1 Configuration

Parameter	Value
risk factors path	None
ptf spec path	inputs/portfolio.csv
load from csv	False
start	2019-01-01
end	2021-06-30
confidence	0.95
n mc scenarios	2000
hs period	500
VaR horizon	10
n bootstrap	10000
lmbda	0.94
rf estim method	ledoit_wolf
vol period	500
corr period	250
lsmc simulations	50
lsmc granularity	50
amer opt p method	crr
crr tree height	50
option pricing	quantlib
bt horizon	W
estimation window	52
riskfree rate	0.0
jarque bera alpha	0.01
cov estim method	ledoit_wolf
nan threshold	0.1

Table 1: Model Configuration

2 Risk Factors

Date	FB	AAPL	GOOG	AMZN
2021-06-29	352.0	136.0	2520.0	3448.0
2021-06-28	356	135	2536	3444
2021-06-25	341	133	2540	3401
2021-06-24	343	133	2546	3449
2021-06-23	341	134	2529	3504
...	...	...	...	...

Table 2: Risk Factor Prices

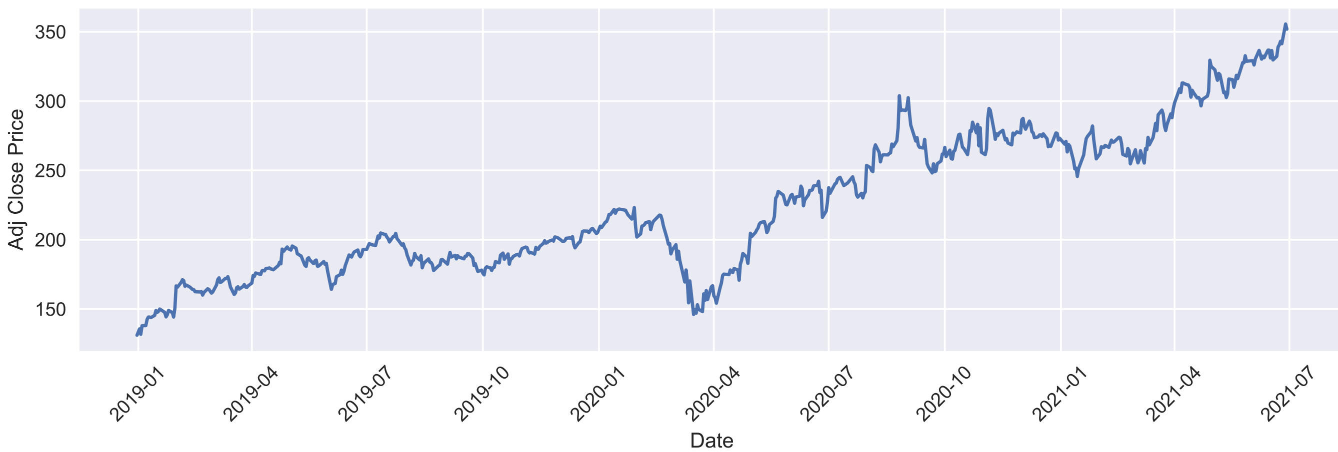

Figure 1: FB Prices

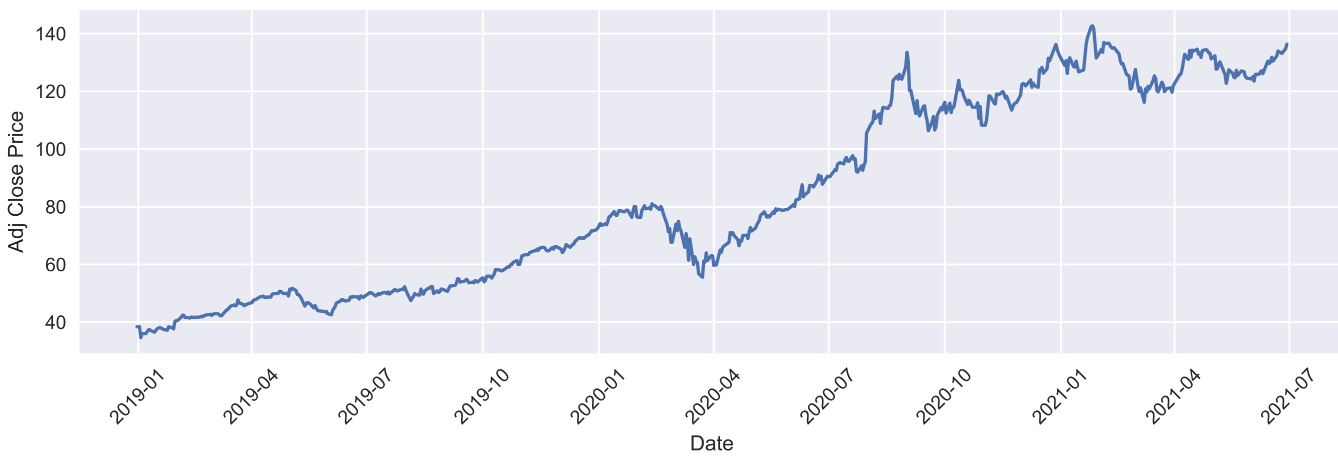

Figure 2: AAPL Prices

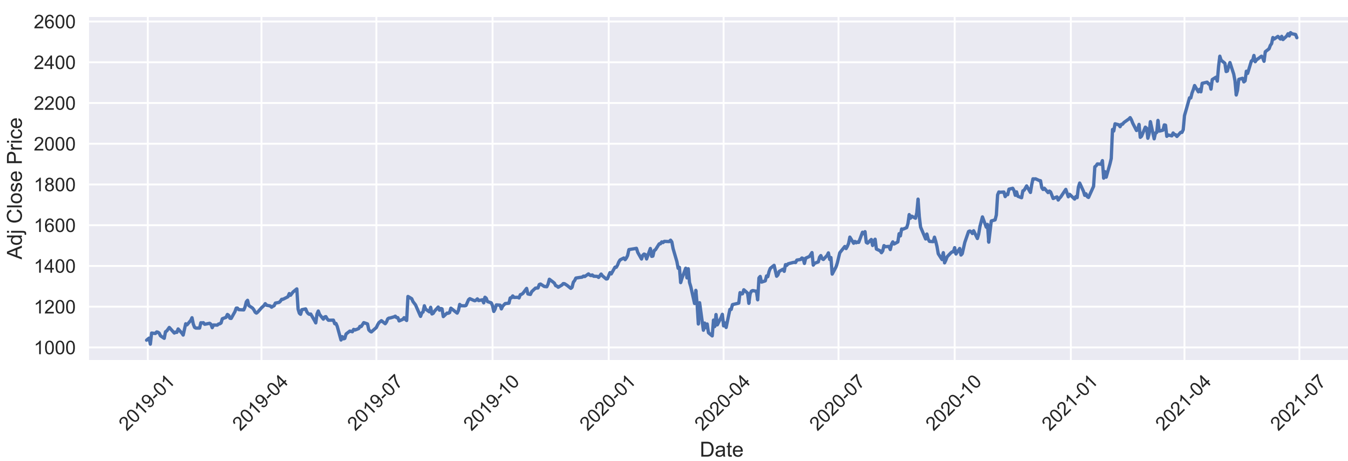

Figure 3: GOOG Prices

Figure 4: AMZN Prices

Date	FB	AAPL	GOOG	AMZN
2021-06-29	-0.0106	0.0114	-0.0063	0.0012
2021-06-28	0.041	0.0125	-0.0014	0.0124
2021-06-25	-0.0053	-0.0023	-0.0023	-0.0139
2021-06-24	0.0076	-0.0022	0.0065	-0.0157
2021-06-23	0.0046	-0.0021	-0.0042	-0.0005
...	...	...	...	...

Table 3: Risk Factor Log Returns

Figure 5: FB Returns

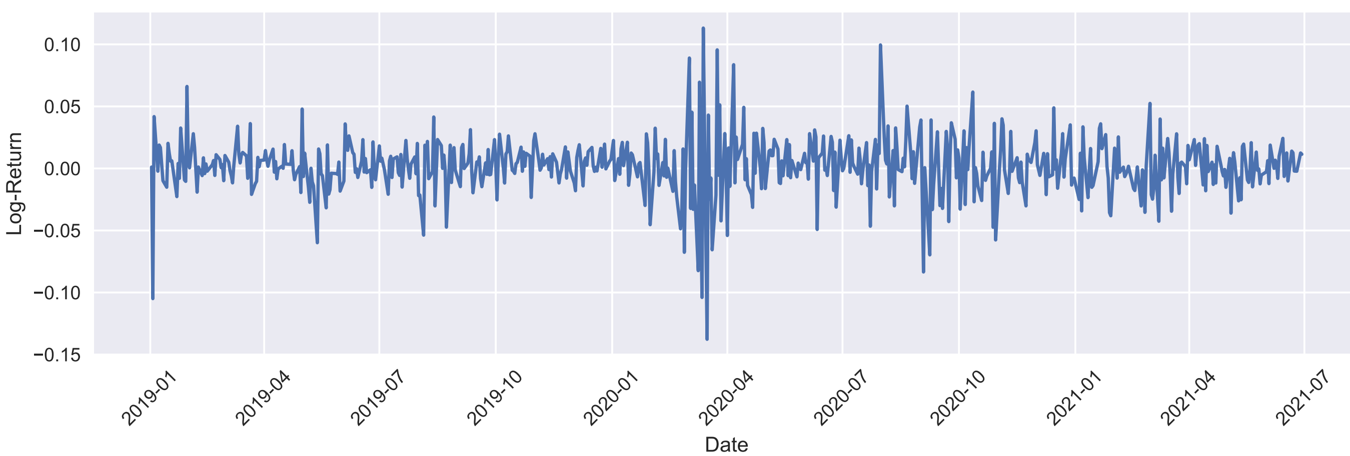

Figure 6: AAPL Returns

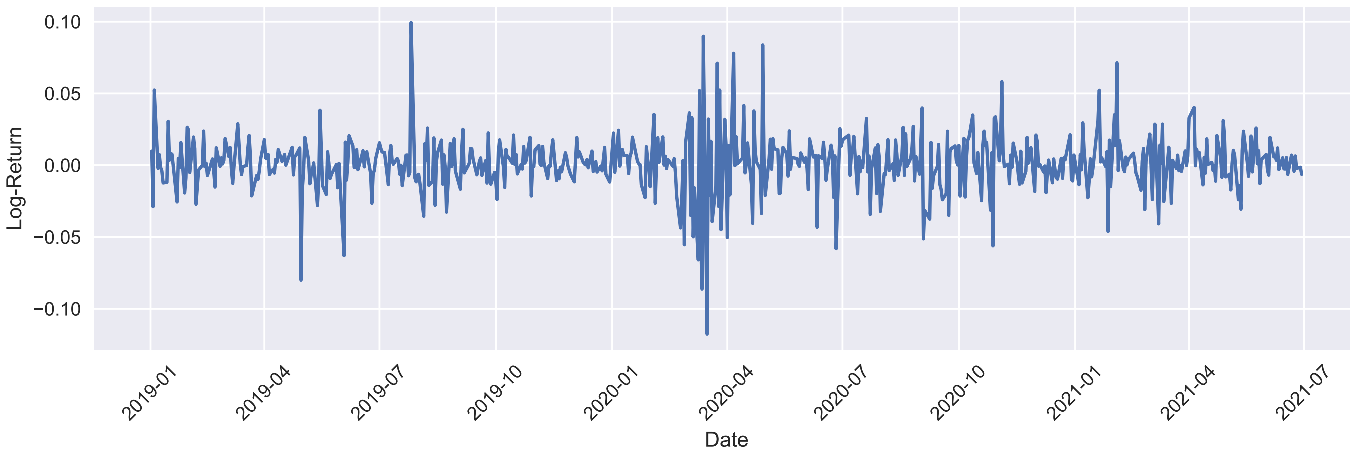

Figure 7: GOOG Returns

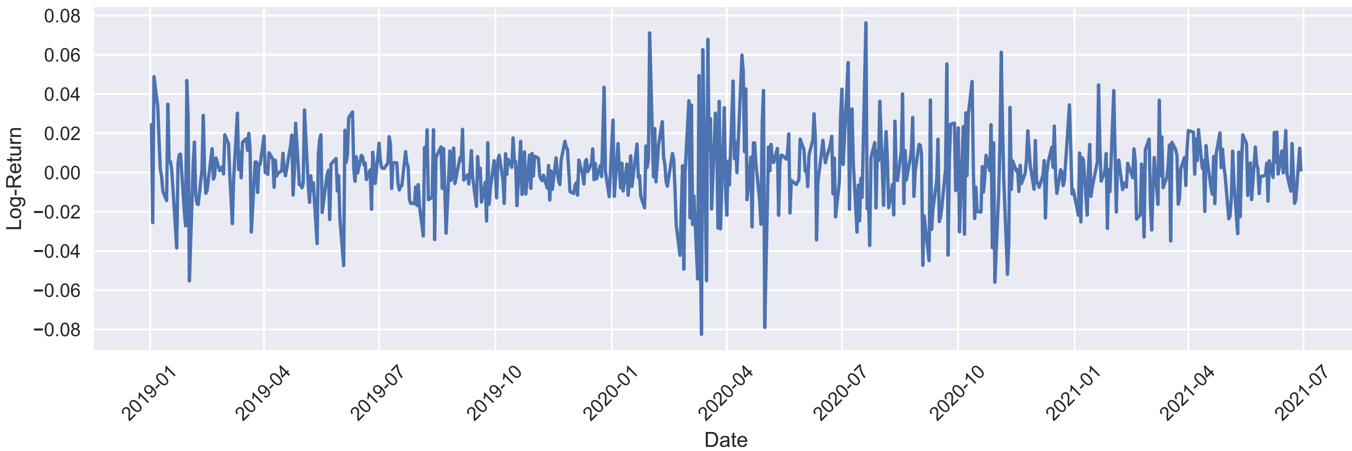

Figure 8: AMZN Returns

	sample	ledoit_wolf	ewma
FB	0.0238	0.0238	0.0172
AAPL	0.0237	0.0237	0.0117
GOOG	0.0203	0.0204	0.0095
AMZN	0.0196	0.0197	0.0123

Table 4: Risk Factor Volatilities

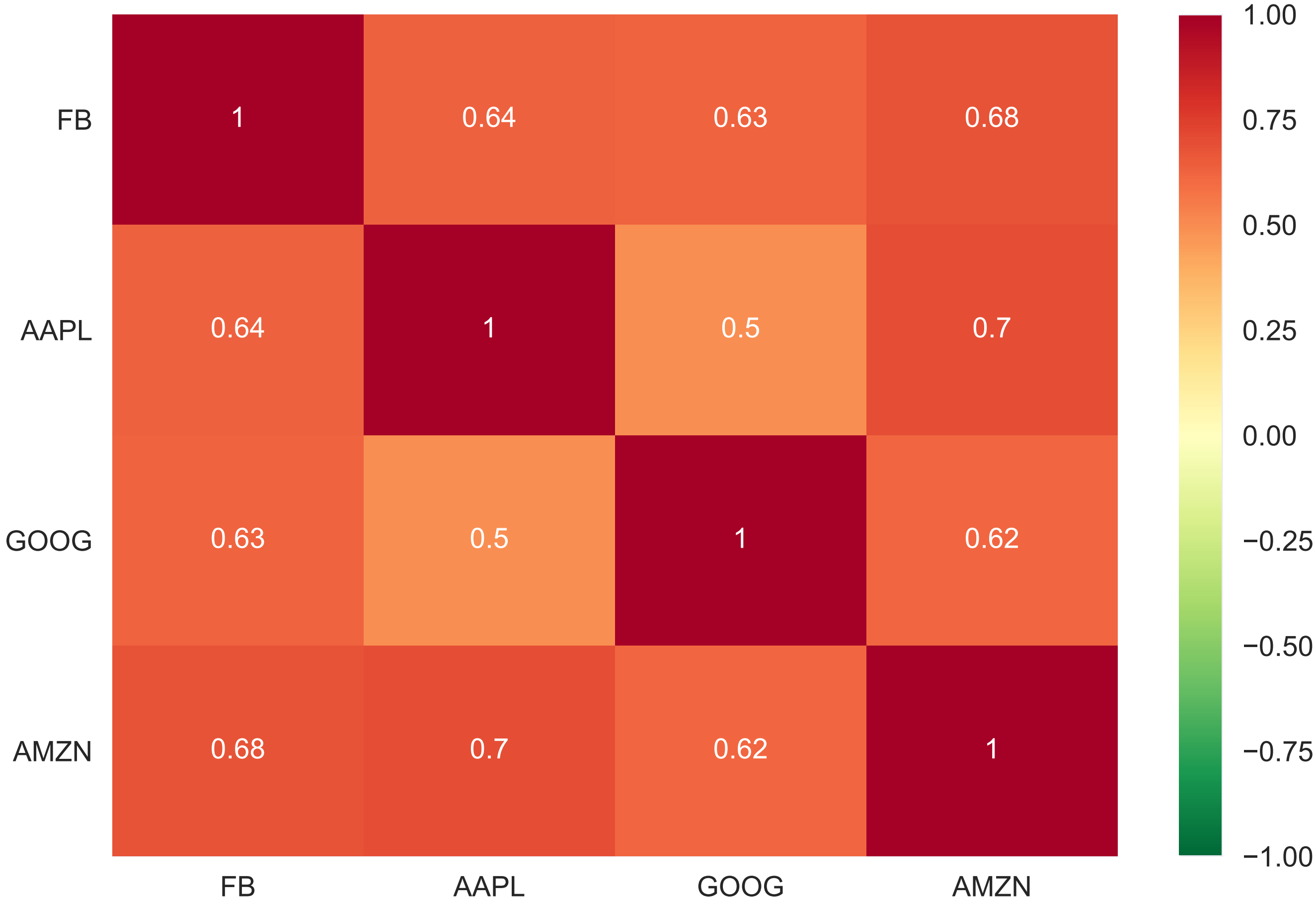

Figure 9: Sample Correlation Matrix

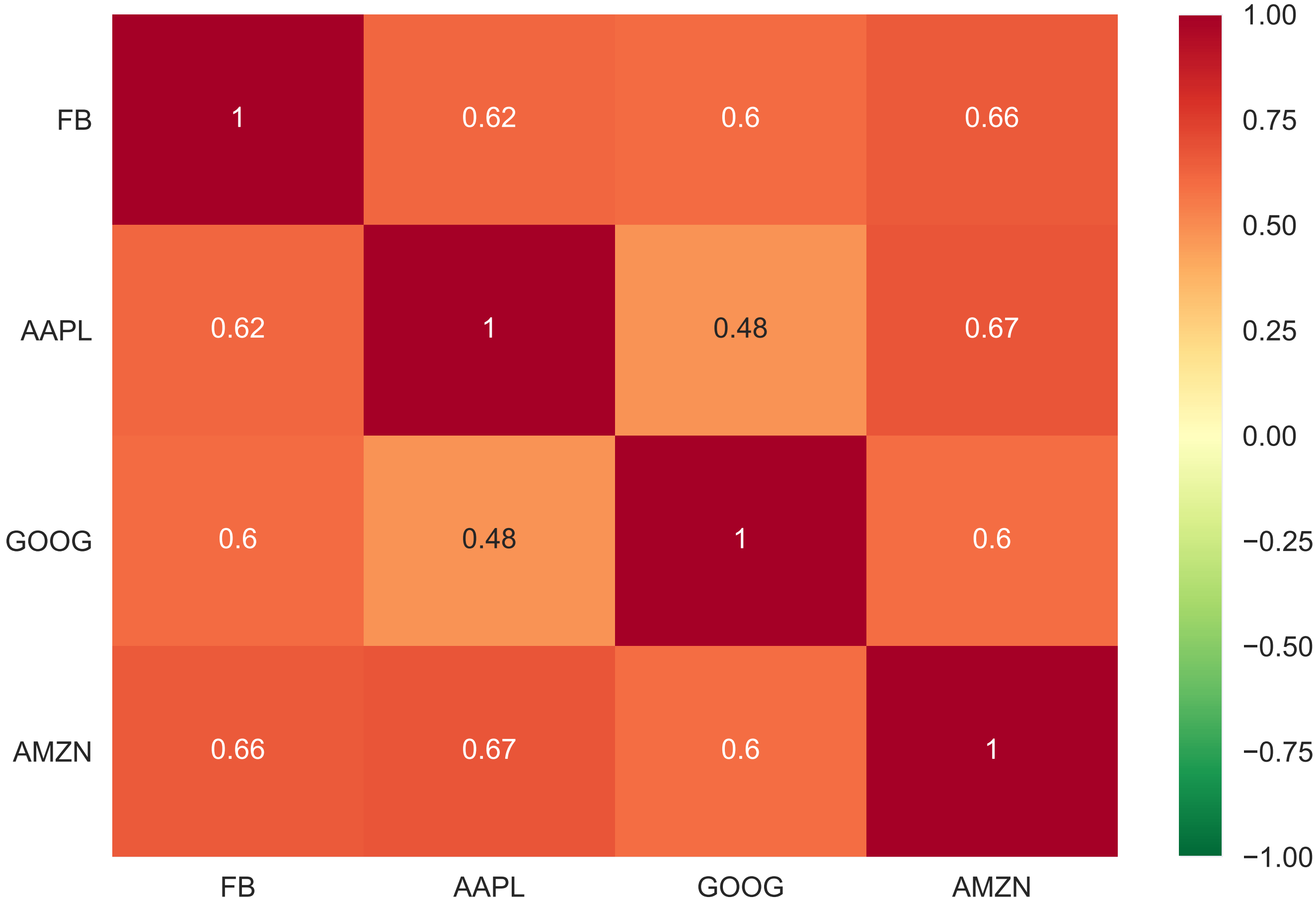

Figure 10: Ledoit Wolf Correlation Matrix

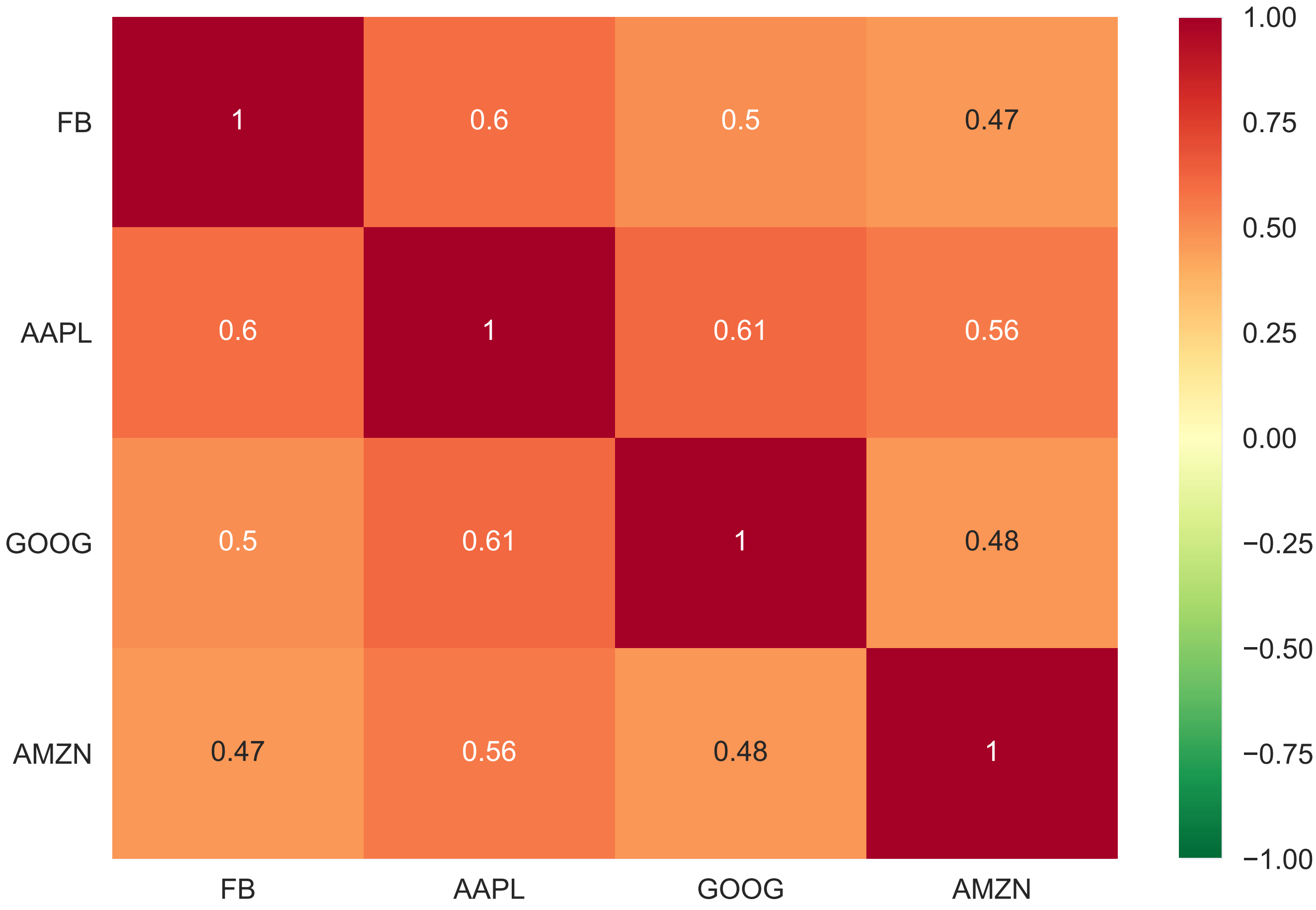

Figure 11: Ewma Correlation Matrix

3 Portfolio

	Position Name
Asset 0	AAPL Long
Asset 1	AMZN Long
Asset 2	FB Long
Asset 3	GOOG Long

