28	7	31	31	5
Gross Exposure	31	13	38	37	12
Gross Exposure Garch	5	40	16	9	39
Max Sharpe Ratio	26	23	27	16	31
Max Sharpe Ratio Shrinkage	23	22	24	17	34
Max Sharpe Ratio Garch	17	26	18	11	30
Global Min Variance	22	18	36	33	17
Global Min Variance Shrinkage	24	17	34	30	18
Global Min Variance Garch	6	15	33	28	16
PCA Equally Weighted	33	3	9	5	2
PCA Risk Parity	37	1	4	2	1
Risk Parity	11	30	28	24	26
Risk Parity Shrinkage	10	31	23	23	27
Risk Parity Garch	8	28	29	21	24
Betting against Beta	27	4	8	1	4
FOA	25	21	25	15	32
FOA2	1	35	7	7	37
FOA3	18	20	26	18	22
CMA Replication	32	5	5	8	6
HML Replication	38	11	37	39	9
MKT Replication	20	25	20	26	20
RMW Replication	34	2	22	14	3
SMB Replication	30	8	6	6	8
Zero Exposure	29	6	40	40	7
GE Static	35	12	39	38	13
GMV Static	21	16	35	34	14
MSR Static	19	19	21	20	19
GE GJR	4	39	17	4	40
GMV GJR	3	14	32	29	15
MSR GJR	14	27	19	10	35
Risk Parity GJR	7	29	30	22	25
Reversal 1	40	32	2	27	23
Reversal 2	12	38	3	32	38
Reversal 3	36	9	1	36	10
Eq. Weighted	9	34	15	25	29
Eq. Weighted Top	13	36	13	19	36

Table 8: Descriptive statistics ranking for excess returns

	Sharpe Ratio	Semi Vol.	Sortino Ratio	Inf. Ratio	Jensen Alpha	Treynor Ratio	App. Ratio
Momentum 1	0.827	0.069	1.141	-0.008	0.075	2.124	0.019
Momentum 2	0.518	0.110	0.714	-0.006	0.082	-2.001	0.013
Momentum 3	0.710	0.120	0.982	0.187	0.103	0.633	0.015
Momentum 4	-0.192	0.160	-0.274	-0.420	-0.025	0.180	-0.003
Momentum 5	0.502	0.057	0.652	-0.248	0.039	-1.281	0.013
Gross Exposure	0.177	0.101	0.220	-0.275	0.030	-0.226	0.006
GE Garch	0.377	0.193	0.501	0.058	0.095	3.500	0.009
MSR	0.341	0.114	0.445	-0.142	0.043	0.527	0.007
MSR Shrinkage	0.418	0.114	0.547	-0.087	0.054	0.635	0.009
MSR Garch	0.492	0.117	0.650	-0.019	0.066	0.606	0.010
GMV	0.479	0.104	0.609	-0.085	0.056	0.687	0.010
GMV Shrinkage	0.451	0.104	0.575	-0.106	0.052	0.661	0.010
GMV Garch	0.720	0.102	0.915	0.074	0.088	1.206	0.016
PCA Eq. Weighted	0.224	0.033	0.318	-0.447	0.008	0.377	0.004
PCA Risk Parity	-0.067	0.021	-0.096	-0.530	-0.002	-0.610	-0.002
Risk Parity	0.546	0.123	0.717	0.042	0.078	0.657	0.012
Risk Parity Shrink	0.541	0.125	0.712	0.044	0.078	0.641	0.011
Risk Parity Garch	0.558	0.123	0.730	0.049	0.079	0.666	0.012
Betting against Beta	0.909	0.034	1.281	-0.222	0.046	-1.745	0.023
FOA	0.352	0.114	0.460	-0.136	0.045	0.550	0.007
FOA2	0.678	0.132	0.968	0.203	0.123	2.140	0.016
FOA3	0.505	0.113	0.663	-0.025	0.068	0.849	0.011
CMA Replication	0.275	0.040	0.390	-0.408	0.013	0.426	0.005
HML Replication	-0.031	0.082	-0.041	-0.477	-0.011	-0.037	-0.002
MKT Replication	0.458	0.115	0.605	-0.050	0.058	0.487	0.009
RMW Replication	0.176	0.035	0.231	-0.450	0.008	-3.967	0.004
SMB Replication	0.321	0.052	0.461	-0.350	0.018	0.344	0.006
Zero Exposure	0.366	0.057	0.441	-0.337	0.023	0.937	0.008
GE Static	0.013	0.101	0.016	-0.382	0.007	-0.025	0.001
GMV Static	0.518	0.104	0.661	-0.059	0.062	0.838	0.011
MSR Static	0.489	0.109	0.648	-0.047	0.060	0.552	0.010
GE GJR	0.385	0.193	0.510	0.063	0.096	3.222	0.009
GMV GJR	0.826	0.098	1.067	0.131	0.099	1.432	0.019
MSR GJR	0.521	0.119	0.686	0.009	0.070	0.574	0.011
Risk Parity GJR	0.561	0.123	0.734	0.052	0.079	0.642	0.012
Reversal 1	-0.499	0.103	-0.799	-0.695	-0.076	0.940	-0.011
Reversal 2	0.340	0.170	0.484	0.010	0.064	0.349	0.006
Reversal 3	-0.001	0.053	-0.002	-0.482	-0.006	-0.002	-0.002
Eq. Weighted	0.511	0.131	0.683	0.235	-0.001	0.079	-0.000
Eq. Weighted Top	0.427	0.143	0.575	0.037	-0.015	0.068	-0.007

