ESG Risk Ratings Correlation with DrawDown Beta

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Outline

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Introduction

I was assigned the task of the ESG project to learn Ding and Uryasev (2022) : Drawdown Beta and Portfolio Optimization paper and realize the calculation of the Standard Beta, $ERoD_{0+}$ Beta, $CDaR_{0.9}$ Beta, Maximum drawdown, Annual Return, like the Drawdown Beta Website from Professor Uryasev website, by writing my own code. Drawdown Beta Website link:
`http://qfdb.ams.stonybrook.edu/index_SP.html`
Use the calculated Standard Beta, $ERoD_{0+}$ Beta, $CDaR_{0.9}$ Beta, Maximum drawdown, Annual Return results to see their correlation with the ESG rating scores.

From this reference link:
`https://www.businessinsider.com/personal-finance/esg-score`:
Jim Probasco claimed that Sustainalytics, a subsidiary of Morningstar, provides ESG ratings on 20,000 companies in 172 countries. ESG ratings, which are based on both quantitative ESG data and qualitative analysis, cover several different areas including governance, environmental impact, social contribution, and financial performance to provide a holistic view of the ESG profile of companies. Risk ratings cover five categories: Negligible risk (0 to 9.99), Low risk (10 to 19.99), Medium risk (20 to 29.99), High risk (30 to 39.99), and Severe risk (40 and above)

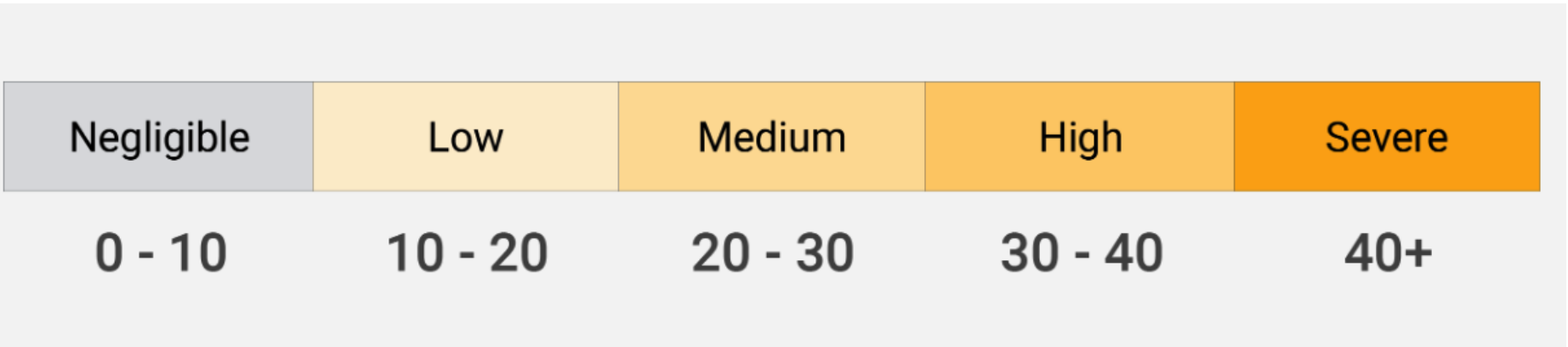

Figure 1: reference: `https://www.sustainalytics.com/corporate-solutions/esg-solutions/esg-risk-ratings#esg`

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Drawdown

Ding and Uryasev (2022)

- Drawdown measures current portfolio value compared to the previous peak value
- Drawdown is a so called static-dynamic risk measures:
  1. it is dynamic because many time periods are considered;
  2. It is static in the sense that decisions are not made on every step of the dynamic process

Drawdown

Definition

Ding and Uryasev (2022) call a set of consecutive vectors of returns of instruments a sample-path. A sample path may be just a table of historical returns of instruments or joint returns simulated with some model. Suppose that $\{r_t\}_{1\leq t\leq T}$ is a sample path of scalar returns of some instrument. Ding and Uryasev (2022) denote:
$\{w_t\}_{1\leq t\leq T}$ = vector of uncompounded cumulative returns,

$$w_t = \sum_{\nu=1}^{t} r_\nu, \quad 1 \leq t \leq T \tag{1}$$

$\{d_t\}_{1\leq t\leq T}$ = vector of drawdowns,

$$d_t = \max_{1\leq \nu\leq t} \{w_\nu\} - w_t, \quad 1 \leq t \leq T \tag{2}$$

For every time moment t the drawdown dt is the difference between the previous peak and the current cumulative return.