Table 5: Portfolio Assets

	0	**1**	**2**	**3**
price ticker	AAPL	AMZN	FB	GOOG
price	136.0	3448.0	352.0	2520.0
securities contracts	10.0	10.0	10.0	10.0
direction	Long	Long	Long	Long
market value	1363.0	34481.0	3519.0	25204.0
risk characteristic	Linear	Linear	Linear	Linear
sec delta	1.0	1.0	1.0	1.0
pos delta	10.0	10.0	10.0	10.0

Table 6: Equity Positions Overview

Portfolio Market Value ($): 64567.0

4 Parametric Value-at-Risk

	FB	AAPL	GOOG	AMZN
Current Level	352	136	2520	3448
Volatility (%)	0.0238	0.0237	0.0204	0.0197
Volatility (units)	8.3585	3.2272	51.3202	67.8697

Table 7: Risk Factor Information

	FB	AAPL	GOOG	AMZN
Asset 0	0.0	10.0	0.0	0.0
Asset 1	0.0	0.0	0.0	10.0
Asset 2	10.0	0.0	0.0	0.0
Asset 3	0.0	0.0	10.0	0.0
Portfolio	10.0	10.0	10.0	10.0

Table 8: Risk Factor Sensitivities

	FB	AAPL	GOOG	AMZN
Asset 0	0.0	32.2717	0.0	0.0
Asset 1	0.0	0.0	0.0	679
Asset 2	83.5853	0.0	0.0	0.0
Asset 3	0.0	0.0	513	0.0
Net	83.5853	32.2717	513	679

Table 9: Dollar Volatilities

	Asset 0	**Asset 1**	**Asset 2**	**Asset 3**
Asset 0	1041.0	14729.0	1666.0	7949.0
Asset 1	14729	460630	37507	207770
Asset 2	1666	37507	6986	25851
Asset 3	7949	207770	25851	263376

Table 10: Asset Covariance Matrix

	Asset 0	**Asset 1**	**Asset 2**	**Asset 3**
Volatility (%)	32.2717	679	83.5853	513
Corr.	0.6839	0.9231	0.749	0.8554
Individual VaR	-168	-3530	-435	-2669

Table 11: Asset Metrics

Asset 0	**Asset 1**	**Asset 2**	**Asset 3**	**Sum**
-115.0	-3259.0	-326.0	-2283.0	-5983.0

Table 12: Component VaR

Asset 0	Asset 1	Asset 2	Asset 3
-114	-2939	-318	-2034

Table 13: Incremental VaR

Undiv. VaR	Div. VaR	Div. Effect ($)	Div. Effect (%)	Div. Ratio
-6802.0	-5983.0	-819.0	0.1205	0.8795

Table 14: Diversification Measures

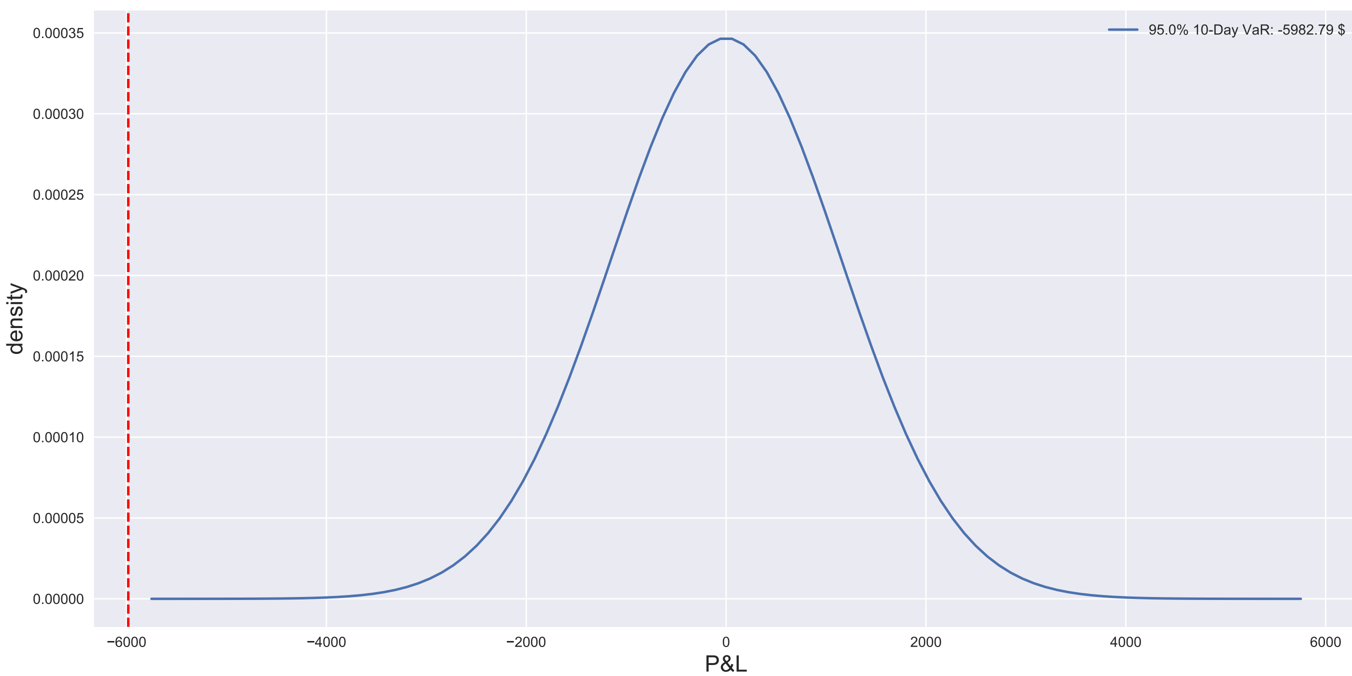

Figure 12: P&L Probability Density Function

Figure 13: 10-Day Stand Alone VaR & Diversification Effect ($)

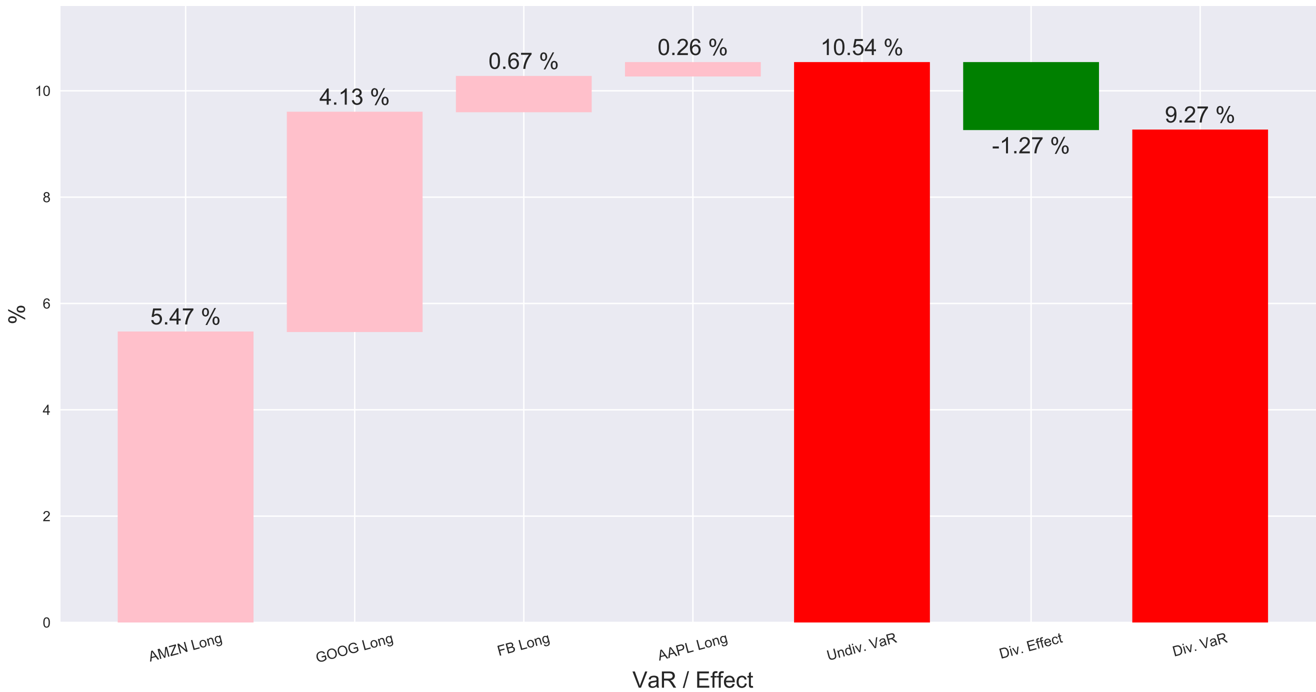

Figure 14: 10-Day Stand Alone VaR & Diversification Effect (%)

Figure 15: $ Diversified VaR - Decomposition (10-Day)

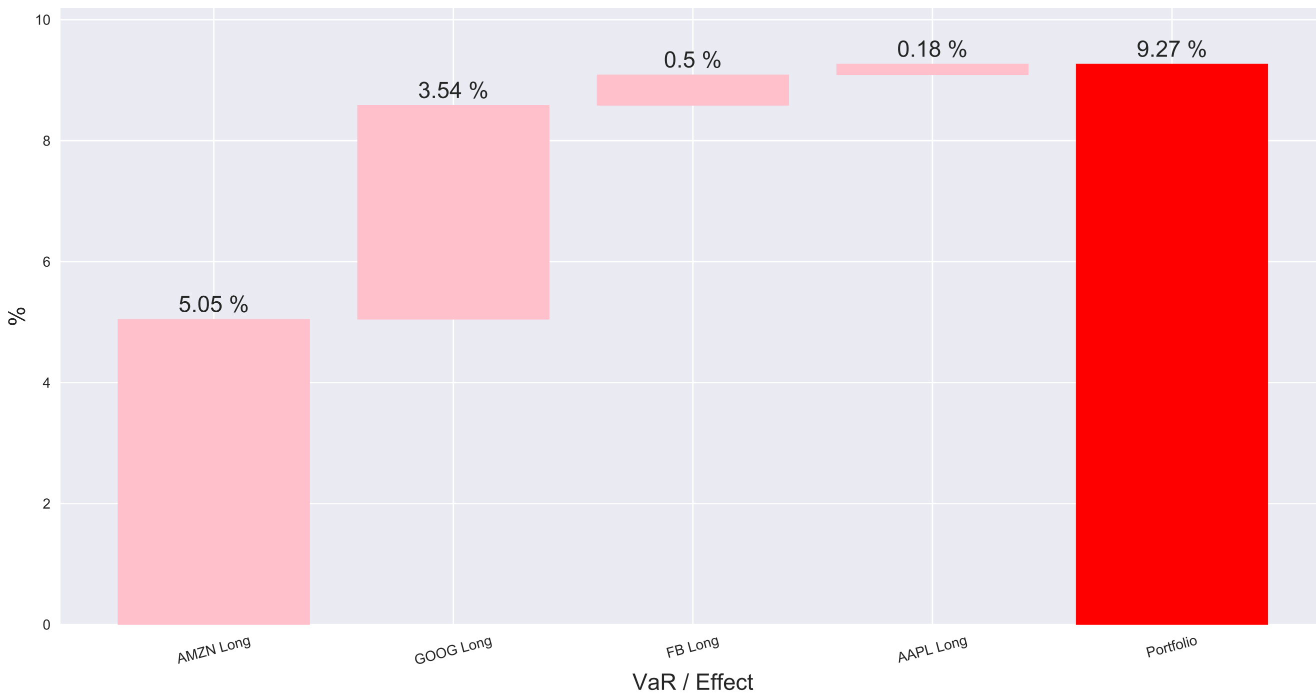

Figure 16: % Diversified VaR - Decomposition (10-Day)

5 Monte Carlo Value-at-Risk

FB	AAPL	GOOG	AMZN
348	124	2354	3265
342	133	2395	3468
326	134	2538	3350
367	151	2416	3453
340	132	2484	3565
...	...	...	...

Table 15: Shifted Levels

Asset 0	Asset 1	Asset 2	Asset 3
-126.0	-1833.0	-39.3696	-1666.0
-28.8564	199	-97.1185	-1251
-26.8494	-986	-263	174
145	49.1929	155	-1046
-41.2779	1173	-119	-365
...	...	...	...

Table 16: Full Revaluation P&L

P&L ($)	P&L (%)
-3665.0	-0.0568
-1178	-0.0182
-1101	-0.0171
-697	-0.0108
648	0.01
...	...

Table 17: Portfolio Revaluation P&L

	Asset 0	**Asset 1**	**Asset 2**	**Asset 3**	**Portfolio**
VaR	-158.0	-3367.0	-403.0	-2588.0	-5761
Corr.	0.6922	0.9224	0.7466	0.8566	

Table 18: Value at Risk

Asset 0	**Asset 1**	**Asset 2**	**Asset 3**
-3538.0	-1832.0	-3625.0	-1999.0
-1149	-1377	-1081	72.8788
-1074	-115	-838	-1276
-842	-746	-852	350
689	-525	766	1013
...	...	...	...

Table 19: Sub-Portfolio P&Ls

	Asset 0	**Asset 1**	**Asset 2**	**Asset 3**
VaR	-5600.0	-2934.0	-5465.0	-3854.0

Table 20: Sub-Portfolio VaR

Asset 0	**Asset 1**	**Asset 2**	**Asset 3**	**Sum**
-110.0	-3106.0	-301.0	-2217.0	-5733.0

Table 21: Component VaR

Asset 0	**Asset 1**	**Asset 2**	**Asset 3**
-161.0	-2827.0	-296.0	-1907.0

Table 22: Incremental VaR

Undiv. VaR	**Div. VaR**	**Div. Effect ($)**	**Div. Effect (%)**	**Div. Ratio**
-6516.0	-5761.0	-755.0	0.1158	0.8842

Table 23: Diversification Measures

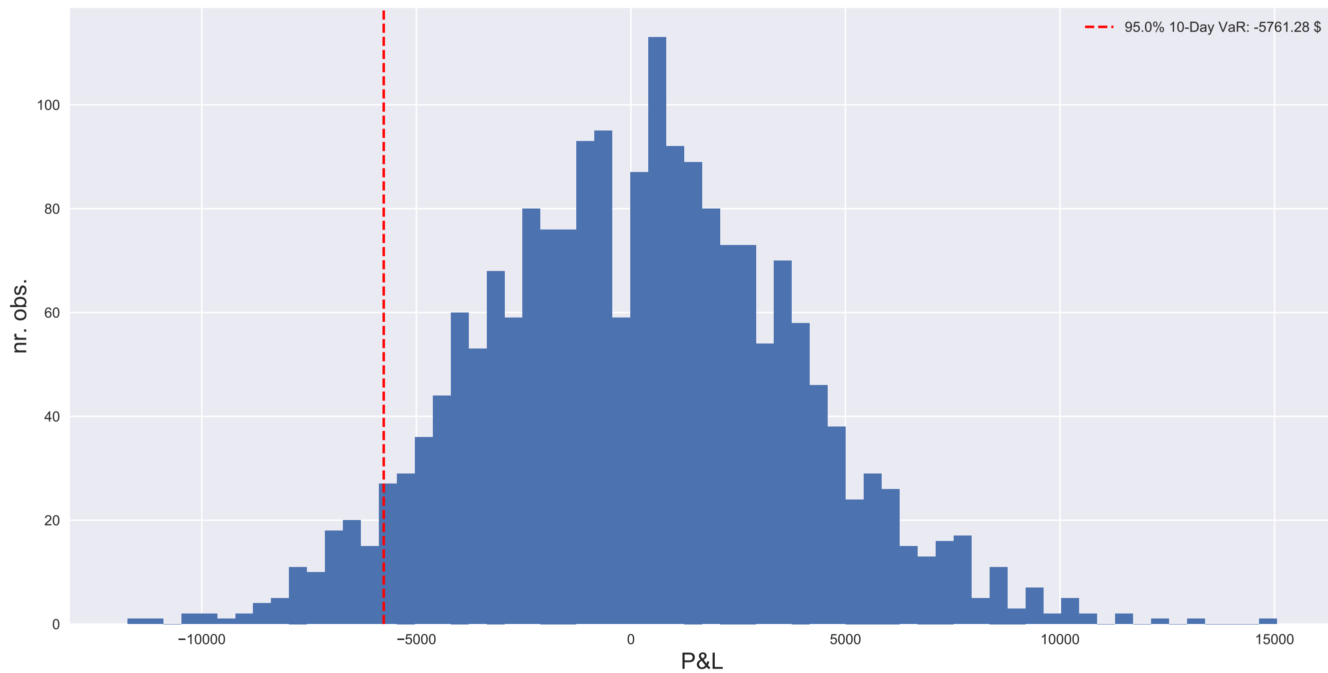

Figure 17: MC P&L (&) Histogram

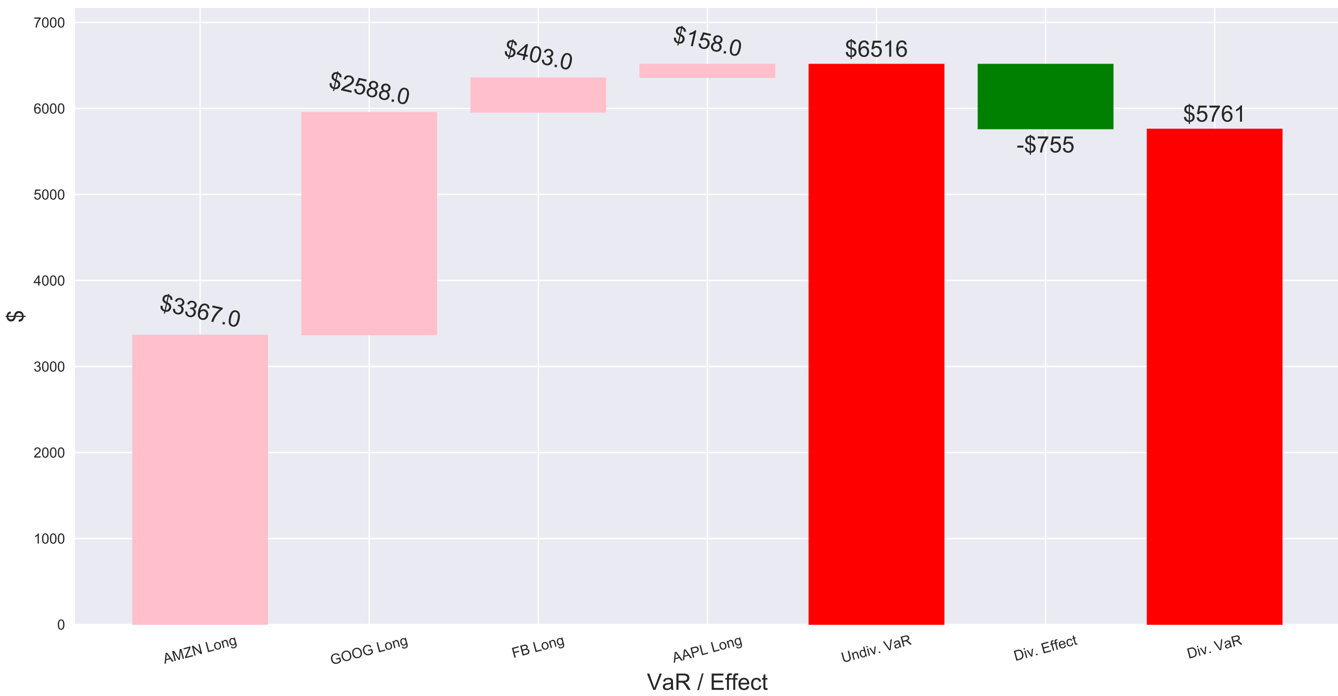

Figure 18: 10-Day Stand Alone VaR & Diversification Effect ($)

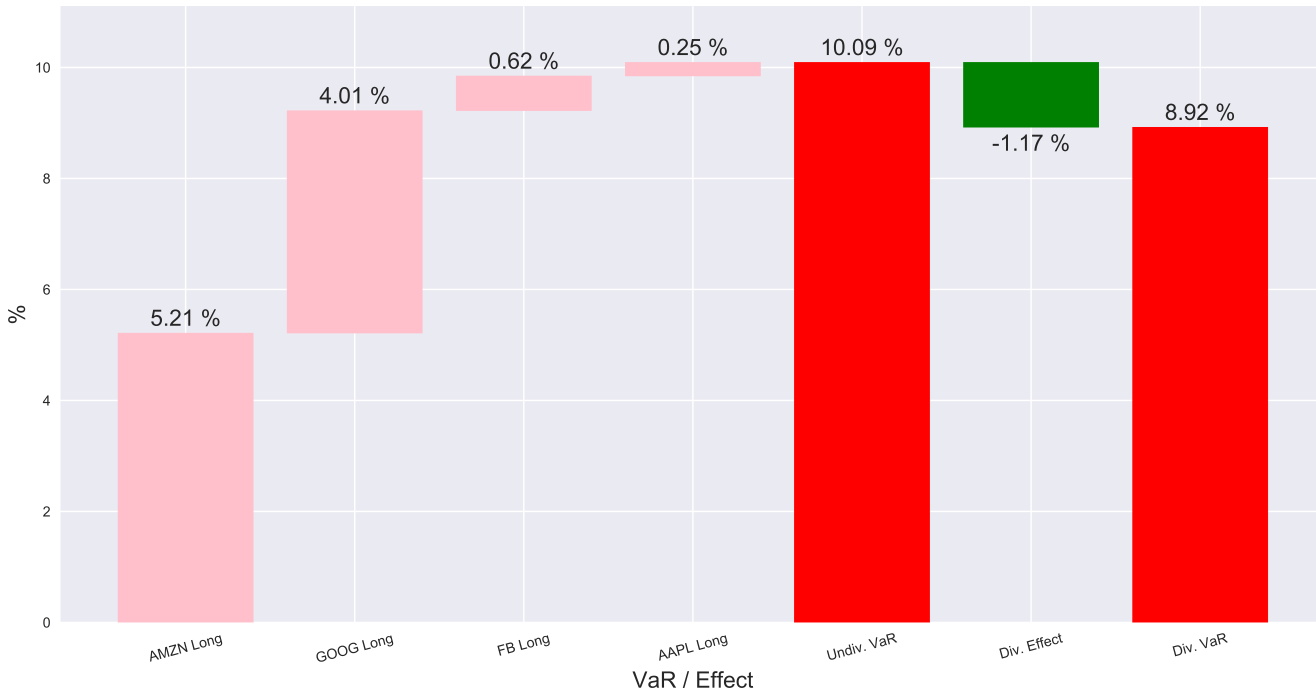

Figure 19: 10-Day Stand Alone VaR & Diversification Effect (%)

Figure 20: $ Diversified VaR - Decomposition (10-Day)

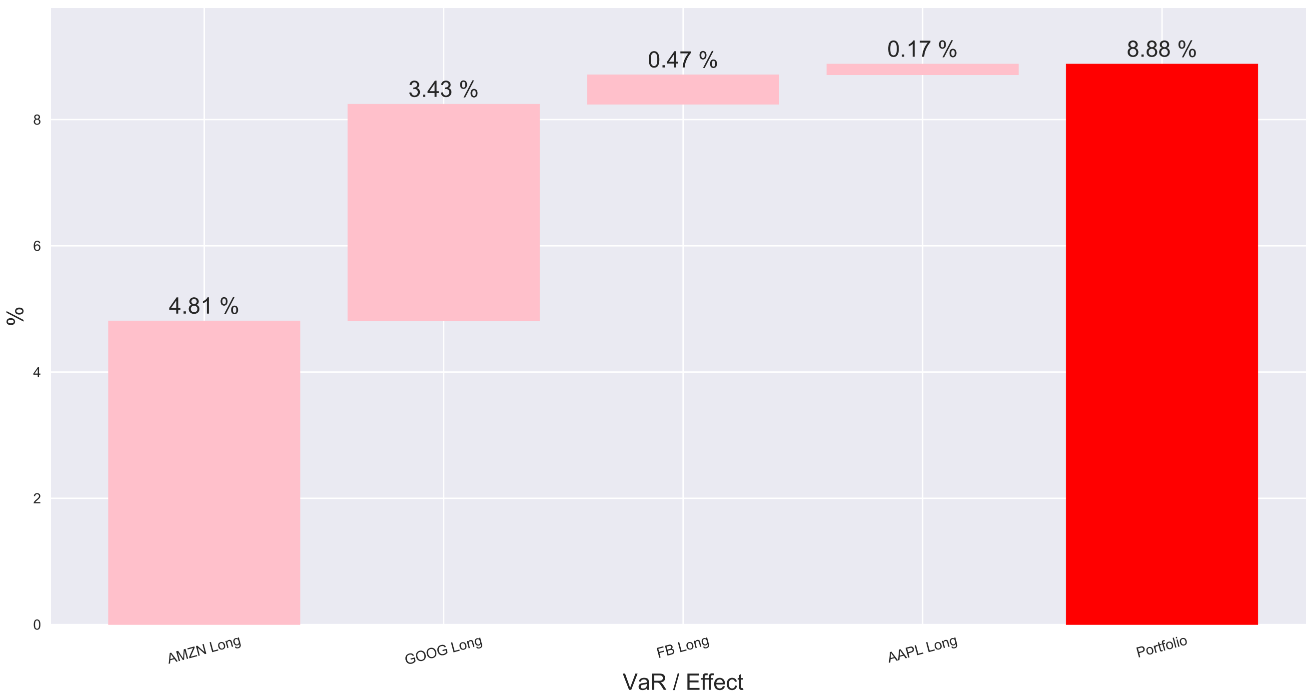

Figure 21: % Diversified VaR - Decomposition (10-Day)

6 Historical Simulation Value-at-Risk

FB	**AAPL**	**GOOG**	**AMZN**
348.0	138.0	2504.0	3452.0
367	138	2517	3491
350	136	2515	3401
355	136	2537	3394
354	136	2510	3447
...	...	...	...