Table 9: Risk adjusted and model based risk measures values

	Sharpe Ratio	Semi Vol.	Sortino Ratio	Inf. Ratio	Jensen Alpha	Treynor Ratio	App. Ratio
Momentum 1	2	10	2	16	12	4	2
Momentum 2	13	21	10	15	7	39	7
Momentum 3	5	29	4	3	2	18	6
Momentum 4	39	37	39	34	39	29	38
Momentum 5	16	9	16	28	26	37	8
GE	33	14	34	29	27	35	29
GE Garch	25	40	25	7	5	1	22
MSR	28	25	29	26	25	23	26
MSR Shrinkage	23	23	23	23	21	17	23
MSR Garch	17	27	17	17	15	19	16
GMV	19	19	19	22	20	11	17
GMV Shrink	21	18	22	24	22	13	19
GMV Garch	4	15	6	5	6	6	4
PCA Eq. Weighted	32	2	32	35	32	26	32
PCA Risk Parity	38	1	38	39	35	36	36
Risk Parity	9	32	9	11	11	14	11
Risk Parity Shrinkage	10	33	11	10	10	16	12
Risk Parity Garch	8	30	8	9	8	12	9
Betting against Beta	1	3	1	27	23	38	1
FOA	27	24	28	25	24	22	25
FOA2	6	35	5	2	1	3	5
FOA3	15	22	14	18	14	9	14
CMA Replication	31	5	31	33	30	25	30
HML Replication	37	11	37	37	37	34	37
MKT Replication	20	26	20	20	19	24	20
RMW Replication	34	4	33	36	31	40	31
SMB Replication	30	6	27	31	29	28	28
Zero Exposure	26	8	30	30	28	8	24
GE Static	35	13	35	32	33	33	33
GMV Static	12	17	15	21	17	10	13
MSR Static	18	20	18	19	18	21	18
GE GJR	24	39	24	6	4	2	21
GMV GJR	3	12	3	4	3	5	3
MSR GJR	11	28	12	14	13	20	15
Risk Parity GJR	7	31	7	8	9	15	10
Reversal 1	40	16	40	40	40	7	40
Reversal 2	29	38	26	13	16	27	27
Reversal 3	36	7	36	38	36	32	35
Eq. Weighted	14	34	13	1	34	30	34
Eq. Weighted Top	22	36	21	12	38	31	39