Drawdown

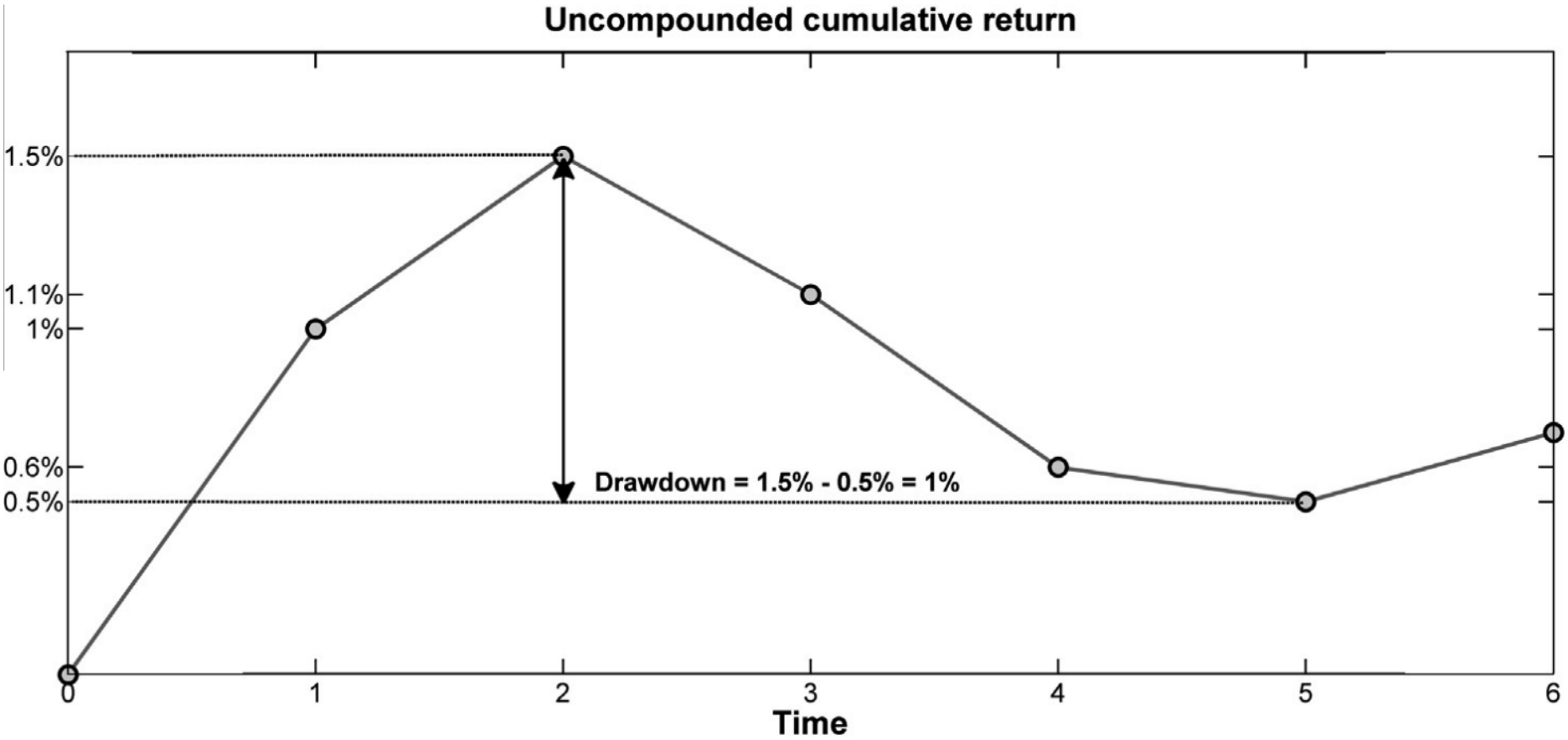

Figure 2: Drawdown Example: Solid line = uncompounded cumulative rate of return (at time t is the sum of rates of return over periods $1, ..., t$). For $t = 5$, $w_5 = 0.5\%$, whereas the maximum of w_t over time moments preceding $t = 5$ occurs at $t = 2$ with $w_2 = 1.5\%$. Consequently $d_5 = 1.5\% - 0.5\% = 1\%$. Maximum drawdown over time period [0, 6] occurs at $t = 5$ (Zabarankin, Pavlikov, Uryasev (2014)).

Drawdown

Maximum drawdown (MaxDD), defined by

$$\mathrm{MaxDD}(w) = \max_{1 \leqslant t \leqslant T} d_t$$

Conditional Drawdown-at-Risk (CDaR)

Definition

For a given $\alpha \in [0, 1)$ and time horizon T such that αT is an integer, the α-$CDaR$ is an average over the worst $(1-\alpha) * 100\%$ drawdowns occurred in the time horizon. Accordingly, Ding and Uryasev (2022) define the single sample-path $CDaR_\alpha$ as:

$$CDaR_\alpha(w) = \sum_{t=1}^{T} q_t^\star d_t \tag{3}$$

where
$q_t^\star = \frac{1}{(1-\alpha)T}$ if d_t is one of the $(1-\alpha)T$ largest portfolio drawdowns, and $q_t^\star = 0$ otherwise.

Drawdown Beta

Ding and Uryasev (2022)

- Standard Beta = normalized correlation of returns of an instrument and the market
- Beta is considered in the framework of Capital Asset Pricing Theory
- Instrument with negative beta is a statistical hedge (protection) which supposed to generate positive returns when market goes down
- Drawdown Betas = show performance of an instrument when market is in drawdown
- Two variants of Drawdown Beta:
  1. Conditional Drawdown-at-Risk (CDaR) Beta
  2. Expected Regret of Drawdown (ERoD) Beta
- Instrument with negative Drawdown Beta generate positive return when market is in drawdown (at least in-sample)

Drawdown Beta

Simplified Explanation (Ding and Uryasev, 2022)

- Conditional Drawdown-at-Risk (CDaR) Beta:
  average instrument losses over x% worst case market drawdown periods

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  average market losses over x% worst case market drawdown periods
- Expected Regret of Drawdown (ERoD) Beta:
  average instrument losses during market drawdowns exceeding threshold

  ---

  average market drawdowns exceeding threshold

CDaR Beta

Zabarankin, Pavlikov, Uryasev (2014) developed CAPM relationships based on $CDaR$. Ding and Uryasev (2022) derived necessary optimality conditions for $CDaR$ portfolio optimization. These conditions resulted in $CDaR$ Beta relating cumulative returns of a market (optimal portfolio) and individual securities. $CDaR$ Beta equals:

$$\beta^i_{CDaR} = \frac{\sum_{s=1}^{S}\sum_{t=1}^{T} p_s q^{\star}_{st}\left(w^i_{s,\tau(s,t)} - w^i_{st}\right)}{CDaR_{\alpha}\left(w^M\right)},$$

CDaR Beta

where

$i =$ index of a security, $i = 1, ..., I$;
$s =$ index of sample path of returns of securities, $s = 1, ..., S$;
$p_s =$ probability of a sample path s;
$t =$ time, $t = 1, ..., T$;
$w^i_{st} =$ uncompounded cumulative return of asset i at time moment t on sample path s;
$w^M =$ vector of uncompounded cumulative returns of market portfolio (optimal portfolio) including components w^M_{st}, $t = 1, ..., T, s = 1, ..., S$;
$\tau(s, t) =$ time moment of the most recent maximum of market cumulative return preceding t on scenario s;
$q^\star_{st} =$ indicator which is equal to $\frac{1}{(1-\alpha)T}$ for the largest $(1-\alpha)T$ drawdowns of market portfolio w^M and zero otherwise;
$CDaR_\alpha\left(w^M\right) = \sum_{s=1}^{S}\sum_{t=1}^{T} p_s q^\star_{st}\left(w^M_{s,\tau(s,t)} - w^M_{st}\right)$ =average of the largest $(1-\alpha)\%$ drawdowns of market portfolio w^M
(e.g., if $\alpha = 0.9$ then $CDaR$ accounts for 10% largest drawdowns).