Table 24: Shifted Levels

Asset 0	**Asset 1**	**Asset 2**	**Asset 3**
15.6783	42.5524	-37.1046	-159.0
17.104	430	147	-34.8302
-3.0657	-476	-18.5594	-56.8301
-2.957	-539	26.7593	164
-2.8491	-15.9339	16.1917	-107
...	...	...	...

Table 25: Full Revaluation P&L

P&L
-138.0
559
-555
-351
-109
...

Table 26: Portfolio Revaluation P&L

Asset 0	**Asset 1**	**Asset 2**	**Asset 3**	**Portfolio**
78.6877	2840	87.7338	1941	4947.0
52.6144	-1006	-133	-519	-1605.0
14.1601	5251	-162	995	6097.0
51.6869	430	219	1138	1838.0
136	1275	293	1264	2967.0
...	...	...	...	...

Table 27: Bootstrapped P&L

	Asset 0	**Asset 1**	**Asset 2**	**Asset 3**	**Portfolio**
VaR	-116	-2696	-337	-1971	-4813
Corr.	0.6941	0.9406	0.7654	0.8465	

Table 28: VaR Measures

Asset 0	**Asset 1**	**Asset 2**	**Asset 3**
4868.0	2107.0	4859.0	3006.0
-1658.0	-599.0	-1472.0	-1086.0
6083.0	847.0	6259.0	5103.0
1786.0	1408.0	1620.0	700.0
2831.0	1692.0	2675.0	1703.0
...	...	...	...

Table 29: Sub-Portfolio P&L

	Asset 0	**Asset 1**	**Asset 2**	**Asset 3**
VaR	-4712.0	-2333.0	-4602.0	-3218.0

Table 30: Sub-Portfolio VaR

Asset 0	**Asset 1**	**Asset 2**	**Asset 3**	**Sum**
-80.7769	-2535.0	-258.0	-1668.0	-4542.0

Table 31: Component VaR

Asset 0	**Asset 1**	**Asset 2**	**Asset 3**
-101.0	-2481.0	-211.0	-1596.0

Table 32: Incremental VaR

Undiv. VaR	**Div. VaR**	**Div. Effect ($)**	**Div. Effect (%)**	**Div. Ratio**
-5120.0	-4813.0	-306.0	0.0599	0.9401

Table 33: Diversification Measures

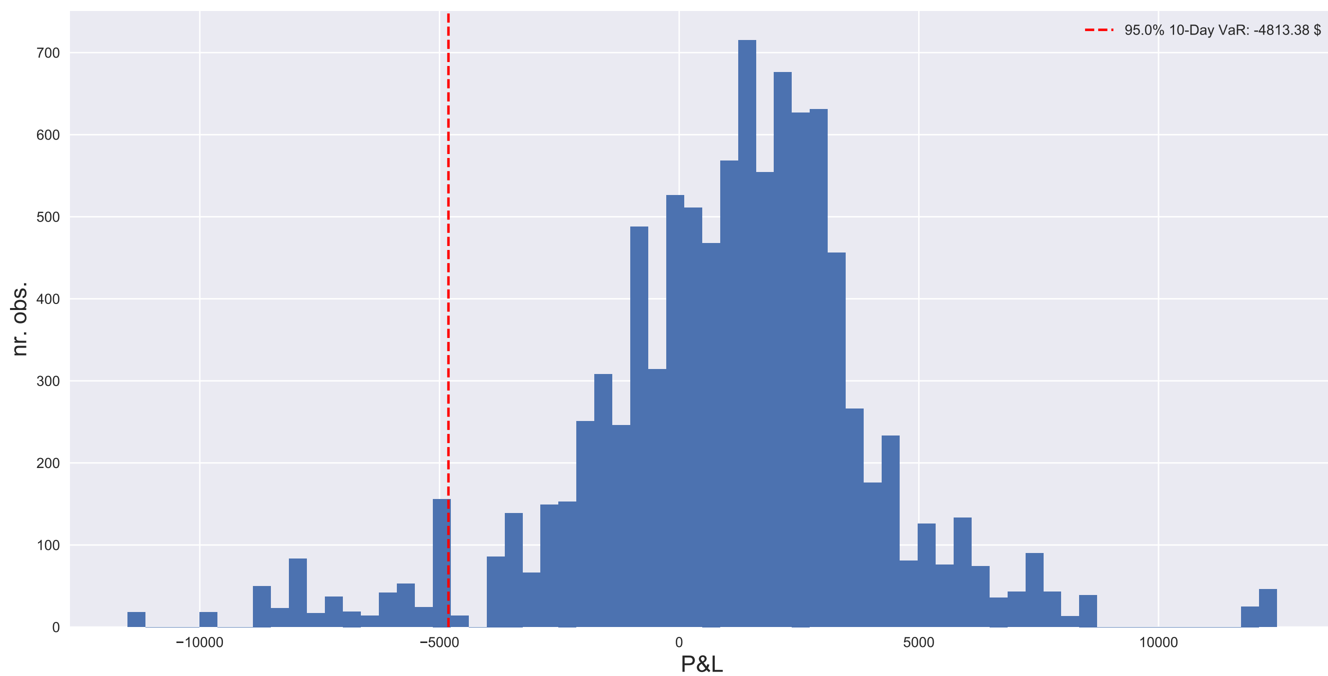

Figure 22: HS Bootstrapped P&L (&) Histogram

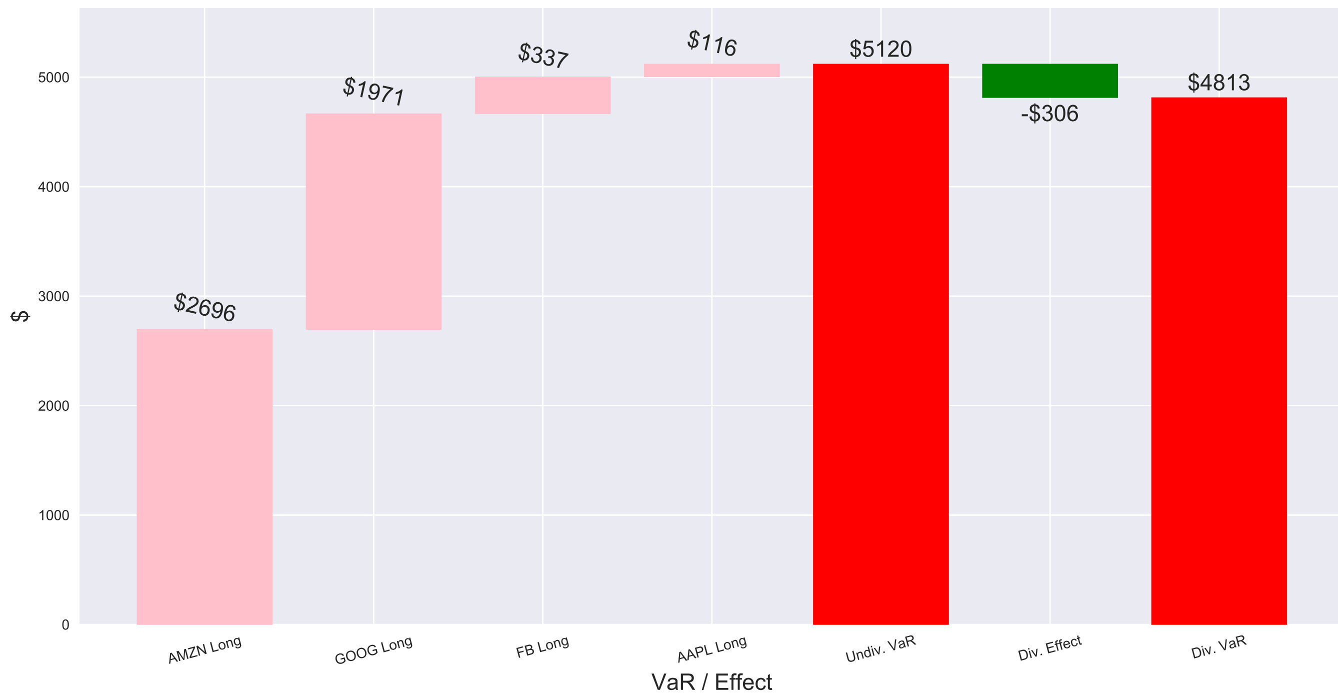

Figure 23: 10-Day Stand Alone VaR & Diversification Effect ($)

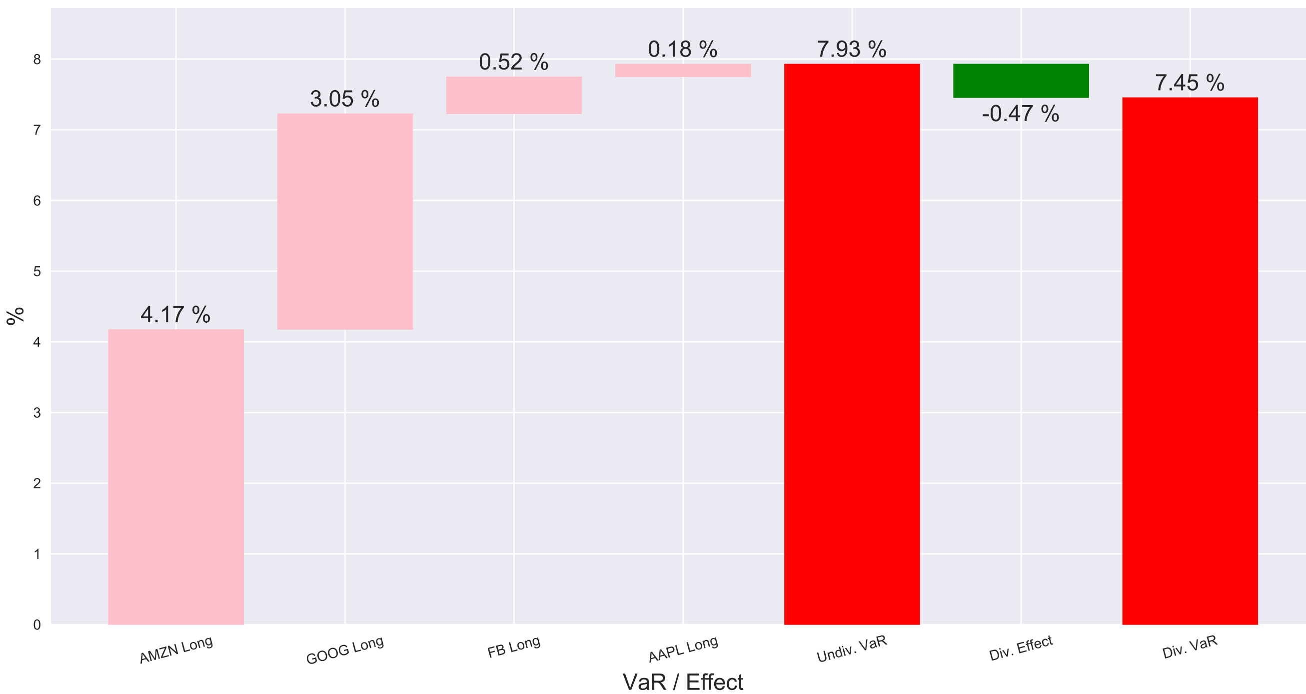

Figure 24: 10-Day Stand Alone VaR & Diversification Effect (%)

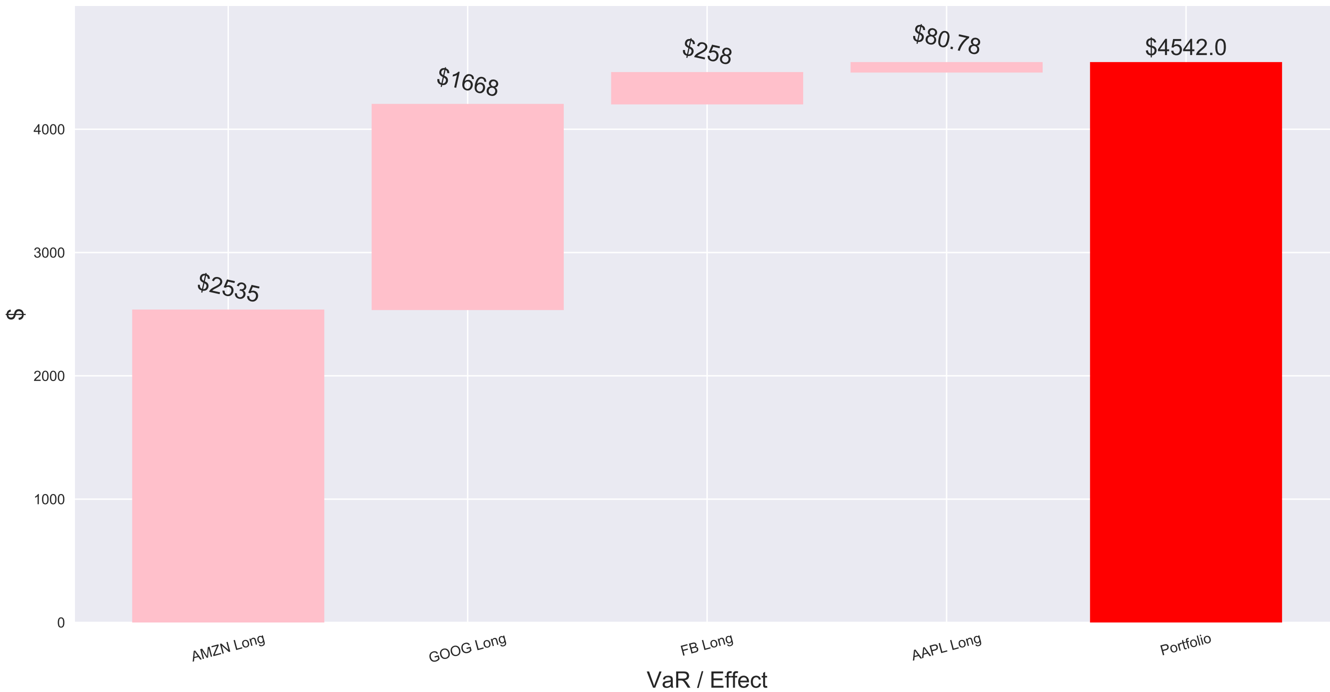

Figure 25: $ Diversified VaR - Decomposition (10-Day)

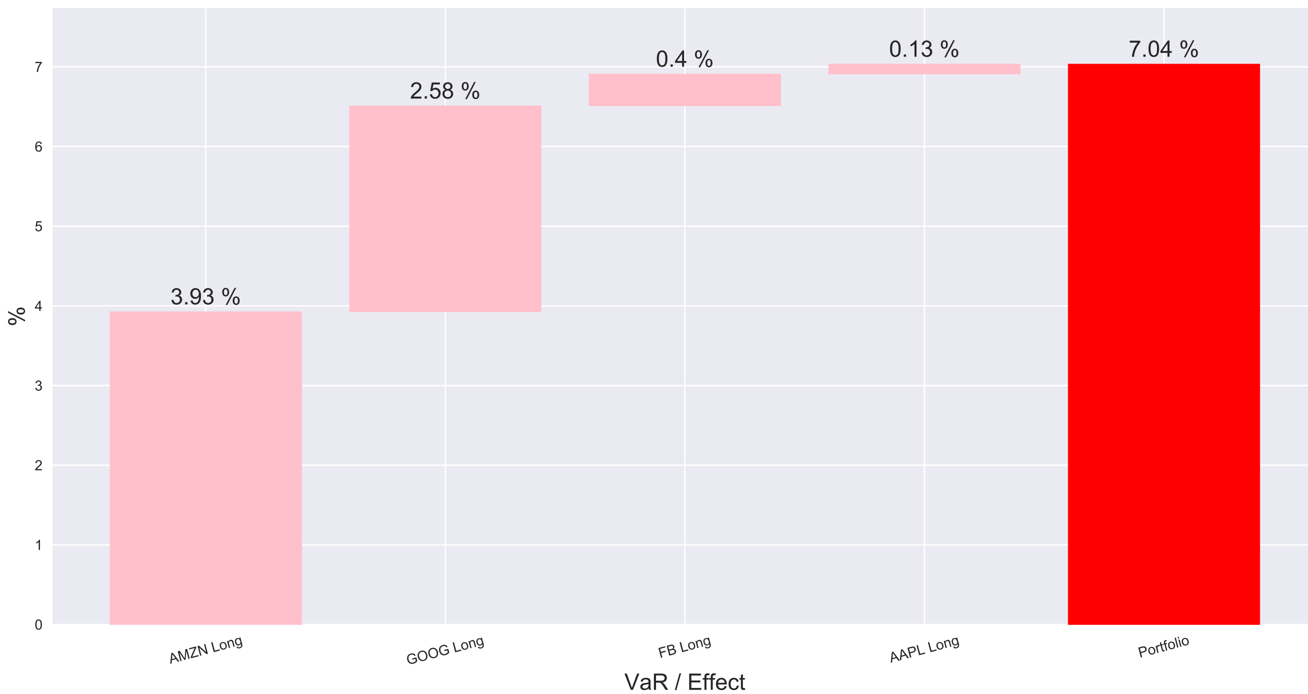

Figure 26: % Diversified VaR - Decomposition (10-Day)

7 Models Comparison

	Asset 0	**Asset 1**	**Asset 2**	**Asset 3**	**Sum**
PVaR	-115	-3259	-326	-2283	-5983
MCVaR	-110	-3106	-301	-2217	-5733
HSVaR	-80.7769	-2535	-258	-1668	-4542

Table 34: Component VaR

	Asset 0	**Asset 1**	**Asset 2**	**Asset 3**
PVaR	-114	-2939	-318	-2034
MCVaR	-161	-2827	-296	-1907
HSVaR	-101	-2481	-211	-1596

Table 35: Incremental VaR

	Undiv. VaR	**Div. VaR**	**Div. Effect ($)**	**Div. Effect (%)**	**Div. Ratio**
PVaR	-6802	-5983	-819	0.1205	0.8795
MCVaR	-6516	-5761	-755	0.1158	0.8842
HSVaR	-5120	-4813	-306	0.0599	0.9401

Table 36: Diversification

8 Ex-Post Portfolio Performance

	AAPL	AMZN	FB	GOOG
2018-12-31	384.0	15020.0	1311.0	10356.0
2019-01-02	384	15391	1357	10458
2019-01-03	346	15003	1317	10161
2019-01-04	361	15754	1379	10707
2019-01-07	360	16295	1381	10684
...	...	...	...	...

Table 37: Asset Valuations

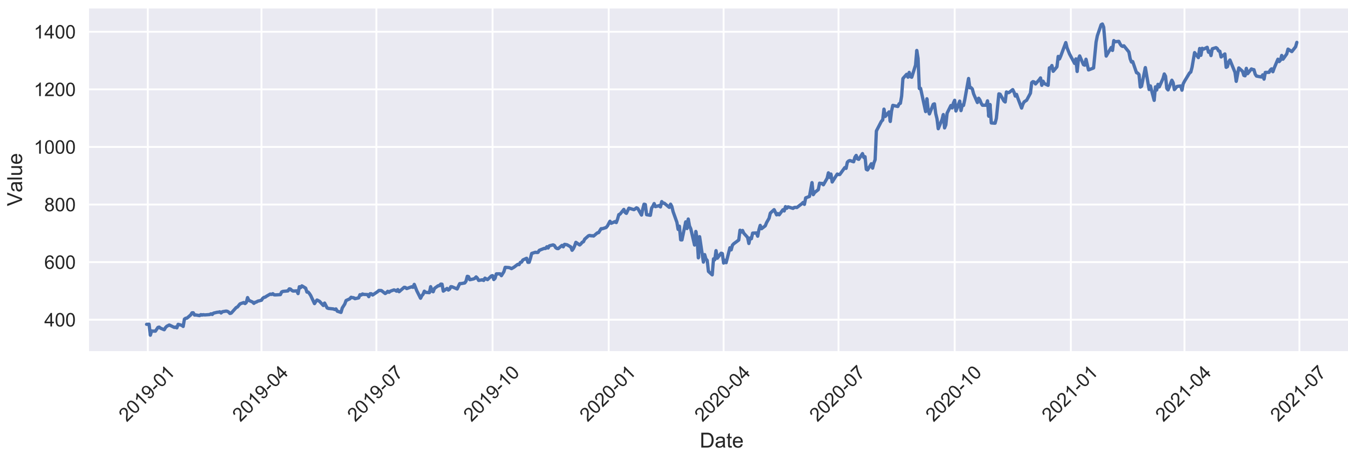

Figure 27: AAPL Value

Figure 28: AMZN Value

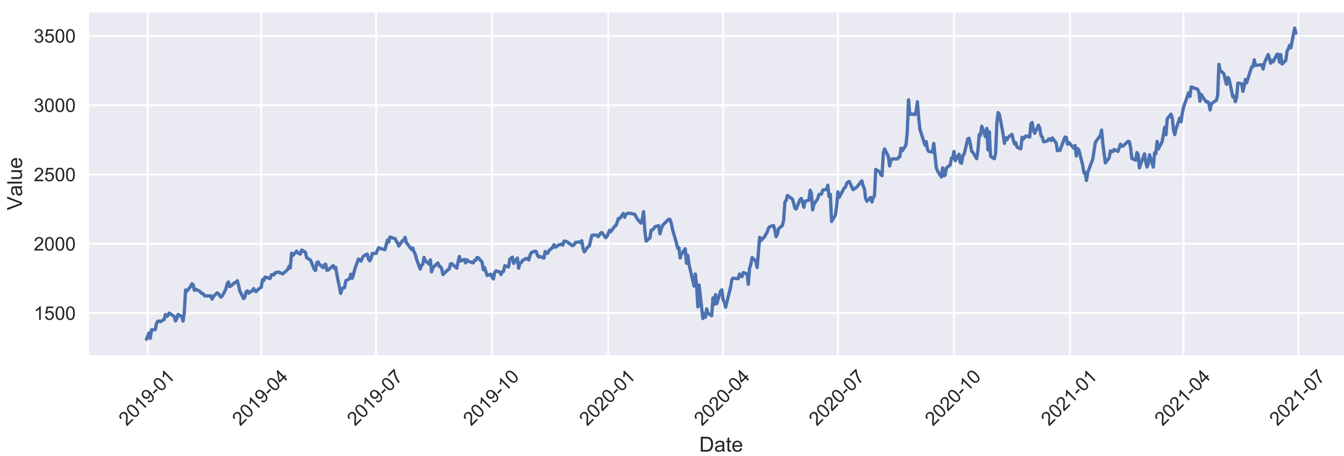

Figure 29: FB Value

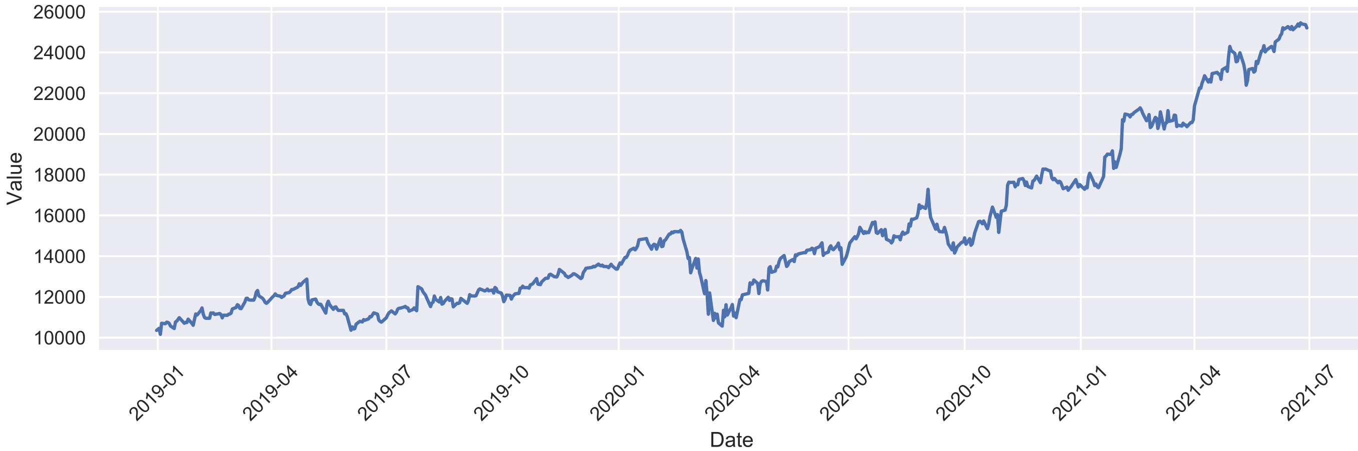

Figure 30: GOOG Value

	Value
2018-12-31	27071.0
2019-01-02	27591
2019-01-03	26827
2019-01-04	28201
2019-01-07	28720
...	...

Table 38: Portfolio Valuation

Figure 31: Portfolio Value

	AAPL	**AMZN**	**FB**	**GOOG**
2019-01-02	0.0011	0.0247	0.035	0.0099
2019-01-03	-0.0996	-0.0252	-0.029	-0.0285
2019-01-04	0.0427	0.0501	0.0471	0.0538
2019-01-07	-0.0022	0.0344	0.0007	-0.0022
2019-01-08	0.0191	0.0166	0.0325	0.0074
...	...	...	...	...

