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MSDS 451 - Financial Engineering
Week 5 Programming Assignment 02

Problem Description

For this assignment, I used the Monte Carlo simulation to compare two portfolio construction strategies for the AG heavy machinery sector:

1. Portfolios allowing short positions and
2. Portfolios constrained to long-only positions.

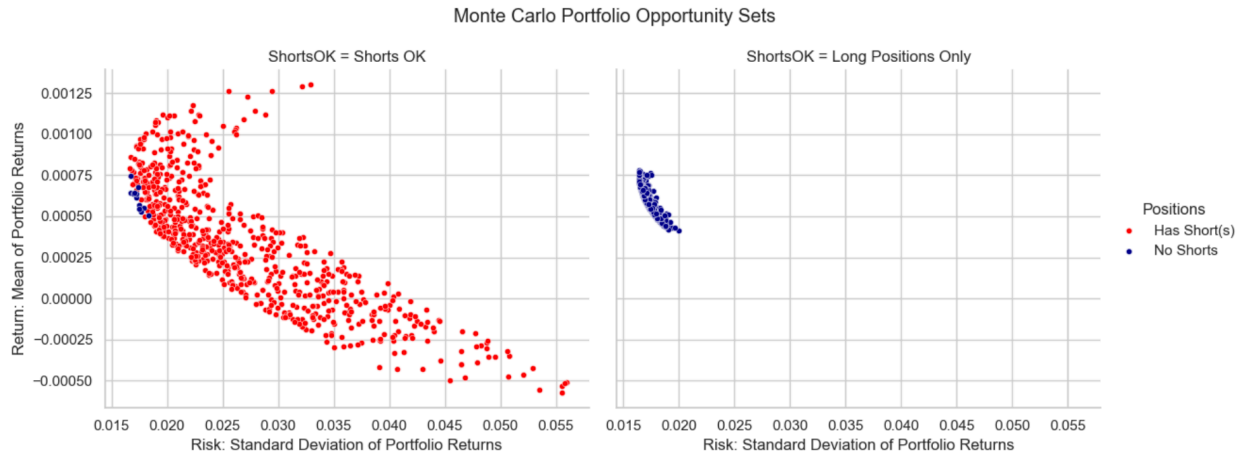
For both the approaches, I used daily return data between 2000-2025 for the companies listed below. The goal behind randomly generating portfolios was to explore the range of possible risk to return combinations under each strategy.

Deere & Company	Caterpillar	AGCO Corporation	CNH Industrial
DE	CAT	AGCO	CNH

Data Preparation and Pipeline

I gathered historical daily adjusted closing prices and trading volumes for the companies listed above from Yahoo Finance (yfinance API). I then calculated daily returns using percentage change, for estimating annualized expected returns, volatilities, and the correlation and covariance matrices across the four assets. These metrics were used as inputs for portfolio simulation and optimization. The pipeline also included reproducibility controls through random seeding and flexible weight generation functions to simulate both long only and short allowed investment strategies. This approach made sure that the data was handled consistently, the statistical estimates were accurate, and the Monte Carlo based portfolio analysis was integrated efficiently into a single, repeatable workflow.

Research Design - Investment Insights and Associated Risk



The resulting opportunity sets differ markedly between the two strategies:

For the long-only portfolios, shown in the blue cluster on the right side plot, average daily returns seem to be approximately 0.0006. Calculating the The average annualized expected return gave 15%, and the volatility was pretty consistent, about 1.7% per day. This was a well constrained range showing that these portfolios are pretty risk-averse, staying within a modest risk zone. In terms of the risk return tradeoff, my takeaway is that the long only strategy aims to be rather risk averse as it avoids portfolios with negative expected returns and limits total volatility. The effect of this is that investors may lose the possibility of high gains but get a stable, positive performance in return.

For the portfolios allowing shorts, shown in the red cluster on the left side plot seem to show average daily returns to be approximately 0.0003. However, this plot shows a rather large dispersion. The dispersion suggested that the portfolio volatility ranged all the way from from 1.6% to over 5.5% per day. Including short exposures seems to expand the feasible set into both high risk as well as high return regions. In terms of risk return tradeoff, my takeaway for the shorts allowed strategy is that it introduces both the upsides and downsides. Some simulated portfolios hit returns of almost 0.0013 per day**,** but at the same instance, others generated losses, showing high uncertainty with this strategy.