CDaR Beta

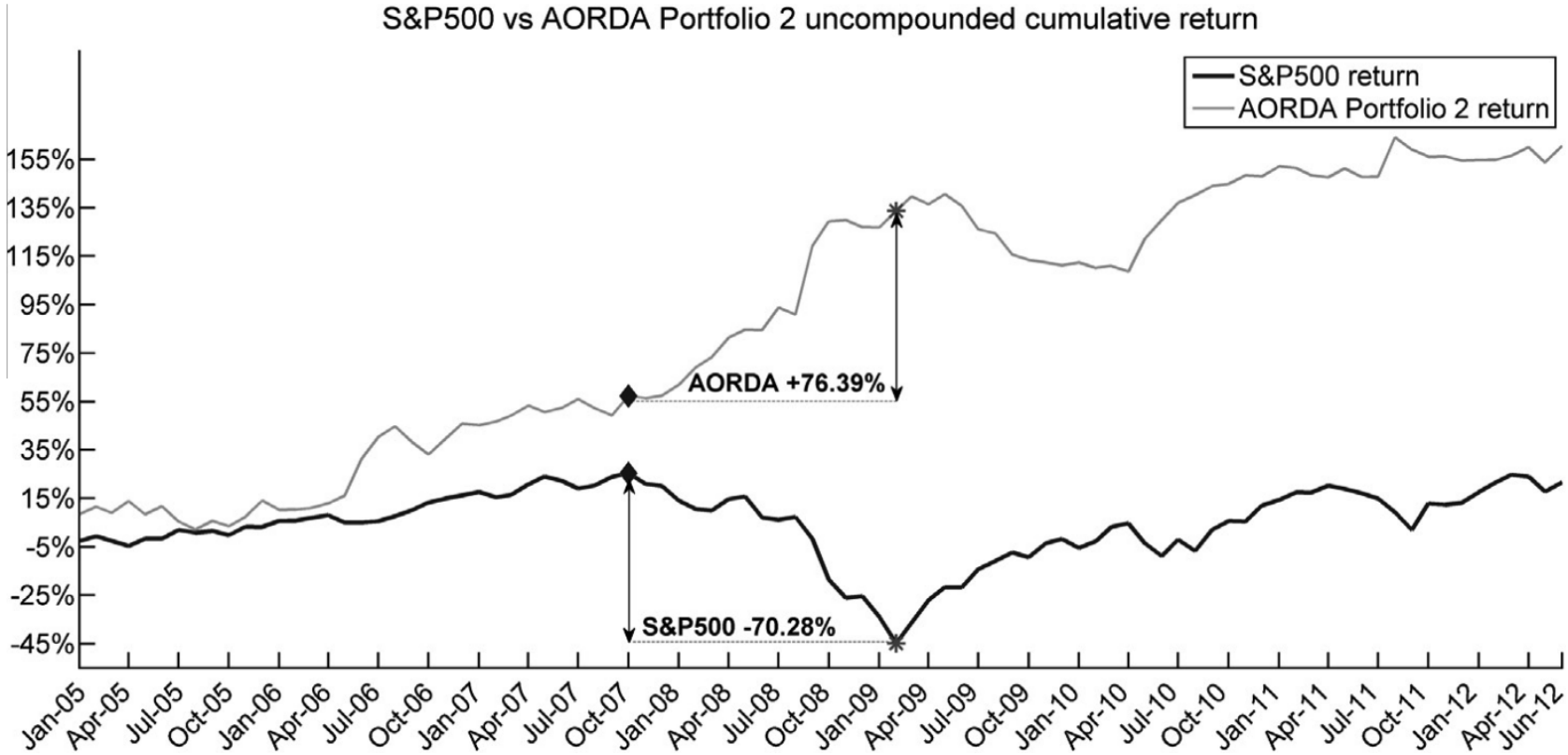

Figure 3: Example: Uncompounded monthly cumulative rates of return of the SP500 index and AORDA Portfolio 2 ($T = \tau = 90$). The S&P500 index had its largest drawdown in February 2009, marked by ($*$): it peaked in October 2007 ($\blacklozenge$) and lost 70.28% from October 2007 to February 2009. During the same period, the AORDA Portfolio 2 earned 76.39%; therefore, $\mathrm{CDaR}_{\alpha=1}$ Beta $=$ MaxDD Beta $= 76.39\%/(-70.28\%) = -1.09$ (Zabarankin, Pavlikov, Uryasev (2014)).

Expected Regret of Drawdown (ERoD) Beta

Ding and Uryasev (2022) introduced a new drawdown based risk measure called Expected Regret of Drawdown (ERoD). By definition, ERoD is an average of drawdowns exceeding a threshold ϵ. The Expected Regret (also termed Low Partial Moment) is defined as the average of losses exceeding a fixed threshold. Therefore, ERoD is the Expected Regret of drawdown observations over considered period. Formula for ERoD Beta can be derived similar to CDaR Beta. Moreover, CDaR Beta and ERoD Beta coincide for some confidence level α in CDaR and some threshold ϵ in ERoD. Ding and Uryasev (2022) show that the ERoD Beta equals:

$$\hat{\beta}^i_{ERoD} = \frac{\frac{1}{T}\sum_{s=1}^{S}\sum_{t=1}^{T} p_s q^{\star}_{st}\left(w^i_{s,\tau(s,t)} - w^i_{st}\right)}{\tilde{E}_{\epsilon}\left(w^M\right)}$$

Expected Regret of Drawdown (ERoD) Beta

where

$i =$ index of a security, $i = 1, ..., I$;
$s =$ index of sample path of returns of securities, $s = 1, ..., S$;
$p_s =$ probability of a sample path s;
$t =$ time, $t = 1, ..., T$;
$w_{st}^i =$ uncompounded cumulative return of asset i at time moment t on sample path s;
$w^M =$ vector of uncompounded cumulative returns of market portfolio (optimal portfolio) including components w_{st}^M, $t = 1, ..., T, s = 1, ..., S$;
$\tau(s,t) =$ time moment of the most recent maximum of market cumulative return preceding t on scenario s;
$\tilde{E}_\epsilon\left(w^M\right) = \frac{1}{T}\sum_{s=1}^{S}\sum_{t=1}^{T} p_s q_{st}^\star \left(w_{s,\tau(s,t)}^M - w_{st}^M\right) =$ threshold adjusted ERoD with threshold ϵ for return w^M;
$d_{st}^M = w_{s,\tau(s,t)}^M - w_{st}^M =$ drawdowns of the market portfolio;
$q_{st}^\star = \mathbb{1}\left(d_{st}^M \geq \epsilon\right) =$ indicator function which is equal to 1 for $d_{st}^M \geq \epsilon$ and 0 otherwise.

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Numerical Study

Using the sustainability function of Python's yfinance package, I loop through all the stocks on Yahoo Finance with ESG rating scores.

	ticker	totalEsg
0	MMM	33.61
1	AOS	24.20
2	ABT	24.98
3	ABBV	27.84
4	ACN	9.71
...	...	...
435	XEL	23.70
436	XYL	15.95
437	YUM	20.55
438	ZBH	27.30
439	ZTS	18.47

440 rows × 2 columns

Figure 4: stocks with ESG rating score

Numerical Study

I calculated Standard Beta, $ERoD_{0+}$ Beta, $CDaR_{0.9}$ Beta, Maximum drawdown, Annual Return for all stocks with ESG rating score from 2016/11/1 to 2022/11/1. All adjusted Close prices data were obtained from Yahoo Finance using Python's pandas datareader package.

