*Start date: 12/9/2023* *Due date: 12/23/2023*

# Final Project

*Note: All files and information related to the final project are located in the various folders starting with "Final Project" prefix on CourseWorks.*

The aim of this Final Project is to practically implement the ideas from the course, specifically from Chapters 7 and 8 of [BKM13]. Using Bloomberg, you will be given a recent 20 years of recent historical daily total return data for ten stocks, which belong in groups to three-four different sectors (according to Yahoo!finance), one (S&P 500) equity index and a proxy for risk-free rate (1-month Fed Funds rate). Additionally, you will be given contemporaneous ESG [ESG3] scores data also from Bloomberg for all of your companies with detailed explanations to them. In order to reduce the non-Gaussian effects, you will need to aggregate the daily data to the monthly observations, and based on those monthly observations, you will need to calculate all proper optimization inputs for the full Markowitz Model ("MM"), alongside the Index Model ("IM"). Using these optimization inputs for MM and IM you will need to find the regions of permissible portfolios (efficient frontier, minimal risk portfolio, optimal portfolio, and minimal return portfolios frontier) for the following four cases of problems:

1. This optimization is designed to simulate the typical limitations existing in the U.S. mutual fund industry: a U.S. open-ended mutual fund is *not allowed to have any short positions*, for details see the Investment Company Act of 1940, Section 12(a)(3) (https://www.law.cornell.edu/uscode/text/15/80a-12):
$$w_i \geq 0, \text{ for } \forall i;$$
2. Now, having the efficient risky portfolio $\{\hat{w}_i\}_{i=1}^{10}$ for the solution for the above problem 1, you will need to solve the problem 1 above with the following constraint on ESG:
$$\sum_{i=1}^{10}(E_i + S_i + G_i)w_i \leq 0.9 \times \sum_{i=1}^{10}(E_i + S_i + G_i)\hat{w}_i;$$
3. This optimization constraint is designed to simulate the *Regulation T by FINRA* (https://www.finra.org/rules-guidance/key-topics/margin-accounts), which allows broker-dealers to allow their customers to have positions, 50% or more of which are funded by the customer's account equity:
$$\sum_{i=1}^{10}|w_i| \leq 2;$$
4. Lastly, having the efficient risky portfolio $\{\hat{w}_i\}_{i=1}^{10}$ for the solution for the above problem 3, you will need to solve the problem 3 above with the following constraint on ESG:
$$\sum_{i=1}^{10}(E_i + S_i + G_i)w_i \leq 0.9 \times \sum_{i=1}^{10}(E_i + S_i + G_i)\hat{w}_i.$$

You will need to present the results in both the tabular and graphical form with the objective to make inferences and comparisons between the sets of constraints for each optimization problem and between the MM and IM models in general. The grading will be done by comparing your tabulated results to exact solutions.

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Again, you will be given 20 years of daily data of total returns for the S&P 500 index (ticker symbol "SPX"), and for ten stocks (ticker symbols see the table below) such that there are three-four sectors of stocks with stocks in each group belonging to one (Yahoo!finance) sector and an instrument representing risk-free rate, 1-month annual Fed Funds rate (ticker symbol "FEDL01"). Note that stocks in each group are completely different. Therefore, each group will have its own results and conclusions.

Below, please, find the table of stock ticker symbols (aka, tickers) for each group to work with:

| | **Group #1** | **Group #2** | **Group #3** | **Group #4** |
|---|---|---|---|---|
| **Stock #1** | ADBE | AMZN | NVDA | QCOM |
| **Stock #2** | IBM | AAPL | CSCO | AKAM |
| **Stock #3** | SAP | CTXS | INTC | ORCL |
| **Stock #4** | BAC | JPM | GS | MSFT |
| **Stock #5** | C | BRK/A | USB | CVX |
| **Stock #6** | WFC | PGR | TD CN | XOM |
| **Stock #7** | TRV | UPS | ALL | IMO |
| **Stock #8** | LUK | FDX | PG | KO |
| **Stock #9** | ALK | JBHT | JNJ | PEP |
| **Stock #10** | HA | LSTR | CL | MCD |



Below, please, find the table which shows the details for each of the stocks and which stocks belong to the same sector in each group.

