FINM 25000 Mark Hendricks

Summer 2020

**Homework #1**

*Due on Monday, June 22, at 6:00pm.*

The Harvard Management Company and Inflation-indexed Bonds [HBS 9-201-053].

1 HMC's Approach

*Section 1 is not graded, and you do not need to submit your answers. But you are encouraged to think about them, and we will discuss them.*

1. The HMC framing of the portfolio allocation problem.
2. Why does HMC focus on real returns when analyzing its portfolio allocation? Is this just a

matter of scaling, or does using real returns versus nominal returns potentially change the

MV solution?

Real return account for taxes/inflation/fees. Since different products have different tax implications and fees associated, they may be penalized accordingly during the MV calculation depending on if their nominal return or real return is used. This would result in 2 different MV-Optimal portfolios.

1. There are thousands of individual risky assets in which HMC can invest. Explain why MV

optimization across 1,000 securities is infeasible.

~~The correlation matrix grows exponentially in size ( O(n~~~~2~~~~) ), So~~ Calculating the full correlation matrix would be computationally expensive when at a large scale. Additionally, If you consider many (10s of thousands) securities, the likelihood of overfitting would be high.

1. Rather than optimize across all securities directly, HMC runs a two-stage optimization.

First, they build asset class portfolios with each one optimized over the securities of the

specific asset class. Second, HMC combines the asset-class portfolios into one total optimized

portfolio.

In order for the two-stage optimization to be a good approximation of the full MV-

Optimization on all assets, what must be true of the partition of securities into asset classes?

They would need to be highly correlated with each other.

1. Should TIPS form a new asset class or be grouped into one of the other 11 classes? They have a 50% correlation with domestic bonds, however they do seem independent enough to make their own asset class.

2. Portfolio constraints.

The case discusses the fact that Harvard places bounds on the portfolio allocation rather than

implementing whatever numbers come out of the MV optimization problem.

1. How might we adjust the stated optimization problem in slide 43 of Lecture 1: Mean-Variance

Allocation to reflect the extra constraints Harvard is using in their bounded solutions given in

Exhibits 5 and 6. Just consider how we might rewrite the optimization; don't try to solve this

extra-constrained optimization.

1. Exhibits 5 shows zero allocation to domestic equities and domestic bonds across the entire

computed range of targeted returns, (5.75% to 7.25%). Conceptually, why is the constraint

binding in all these cases? What would the unconstrained portfolio want to do with those

allocations and why?

Since the allocation given to domestic equity and foreign equity are both = to the lower bound, they are considered binding constraints. By definition, a binding constraint means that if you change the constraint, then the objective function also changes.

If you unconstrained this portfolio optimization program, then the optimal portfolio would allocate negative weight to domestic equity and bonds. Negative weight means that the security is shorted.

1. Exhibit 6 changes the constraints, (tightening them in most cases.) How much deterioration do we see in the mean-variance tradeoff that Harvard achieved?

While exhibit 5 returns a portfolio with sharp .38 for each expected real return assumption, exhibit 6 returns between a .35-.36 sharp ratio, depending on the expected real return assumption. This means that the sharp ratio deterioration experienced is .02-.03 depending on the expected real return.

2 Mean-Variance Optimization

This section is graded for a good-faith effort by your group. Submit your write-up along with your

supporting code. Don't just submit code or messy numbers; submit a coherent write-up based on your

work.

• The exhibit data is in a spreadsheet posted on Canvas, but you do not need to use it; I provide

it only in case you wish to do extra comparisons to the case data.

• For our analysis, we use more current data found in asset class data monthly 2009.xlsx.1

• The time-series data gives monthly returns for the 11 asset classes and \Cash" from March 2009

to Sep 2019.

• Assume that the risk-free rate is the return on \Cash".2

• We will be working with the risky MV frontier for 11 risky asset classes, and we will use the

excess-return formulation and frontier. To do the analysis below, you will want to subtract the

risk-free rate from each of the other 11 security returns to get 11 time-series of excess returns.

• These are nominal returns|they are not adjusted for inflation, and in our calculations, we are not

making any adjustment for inflation.

In the questions below, annualize the statistics you report.

1. Summary Statistics
2. Calculate and display the mean and volatility of each asset's excess return. (Recall we use

volatility to refer to standard deviation.)

1. Which assets have the best and worst Sharpe ratios?

2. The MV frontier.

(a) Compute and display the weights of the tangency portfolios: .

(b) Compute the mean, volatility, and Sharpe ratio for the tangency portfolio corresponding to

3. The allocation.

(a) Compute and display the weights of MV portfolios with target returns of p = :0067.3

(b) What is the mean, volatility, and Sharpe ratio for wp?

(c) Discuss the allocation. In which assets is the portfolio most long? And short?

(d) Does this line up with which assets have the strongest Sharpe ratios?

4. Long-short positions.

(a) Consider an allocation between only domestic and foreign equities. (Drop all other return

columns and recompute wp for p = :0067.)

(b) What is causing the extreme long-short position?

(c) Make an adjustment to foreign equities of +0.001, (+0.012 annualized.) Recompute wp for

p = :0067 for these two assets.

How does the allocation among the two assets change?

(d) What does this say about the statistical precision of the MV solutions?

5. Robustness

(a) Recalculate the full allocation, again with the unadjusted and again for =

0.0067. This time, make one change: in building , do not use as given in the formulas

in the lecture. Rather, use a diagonalized , which zeroes out all non-diagonal elements

of the full covariance matrix, .

How does the allocation look now?

(b) What does this suggest about the sensitivity of the solution to estimated means and estimated

covariances?

(c) HMC deals with this sensitivity by using explicit constraints on the allocation vector.

Conceptually, what are the pros/cons of doing that versus modifying the formula with ?

6. Out-of-Sample Performance

Let's divide the sample to both compute a portfolio and then check its performance out of

sample.

(a) Using only data through the end of 2016, compute for = .0067, allocating to all 11

assets.

(b) Calculate the portfolio's Sharpe ratio within that sample, through the end of 2016.

(c) Calculate the portfolio's Sharpe ratio based on performance in 2017-2019.

(d) How does this out-of-sample Sharpe compare to the 2009-2016 performance of a portfolio

optimized to using 2009-2016 data?

7. Robust Out-of-Sample Performance

Recalculate wp on 2009-2016 data using the diagonalized covariance matrix, . What is the

performance of this portfolio in 2017-2019? Does it do better out of sample than the portfolio

constructed on 2009-2016 data using the full covariance matrix?