	ticker	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
0	MMM	1.157728	1.372000	0.819897	-0.013297	0.513593	33.61
1	AOS	1.589278	1.592544	0.851002	0.051687	0.468063	24.20
2	ABT	0.910582	0.628401	0.866542	0.188647	0.316732	24.98
3	ABBV	-0.206989	0.218182	0.704196	0.226182	0.450898	27.84
4	ACN	1.525763	1.328573	1.075946	0.178986	0.389819	9.71
...	...	...	...	...	...	...	...
435	XEL	-0.046353	-0.296847	0.589422	0.112734	0.292807	23.70
436	XYL	1.268983	1.339998	1.089086	0.152210	0.466932	15.95
437	YUM	0.890151	0.674884	0.805223	0.136890	0.521706	20.55
438	ZBH	0.888738	0.967530	0.917750	0.027934	0.497319	27.30
439	ZTS	1.412501	0.785067	0.921918	0.221556	0.412293	18.47

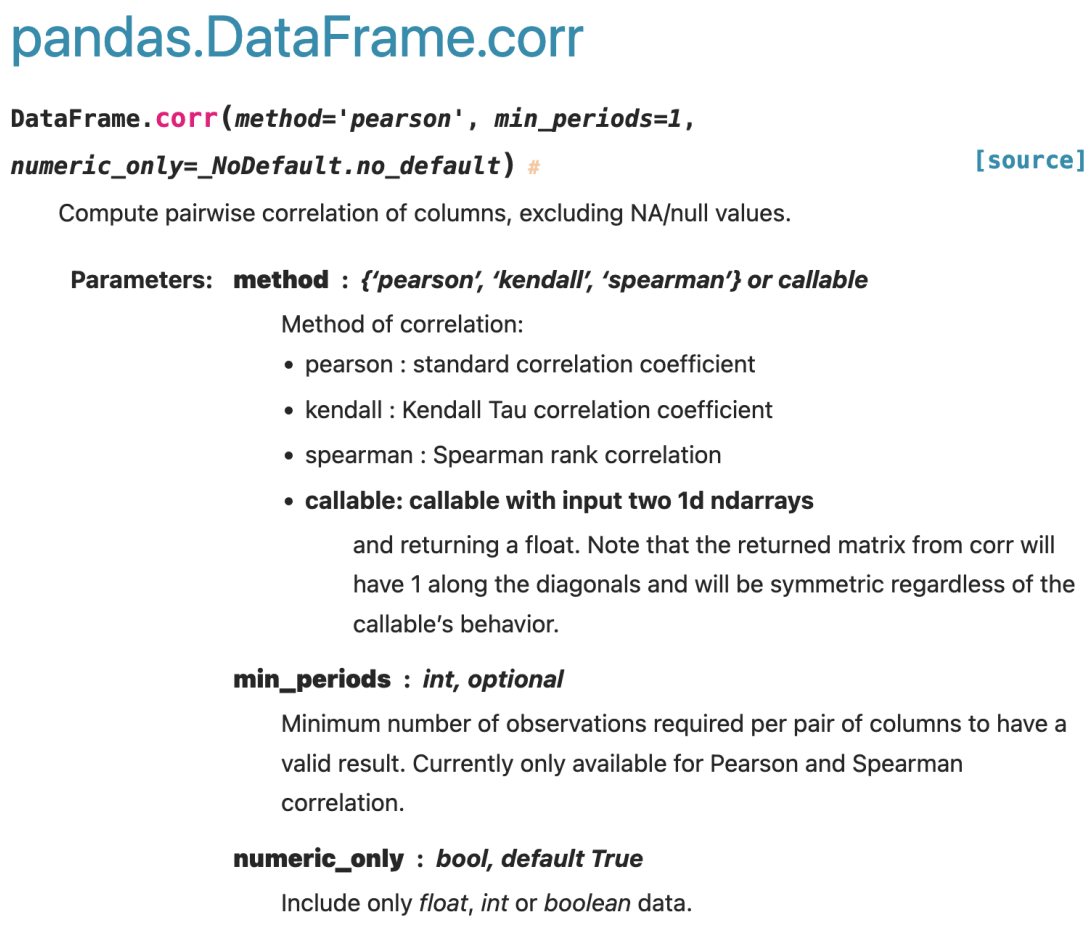
440 rows × 7 columns

	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
Average	0.816408	0.780146	1.001557	0.116293	0.501333	21.498591

Figure 5: Standard Beta, $ERoD_{0+}$ Beta, $CDaR_{0.9}$ Beta, Maximum drawdown, Annual Return calculation result

Numerical Study

Using the function pandas.Datafame.corr, I use two different methods to calculate correlation. One is pearson: standard correlation coefficient; spearman: Spearman rank correlation.



pandas.DataFrame.corr

DataFrame.corr(*method='pearson', min_periods=1, numeric_only=_NoDefault.no_default*) # [source]

Compute pairwise correlation of columns, excluding NA/null values.

Parameters: **method** : *{'pearson', 'kendall', 'spearman'} or callable*

Method of correlation:

- pearson : standard correlation coefficient
- kendall : Kendall Tau correlation coefficient
- spearman : Spearman rank correlation
- **callable: callable with input two 1d ndarrays**

  and returning a float. Note that the returned matrix from corr will have 1 along the diagonals and will be symmetric regardless of the callable's behavior.

min_periods : *int, optional*

Minimum number of observations required per pair of columns to have a valid result. Currently only available for Pearson and Spearman correlation.

numeric_only : *bool, default True*

Include only *float*, *int* or *boolean* data.

Figure 6: reference link: `https://pandas.pydata.org/pandas-docs/stable/reference/api/pandas.DataFrame.corr.html`.

Spearman's rank correlation coefficient

From Wikipedia, the free encyclopedia

In statistics, **Spearman's rank correlation coefficient** or **Spearman's ρ**, named after Charles Spearman and often denoted by the Greek letter ρ (rho) or as r_s, is a nonparametric measure of rank correlation (statistical dependence between the rankings of two variables). It assesses how well the relationship between two variables can be described using a monotonic function.

The Spearman correlation between two variables is equal to the Pearson correlation between the rank values of those two variables; while Pearson's correlation assesses linear relationships, Spearman's correlation assesses monotonic relationships (whether linear or not). If there are no repeated data values, a perfect Spearman correlation of +1 or −1 occurs when each of the variables is a perfect monotone function of the other.

Intuitively, the Spearman correlation between two variables will be high when observations have a similar (or identical for a correlation of 1) rank (i.e. relative position label of the observations within the variable: 1st, 2nd, 3rd, etc.) between the two variables, and low when observations have a dissimilar (or fully opposed for a correlation of −1) rank between the two variables.

Spearman's coefficient is appropriate for both continuous and discrete ordinal variables.[1][2] Both Spearman's ρ and Kendall's τ can be formulated as special cases of a more general correlation coefficient.

Figure 7: reference link: `https://en.wikipedia.org/wiki/Spearman%27s_rank_correlation_coefficient`.