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| # | Group #1 | Full Name | Sector (Yahoo!finance) |
|---|---|---|---|
| 1 | ADBE | Adobe Inc. | Technology |
| 2 | IBM | International Business Machines Corporation | Technology |
| 3 | SAP | SAP SE | Technology |
| 4 | BAC | Bank of America Corporation | Financial Services |
| 5 | C | Citigroup Inc. | Financial Services |
| 6 | WFC | Wells Fargo & Company | Financial Services |
| 7 | TRV | The Travelers Companies, Inc. | Financial Services |
| 8 | LUV | Southwest Airlines Co. | Industrials |
| 9 | ALK | Alaska Air Group, Inc. | Industrials |
| 10 | HA | Hawaiian Holdings, Inc. | Industrials |

| # | Group #2 | Full Name | Sector (Yahoo!finance) |
|---|---|---|---|
| 1 | AMZN | Amazon.com, Inc. | Consumer Cyclical |
| 2 | AAPL | Apple Inc. | Technology |
| 3 | FFIV | F5 Networks, Inc. | Technology |
| 4 | JPM | JPMorgan Chase & Co. | Financial Services |
| 5 | BRK/A | Berkshire Hathaway Inc. | Financial Services |
| 6 | PGR | The Progressive Corporation | Financial Services |
| 7 | UPS | United Parcel Service, Inc. | Industrials |
| 8 | FDX | FedEx Corporation | Industrials |
| 9 | JBHT | J.B. Hunt Transport Services, Inc. | Industrials |
| 10 | LSTR | Landstar System, Inc. | Industrials |



| # | Group #3 | Full Name | Sector (Yahoo!finance) |
|---|---|---|---|
| 1 | NVDA | NVIDIA Corporation | Technology |
| 2 | CSCO | Cisco Systems, Inc. | Technology |
| 3 | INTC | Intel Corporation | Technology |
| 4 | GS | The Goldman Sachs Group, Inc. | Financial Services |
| 5 | USB | U.S. Bancorp | Financial Services |
| 6 | TD CN | The Toronto-Dominion Bank | Financial Services |
| 7 | ALL | The Allstate Corporation | Financial Services |
| 8 | PG | The Procter & Gamble Company | Consumer Defensive |
| 9 | JNJ | Johnson & Johnson | Healthcare |
| 10 | CL | Colgate-Palmolive Company | Consumer Defensive |

| # | Group #4 | Full Name | Sector (Yahoo!finance) |
|---|---|---|---|
| 1 | QCOM | QUALCOMM Incorporated | Technology |
| 2 | AKAM | Akamai Technologies, Inc. | Technology |
| 3 | ORCL | Oracle Corporation | Technology |
| 4 | MSFT | Microsoft Corporation | Technology |
| 5 | CVX | Chevron Corporation | Energy |
| 6 | XOM | Exxon Mobil Corporation | Energy |
| 7 | IMO | Imperial Oil Limited | Energy |
| 8 | KO | The Coca-Cola Company | Consumer Defensive |
| 9 | PEP | PepsiCo, Inc. | Consumer Defensive |
| 10 | MCD | McDonald's Corporation | Consumer Cyclical |

Using this data you will need to prepare an Excel spreadsheet that makes all the necessary calculations to plot a *Permissible Portfolios Region*, which combines the *Efficient Frontier*, the *Minimal Risk or Variance Frontier*, and the *Minimal Return Frontier* for a given set of constraints (1-4 above). The *Minimal Return Frontier* and the *Efficient Frontier* together are forming the *Minimal Risk or Variance Frontier* – it is just a matter of reformulating the optimization problem, as follows:

*Minimal Risk or Variance Frontier*:

$$\begin{cases} \sigma(\vec{w}) \to \min\limits_{\vec{w}} \\ \text{subject to}: r(\vec{w}) = const \end{cases};$$

*Minimal Return Frontier*:

$$\begin{cases} r(\vec{w}) \to \min\limits_{\vec{w}} \\ \text{subject to}: \sigma(\vec{w}) = const \end{cases};$$

*Efficient Frontier*:

$$\begin{cases} r(\vec{w}) \to \max\limits_{\vec{w}} \\ \text{subject to}: \sigma(\vec{w}) = const \end{cases};$$



Two unique points that you need to find on the *Efficient Frontier* are of special interest:



*Minimal Risk Portfolio*:

$$\{\sigma(\vec{w}) \to \min\limits_{\vec{w}};$$



and

*Efficient Risky Portfolio*:

$$\begin{cases} \dfrac{r(\vec{w})}{\sigma(\vec{w})} \to \max\limits_{\vec{w}} \end{cases}.$$

For each of the markets in the above table we have uploaded adjusted most recent data containing the Adjusted Closing daily price.

This Final Project in an open-book which means that you can and should use the Instructor's handouts and the corresponding Chapter copy reading material provided by the Instructor, as well as any additional materials provided to you. Instructor and TAs have performed all these calculations for each of the group's portfolios and will be able to compare your numbers, specific points and graphs to theirs. If your spreadsheet calculations are done correctly, you and we should be able to match the results with sufficient accuracy.

