Algorithmic Trading (Beta Hedging)

1. Introduction

This is my third personal project on algorithmic trading.

My strategy for this project is to calculate the beta of a portfolio of mega-cap tech stocks ("Mag 7 Mega Cap Tech Stocks") relative to a benchmark (the QQQ index) using linear regression. Subsequently, implement a hedging strategy by shorting QQQ to neutralize market risk and longing my portfolio, with a rebalancing period of 30 days.

The strategy:

1. Calculate beta of portfolio relative to benchmark using Linear Regression (Ordinary Least Squares)
2. With the beta value, calculate the long/short ratio = 1/beta
3. Allocate respective long/short portfolio size using the long/short ratio, and determine position size of each Mag 7 stock based on vol-weightage
4. Rebalance every 30 days, and repeat steps 1-3.

2. Methodology

- Data processing
  - Downloaded Price and Vol data of Mag 7 stocks from yfinance

Ticker	AAPL	AMZN	GOOG	META	MSFT	NVDA	QQQ	TSLA
Date								
2022-01-03 00:00:00+00:00	179.273621	170.404495	144.719086	337.523743	326.940826	30.073059	394.300751	399.926666
2022-01-04 00:00:00+00:00	176.998337	167.522003	144.062714	335.519806	321.334747	29.243383	389.186401	383.196655
2022-01-05 00:00:00+00:00	172.290207	164.356995	137.316284	323.196899	308.999390	27.560070	377.230225	362.706665
2022-01-06 00:00:00+00:00	169.414093	163.253998	137.214035	331.462006	306.557709	28.133154	376.965118	354.899994
2022-01-07 00:00:00+00:00	169.581558	162.554001	136.668869	330.794006	306.713959	27.203632	372.881531	342.320007
...	...	...	...	...	...	...	...	...
2024-10-28 00:00:00+00:00	233.399994	188.389999	168.339996	578.159973	426.589996	140.520004	495.399994	262.510010
2024-10-29 00:00:00+00:00	233.669998	190.830002	171.139999	593.280029	431.950012	141.250000	500.160004	259.519989
2024-10-30 00:00:00+00:00	230.100006	192.729996	176.139999	591.799988	432.529999	139.339996	496.380005	257.549988
2024-10-31 00:00:00+00:00	225.910004	186.399994	172.690002	567.580017	406.350006	132.759995	483.850006	249.850006
2024-11-01 00:00:00+00:00	222.910004	197.929993	172.649994	567.159973	410.369995	135.399994	487.429993	248.979996

Ticker	AAPL	AMZN	GOOG	META	MSFT	NVDA	QQQ	TSLA
Date								
2022-01-03 00:00:00+00:00	104487900	63520000	25214000	14537900	28865100	391547000	40575900	103931400
2022-01-04 00:00:00+00:00	99310400	70726000	22928000	15998000	32674300	527154000	58027200	100248300
2022-01-05 00:00:00+00:00	94537600	64302000	49642000	20564500	40054300	498064000	75739800	80119800
2022-01-06 00:00:00+00:00	96904000	51958000	29050000	27962800	39646100	454186000	70814300	90336600
2022-01-07 00:00:00+00:00	86709100	46606000	19408000	14722000	32720000	409939000	72652300	84164700
...	...	...	...	...	...	...	...	...
2024-10-28 00:00:00+00:00	36087100	27930800	20858300	10925100	14882400	173586700	20477800	107653600
2024-10-29 00:00:00+00:00	35417200	35690200	28916100	13019100	17644100	157593600	28014100	80521800
2024-10-30 00:00:00+00:00	47070900	37707600	49698300	26864900	29749100	179418100	29756000	53993600
2024-10-31 00:00:00+00:00	64370100	75146800	32801900	26838400	53971000	270039600	41245200	66575300
2024-11-01 00:00:00+00:00	65242200	99571700	21626900	15267400	24209400	202737100	33631200	57424000

Figure 1: Price and Volume Data of the Mag 7 Mega Cap Tech Stocks

  - Obtain returns of benchmark index (“QQQ”) and portfolio (“Mag 7”)

Date	
2022-02-15 00:00:00+00:00	0.024864
2022-02-16 00:00:00+00:00	-0.000253
2022-02-17 00:00:00+00:00	-0.029744
2022-02-18 00:00:00+00:00	-0.011405
2022-02-22 00:00:00+00:00	-0.010044
...	...
2024-10-28 00:00:00+00:00	0.000161
2024-10-29 00:00:00+00:00	0.009608
2024-10-30 00:00:00+00:00	-0.007558
2024-10-31 00:00:00+00:00	-0.025243
2024-11-01 00:00:00+00:00	0.007399

Date	
2022-02-15 00:00:00+00:00	0.062412
2022-02-16 00:00:00+00:00	0.000622
2022-02-17 00:00:00+00:00	-0.057328
2022-02-18 00:00:00+00:00	-0.026111
2022-02-22 00:00:00+00:00	-0.014393
...	...
2024-10-28 00:00:00+00:00	-0.006808
2024-10-29 00:00:00+00:00	0.003528
2024-10-30 00:00:00+00:00	-0.008730
2024-10-31 00:00:00+00:00	-0.039376
2024-11-01 00:00:00+00:00	0.013704