Numerical Study

Definition and calculation [edit]

The Spearman correlation coefficient is defined as the Pearson correlation coefficient between the rank variables.[3]

For a sample of size *n*, the *n* raw scores X_i, Y_i are converted to ranks $\mathrm{R}(X_i), \mathrm{R}(Y_i)$, and r_s is computed as

$$r_s = \rho_{\mathrm{R}(X),\mathrm{R}(Y)} = \frac{\mathrm{cov}(\mathrm{R}(X), \mathrm{R}(Y))}{\sigma_{\mathrm{R}(X)} \sigma_{\mathrm{R}(Y)}},$$

where

ρ denotes the usual Pearson correlation coefficient, but applied to the rank variables,

$\mathrm{cov}(\mathrm{R}(X), \mathrm{R}(Y))$ is the covariance of the rank variables,

$\sigma_{\mathrm{R}(X)}$ and $\sigma_{\mathrm{R}(Y)}$ are the standard deviations of the rank variables.

Only if all *n* ranks are *distinct integers*, it can be computed using the popular formula

$$r_s = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)},$$

where

$d_i = \mathrm{R}(X_i) - \mathrm{R}(Y_i)$ is the difference between the two ranks of each observation,

n is the number of observations.

Figure 8: reference link:
https://en.wikipedia.org/wiki/Spearman%27s_rank_correlation_coefficient.

Numerical Study

	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
CDaR_beta	1.000000	0.879059	0.486974	-0.194931	0.274649	-0.311466
ERod_Beta	0.879059	1.000000	0.598110	-0.320490	0.450465	-0.199261
Standard_Beta	0.486974	0.598110	1.000000	0.050847	0.661465	-0.009661
Annual Return	-0.194931	-0.320490	0.050847	1.000000	-0.417941	-0.105915
Max Drawdown	0.274649	0.450465	0.661465	-0.417941	1.000000	0.196590
TotalEsg	-0.311466	-0.199261	-0.009661	-0.105915	0.196590	1.000000

Figure 9: all correlation matrix using use pearson standard correlation coefficient

	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
CDaR_beta	1.000000	0.866321	0.519213	-0.177445	0.383053	-0.248177
ERod_Beta	0.866321	1.000000	0.604927	-0.269501	0.493107	-0.144288
Standard_Beta	0.519213	0.604927	1.000000	0.069763	0.662962	-0.016361
Annual Return	-0.177445	-0.269501	0.069763	1.000000	-0.376769	-0.106528
Max Drawdown	0.383053	0.493107	0.662962	-0.376769	1.000000	0.111638
TotalEsg	-0.248177	-0.144288	-0.016361	-0.106528	0.111638	1.000000