Table 39: Asset Returns

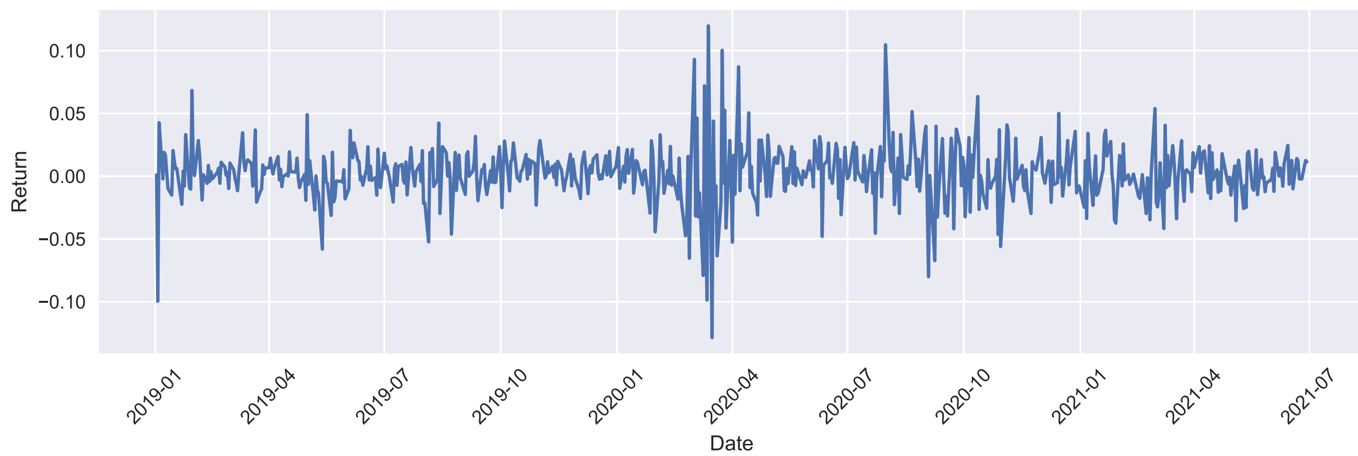

Figure 32: AAPL Return

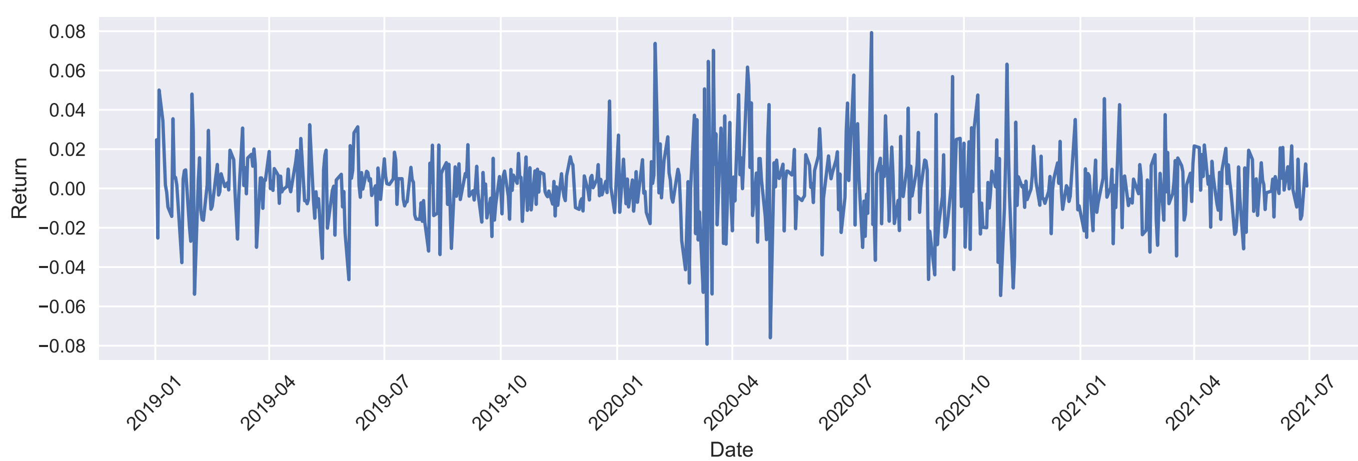

Figure 33: AMZN Return

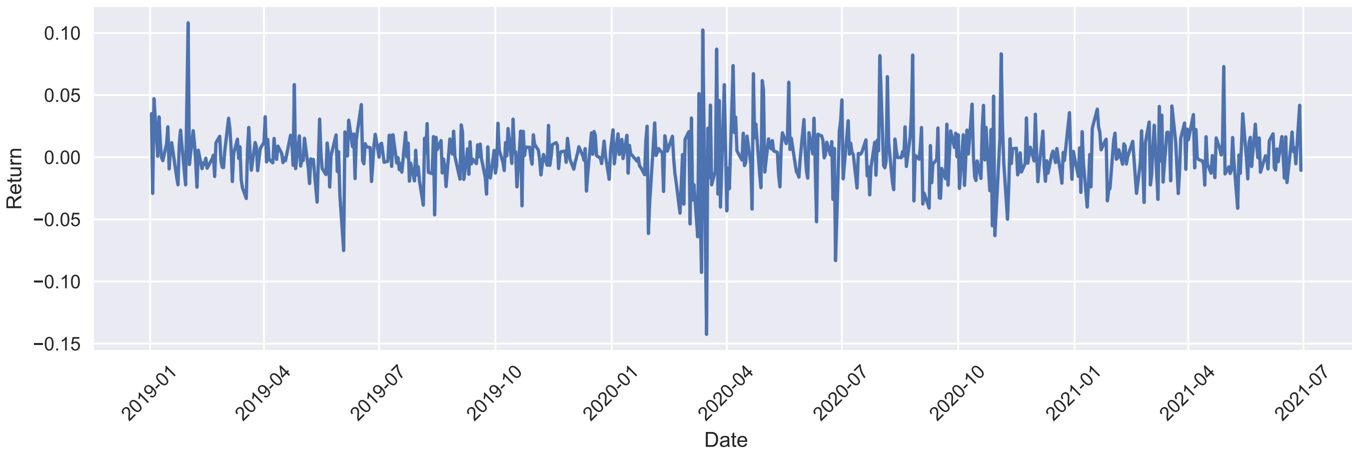

Figure 34: FB Return

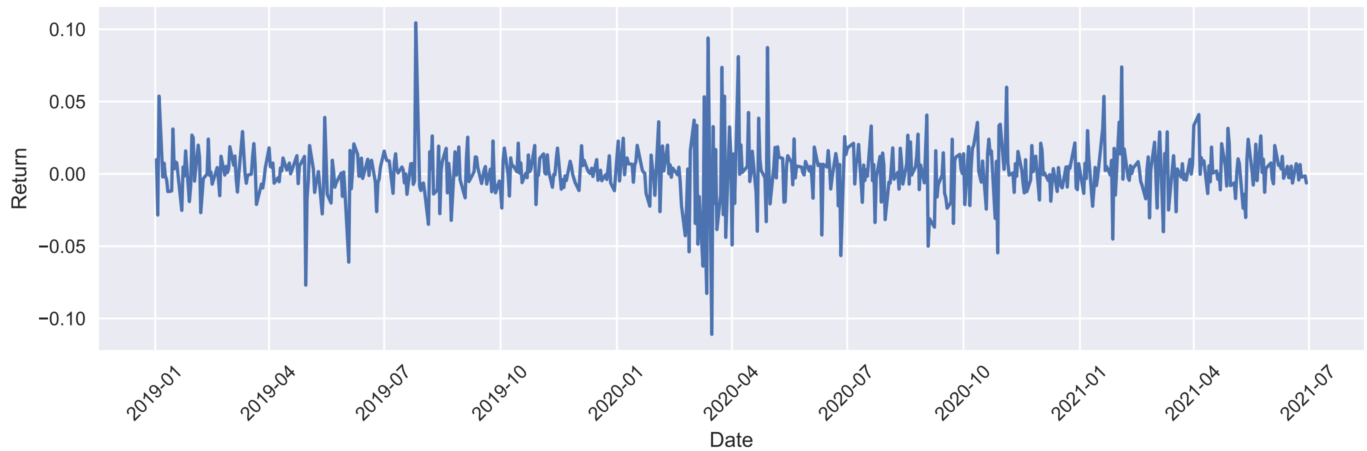

Figure 35: GOOG Return

	Return
2019-01-02	0.0192
2019-01-03	-0.0277
2019-01-04	0.0512
2019-01-07	0.0184
2019-01-08	0.014
...	...

Table 40: Portfolio Returns

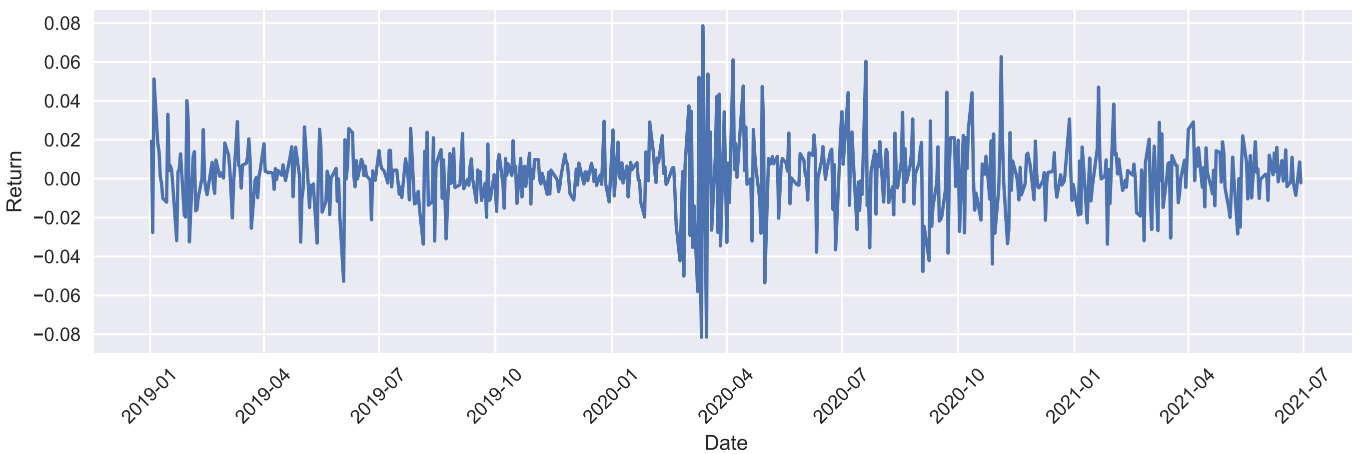

Figure 36: Portfolio Returns

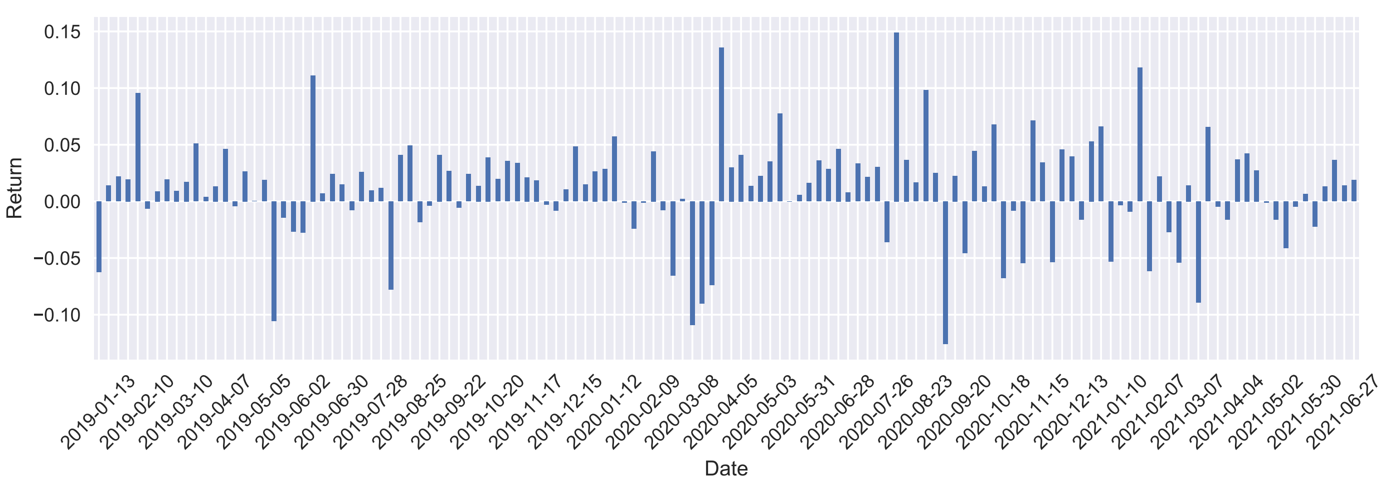

Figure 37: AAPL Weekly Returns

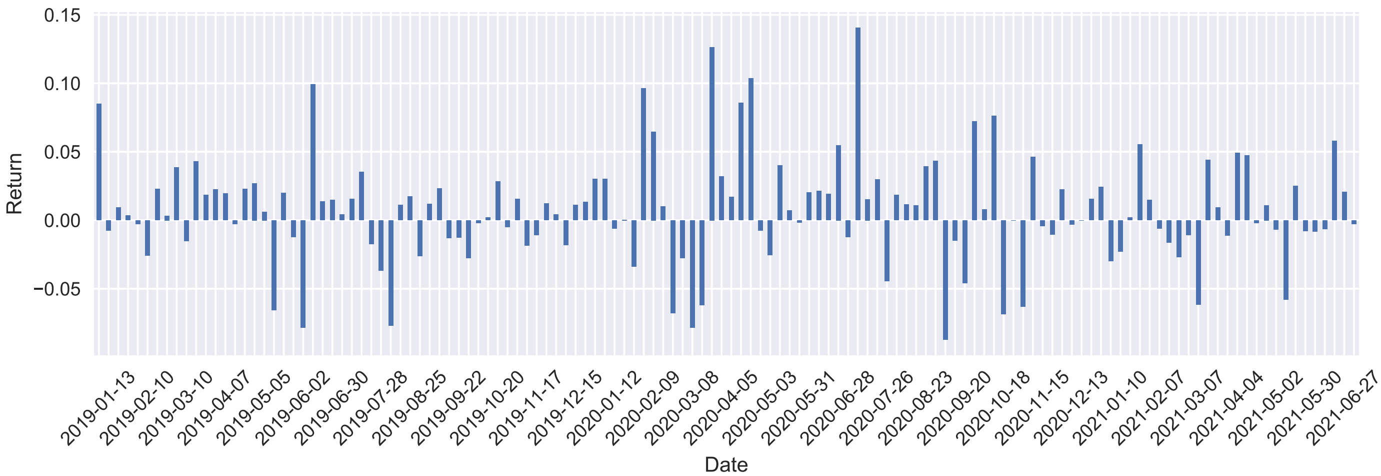

Figure 38: AMZN Weekly Returns

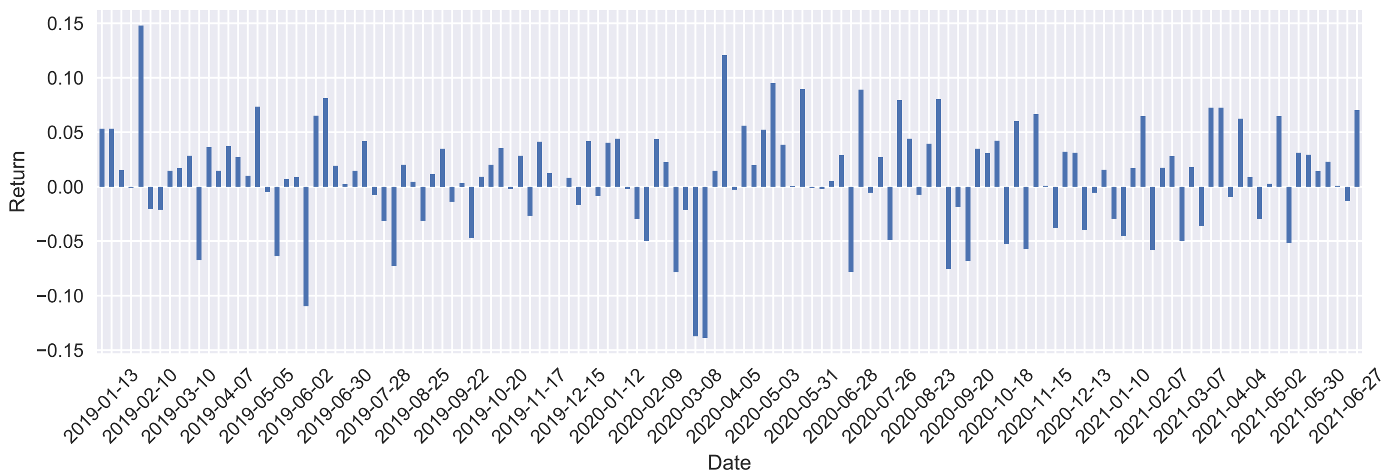

Figure 39: FB Weekly Returns

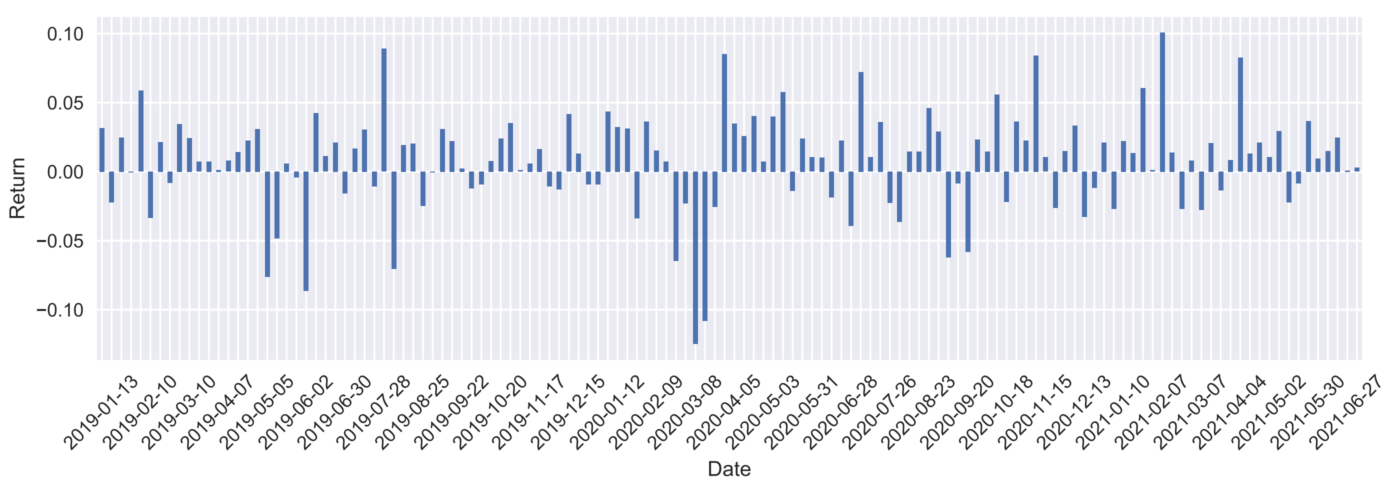

Figure 40: GOOG Weekly Returns

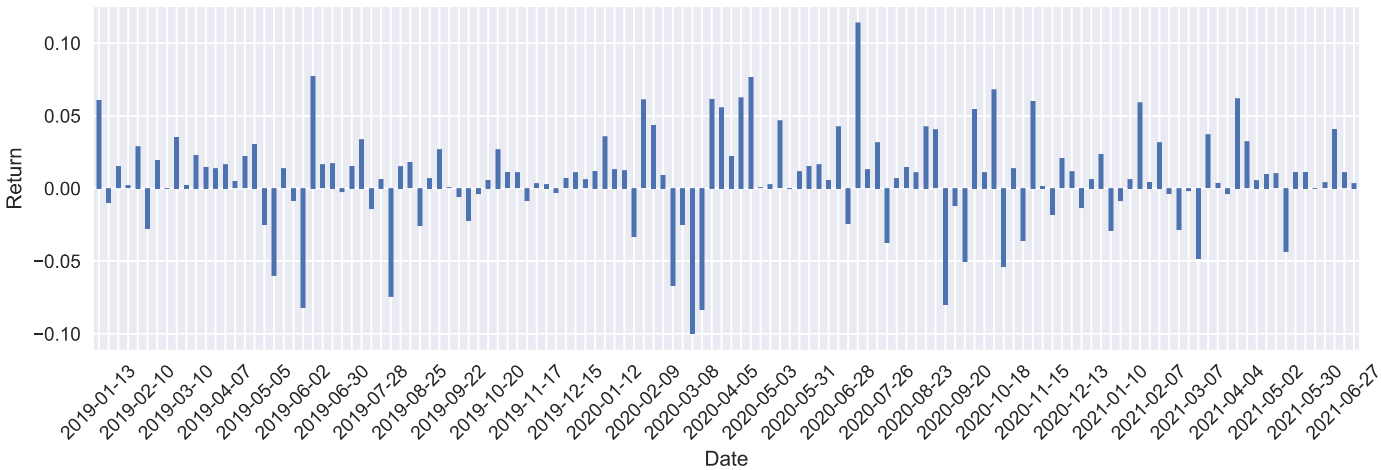

Figure 41: Weekly Portfolio Returns

AAPL	**AMZN**	**FB**	**GOOG**
0.6525	0.3937	0.4907	0.4309

Table 41: Expected Annualized Returns

AAPL	**AMZN**	**FB**	**GOOG**
0.3251	0.2856	0.3407	0.2595

Table 42: Expected Annualized Volatilities

	AAPL	**AMZN**	**FB**	**GOOG**
AAPL	1.0	0.5512	0.6468	0.6153
AMZN	0.5512	1.0	0.5693	0.5628
FB	0.6468	0.5693	1.0	0.6711
GOOG	0.6153	0.5628	0.6711	1.0

Table 43: Correlation Matrix

	AAPL	**AMZN**	**FB**	**GOOG**
AAPL	0.002	0.0009	0.0013	0.0009
AMZN	0.0009	0.0016	0.001	0.0007
FB	0.0013	0.001	0.0022	0.0011
GOOG	0.0009	0.0007	0.0011	0.0013

Table 44: Covariance Matrix

	AAPL	**AMZN**	**FB**	**GOOG**
AAPL	0.104	0.0473	0.0663	0.048
AMZN	0.0473	0.0817	0.0512	0.0386
FB	0.0663	0.0512	0.1136	0.0549
GOOG	0.048	0.0386	0.0549	0.0685

Table 45: Annualized Covariance Matrix

	AAPL	AMZN	FB	GOOG
2019-01-13	595.22 B	821.8 B	329.08 B	342.06 B
2019-01-20	603.55 B	815.6 B	346.58 B	334.48 B
2019-01-27	616.83 B	823.14 B	351.78 B	342.75 B
2019-02-03	628.9 B	826.03 B	351.54 B	342.61 B
2019-02-10	689.05 B	823.72 B	403.46 B	362.69 B
...	...	...	...	...

Table 46: Market Capitalizations

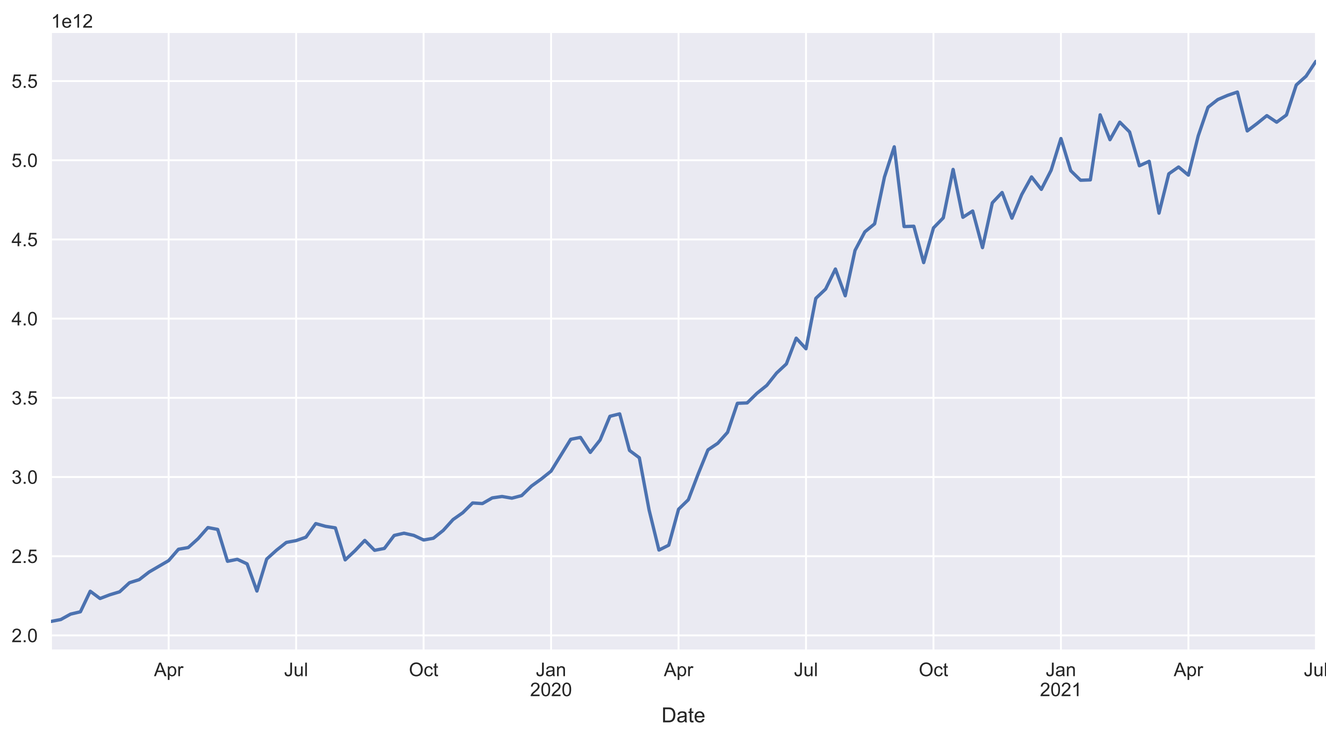

Figure 42: Evolution of Market Capitalization of Index

	AAPL	AMZN	FB	GOOG
2019-01-13	0.285	0.3936	0.1576	0.1638
2019-01-20	0.2874	0.3883	0.165	0.1593
2019-01-27	0.289	0.3856	0.1648	0.1606
2019-02-03	0.2926	0.3844	0.1636	0.1594
2019-02-10	0.3024	0.3615	0.177	0.1591
...	...	...	...	...

