Optimal Hedging Strategy

Description: Market making is a critical activity performed by financial institutions. These firms provide liquidity to financial markets by quoting bid and ask prices for various assets, enabling investors to buy and sell securities efficiently. Market makers generate revenue primarily through the bid-ask spread. They also profit from inventory management and taking positions based on market views.

However, market making activities inherently expose firms to market risk. Market risk refers to the potential for losses arising from changes in market conditions, such as fluctuations in asset prices, interest rates, or exchange rates etc. For an equities trader, this risk can manifest as potential losses due to adverse movements in the prices of the stocks they hold in their inventory or are obligated to trade.

To mitigate market risk, financial institutions employ various hedging strategies. Hedging involves taking offsetting positions in related assets to reduce the overall exposure to adverse market movements. The costs associated with hedging include transaction fees, bid-ask spreads, and the capital cost of holding the hedges.

Objective: In this hackathon, you'll be stepping into the shoes of an equities trader facing market risk from an unhedged portfolio comprised of both equity stock and derivative products. You are given an unhedged portfolio's historical Profit and Loss (P&L) distribution, simulated using the last year's historical returns of the portfolio's constituent assets.

Ideally, hedging can be done with liquid equity stock to minimize transaction costs and ensure the ability to adjust positions quickly. Your objective is to identify a set of hedging stocks from a universe of publicly traded equity stocks and determine the quantity of each stock needed to minimize risk, while also considering the cost of implementing the hedge. These equity stocks have known risk profiles, represented by their historical daily returns, and a known hedging cost per share. The daily return of a stock is the percentage change in its price from one day to the next. For example, if a stock's price was 100 yesterday and 101 today, the daily return would be (101-100)/100 = 0.01 or 1%.

The effectiveness of your hedge will be evaluated based on the historical Value at Risk (VaR) of the hedged portfolio. Value at Risk (VaR) is a statistical measure of the potential loss in value of an asset or portfolio over a defined period for a given confidence level. VaR (confidence level) = The (1 - confidence level)th percentile of the portfolio's return distribution.

Here's how you can calculate 95%ile VaR using Python:

```
import numpy as np

portfolio_pnl = np.array([-10, -5, 0, 2, 5, -20, -12, -3, 7, 10]) # Example Portfolio P&L

VaR_95 = np.percentile(portfolio_pnl, 5)
print(VaR_95)

# In this code, np.percentile(portfolio_pnl, 5) calculates the 5th percentile of the portfolio_pnl array,
which represents the 95% VaR.
```

Hedging can involve taking long or short positions in the hedging stocks. Going long means buying the stock (profiting from price increases), while going short means selling borrowed stock (profiting from price decreases). The cost of hedging can be assumed to be a simple linear sum of absolute value of quantity times cost for each stock. In other words, if you buy 'x' shares of Stock A, which costs C_A per share, and 'y' shares of Stock B, which costs C_B per share the total cost is:

Total Cost = (Abs(x) * C_A) + (Abs(y) * C_B).

In this example, the VaR of hedged portfolio can be calculated as: VaR(Unhedged Portfolio P&L + x * Return_A + y * Return_B)

Training Dataset: The training dataset comprises information on various publicly traded stocks. Each stock has metadata and a historical daily returns time series. Here's how you can read this dataset using Python (please note the returns are quoted in percentage terms - so to calculate P&L you'll need to divide the returns data by 100):

```
import pandas as pd

returns = pd.read_csv("stocks_returns.csv")/100

metadata = pd.read_csv("stocks_metadata.csv")
```

Data Schema: The dataset is provided in two CSV files:

Stocks Metadata: Contains information about each stock. The file includes columns like:

- stock_id: Unique identifier for the stock (string).
- stock_exchange: The exchange where the stock is listed (e.g., "NASDAQ", "NYSE") (string).
- country: Country where the company is based (string).
- rating: Credit rating of the company (string).
- region: Geographic region where the company operates (string).
- sector: Industry sector of the company (e.g., "Technology", "Finance") (string).
- market_cap: Market capitalization of the company (string).
- capital_cost: Cost of acquiring one unit of stock (numeric).

Dataset link: stocks metadata

Historical Returns: Contains daily historical returns for each stock. The file has the following structure:

- date: Date of the return (YYYYMMDD) (date).
- stock_1: Daily return for stock with ID 'stock_1' on the given date (numeric).
- stock_2: Daily return for stock with ID 'stock_2' on the given date (numeric).
- ...and so on for all stocks. Each row represents a specific date, and the columns contain the corresponding daily returns for each stock.