Figure 10: all correlation matrix using Spearman rank correlation method

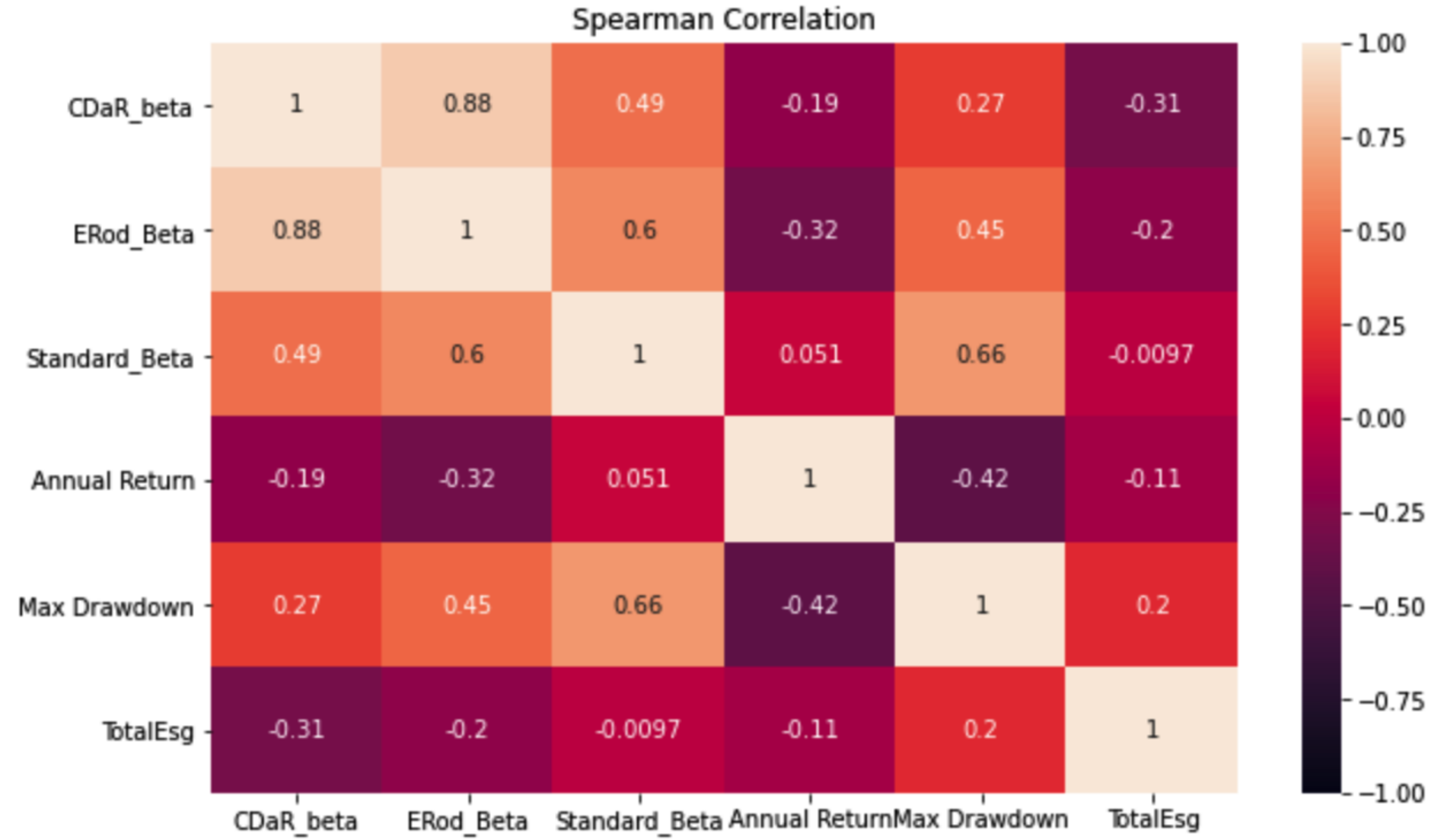


Figure 11: Heatmap

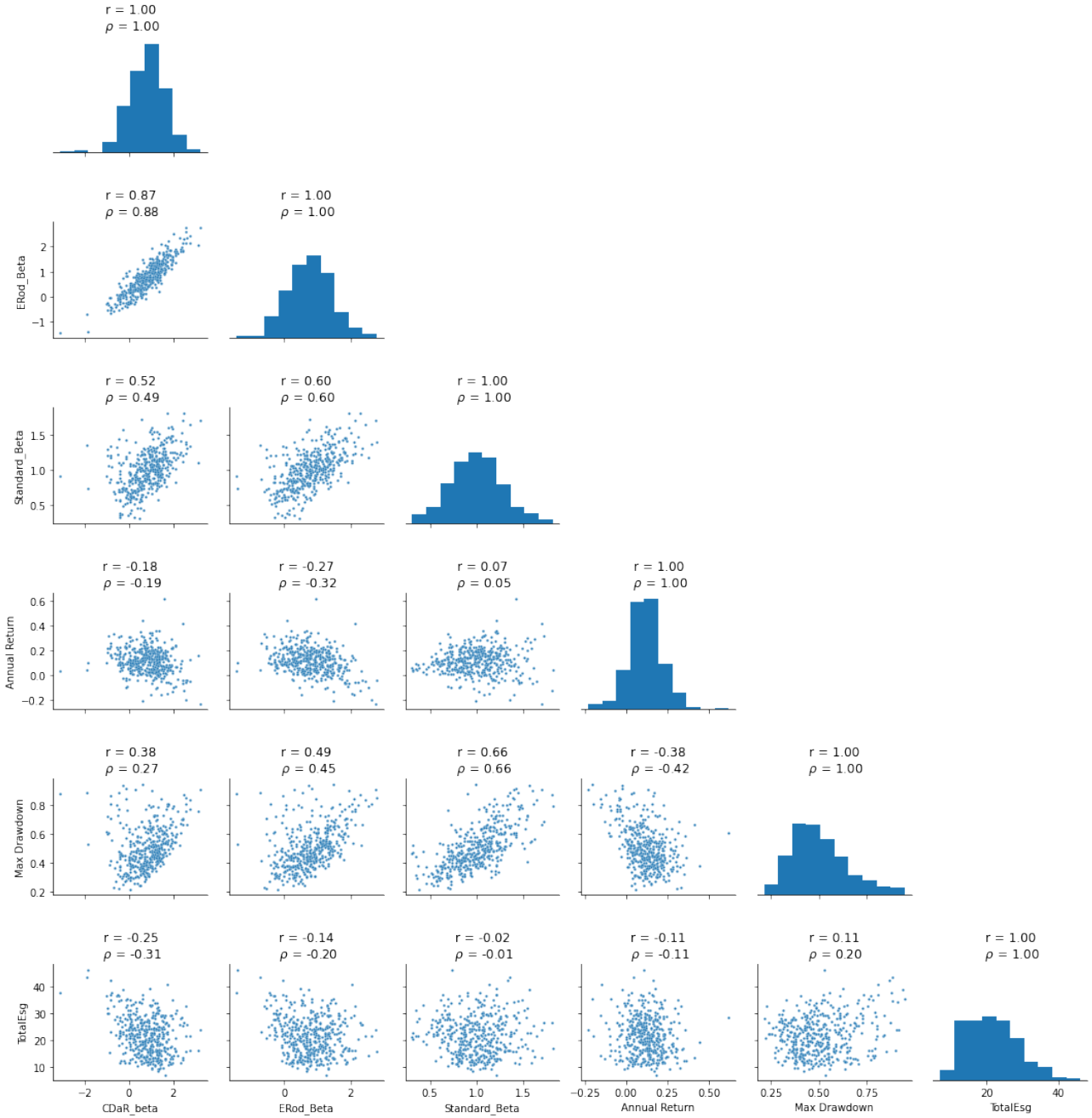


Figure 12: Correlation graph r(use Spearman rank correlation method) and ρ(use pearson correlation coefficient method)

Numerical Study

I found the five ESG ratings categories following the Sustainalytics Company definition, and calculated the mean of their $ERoD_{0+}$ Beta, $CDaR_{0.9}$ Beta and see if Negligible and Severe ESG ratings have low Beta.

	ticker	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
4	ACN	1.525763	1.328573	1.075946	0.178986	0.389819	9.71
81	CBRE	1.640290	1.257751	1.217167	0.183480	0.535720	6.99
82	CDW	1.010611	0.698679	1.156875	0.265560	0.448341	9.14
199	HAS	1.323473	1.335865	0.936902	-0.009806	0.638429	9.36
201	PEAK	1.398076	0.663757	0.900404	0.005859	0.465577	9.73
240	KEYS	1.019078	0.390347	1.089903	0.322489	0.371856	9.42
334	PLD	1.299031	0.672323	0.959737	0.169666	0.420587	8.51
352	RHI	1.358794	0.946228	1.036018	0.150827	0.555554	9.26

	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
Average	1.32189	0.91169	1.046619	0.158383	0.478235	9.015

Figure 13: Negligible ESG ratings calculation

Numerical Study

	ticker	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
5	ATVI	-0.319458	0.210689	0.697042	0.100311	0.519007	18.94
7	ADBE	1.628851	0.980486	1.262884	0.200050	0.600215	12.46
8	ADP	0.515638	0.444435	1.033099	0.211466	0.394512	13.97
9	AAP	1.095840	0.777955	0.890394	0.061998	0.591891	12.97
11	AFL	0.311942	0.287694	0.978714	0.140645	0.548902	17.30
...	...	...	...	...	...	...	...
430	WHR	1.622830	1.464654	1.183530	0.016955	0.645970	15.80
432	WTW	0.595669	0.373894	0.839865	0.114529	0.329456	18.24
433	GWW	0.244202	0.485517	0.932431	0.213813	0.415955	14.60
436	XYL	1.268983	1.339998	1.089086	0.152210	0.466932	15.95
439	ZTS	1.412501	0.785067	0.921918	0.221556	0.412293	18.47

186 rows × 7 columns

	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
Average	1.000454	0.874746	1.027019	0.12787	0.490397	15.225753

Figure 14: Low ESG ratings calculation

Numerical Study

	ticker	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
1	AOS	1.589278	1.592544	0.851002	0.051687	0.468063	24.20
2	ABT	0.910582	0.628401	0.866542	0.188647	0.316732	24.98
3	ABBV	-0.206989	0.218182	0.704196	0.226182	0.450898	27.84
15	ALB	0.010679	1.017077	1.259873	0.241453	0.632742	28.80
17	ALLE	1.147152	1.148763	0.996771	0.099272	0.432501	23.59
...	...	...	...	...	...	...	...
431	WMB	-0.437469	-0.079135	0.945408	0.083018	0.680840	23.50
434	WYNN	1.675213	1.824548	1.462010	-0.056416	0.774003	26.50
435	XEL	-0.046353	-0.296847	0.589422	0.112734	0.292807	23.70
437	YUM	0.890151	0.674884	0.805223	0.136890	0.521706	20.55
438	ZBH	0.888738	0.967530	0.917750	0.027934	0.497319	27.30