Table 47: Capitalization Weights

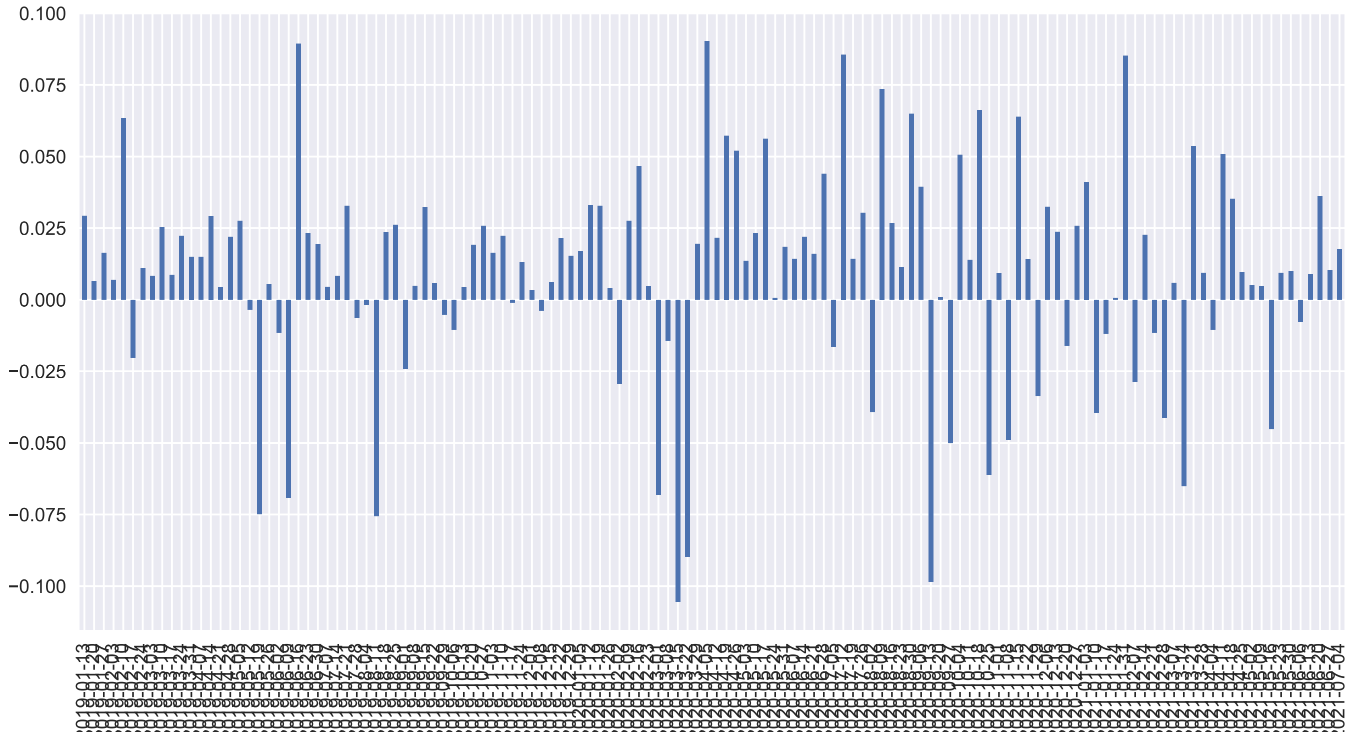

Figure 43: Returns of Cap-Weighted Index

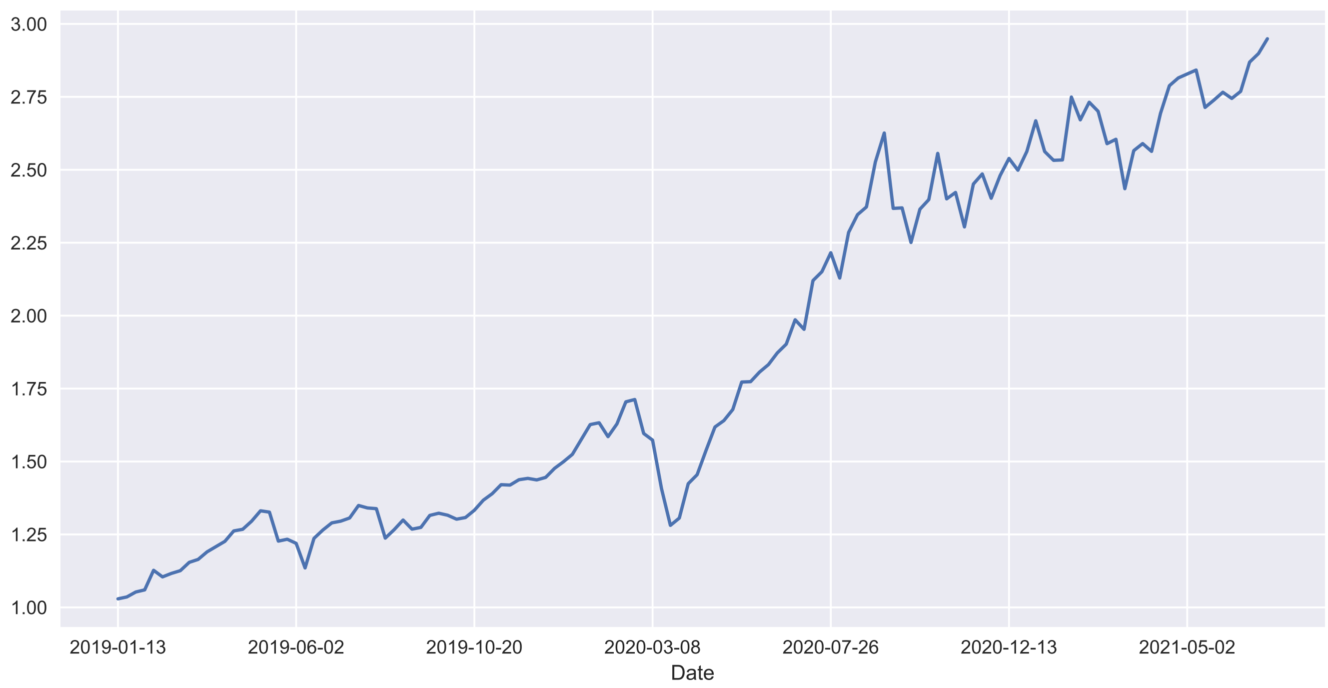

Figure 44: Cumulative Return Cap-Weighted Index

AAPL	AMZN	FB	GOOG
0.392	0.3067	0.1604	0.1409

Table 48: Weights of Capweight Scheme

Portfolio Return for Capweight Scheme: 0.5159
Portfolio Volatility for Capweight Scheme: 0.2526

AAPL	AMZN	FB	GOOG
0.25	0.25	0.25	0.25

Table 49: Weights of Equal Weighted Scheme

Portfolio Return for Equal Weighted Scheme: 0.4919
Portfolio Volatility for Equal Weighted Scheme: 0.2475

	AAPL	AMZN	FB	GOOG
2019-01-13	0.25	0.25	0.25	0.25
2019-01-20	0.25	0.25	0.25	0.25
2019-01-27	0.25	0.25	0.25	0.25
2019-02-03	0.25	0.25	0.25	0.25
2019-02-10	0.25	0.25	0.25	0.25
...	...	...	...	...