Target Correlation Matrix:				
	DE	CAT	AGCO	CNH
DE	1.000000	0.680886	0.755706	0.633669
CAT	0.680886	1.000000	0.622298	0.617889
AGCO	0.755706	0.622298	1.000000	0.646099
CNH	0.633669	0.617889	0.646099	1.000000

Correlation and Diversification Impact

Another thing I noticed was that the correlation matrix showed strong positive relationships across all four of my stocks. Given that I have picked similar firms competing in the same business, this high interdependence is a limiter of diversification benefits. Therefore diversification between these companies is not going to yeild much benefit but this is a strong takeaway for me as my final goal is to compare the impact of commodity price fluctuations on this portfolio of companies.

Appendix

Expected Returns:	
DE	0.20577706
CAT	0.19907316
AGCO	0.11267177

CNH	0.08444244

Volatilities:	
DE	0.282435
CAT	0.287866
AGCO	0.327162
CNH	0.351836

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Actual Correlation Matrix:				
	DE	CAT	AGCO	CNH
DE	1.000000	0.680886	0.755706	0.633669
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AGCO	0.755706	0.622298	1.000000	0.646099
CNH	0.633669	0.617889	0.646099	1.000000

Target Covariance Matrix:				
	DE	CAT	AGCO	CNH
DE	0.07976933	0.05535837	0.06982874	0.06296801
CAT	0.05535837	0.08286706	0.05860741	0.06258084
AGCO	0.06982874	0.05860741	0.10703519	0.07437068
CNH	0.06296801	0.06258084	0.07437068	0.12378825

Actual Covariance Matrix:				
	DE	CAT	AGCO	CNH
DE	0.000317	0.000220	0.000277	0.000250
CAT	0.000220	0.000329	0.000233	0.000248

AGCO	0.000277	0.000233	0.000425	0.000295
CNH	0.000250	0.000248	0.000295	0.000491

returns_df_head():

Date	DE	CAT	AGCO	CNH
2013-10-01	0.010198	0.004316	0.005627	0.033600
2013-10-02	0.000973	0.003701	0.006419	-0.001548
2013-10-03	-0.002552	-0.001189	0.004742	-0.022481
2013-10-04	0.005604	0.002738	0.009278	0.002379
2013-10-07	-0.001090	-0.007957	-0.011450	-0.031645

Summary statistics for generated returns:

	DE	CAT	AGCO	CNH
count	2832.000000	2832.000000	2832.000000	2832.000000
mean	0.000817	0.000790	0.000447	0.000335
std	0.017792	0.018134	0.020609	0.022164
min	-0.140722	-0.142822	-0.187830	-0.149533
25%	-0.007588	-0.008165	-0.009766	-0.011325
50%	0.000658	0.000682	0.000953	0.000000
75%	0.009318	0.010104	0.010890	0.012202
max	0.134911	0.103320	0.200162	0.172684

Summary of portfolio results with short positions allowed:

	w1	w2	w3	w4	returnMean	returnSD
count	700.000000	700.000000	700.000000	700.000000	700.000000	700.000000
mean	-0.014713	-0.007042	0.029627	0.992128	0.000328	0.027067
std	0.557582	0.573073	0.569792	0.989690	0.000379	0.008229
min	-0.994831	-0.991634	-0.999805	-1.753869	-0.000573	0.016640
25%	-0.502010	-0.498816	-0.432321	0.322851	0.000042	0.020532
50%	0.007990	-0.007067	0.022068	0.999672	0.000326	0.024912
75%	0.421484	0.482402	0.534044	1.711077	0.000604	0.032276

max	0.997148	0.998624	0.999038	3.490209	0.001301	0.055960

Summary of portfolio results with long positions only:						
	w1	w2	w3	w4	returnMean	returnSD
count	700.000000	700.000000	700.000000	700.000000	700.000000	700.000000
mean	0.240186	0.260686	0.252060	0.247068	0.000598	0.017254
std	0.134779	0.141794	0.138128	0.136837	0.000067	0.000554
min	0.000397	0.000777	0.000346	0.000074	0.000412	0.016395
25%	0.136629	0.157982	0.141819	0.138799	0.000553	0.016868
50%	0.235841	0.262977	0.256370	0.248044	0.000600	0.017132
75%	0.326402	0.354180	0.342980	0.337451	0.000641	0.017543
max	0.825732	0.854155	0.769339	0.767189	0.000779	0.019995

References:

Ross, Sheldon M. 2011. *An Elementary Introduction to Mathematical Finance* (third edition). Cambridge, UK: Cambridge University Press. [ISBN-13: 978-0521192538]

Wilmott, Paul. 2009. *Frequently Asked Questions in Quantitative Finance* (second edition). New York: Wiley. [ISBN-13: 978-0-470-74875-6]

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