Figure 2: Return of QQQ Index (left), return of vol-weightage Mag 7 portfolio(right)

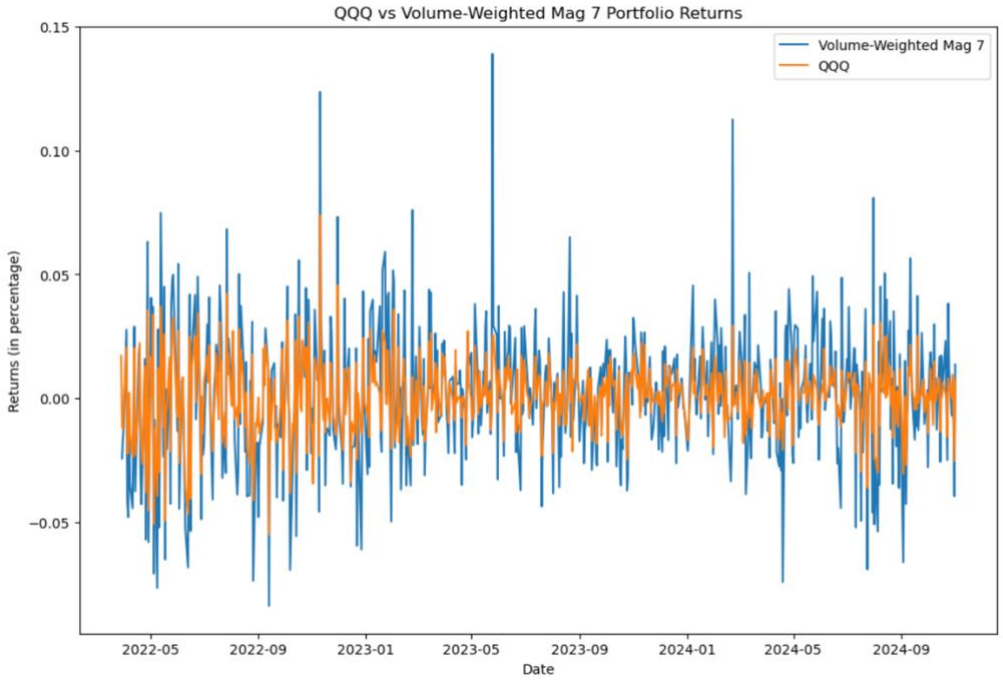

Figure 3: Comparison between performance of QQQ index and portfolio

- Implementing Strategy

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Initial Portfolio Size: 1,000,000.00
Final Portfolio Size: 2,098,184.12
Total Realized Returns: 109.82%
Annual Returns: 48.00%
Benchmark Annualized Returns: 21.02%
Sharpe Ratio: 1.36

Portfolio and Beta values at each rebalancing:
    Rebalancing Step  Portfolio Value  Beta Value
0                  1    1,000,000.00        1.65
1                  2    1,009,178.77        0.33
2                  3      795,464.56        0.27
3                  4      807,007.88        0.27
4                  5      840,379.57        0.27
5                  6      728,667.38        0.29
6                  7      712,063.80        0.19
7                  8      794,310.65        0.29
8                  9      844,838.58        0.43
9                 10      936,890.42        0.27
10                11      972,414.25        0.19
11                12    1,252,719.55        0.53
12                13    1,330,321.15        0.36
13                14    1,378,668.17        0.35
14                15    1,318,680.31        0.24
15                16    1,378,047.52        0.24
16                17    1,440,021.40        0.28
17                18    1,705,518.13        0.52
18                19    1,759,857.98        0.25
19                20    1,859,378.34        0.51
20                21    2,175,392.22        0.43
21                22    2,153,417.03        0.46
22                23    2,098,184.12        0.50
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Figure 4: Performance of hedged portfolio

  - Performance Comparison with Benchmark
    - With an annualized return of 48% compared to the benchmark's 21.02%, the strategy seems to generate excess return
    - This positive difference suggests that the hedging and rebalancing approach has been effective in capturing alpha
  - Risk Metrics and Adjusted Returns
    - A Sharpe Ratio of 1.36 suggests the strategy is performing well in generating risk-adjusted returns
  - Beta Analysis and Hedging Effectiveness

        - The relatively low and varying beta values in each rebalancing period indicate that the portfolio is less correlated with the market
    - Overall, the strategy shows promising results, especially when compared to the benchmark. It has effectively controlled market exposure (low beta values) while producing high returns.

3. Learning Summary

- **How I can improve this project:**
    - Look into testing the strategy across various market cycles (bull, bear, and sideways markets) to confirm its robustness in alpha generation
    - Experiment with slightly longer rebalancing periods (e.g., 45 or 60 days) to see if performance remains strong while reducing the number of transactions. This might improve net returns if transaction costs are a concern
    - Extend the backtest to include data over different economic cycles, especially during market downturns
    - Instead of a fixed rebalancing period, explore rebalancing based on a trigger, such as changes in market volatility or a significant deviation in portfolio beta