Table 50: Weights of Equal-Weighted Benchmark

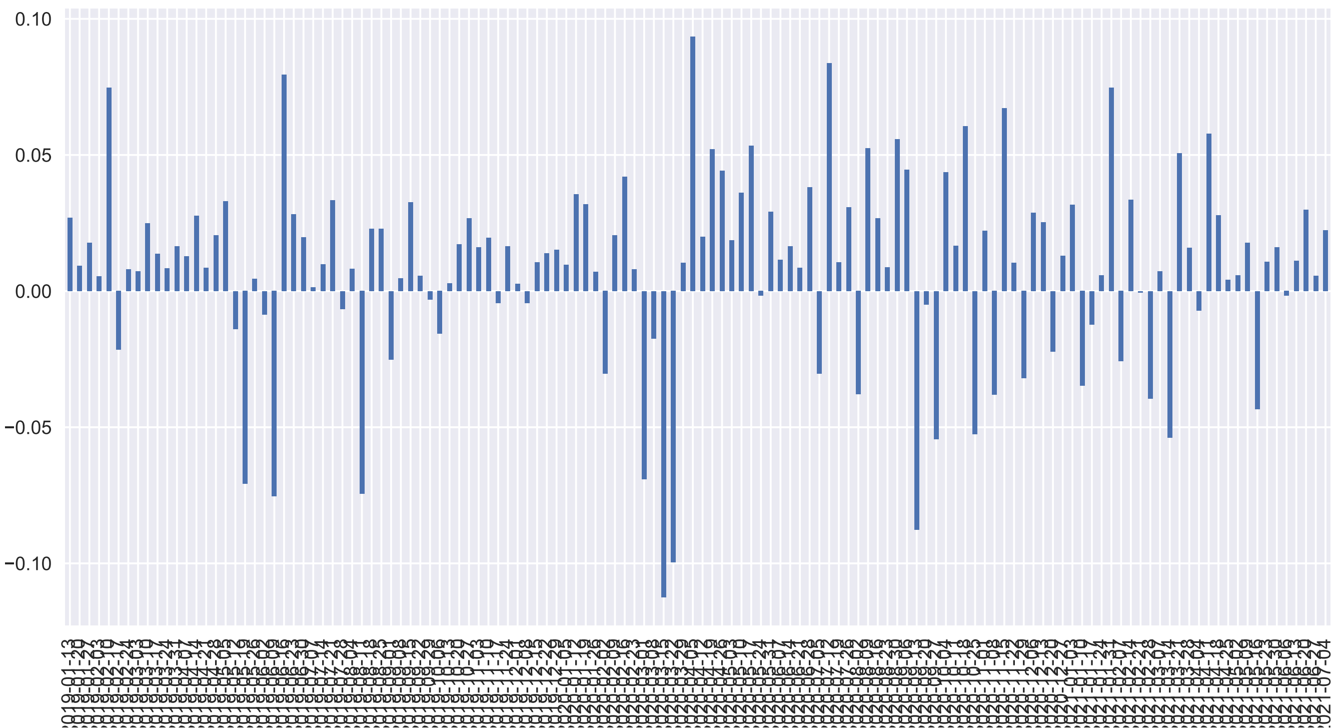

Figure 45: Returns of Equal-Weighted Index

Figure 46: Cumulative Return Equal-Weighted Index

Figure 47: Equal Cap Weighted Vs. Market Cap Weighted Indices

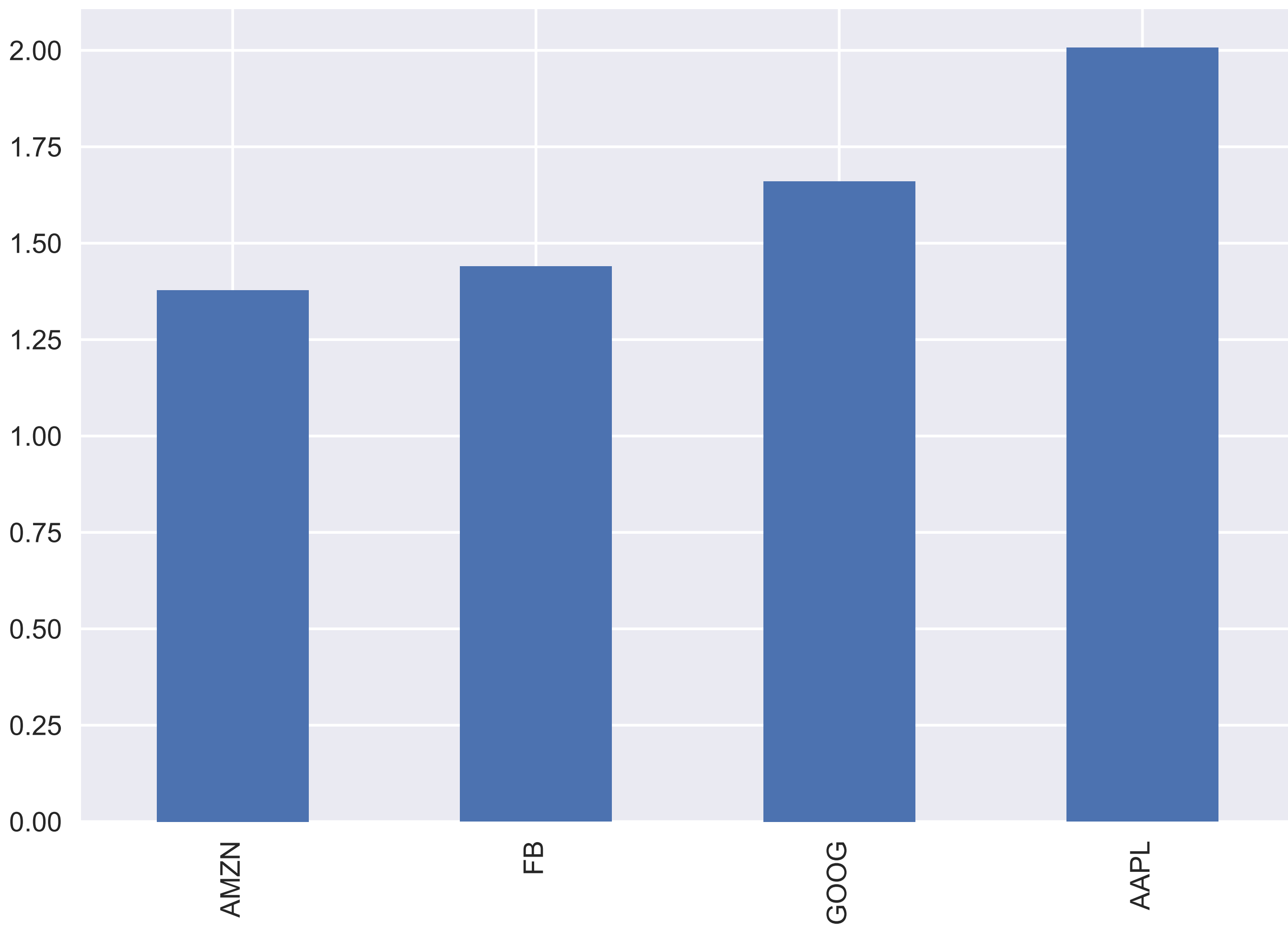

Figure 48: Sharpe Ratio

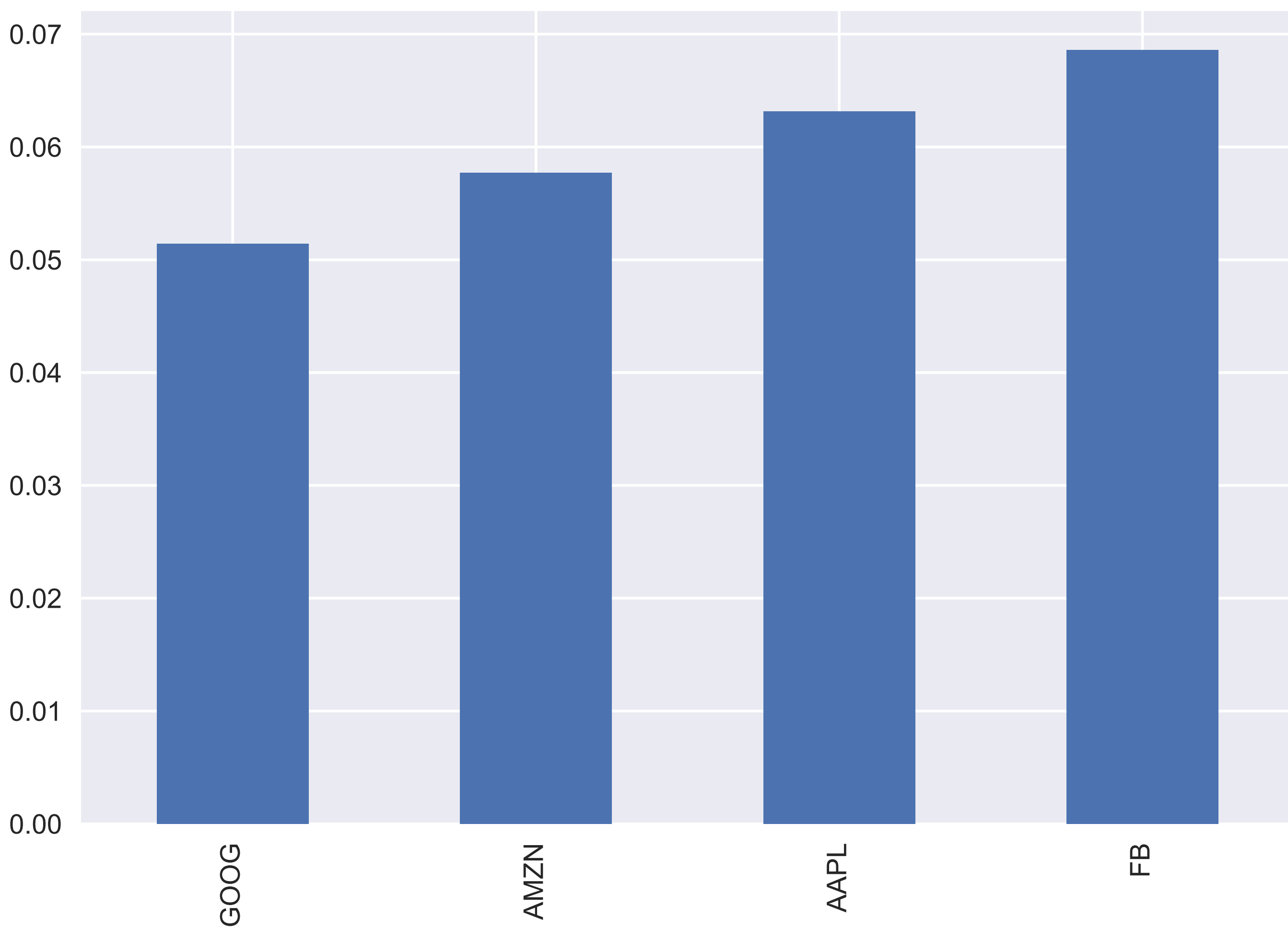

Figure 49: Parametric (Gaussian) VaR @ 95.0%

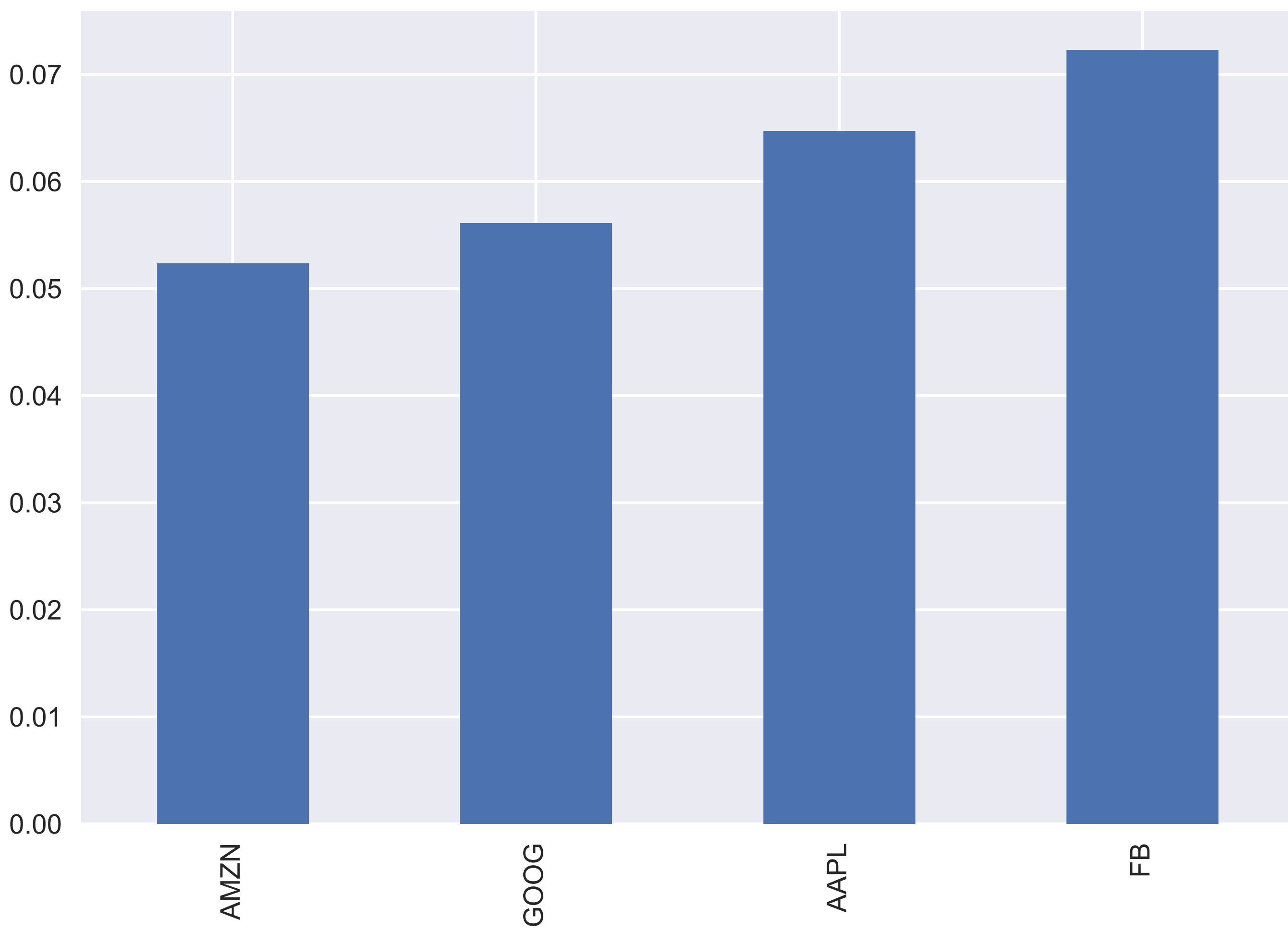

Figure 50: Modified (Cornish-Fisher) VaR @ 95.0%

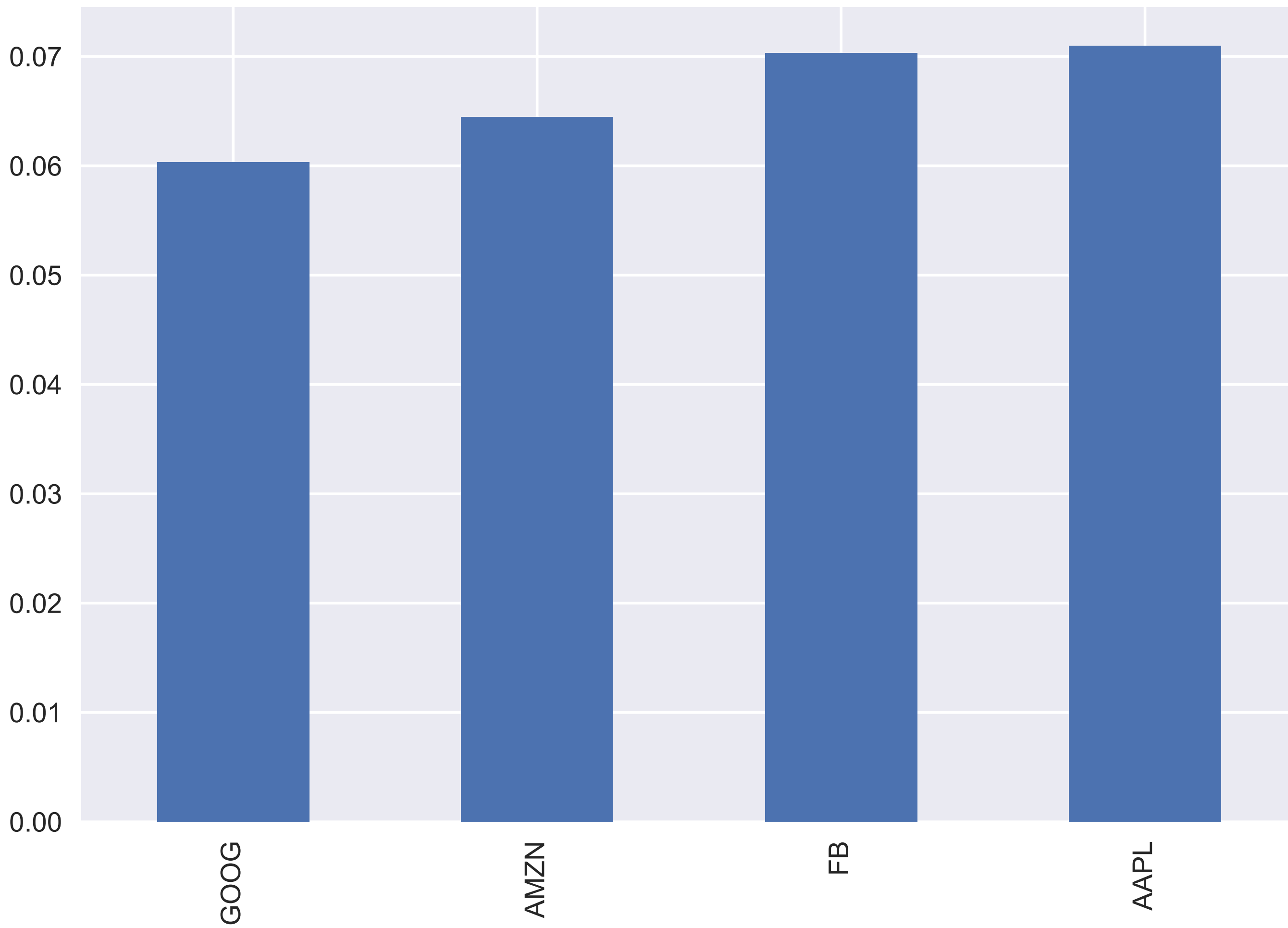

Figure 51: Historic VaR @ 95.0%

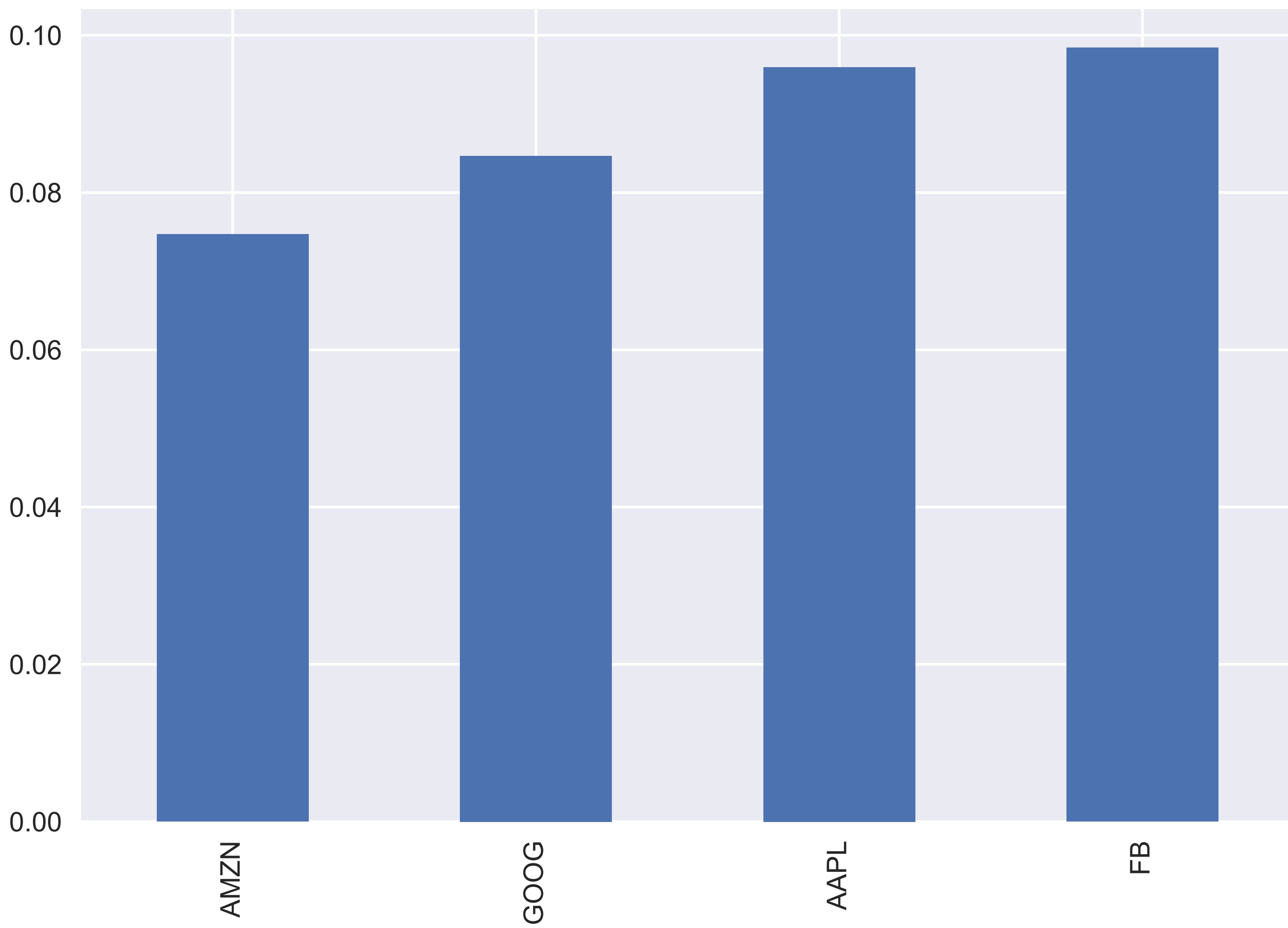

Figure 52: Conditional VaR @ 95.0%

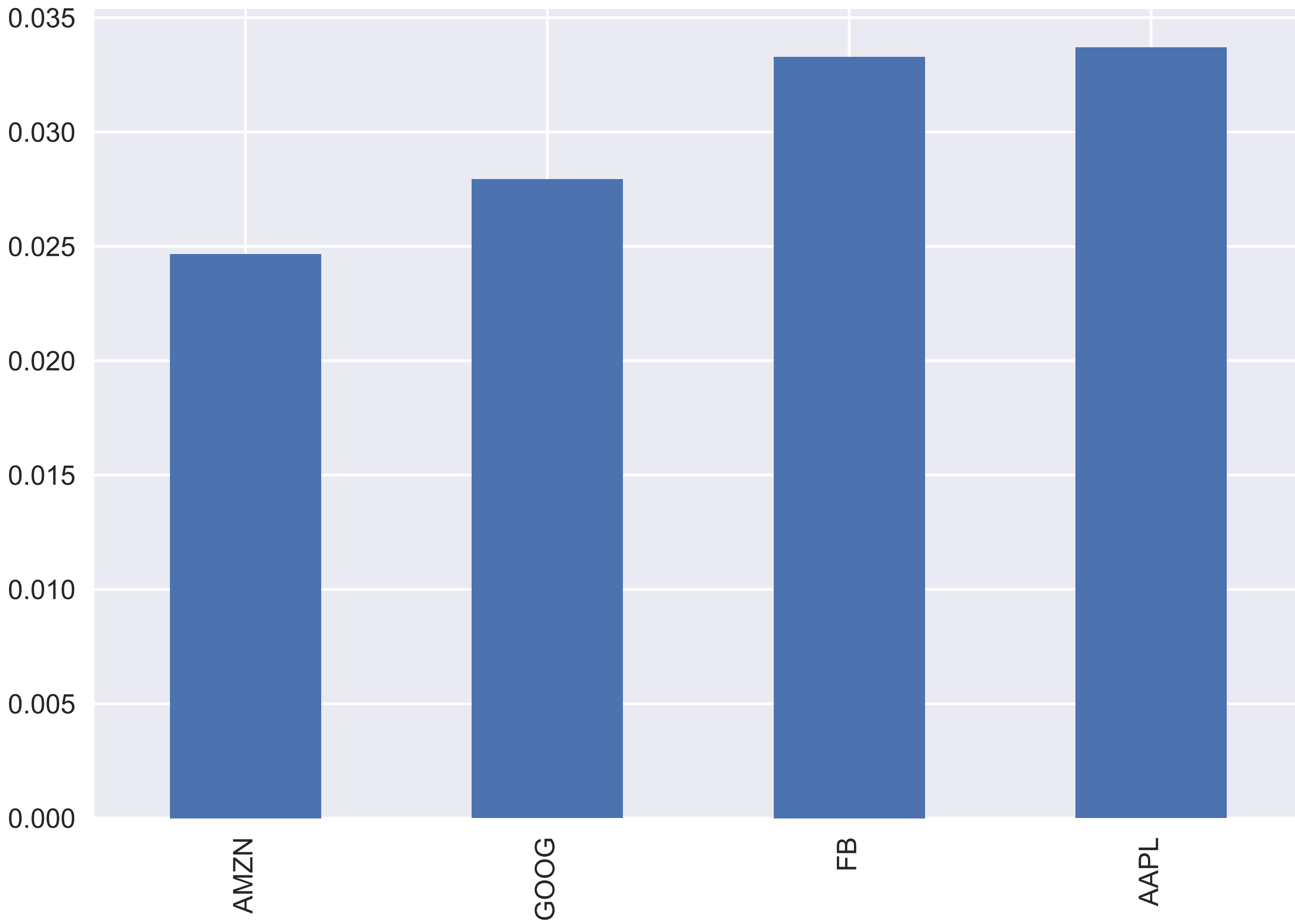

Figure 53: Negative Semi-Deviation

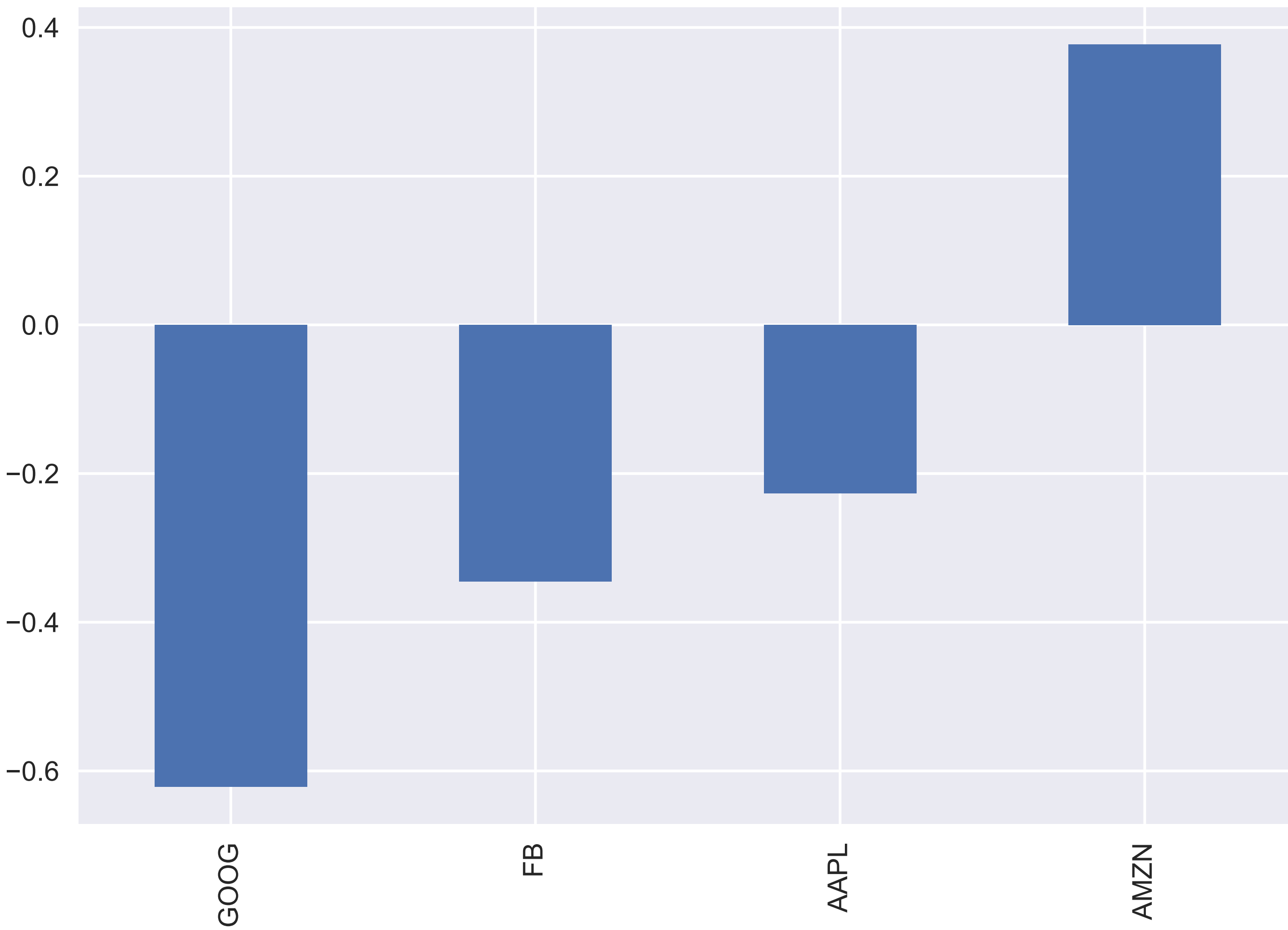

Figure 54: Skewness

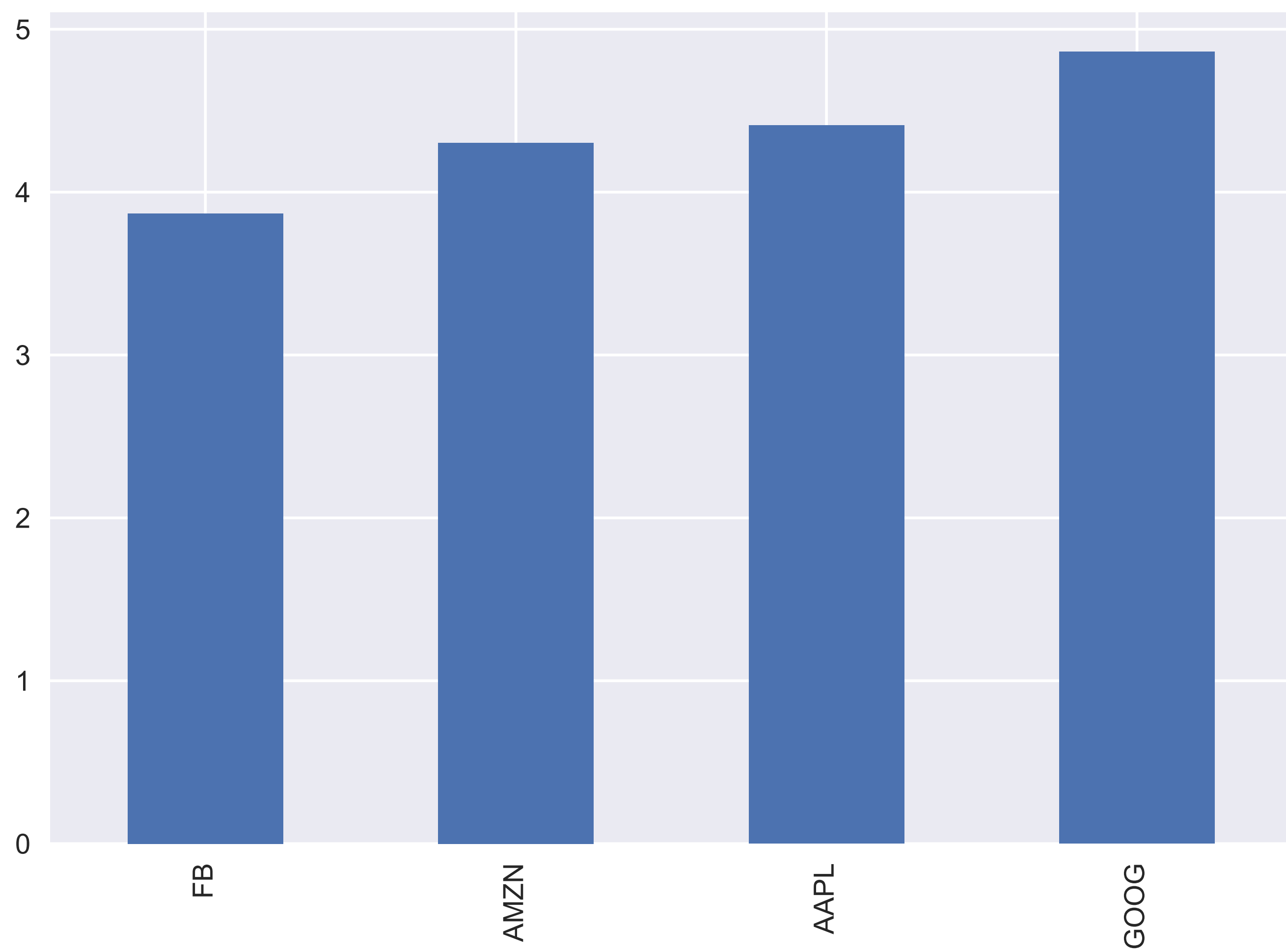

Figure 55: Kurtosis

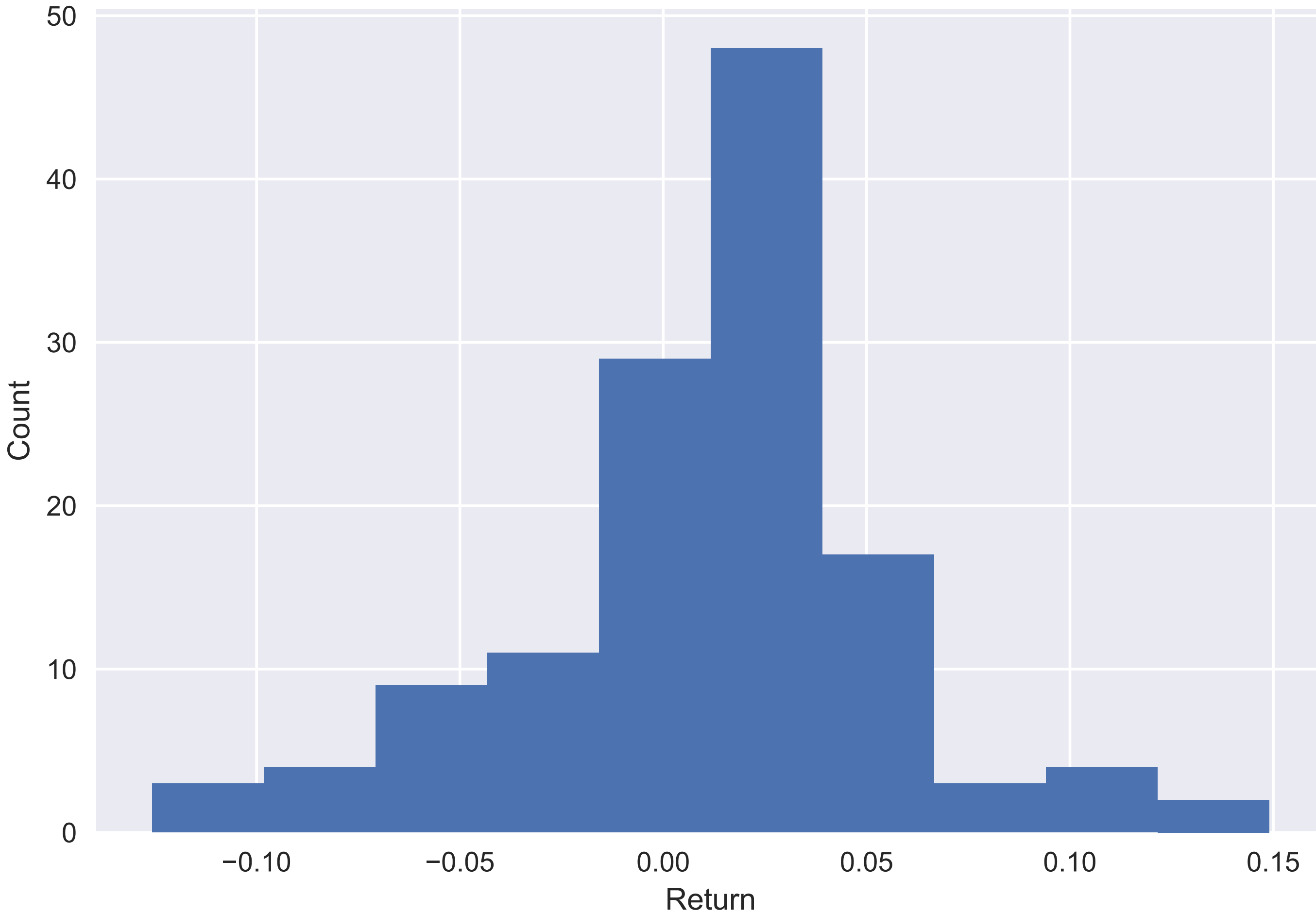

Figure 56: Empirical AAPL Returns Distribution

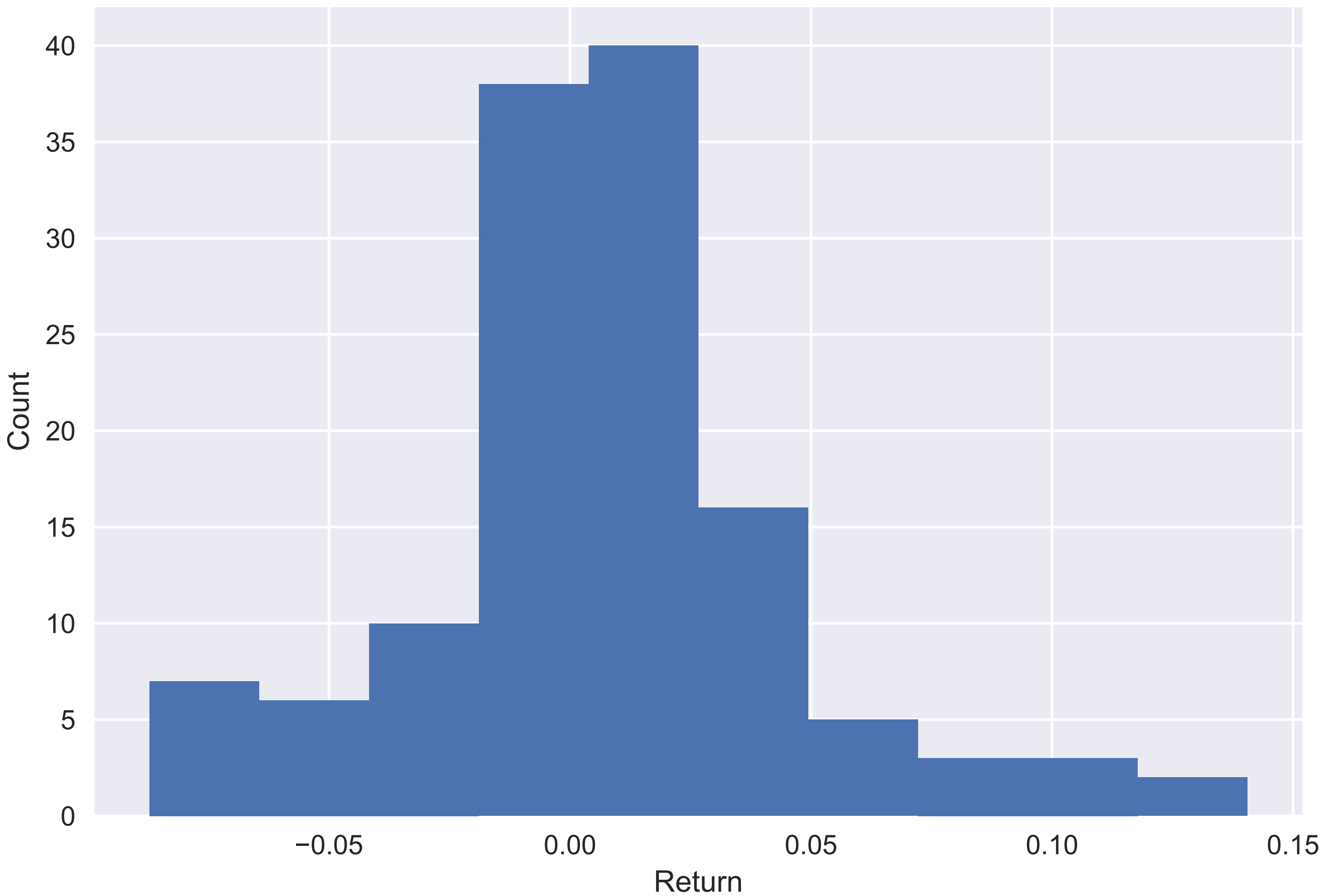

Figure 57: Empirical AMZN Returns Distribution

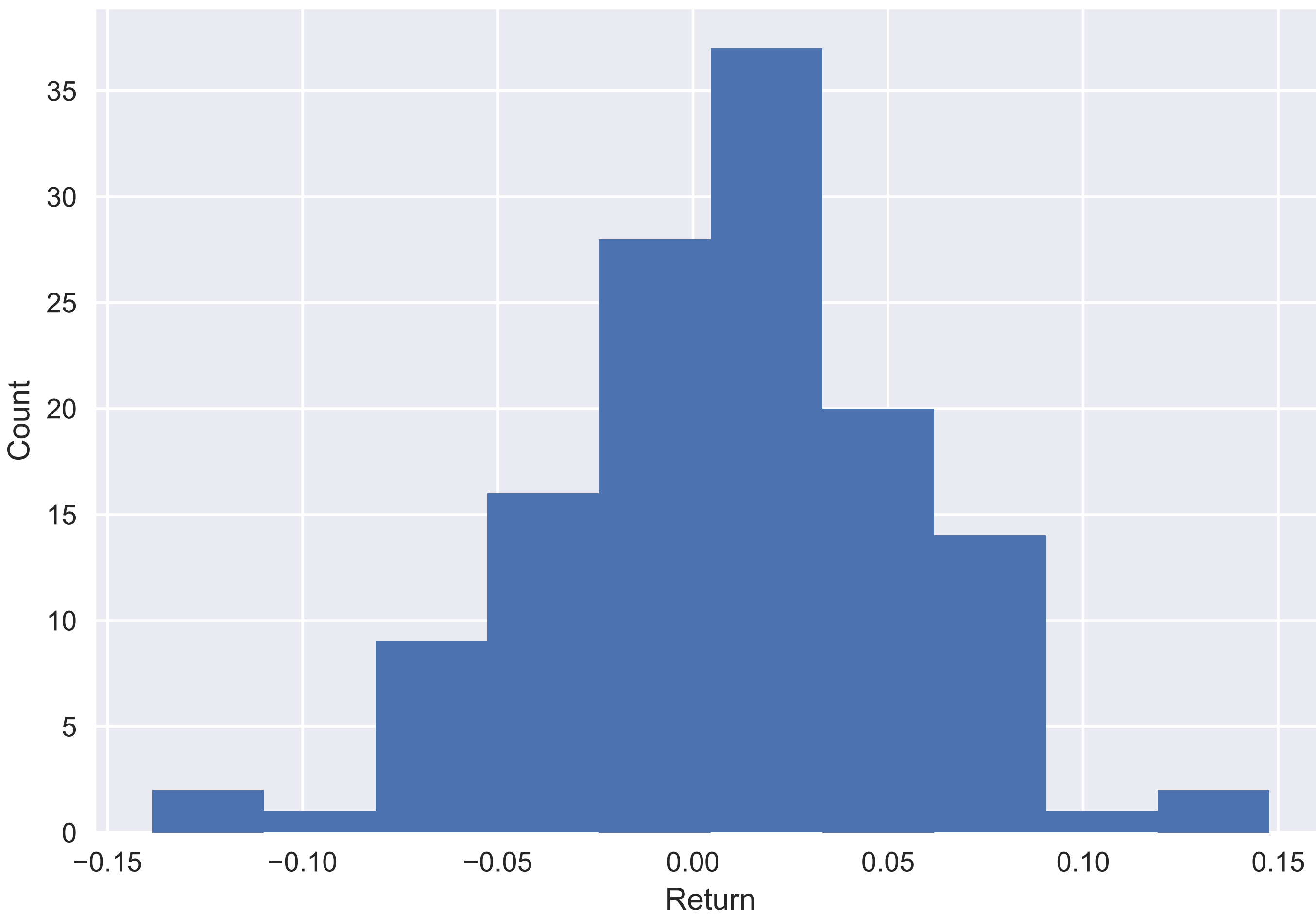

Figure 58: Empirical FB Returns Distribution

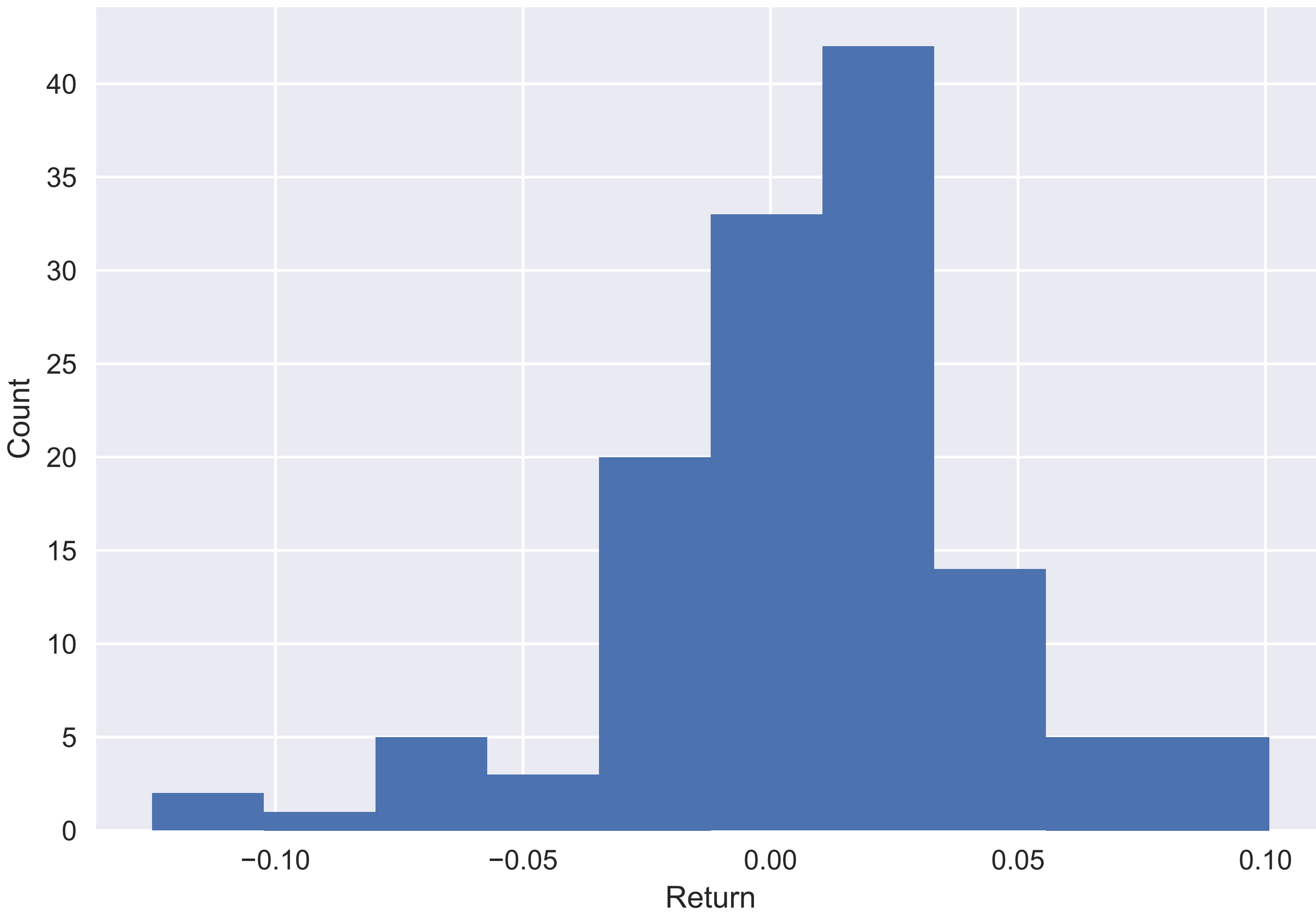

Figure 59: Empirical GOOG Returns Distribution