Table 10: Risk adjusted and model based risk measures ranking

	Intercept	r_m	R^2_{adj}
Equally Weighted	0.000	1.130	0.958
Equally Weighted Top 10	-0.001	1.216	0.919
PCA Equally Weighted	-0.001	0.217	0.486
Global Min Variance	-0.000	0.822	0.880
Global Min Variance, shrinkage	-0.000	0.820	0.883
Global Minimum Variance Static	0.000	0.814	0.870
Global Minimum Variance Garch	0.002	0.814	0.895
Global Minimum Variance GJR	0.003	0.712	0.808
4th order Minimum Risk	0.001	0.859	0.777
Max Sharpe Ratio	0.000	0.612	0.381
Max Sharpe Ratio, shrinkage	0.001	0.628	0.404
Max Sharpe Ratio Static	0.002	0.627	0.431
Max Sharpe Ratio Garch	0.002	0.663	0.421
Max Sharpe Ratio GJR	0.002	0.595	0.366
4th order Sharpe ratio	0.000	0.614	0.387
Risk Parity	0.000	1.055	0.976
Risk Parity, shrinkage	0.000	1.070	0.975
PCA Risk Parity	-0.001	0.081	0.156
Risk Parity Garch	0.001	1.050	0.977
Risk Parity GJR	0.000	0.937	0.860
Gross Exposure	0.002	-0.002	-0.008
Gross Exposure Static	-0.000	0.039	-0.005
Gross Exposure Garch	0.005	0.425	0.056
Gross Exposure GJR	0.007	0.391	0.072
Betting Against Beta	0.004	-0.002	-0.008
MKT Replication	-0.001	0.986	0.963
SMB Replication	0.000	0.261	0.275
HML Replication	-0.001	0.185	0.062
RMW Replication	0.001	-0.052	0.021
CMA Replication	0.001	0.098	0.060
Zero Exposure Replication	0.001	0.187	0.166
Momentum1	0.004	0.392	0.387
Momentum2	0.008	-0.217	0.040
Momentum3	0.004	0.961	0.767
Momentum4	0.005	-1.357	0.807
Momentum5	0.004	-0.198	0.160
Reversal1	-0.001	-0.946	0.747
Reversal2	-0.002	1.406	0.769
Reversal3	-0.002	0.230	0.148
Fourth Order Utility Expansion	0.006	0.685	0.300

Table 11: Risk factor exposures in the CAPM model

	Intercept	r_m	SMB	HML	R^2_{adj}
Equally Weighted	0.000	1.081	0.204	0.046	0.966
Equally Weighted Top 10	-0.001	1.169	0.169	0.074	0.924
PCA Equally Weighted	-0.001	0.215	0.053	-0.045	0.492
Global Min Variance	-0.000	0.855	-0.108	-0.063	0.884
Global Min Variance, shrinkage	-0.000	0.861	-0.101	-0.107	0.890
Global Minimum Variance Static	0.000	0.850	-0.101	-0.084	0.875
Global Minimum Variance Garch	0.002	0.857	-0.144	-0.080	0.903
Global Minimum Variance GJR	0.003	0.719	-0.058	0.026	0.806
4th order Minimum Risk	0.000	0.887	-0.039	-0.105	0.778
Max Sharpe Ratio	-0.000	0.765	-0.410	-0.375	0.468
Max Sharpe Ratio, shrinkage	0.001	0.774	-0.374	-0.377	0.486
Max Sharpe Ratio Static	0.001	0.765	-0.243	-0.467	0.526
Max Sharpe Ratio Garch	0.002	0.829	-0.397	-0.456	0.523
Max Sharpe Ratio GJR	0.002	0.722	-0.347	-0.305	0.424
4th order Sharpe ratio	-0.000	0.760	-0.392	-0.361	0.467
Risk Parity	0.000	1.027	0.124	0.021	0.979
Risk Parity, shrinkage	0.000	1.038	0.140	0.025	0.979
PCA Risk Parity	-0.001	0.083	0.032	-0.044	0.165
Risk Parity Garch	0.001	1.021	0.133	0.018	0.981
Risk Parity GJR	0.001	0.902	0.108	0.072	0.863
Gross Exposure	0.001	0.168	-0.195	-0.682	0.231
Gross Exposure Static	-0.001	0.202	-0.164	-0.677	0.226
Gross Exposure Garch	0.004	0.777	-0.651	-1.161	0.248
Gross Exposure GJR	0.006	0.603	-0.307	-0.786	0.184
Betting Against Beta	0.004	0.069	-0.284	-0.081	0.203
MKT Replication	-0.001	0.955	0.134	0.022	0.967
SMB Replication	0.000	0.224	0.206	-0.015	0.307
HML Replication	-0.001	0.086	0.122	0.391	0.164
RMW Replication	0.001	0.011	-0.189	-0.134	0.171
CMA Replication	0.001	0.123	-0.076	-0.051	0.062
Zero Exposure Replication	0.001	0.221	-0.118	-0.060	0.177
Momentum1	0.004	0.400	-0.021	-0.025	0.378
Momentum2	0.008	-0.199	-0.042	-0.049	0.026
Momentum3	0.004	0.945	0.124	-0.040	0.767
Momentum4	0.005	-1.271	-0.364	-0.075	0.819
Momentum5	0.004	-0.163	-0.120	-0.057	0.167
Reversal1	-0.000	-1.014	-0.099	0.451	0.804
Reversal2	-0.002	1.245	0.296	0.531	0.813
Reversal3	-0.001	0.115	0.099	0.491	0.393
Fourth Order Utility Expansion	0.006	0.807	-0.096	-0.535	0.356