The main tool that we would like you to use to solve the optimization problems for each point on the *Minimal Risk or Variance Frontier* is the Excel Solver. Please, try to learn how to use it on your own, if

you have not done so already. The TAs will be helping you to address any issues related to Solver during the TAs sessions. To calculate large numbers of multiple points on any of the required frontiers, you will need to use the Excel Solver Table, which the TAs will teach you how to install and use. Both Excel Solver and Excel Solver Table will also be covered in lectures with illustrations which are very similar to your Final Project.

For your calculations, you need to use the full available historical data range:

- start date 2/28/2003;
- end date 3/6/2023.

As it was mentioned above, you will need to calculate the solutions to two optimizations covered in lectures:

- The full Markowitz Model (MM);
- The Index Model (IM).

As we have described this in detail above, each of these optimization problems MM and IM you will need to implements and solve with the following additional four optimization constraints:

1. $w_i \geq 0$, for $\forall i$;
2. $w_i \geq 0$, for $\forall i$, and $\sum_{i=1}^{10}(E_i+S_i+G_i)w_i \leq 0.9\times\sum_{i=1}^{10}(E_i+S_i+G_i)\hat{w}_i$
3. $\sum_{i=1}^{10}|w_i| \leq 2$;
4. $\sum_{i=1}^{10}|w_i| \leq 2$ and $\sum_{i=1}^{10}(E_i+S_i+G_i)w_i \leq 0.9\times\sum_{i=1}^{10}(E_i+S_i+G_i)\hat{w}_i$,



where $\{\hat{w}_i\}_{i=1}^{10}$ in each case corresponds to the efficient risky portfolio solution of the corresponding non ESG-constrained problem.

As we have already mentioned, your task is to produce the following objects on the Permissible Portfolios Region in the numerical (and the template spreadsheet does it in the graphical for you) form:

- Minimal Risk or Variance Frontier (a curve), range for portfolio returns: from -10% to 50% with step of 0.5%;
- Global Minimal Risk or Variance Portfolio (a point);
- Maximal Sharpe Ratio or Efficient Risky Portfolio (a point);
- Maximal Return or Efficient Frontier (a curve), range for portfolio standard deviation: from 10% to 50% with step of 0.5%;
- Capital Allocation Line or CAL (a straight line);
- Minimal Return or Inefficient Frontier (a curve), range for portfolio standard deviation: from 10% to 50% with step of 0.5%.

The curves above must be produced in tabular form (Excel), using the template provided, preserving the formats in the template, with which comparison to exact solution will be made for grading, using specifically the above ranges. If a numerical solution cannot be found, just leave the corresponding cell

empty. The points above should also be tabulated. All the tabulation should be done similar to example provided by the Instructor (see the file "Final Project Group0.xlsx" provided).

Do not hesitate to ask TAs, Lecturer any questions related to this.

Good luck!

You are given two weeks to complete the Final Project and to prepare the presentations. We encourage you not to delay starting the work as workload is meant for several days of work and not as a one-night effort.

**Final Project presentations will take place on December 23rd, 2023 at 7:00 PM EST**.

Your spreadsheet should be named following the following convention which is similar to the homework naming convention: "FinalProject-1 Alexei Chekhlov.xlsx". Here "1" is the number of your Final project group, and instead of "Alexei Chekhlov" should be your name in the following format: "FirstName Last Name".

To re-iterate, in this Final Project you will need to achieve the following goals:



1. Get familiar with the markets allocated to your group, download the data, and review all the necessary information from Bloomberg slides.
2. Prepare the data for optimization problem solution (aggregate it from daily to monthly frequency), calculate all the required inputs for each of the optimization problems MM and IM, and for each of the four sets of additional optimization constraints.
3. Calculate both of the two key frontier points (maximal Sharpe Ratio and Minimal Risk), and three frontiers: the Efficient Frontier, the Minimal Return Frontier, and the Minimal Variance Frontier.
4. Prepare the Excel file with your results using the template provided, preserving the formatting, the ranges, etc. Name it using the convention "FinalProject-1 Alexei Chekhlov.xlsx" and submit through the portal on CourseWorks.

Remember, that you can always ask both the Lecturer and the TAs any questions.

**References:**

[BKM13] Z. Bodie, A. Kane, A. J. Marcus, "Investments", Thirteenth Edition, McGraw Hill, 2024.

[CFA3] "Certificate in ESG Investing Curriculum". CFA Institute. Edition 3. CFA Society of the UK, 2021.