AAPL	**AMZN**	**FB**	**GOOG**
False	False	True	False

Table 51: Normality Test Results

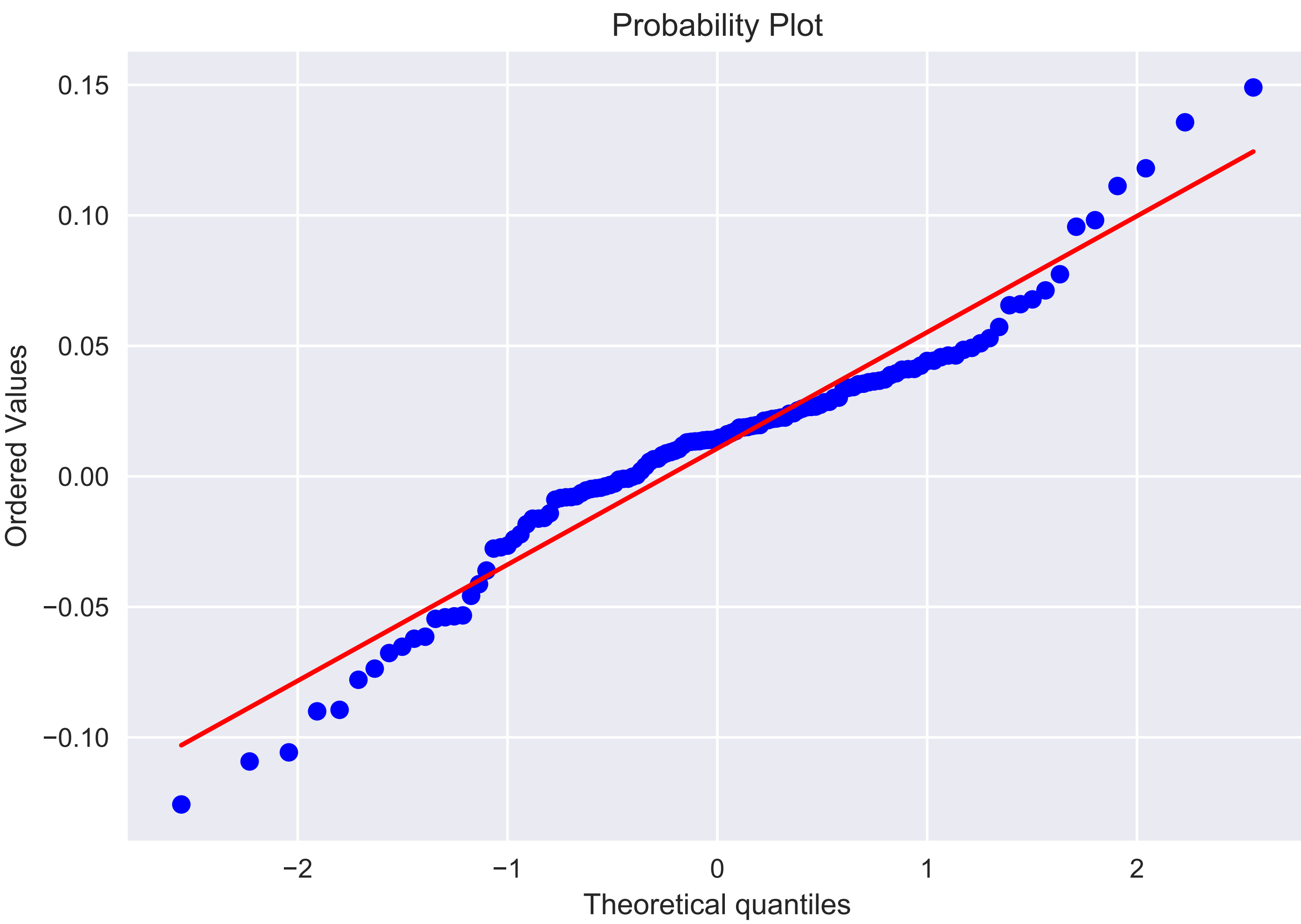

Figure 60: AAPL

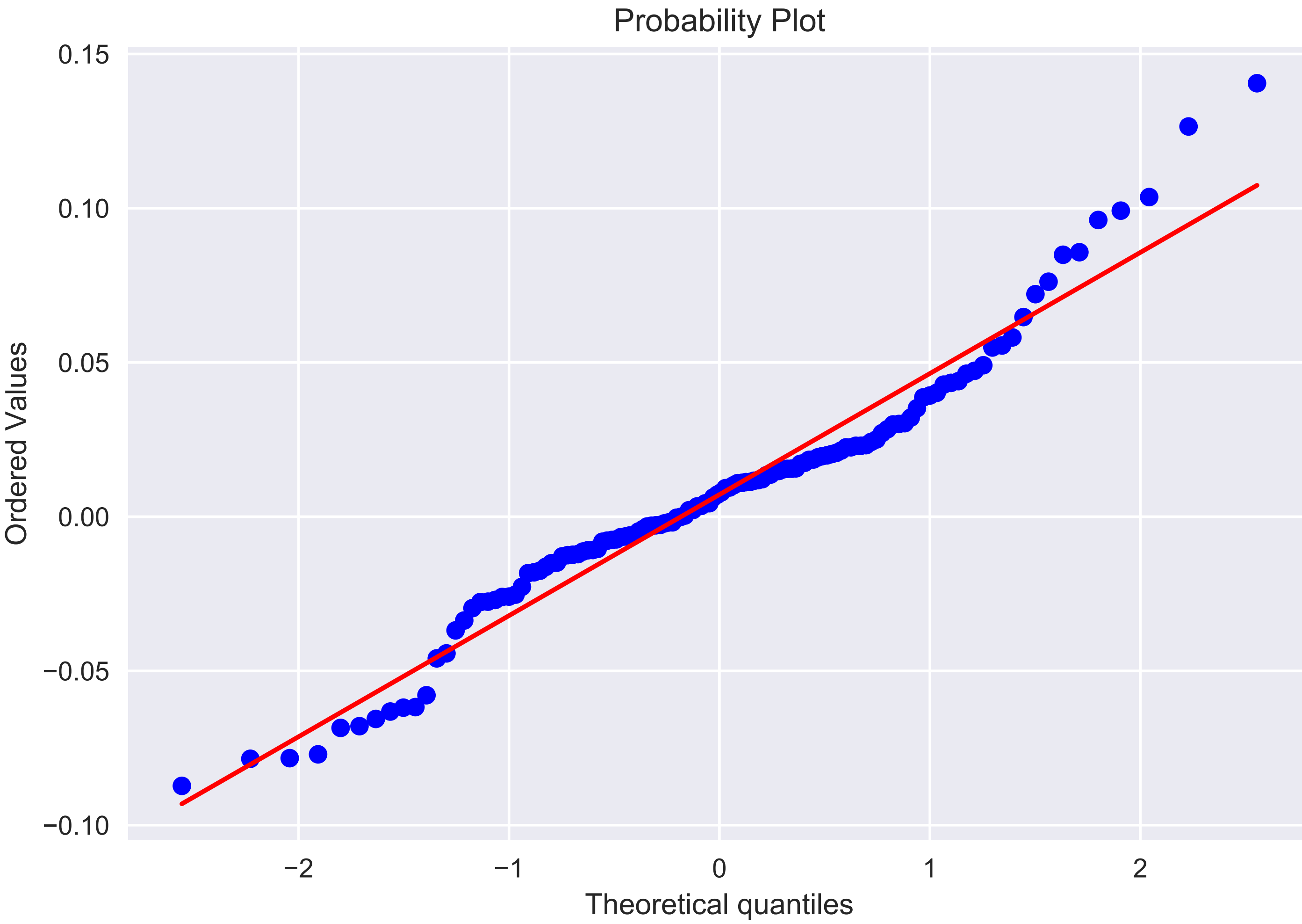

Figure 61: AMZN

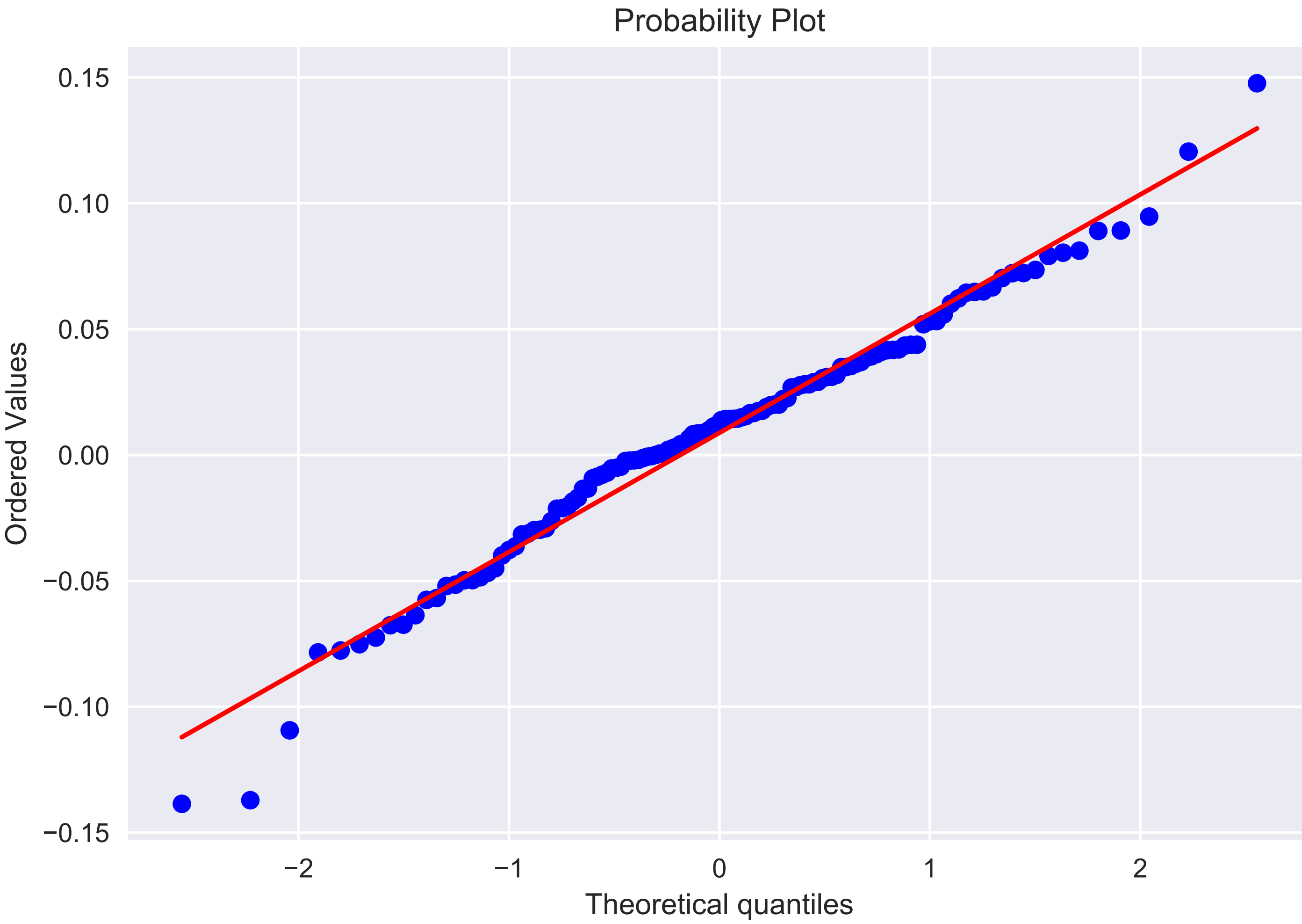
Probability Plot
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
Ordered Values
−2
−1
0
1
2
Theoretical quantiles

Figure 62: FB

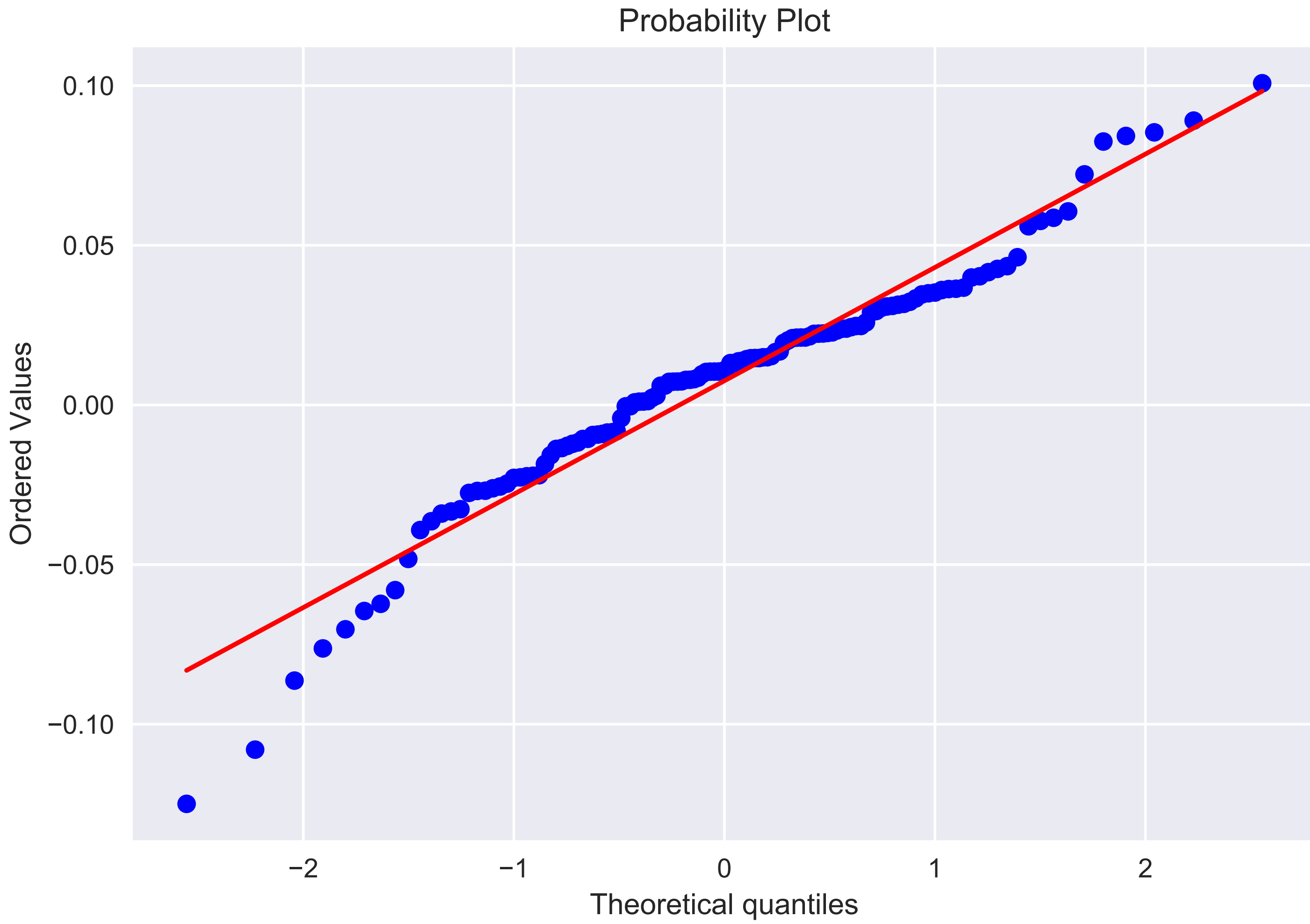

Figure 63: GOOG

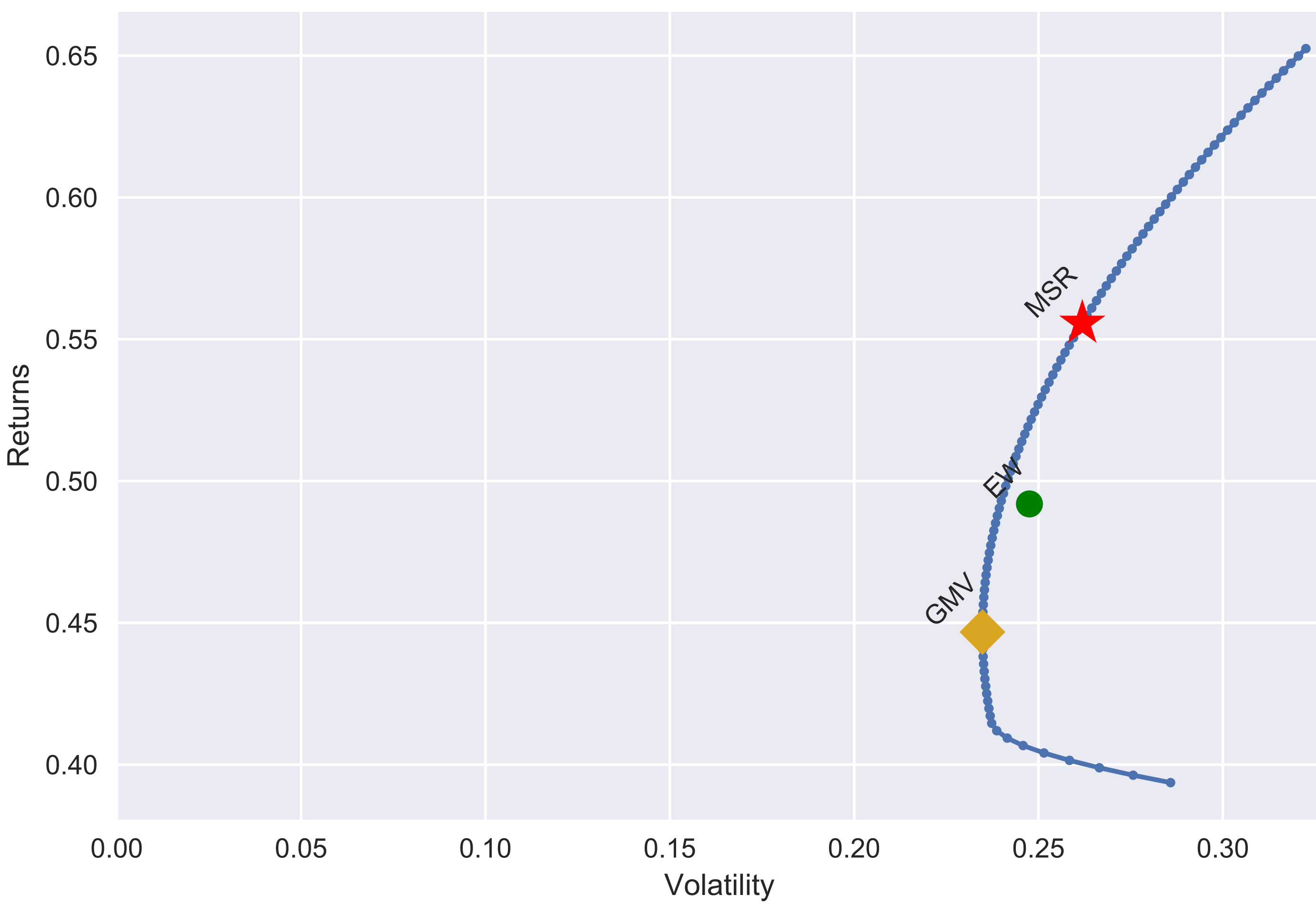

Figure 64: Ex-Ante Efficient Frontier

AAPL	AMZN	FB	GOOG
0.5821	0.1138	0.0	0.3041

Table 52: Weights of Maximum Sharpe Ratio Scheme

Portfolio Return for Maximum Sharpe Ratio Scheme: 0.5556
Portfolio Volatility for Maximum Sharpe Ratio Scheme: 0.2619

AAPL	AMZN	FB	GOOG
0.1312	0.3569	0.0011	0.5107

Table 53: Weights of Global Minimum Variance Scheme

Portfolio Return for Global Minimum Variance Scheme: 0.4467
Portfolio Volatility for Global Minimum Variance Scheme: 0.2348

AAPL	AMZN	FB	GOOG
0.2297	0.2717	0.2143	0.2843

Table 54: Weights of Equal Risk Contribution Scheme

Portfolio Return for Equal Risk Contribution Scheme: 0.4845
Portfolio Volatility for Equal Risk Contribution Scheme: 0.2441