191 rows × 7 columns

	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
Average	0.78044	0.77378	0.960808	0.107879	0.483534	24.528586

Figure 15: Medium ESG ratings calculation

Numerical Study

	ticker	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
0	MMM	1.157728	1.372000	0.819897	-0.013297	0.513593	33.61
6	ADM	-0.578652	-0.310764	0.820271	0.162799	0.405223	36.40
10	AES	0.488674	0.192291	1.023427	0.183873	0.545411	34.15
22	AMZN	1.256257	0.786994	1.076385	0.173650	0.451628	30.28
37	APA	-0.276730	0.727498	1.575506	-0.025074	0.934866	38.81
...	...	...	...	...	...	...	...
401	USB	1.208373	1.203019	1.064911	0.024061	0.519860	30.05
405	UAL	1.057832	1.109978	1.446026	-0.042857	0.794002	30.10
409	UHS	0.958278	0.601052	1.081933	-0.002211	0.563027	32.90
410	VLO	-0.989328	-0.238229	1.206657	0.184946	0.718813	30.05
426	WFC	1.008366	1.281765	1.195361	0.029512	0.644571	32.84

49 rows × 7 columns

	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
Average	0.276422	0.475212	1.038447	0.104147	0.595097	33.638367

Figure 16: High ESG ratings calculation

Numerical Study

	ticker	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
116	CTRA	-1.886263	-1.402544	0.734571	0.104436	0.525571	46.16
189	GE	1.736379	2.019482	1.133680	-0.148830	0.809436	40.71
260	MRO	-0.832264	-0.029804	1.337207	0.163646	0.867047	42.05
309	OXY	-1.909379	-0.717511	1.363360	0.043982	0.883888	43.23

	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
Average	-0.722882	-0.032594	1.142204	0.040809	0.771486	43.0375

Figure 17: Severe ESG ratings calculation

	ticker	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
4	ACN	1.525763	1.328573	1.075946	0.178986	0.389819	9.71
7	ADBE	1.628851	0.980486	1.262884	0.200050	0.600215	12.46
8	ADP	0.515638	0.444435	1.033099	0.211466	0.394512	13.97
9	AAP	1.095840	0.777955	0.890394	0.061998	0.591891	12.97
13	APD	0.836416	0.791870	0.943549	0.139472	0.309675	10.81
...	...	...	...	...	...	...	...
411	VTR	0.767902	0.286304	1.027037	-0.036414	0.769242	12.75
416	VFC	2.421051	1.814728	1.122154	-0.068139	0.702569	12.84
418	VNO	1.979087	1.487784	1.031751	-0.130200	0.687373	12.98
427	WELL	0.863126	0.410001	0.949624	0.028073	0.633284	12.01
428	WDC	1.865623	1.854016	1.455389	-0.063533	0.704929	11.07

88 rows × 7 columns

	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
Average	1.072633	0.861437	1.013172	0.121586	0.496263	12.292045

Figure 18: 20% lowest ESG ratings

	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
CDaR_beta	1.000000	0.819293	0.591566	-0.240796	0.509950	-0.071896
ERod_Beta	0.819293	1.000000	0.710707	-0.239185	0.584883	0.007399
Standard_Beta	0.591566	0.710707	1.000000	0.136102	0.528505	-0.012082
Annual Return	-0.240796	-0.239185	0.136102	1.000000	-0.594695	-0.086631
Max Drawdown	0.509950	0.584883	0.528505	-0.594695	1.000000	0.049718
TotalEsg	-0.071896	0.007399	-0.012082	-0.086631	0.049718	1.000000