Dataset link: stocks returns

Evaluation Criteria: The evaluation criteria will be based on the 95%ile VaR of the hedged portfolio and the total capital cost of implementing the hedge. The goal is to minimize both VaR and cost. A test case is considered passing if both the VaR and the total cost of your hedged portfolio are less than or equal to the VaR and cost values specified in the test case.

You will earn 0.5 point if only the VaR criteria is met and 1 point if both criteria are met. No points are awarded for meeting the cost criteria alone.

Note: This problem statement has additional test cases that'll run post your submission. You final score is subject to change, your current score is not the final score.

Input Format

portfolio_id_1 -5000 -2000 1000 3000 -10000 …

Sample input includes a portfolio identifier portfolio_id_1 and 250 numeric values, each representing the simulated P&L of the unhedged portfolio based on historical returns.

Constraints

-

Output Format

stock_1 1000

stock_2 -2000

The output consists of multiple rows, each indicating the stock_id and the quantity of that stock to include in the hedge. A positive quantity means a long position, and a negative quantity means a short position. For example, if stock_1 has a cost of USD 10 per share and stock_2 has a cost of USD 20 per share, then the total cost of this hedge would be: Total Cost = (1000 * 10) + (2000 * 10) = USD 30,000.
Please note there can be multiple possible combinations that can pass the evaluation criteria - the output will be tested to see if the overall VaR and Cost of the portfolio are within required thresholds

Sample Input 0

```
Portfolio_0 64.519 -27.184 -7.486 -23.389 -59.758 -32.51 10.709 30.091 23.171 8.287 0.685 -39.95 -8.559
-41.953 -35.853 -24.688 -35.236 56.744 79.524 -4.436 31.402 -14.708 -5.235 24.395 18.312 -50.646 -61.176
76.292 51.243 -38.15 32.702 3.362 -72.519 -12.151 13.526 -5.445 11.683 20.39 71.556 16.058 59.782 23.123
63.49 -73.324 14.685 29.85 -14.55 12.929 -42.592 8.43 53.359 -20.301 -53.67 34.028 46.344 -22.197 33.436
8.191 -72.934 -58.64 8.572 -43.509 53.446 73.564 -64.034 0.063 90.673 23.256 -35.493 4.473 -0.408 101.233
2.074 1.881 86.152 13.618 48.136 -28.199 24.667 39.558 4.197 40.523 -20.493 6.912 32.867 -37.858 16.801
-19.829 -16.219 64.059 5.848 22.903 43.011 -2.536 -28.976 -70.6 70.003 44.239 -22.269 -1.339 24.281 -45.394
-35.547 -17.417 -14.146 15.323 -26.936 -29.636 -19.969 -35.087 71.375 4.233 -5.272 -11.89 24.386 -1.989
-18.999 -21.665 -6.07 36.756 -13.734 66.281 -41.605 16.535 -38.988 61.495 19.85 -27.184 -8.556 13.381 -38.734
-15.543 22.72 23.5 51.58 20.624 -26.402 45.586 -91.622 -65.812 -4.672 67.459 -3.269 -1.89 33.056 -23.23
-35.702 121.729 -19.507 -42.295 5.357 -6.842 8.53 78.413 20.732 -11.487 -16.505 -11.483 -2.928 22.009 -17.077
54.633 -22.158 9.628 -22.968 21.34 -17.681 15.522 1.615 -50.879 -37.472 -6.231 -45.596 -9.018 14.151 22.85
-19.619 -53.855 52.707 28.541 -8.261 -79.694 78.373 15.453 32.206 1.269 18.53 1.585 -33.701 -2.377 -8.972
-24.417 -12.871 -2.071 2.126 -78.813 -17.967 -44.014 3.921 12.522 -52.362 -43.616 -25.943 -71.369 -47.09
-21.327 52.426 -64.284 -4.786 -44.108 17.379 -81.296 19.933 -54.466 26.926 -61.874 -10.773 98.22 39.328
-26.459 8.75 3.878 9.435 -45.276 -47.71 -51.774 51.038 28.418 14.255 44.815 -14.741 29.208 -61.269 13.115
-28.616 8.015 27.876 45.914 -47.445 -43.606 2.966 36.819 51.178 19.035 40.15 5.011 27.612 6.392 -27.091
-21.816
```