Table 12: Risk factor exposures in the Fama-French 3-factor model

	Intercept	r_m	SMB	HML	WML	R^2_{adj}
Equally Weighted	0.001	1.058	0.214	-0.011	-0.113	0.971
Equally Weighted Top 10	-0.000	1.133	0.185	-0.013	-0.171	0.933
PCA Equally Weighted	-0.000	0.208	0.056	-0.063	-0.035	0.495
GMV	-0.000	0.860	-0.110	-0.051	0.024	0.883
GMV, shrinkage	-0.001	0.872	-0.106	-0.079	0.056	0.891
GMV Static	0.000	0.853	-0.103	-0.076	0.016	0.874
GMV Garch	0.002	0.879	-0.154	-0.027	0.105	0.911
GMV GJR	0.003	0.728	-0.062	0.049	0.046	0.807
4th order Minimum Risk	-0.000	0.913	-0.050	-0.042	0.123	0.785
Max Sharpe Ratio	-0.001	0.790	-0.421	-0.314	0.121	0.472
Max Sharpe Ratio, shrinkage	0.000	0.808	-0.389	-0.297	0.159	0.496
Max Sharpe Ratio Static	0.001	0.793	-0.256	-0.400	0.132	0.533
Max Sharpe Ratio Garch	0.001	0.872	-0.416	-0.352	0.206	0.542
Max Sharpe Ratio GJR	0.001	0.766	-0.366	-0.200	0.208	0.444
4th order Sharpe ratio	-0.001	0.785	-0.403	-0.300	0.120	0.471
Risk Parity	0.001	1.012	0.131	-0.015	-0.072	0.982
Risk Parity, shrinkage	0.001	1.021	0.147	-0.015	-0.079	0.981
PCA Risk Parity	-0.001	0.076	0.035	-0.061	-0.034	0.175
Risk Parity Garch	0.001	1.008	0.138	-0.012	-0.059	0.982
Risk Parity GJR	0.001	0.899	0.109	0.066	-0.014	0.862
Gross Exposure	-0.001	0.292	-0.249	-0.385	0.590	0.502
Gross Exposure Static	-0.003	0.322	-0.216	-0.388	0.571	0.481
Gross Exposure Garch	-0.000	0.996	-0.747	-0.634	1.044	0.452
Gross Exposure GJR	0.002	0.795	-0.391	-0.323	0.917	0.417
Betting Against Beta	0.003	0.088	-0.293	-0.035	0.091	0.242
MKT Replication	-0.000	0.933	0.144	-0.031	-0.105	0.973
SMB Replication	0.000	0.224	0.206	-0.014	0.001	0.301
HML Replication	-0.001	0.079	0.125	0.375	-0.031	0.159
RMW Replication	0.001	0.025	-0.195	-0.099	0.069	0.192
CMA Replication	0.000	0.142	-0.084	-0.004	0.093	0.089
Zero Exposure Replication	0.000	0.238	-0.125	-0.020	0.081	0.188
Momentum1	0.004	0.420	-0.030	0.022	0.092	0.385
Momentum2	0.007	-0.161	-0.059	0.043	0.183	0.037
Momentum3	0.003	0.956	0.119	-0.012	0.056	0.767
Momentum4	0.003	-1.181	-0.404	0.143	0.432	0.863
Momentum5	0.003	-0.112	-0.143	0.066	0.244	0.300
Reversal1	0.001	-1.054	-0.081	0.356	-0.187	0.819
Reversal2	0.001	1.129	0.346	0.252	-0.553	0.878
Reversal3	0.001	0.038	0.132	0.304	-0.370	0.610
F4th Utility Expansion	0.004	0.887	-0.130	-0.343	0.380	0.403