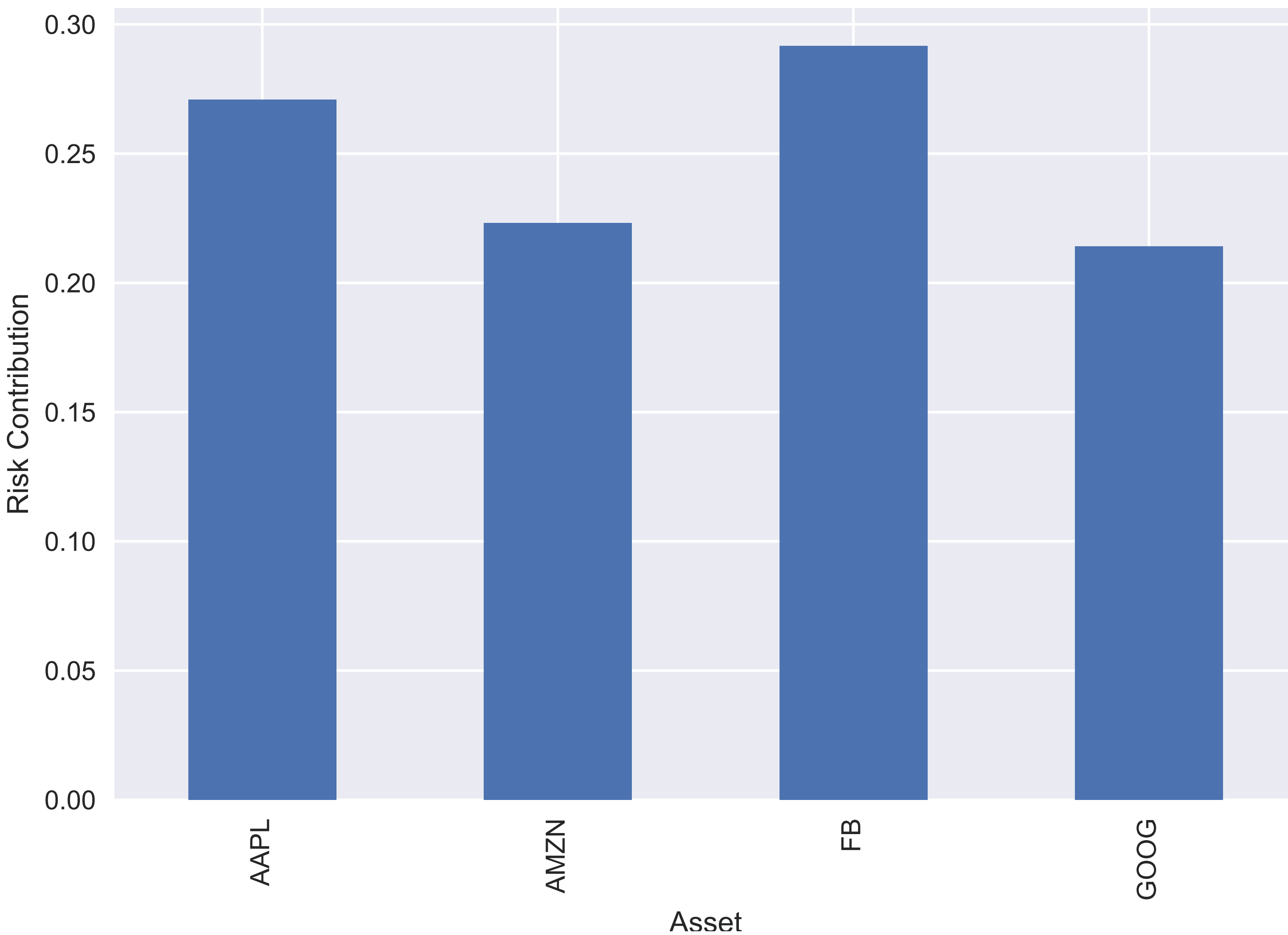

Figure 65: Relative (%) Risk Contributions of the Equal Weights Portfolio

Equal Weights Portfolio volatility: 0.0343

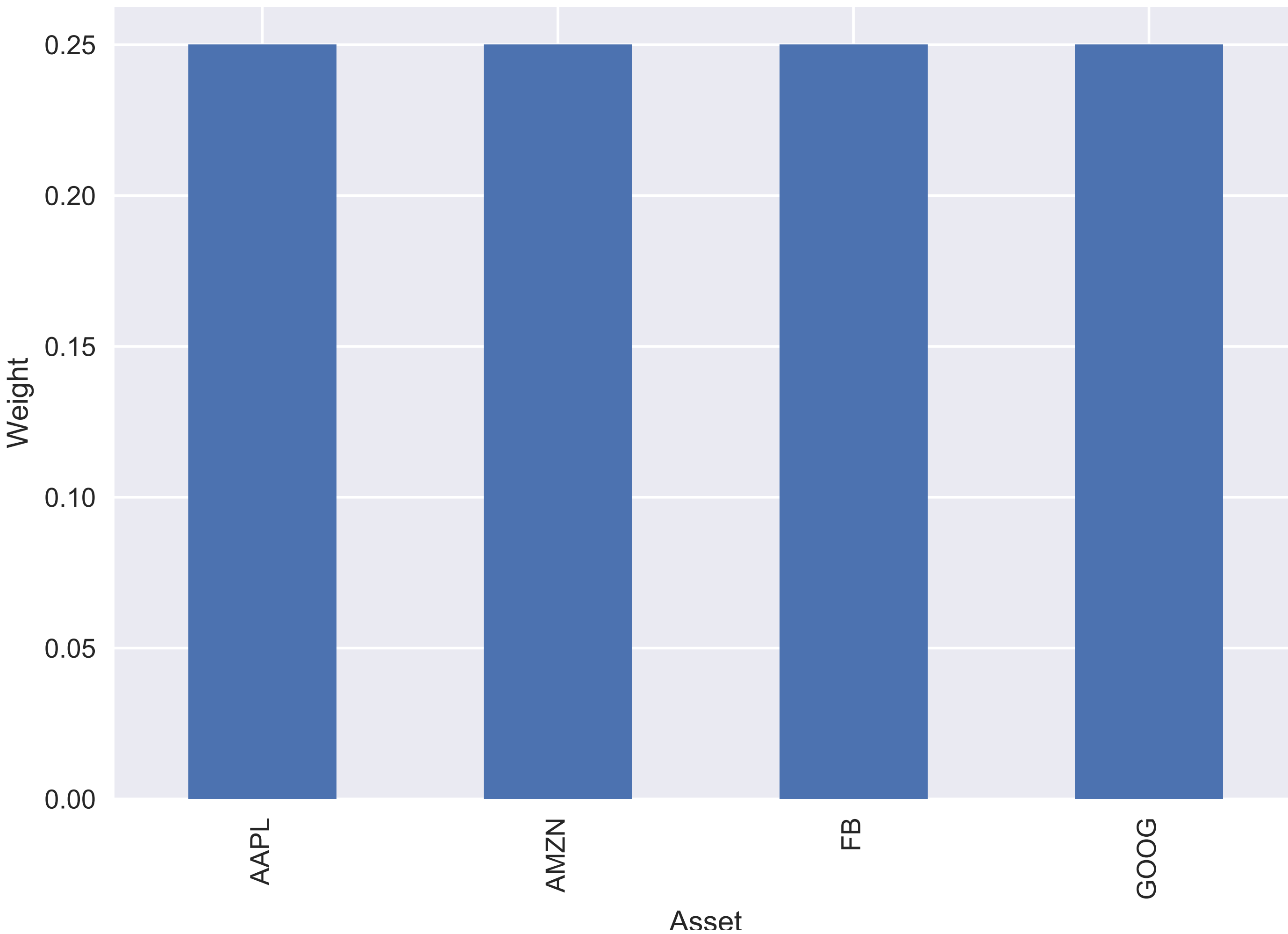

Figure 66: Asset Weights - Equal Weights Portfolio

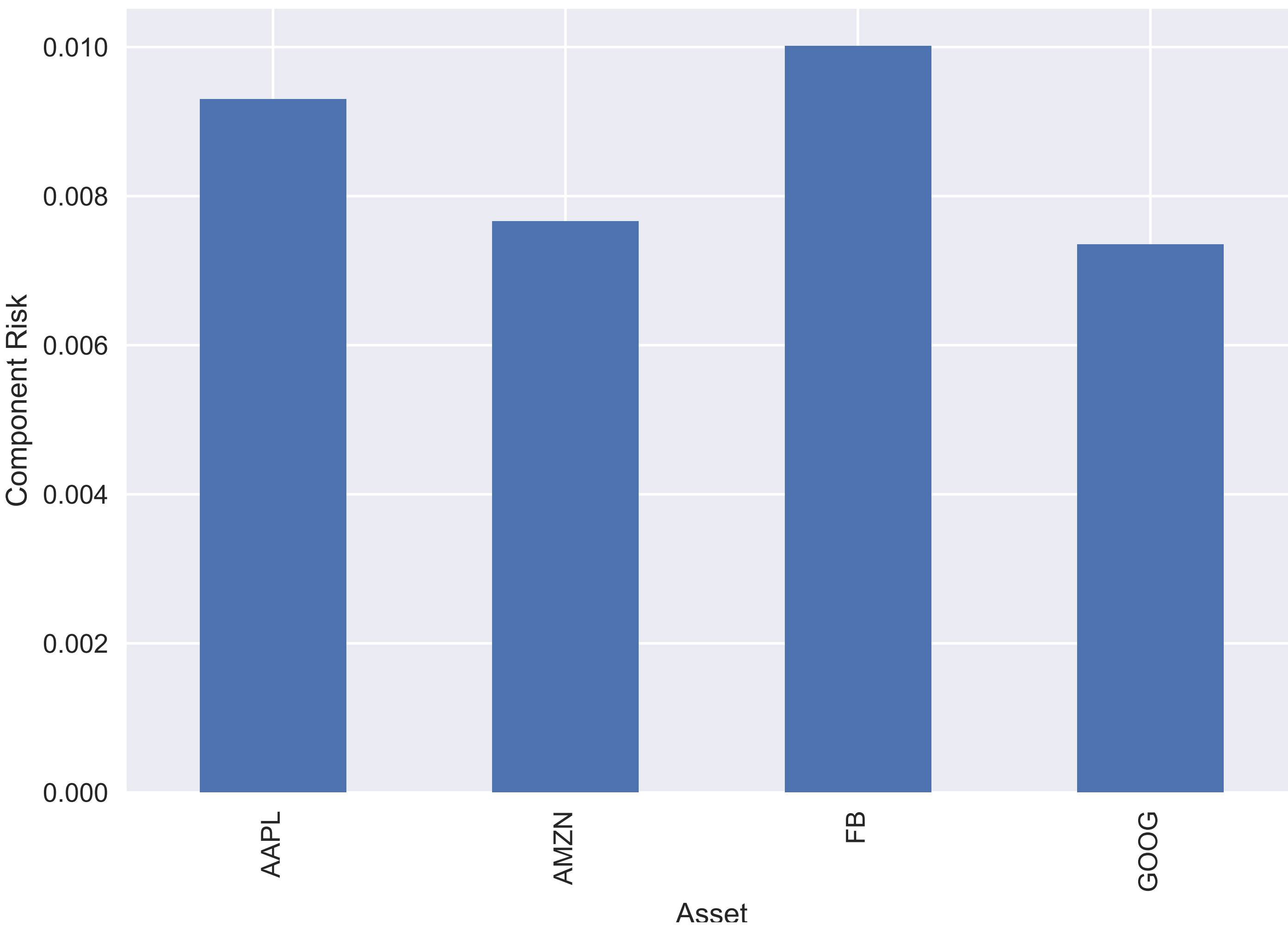

Figure 67: Component Risk of the Equal Weights Portfolio

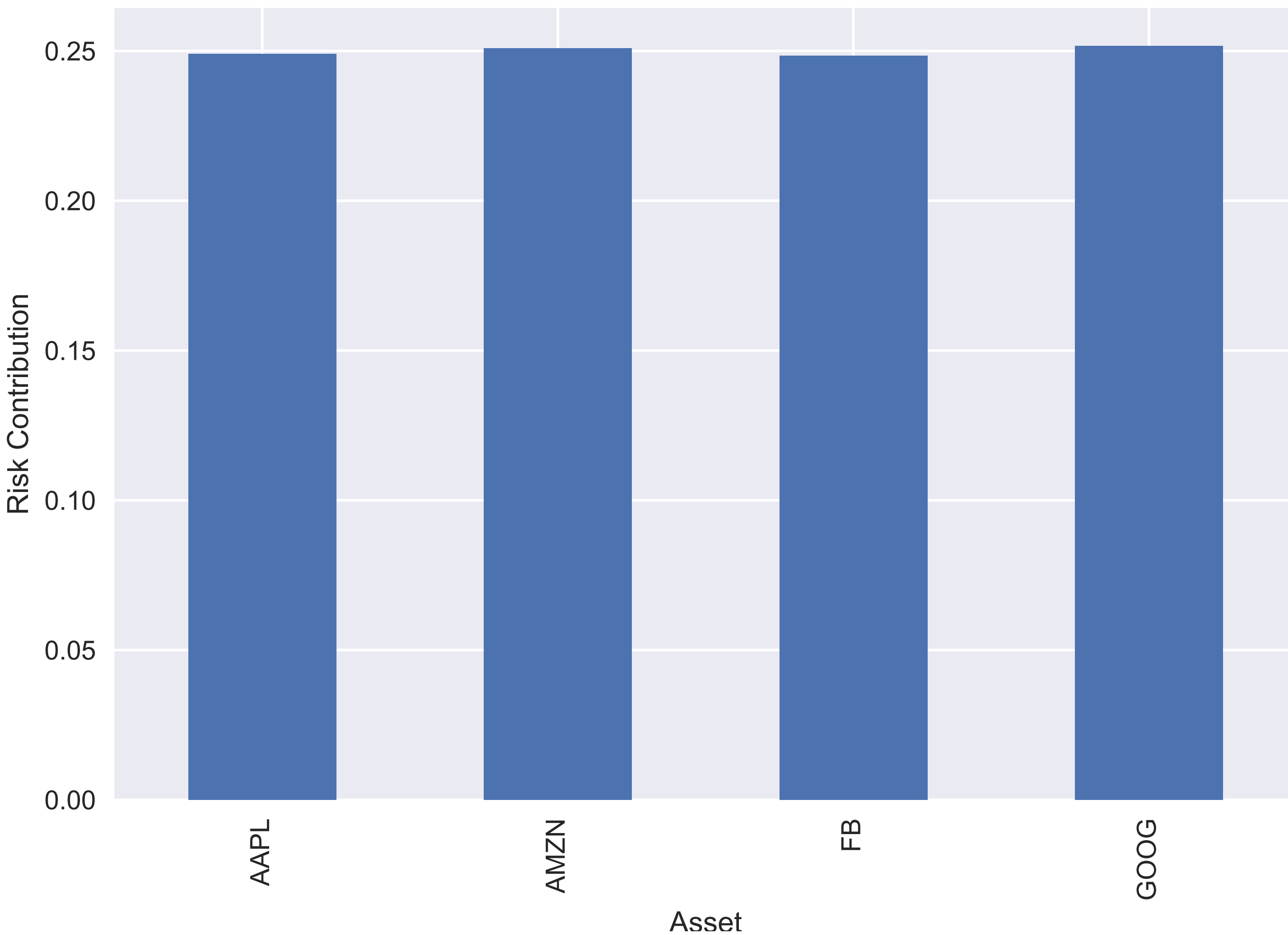

Figure 68: Relative (%) Risk Contributions of the Equal Risk Contribution Portfolio

Equal Risk Contribution Portfolio volatility: 0.0339

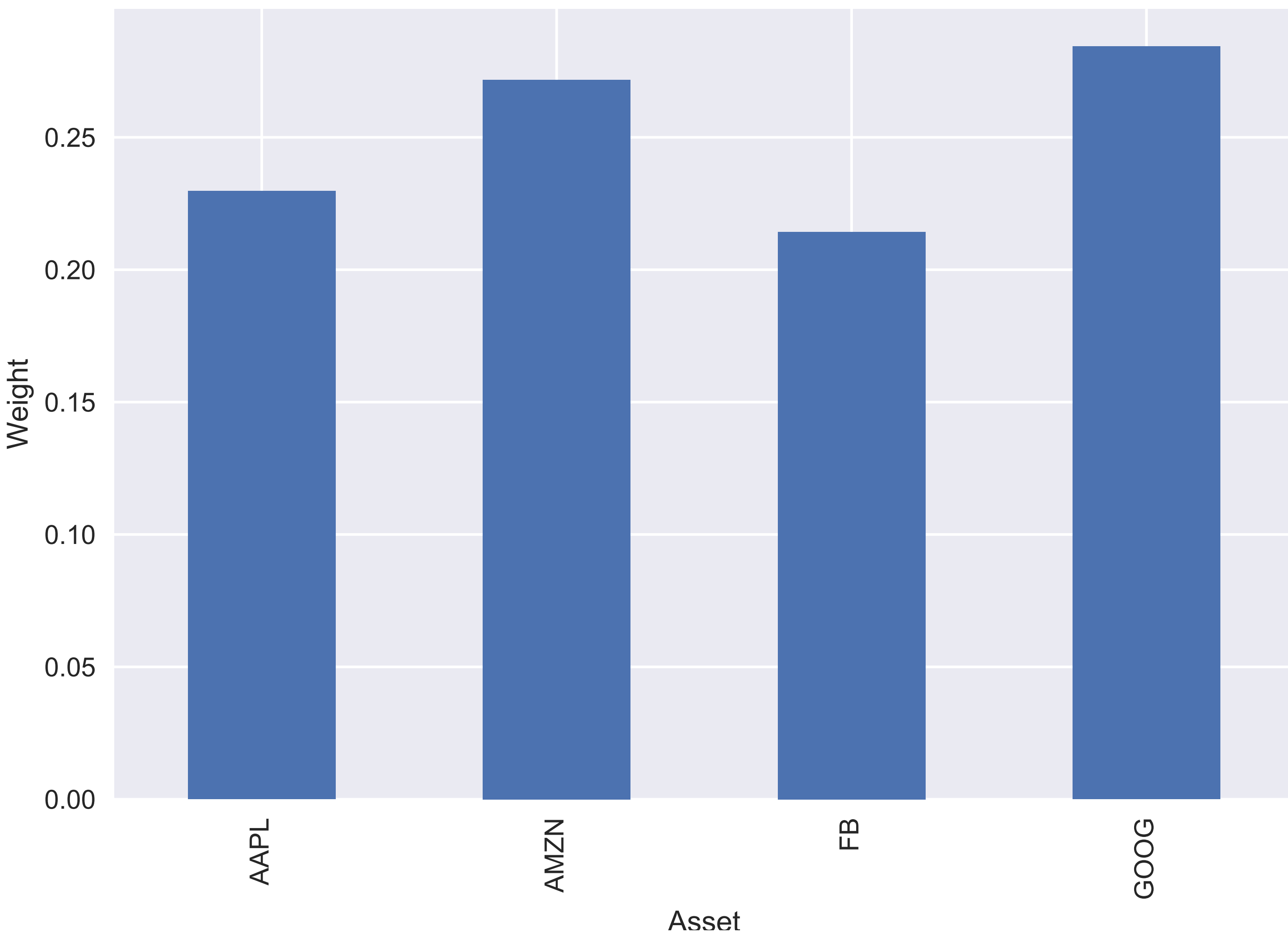

Figure 69: Asset Weights - Equal Risk Contribution Portfolio

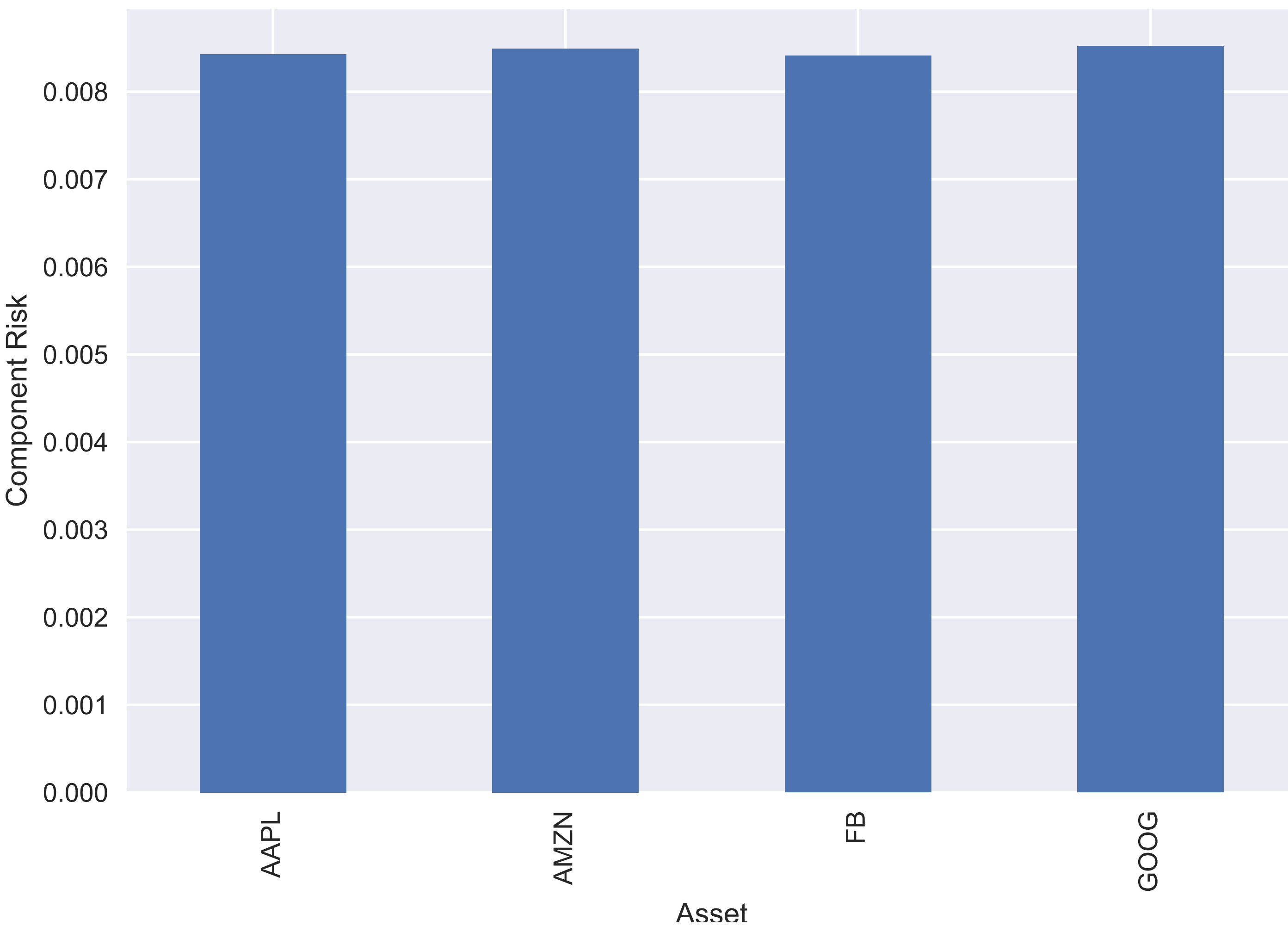

Figure 70: Component Risk of the Equal Risk Contribution Portfolio

	Historical	EW	CW	MSR	GMV	ERC
2020-01-12	0.0358	0.0356	0.033	0.0312	0.0351	0.0354
2020-01-19	0.0119	0.0318	0.0321	0.056	0.0246	0.0304
2020-01-26	0.0121	0.0071	0.0037	-0.0013	0.0103	0.0077
2020-02-02	-0.0335	-0.0304	-0.0292	-0.0245	-0.0315	-0.0306
2020-02-09	0.0648	0.0205	0.0249	-0.0016	0.046	0.0255
...	...	...	...	...	...	...

Table 55: Backtesting Returns

	Historical	EW	CW	MSR	GMV	ERC
2020-01-12	1.0358	1.0356	1.033	1.0312	1.0351	1.0354
2020-01-19	1.0481	1.0685	1.0662	1.089	1.0606	1.0669
2020-01-26	1.0608	1.0761	1.0702	1.0876	1.0715	1.0752
2020-02-02	1.0253	1.0434	1.0389	1.0609	1.0377	1.0423
2020-02-09	1.0918	1.0648	1.0648	1.0592	1.0855	1.0688
...	...	...	...	...	...	...

Table 56: Cumulative Returns

Figure 71: Strategies Cumulative Return

	Historical	**EW**	**CW**	**MSR**	**GMV**	**ERC**
Return	0.5339	0.5253	0.5081	0.4878	0.6466	0.5433
Volatility	0.2725	0.2864	0.295	0.3211	0.2769	0.2842
Semi-Deviation	0.1963	0.2147	0.2051	0.2355	0.2198	0.2155
Skewness	-0.3571	-0.7303	-0.6175	-0.2811	-0.7214	-0.7376
Kurtosis	3.6369	3.7844	3.4324	3.9299	4.0698	3.8472
Gaussian VaR (95.0%)	0.0528	0.056	0.0581	0.0641	0.0524	0.0552
Modified VaR (95.0%)	0.056	0.0632	0.0646	0.0668	0.059	0.0624
Historic VaR (95.0%)	0.0539	0.0565	0.066	0.0689	0.0537	0.0561
Historic CVaR (95.0%)	0.082	0.0922	0.0909	0.0963	0.0904	0.0918
Max. Drawdown	-0.2495	-0.269	-0.2531	-0.3013	-0.2618	-0.2677
Sharpe Ratio	1.9595	1.8337	1.7223	1.519	2.3353	1.9119
Sortino Ratio	2.7199	2.4465	2.477	2.071	2.9421	2.521

Table 57: Performance Summary (Annualized)