Sample Output 0

```
stock_286 -1000
```

Sample Input 1

```
Portfolio_2 -538.72 238.18 128.025 -204.53 -305.72 3.77 217.61 96.445 -391.92 -222.47 746.785 -279.58 -43.335
93.36 -151.925 -1.885 525.9 417.56 223.405 -150.66 25.19 -247.055 -0.18 172.41 114.31 -223.035 -613.89
326.825 -124.405 208.16 -58.82 -139.625 -219.755 6.675 -298.135 11.13 -5.715 -166.475 66.23 194.235 114.44
-21.48 111.985 -387.525 -83.595 163.195 133.46 196.795 -409.04 15.205 754.325 339.95 53.135 69.325 285 73.96
561.92 20.805 -356.57 -185.88 -7.065 -361.25 199.335 -32.44 173.54 125.07 74.515 -183.66 -623.11 290.445
-78.895 85.08 90.12 105.11 105.88 -34.765 353.98 18.185 -229.455 -44.71 -344.08 368.04 -231.125 -206.695
59.27 -340.345 -152.695 -246.265 -73.375 303.5 -19.19 -248.565 110.695 -338.925 -63.19 -306.165 -113.885
67.68 -334.73 -57.455 -33.09 -49.08 102.445 -301.68 -396.385 -138.27 -484.795 -12.905 43.54 86.485 -276.21
276.165 -234.77 33.44 -12.41 56.83 -268.61 89.575 -150.34 -67.17 263.275 193.89 -114.89 -104.66 145.79 134.81
-175.425 -212.735 -373.6 428.135 236.57 -130.685 -187.545 -251.815 93.865 -353.675 117.18 -75.735 325.84
95.025 181.825 180.91 69.495 3.09 181.745 -655.295 -33.06 536.48 263.91 270.34 -152.9 -287.75 -212.31 211.96
-395.78 161.375 248.005 -61.41 365.295 280.52 -217.26 -256.14 -262.045 -225.245 -159.81 597.26 16.065
-592.625 64.505 -485.195 -232.195 171.835 -245.205 -34.53 -15.52 135.35 36.82 29.745 -26.31 -9.84 -56.73
-156.26 394.515 144.675 -314.075 260.25 129.04 -360.405 125.915 137.24 244.195 237.16 -362.265 -111.595
239.495 95 -131.065 -347.055 183.98 148.825 -57.13 187.12 -103.29 -468.99 87.53 -40.695 -25.94 -449.275 68.09
-517.7 467.93 46.43 -289.65 -43.365 265.52 -145.825 92.865 -213.035 375.665 -229.815 248.805 61.825 35.275
-278.25 -74.99 -1.02 -260.515 -221.82 244.485 317.54 -8.845 -394.21 129.465 -66.26 -222.825 179.175 -129.005
449.46 3.765 -244.82 -134.64 -102.01 -248.725 -141.27 114.405 -183.515 -25.13 226.205 -303.79 -226.275
```

Sample Output 1

```
stock_120 -5000
stock_280 -5000
```

Sample Input 2

```
Portfolio_7 -474.759 -930.042 -158.064 -184.248 95.178 133.95 -453.465 -15.765 210.438 55.95 -172.425 180.804
-103.506 133.791 167.73 205.065 -312.33 36.873 105.81 42.543 62.565 -146.691 23.307 -494.463 -491.202
-233.589 54.735 115.443 109.941 59.991 -318.939 304.662 -142.329 -3.687 11.766 -82.959 2.793 -165.09 -134.637
106.275 43.779 -24.627 -356.307 -56.304 255.003 294.429 59.028 151.989 145.611 235.764 237.459 -311.133
-85.824 158.823 125.19 148.341 -355.884 -479.121 116.82 358.842 247.806 172.425 114.912 301.752 109.683
-28.422 109.203 245.625 140.781 -82.23 -39.447 38.925 206.298 -338.805 -13.152 -337.608 -93.081 -34.596
-124.494 209.208 265.8 -151.971 -167.172 -169.818 91.818 -49.611 -184.179 231.303 -218.79 -86.007 -103.392
-73.074 388.383 454.671 -131.547 -184.959 55.404 -185.112 18.453 46.908 -153.735 453.681 -10.689 154.614
384.564 142.515 74.316 181.092 -487.494 128.835 62.091 -257.439 -105.744 -40.644 -20.946 12.657 -177.318
-44.781 -194.673 -81.873 -227.775 -337.695 -75.609 405.024 -318.591 -45.579 142.692 -293.688 626.238 151.215
-217.449 -128.58 -201.411 -8.508 -92.943 160.14 121.653 133.521 -207.27 -205.815 -58.92 367.59 379.38 -85.944
0.846 122.211 -60.141 110.907 12.087 41.64 -387.264 -93.618 243.825 -362.934 191.733 191.184 143.508 -74.256
-363.681 278.391 324.708 38.889 188.892 101.061 183.909 -239.745 223.116 278.529 454.713 75.219 383.433
-65.415 154.221 374.316 -168.441 25.512 -58.914 -46.188 -163.14 151.185 -75.741 -231.228 115.974 -272.391
191.388 51.057 209.943 309.807 -107.826 -306.915 -48.756 -5.502 215.847 -167.103 432.42 -84.408 79.989
-118.101 453.033 2.232 -32.889 -142.5 -309.552 -285.162 153.297 59.649 -18.861 260.73 -126.126 -377.274
-251.847 -190.257 -40.566 43.389 -76.569 -230.919 -119.457 -168.63 136.53 -35.349 -93.24 -392.82 628.542
-14.418 156 234.312 76.539 -191.043 -84.666 107.619 -268.254 13.548 -196.122 -5.994 114.066 194.334 105.369
261.255 96.828 277.077 -28.914 344.433 -17.133 9.204 -200.727 21.591 18.048 -231.159 -263.742 118.86
```