Figure 19: 20% lowest ESG ratings correlation matrix

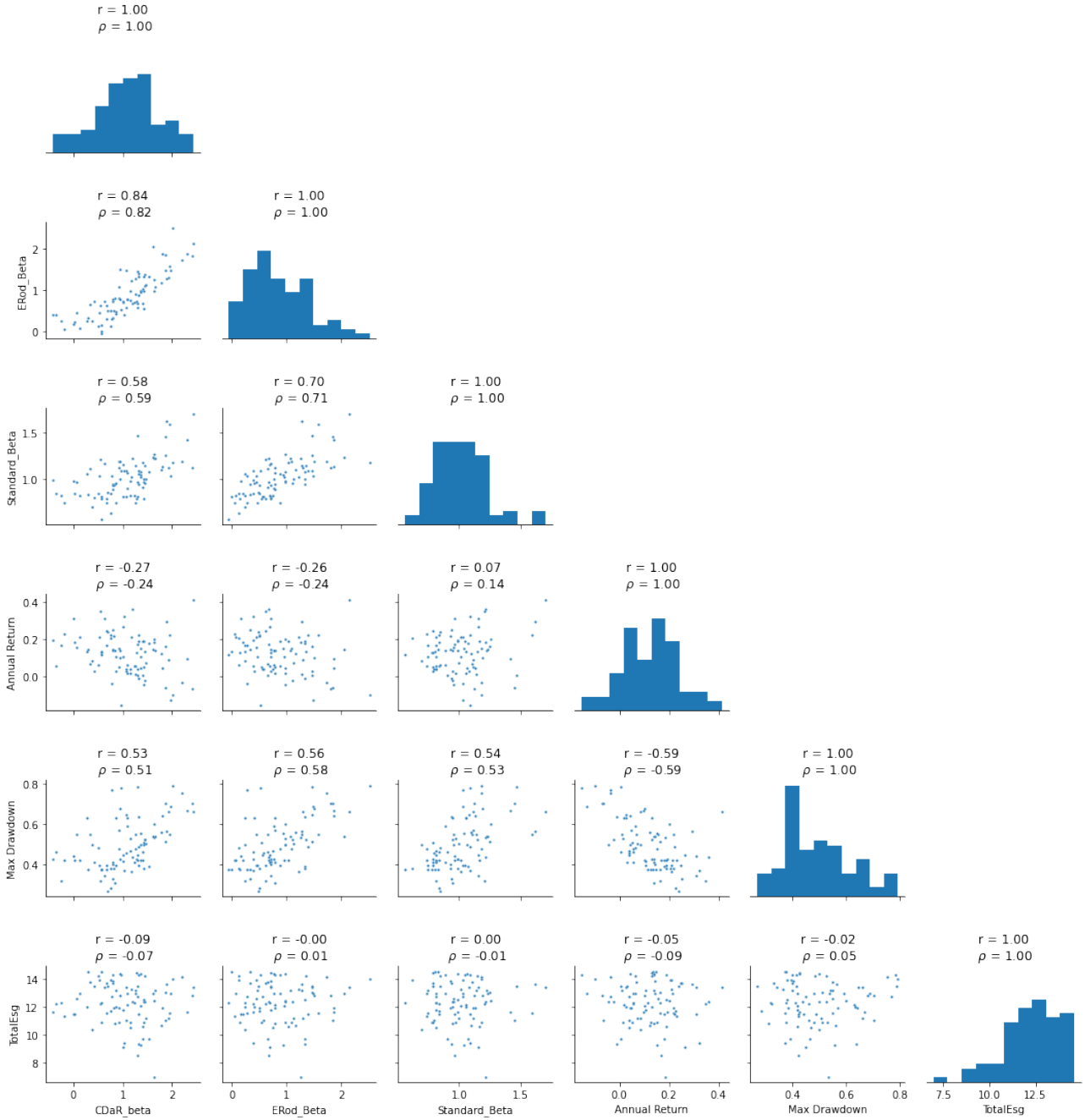


Figure 20: 20% lowest ESG ratings

	ticker	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
0	MMM	1.157728	1.372000	0.819897	-0.013297	0.513593	33.61
3	ABBV	-0.206989	0.218182	0.704196	0.226182	0.450898	27.84
6	ADM	-0.578652	-0.310764	0.820271	0.162799	0.405223	36.40
10	AES	0.488674	0.192291	1.023427	0.183873	0.545411	34.15
15	ALB	0.010679	1.017077	1.259873	0.241453	0.632742	28.80
...	...	...	...	...	...	...	...
405	UAL	1.057832	1.109978	1.446026	-0.042857	0.794002	30.10
409	UHS	0.958278	0.601052	1.081933	-0.002211	0.563027	32.90
410	VLO	-0.989328	-0.238229	1.206657	0.184946	0.718813	30.05
419	VMC	1.156020	1.125245	0.936338	0.069614	0.492281	29.02
426	WFC	1.008366	1.281765	1.195361	0.029512	0.644571	32.84

88 rows × 7 columns

	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
Average	0.478437	0.590661	1.036799	0.108461	0.570848	32.138295

Figure 21: 20% Highest ESG ratings

	CDaR_beta	ERod_Beta	Standard_Beta	Annual Return	Max Drawdown	TotalEsg
CDaR_beta	1.000000	0.900426	0.275653	-0.213386	-0.050465	-0.478221
ERod_Beta	0.900426	1.000000	0.419432	-0.346873	0.193020	-0.359101
Standard_Beta	0.275653	0.419432	1.000000	0.089928	0.703334	0.075562
Annual Return	-0.213386	-0.346873	0.089928	1.000000	-0.274462	-0.174128
Max Drawdown	-0.050465	0.193020	0.703334	-0.274462	1.000000	0.414938
TotalEsg	-0.478221	-0.359101	0.075562	-0.174128	0.414938	1.000000

Figure 22: 20% Highest ESG ratings correlation matrix

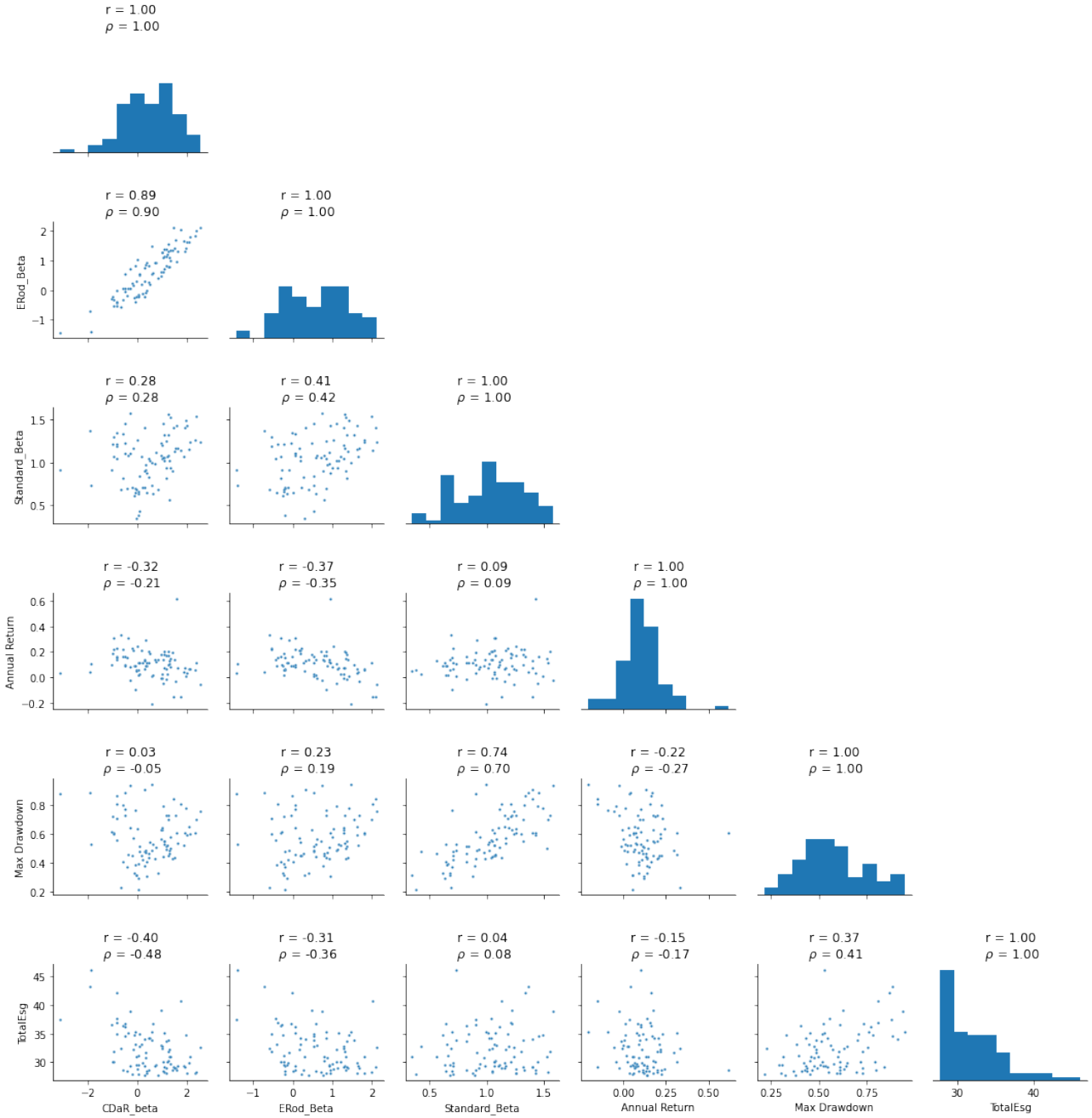


Figure 23: 20% Highest ESG ratings

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Thank you!