Table 13: Risk factor exposures in the Carhart model

	Intercept	r_m	SMB	HML	RMW	CMA	R^2_{adj}
Equally Weighted	0.010	0.685	0.446	-0.855	-0.511	-1.211	0.346
Equally Weighted Top 10	0.010	0.687	0.532	-0.939	-0.632	-0.834	0.330
PCA Equally Weighted	0.001	0.156	0.038	-0.124	-0.102	-0.081	0.121
GMV	0.008	0.273	0.257	-0.702	-0.287	-0.828	0.195
GMV, shrinkage	0.007	0.270	0.201	-0.749	-0.249	-0.704	0.192
GMV Static	0.008	0.281	0.214	-0.684	-0.208	-0.883	0.178
GMV Garch	0.011	0.231	0.240	-0.703	-0.255	-1.101	0.180
GMV GJR	0.010	0.249	0.289	-0.626	-0.242	-1.323	0.221
4th order Minimum Risk	0.008	0.345	0.140	-0.747	-0.004	-1.009	0.161
MSR	0.008	-0.144	-0.187	-0.959	0.176	-1.119	0.068
MSR, shrink	0.008	-0.093	-0.163	-0.905	0.089	-0.861	0.060
MSR Static	0.009	0.046	-0.269	-0.817	0.105	-1.410	0.068
MSR Garch	0.010	-0.116	-0.227	-1.054	0.066	-0.476	0.087
MSR GJR	0.009	-0.122	-0.088	-0.963	-0.013	-0.082	0.074
4th order Sharpe ratio	0.008	-0.126	-0.175	-0.950	0.170	-1.162	0.068
Risk Parity	0.010	0.580	0.397	-0.824	-0.439	-1.420	0.323
Risk Parity, shrinkage	0.010	0.600	0.406	-0.833	-0.454	-1.375	0.329
PCA Risk Parity	-0.000	0.077	-0.004	-0.025	-0.067	0.010	0.025
Risk Parity Garch	0.011	0.579	0.388	-0.840	-0.429	-1.399	0.328
Risk Parity GJR	0.010	0.479	0.399	-0.828	-0.399	-1.273	0.313
Gross Exposure	0.002	-0.209	-0.730	-0.447	0.371	0.980	0.228
Gross Exposure Static	0.000	-0.170	-0.637	-0.461	0.071	1.403	0.203
Gross Exposure Garch	0.011	-0.351	-0.705	-0.711	-0.589	1.007	0.098
Gross Exposure GJR	0.010	-0.095	-0.495	-0.628	-0.350	1.910	0.050
Betting Against Beta	0.004	-0.235	-0.043	0.007	0.097	-0.277	0.162
MKT Replication	0.009	0.547	0.392	-0.802	-0.503	-1.367	0.343
SMB Replication	0.001	0.303	-0.018	-0.262	0.085	1.345	0.175
HML Replication	0.002	0.228	0.370	0.219	0.208	-4.243	0.207
RMW Replication	0.001	-0.206	-0.146	-0.091	0.136	-0.436	0.191
CMA Replication	0.002	-0.048	-0.100	-0.205	0.320	-0.788	0.040
Zero Exp. Replication	0.003	-0.078	-0.027	-0.410	0.094	0.598	0.054
Momentum1	0.009	0.105	0.047	-0.484	0.116	-1.454	0.100
Momentum2	0.007	-0.209	-0.299	-0.085	0.713	-1.157	0.023
Momentum3	0.011	0.549	0.256	-0.764	-0.230	-0.081	0.223
Momentum4	-0.007	-0.942	-0.621	0.972	0.950	1.394	0.343
Momentum5	0.002	-0.196	-0.183	0.104	0.360	0.657	0.125
Reversal1	-0.009	-0.545	-0.028	0.782	0.810	-0.721	0.221
Reversal2	0.009	0.881	0.938	-0.937	-0.423	-0.952	0.375
Reversal3	0.000	0.168	0.455	-0.078	0.193	-0.837	0.368
4th Utility Expansion	0.008	0.290	-0.147	-0.650	-0.640	5.907	0.091

Table 14: Risk factor exposures in the Fama-French 5-factor model

References