Sample Output 2

```
stock_127 -3000
stock_130 6000
```

Sample Input 3

```
Portfolio_15 -143.947242 -54.696053 -194.050843 -114.379762 -250.914222 94.525127 -38.578749 87.924437
71.989914 11.229715 294.581902 -280.166856 164.614297 -65.917684 5.897927 150.181106 263.998383 174.068129
88.060921 -223.012161 266.605458 80.822122 158.287567 -9.023034 22.444253 -33.883753 -261.471284 -91.303422
-83.428574 33.292501 -73.951395 -176.659194 -135.428729 62.436845 -136.566712 -173.370305 -283.001479
107.665112 -53.090612 95.636076 139.235617 -19.10865 85.199601 -209.1056 -310.955306 -2.165499 35.976801
7.50174 73.062716 -203.179266 469.00358 127.236235 3.716109 252.211904 174.502566 6.919277 339.092547
4.422581 5.965394 -173.426425 -30.290419 -185.455906 65.674427 116.629944 -109.198075 78.179203 -115.110464
-177.391446 -119.218134 166.293029 -76.239738 171.411876 -141.504239 139.137473 -25.01957 -20.231675
55.088898 2.876409 -44.997561 -9.161336 -72.560697 283.933358 -34.321216 -135.798794 110.626876 -192.54237
119.526443 -1.670631 27.555595 -40.781872 -235.559946 107.050236 -56.895824 -147.281255 -156.770645
-75.445617 82.642868 265.12137 -196.013666 87.095452 56.390496 -72.333542 -88.827275 8.286346 -170.446357
-148.334462 -280.558408 4.362755 46.400015 -6.847279 91.234663 165.416968 20.210035 145.796151 22.934237
-112.741297 31.012431 -22.119119 68.527919 95.182339 42.33652 140.188056 9.100858 103.606242 180.677244
206.1336 -320.051696 107.214837 -275.824155 101.115325 -11.629589 -118.879814 179.147753 -67.162632
196.397848 47.642698 30.792682 41.573022 44.183258 -16.676944 -247.958614 339.049795 -155.912637 -138.184113
152.162531 -361.782844 -18.957799 239.77323 293.220672 -58.43556 269.09757 121.316655 -226.5609 91.962242
-58.319922 131.039805 207.790177 5.537777 176.764472 110.922365 -199.574635 -235.721358 -267.523291 33.088489
-56.281509 133.278441 -48.862124 -167.373615 19.464542 -160.257798 -149.425146 297.139127 -178.140481
42.800719 -88.711313 -141.499563 -22.497015 -178.339219 89.77678 -76.572525 135.606513 -126.414028 -13.139711
139.544421 -166.822281 164.313625 -98.407028 -264.842666 238.055878 139.604803 -61.628126 -1.396826
-193.065595 -165.36715 -114.776197 -140.0188 -149.45157 62.355782 -143.783067 -9.581666 7.968838 230.406302
-165.656265 -74.449799 -49.687282 -200.097204 51.320385 -169.522404 72.792048 -140.198797 296.193869
-166.100215 -235.234293 -208.255771 114.320455 -32.605264 96.040885 124.16604 109.84381 -100.553086 92.345497
-24.857538 -155.040899 225.620404 -27.926196 126.356083 -262.033456 158.129422 -64.263922 34.925883 78.358089
-16.682323 -80.531757 126.170745 -122.257938 97.482713 4.582632 140.674958 -242.783119 -79.575146 62.659014
-45.79654 30.429683 -416.711845 230.05549 -205.179518 46.296581 155.942441 -128.055691 -95.994111
```

Sample Output 3

```
stock_1 -708
stock_12 -101
stock_120 -645
stock_132 -8
stock_15 -634
stock_159 -831
stock_160 -479
stock_182 -62
stock_184 -191
stock_195 -363
stock_211 -898
stock_213 -758
stock_225 -898
stock_247 -475
stock_282 -246
stock_290 -294
stock_5 -115
stock_59 -805
stock_78 -282
stock_98 -358
```