MIE377 – Financial Optimization Models

Project 1

Due Date: 06-Mar-2018 by 11:59 AM

Please use MATLAB to solve this project. This is an individual project, and each student is expected to submit their own original work.

You are given:

- Raw market data consisting of adjusted closing prices for 20 U.S. stocks (Quandl.com, 2017), and factor rates of return for the Fama–French three-factor model (French, 2016).
- A MATLAB program template for portfolio construction and rebalancing.
- Three MATLAB function templates to code the three different models we will study in this project.
- (Optional) A LaTeX template for you to write your report. Anyone interested in learning how to use LaTeX is welcome to use this template. However, no penalties or rewards will be given for using LaTeX.

You should hand in:

- A formal report composed of an introduction, methodology, results and conclusion.
- The MATLAB program and functions you wrote to solve this project.
- Please submit all your files inside a compressed folder, including your report and MATLAB code. The name of the submitted file should be **StudentID.zip**. Please submit this file electronically through the Blackboard portal (a printed copy is not required).

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1 Introduction

The purpose of this project is to compare three different investment strategies based on some of the models we have studied in class. We will build portfolios based on these models and we will rebalance them periodically over a three-year period. The three investment strategies are the following:

1) The mean–variance optimization (MVO) model.
2) Cardinality-constrained MVO model.
3) The Black–Litterman model.

(1) The MVO model seeks to minimize risk (variance) while subject to a target return constraint. The target return should be the average expected return of all assets in the portfolio (i.e., take the average value of the estimated expected returns from all 20 assets and use this as the target return).

Note that, by design, our target return will change every time we re-estimate our parameters. We are allowed to short-sell the assets.

(2) The cardinality-constrained MVO model also seeks to minimize variance while subject to a target return. The cardinality constraint must limit the number of assets we can hold to 12. However, the target return should be the same as the previous MVO model, averaging the expected return of all 20 potential assets. We are not allowed to short-sell.

(3) Finally, the Black–Litterman model will have us compute a portfolio that combines the market portfolio with our own subjective views. The market portfolio can be derived from the total number of shares outstanding per stock. We must have at least 6 different views of varying confidence levels. We are allowed to change our views every time the portfolio is rebalanced. We must attempt to justify our choice of views. In other words, we must state why our choices are reasonable (but we do not need to provide a thorough analysis for our choices). We are allowed to short-sell. Refer to Idzorek (2007) for additional information on how to compute the Black–Litermann model.

2 Methodology

Our investment universe in this project consists of 20 stocks ($n = 20$), all constituents of the S&P500. The list of stocks and their number of shares outstanding can be found in Table 1. We are given weekly adjusted closing prices corresponding to these 20 stocks from 30-Dec-2011 to 31-Dec-2015 (Quandl.com, 2017). Using adjusted closing prices during computational experiments is standard. The reason we use adjusted closing prices is to adjust for stock splits and dividend payments, which could otherwise distort the historical timeseries. For example, if we perceive a 2:1 stock split, we would observe our share price dropping by 50% overnight, while in reality we would not have lost any money since we would now hold double the number of shares. We must use this weekly raw data to compute the weekly *excess* returns, which means we must adjust these by the risk-free rate. The MATLAB template provided already performs this calculation for us, but please read the code to understand the process.

Table 1: List of assets and their number of shares outstanding

	F	CAT	DIS	MCD	KO	PEP	WMT	C	WFC	JPM
# of Shares (billions)	3.640	0.986	1.505	1.091	4.544	1.543	4.345	3.326	5.157	4.525
	AAPL	IBM	PFE	JNJ	XOM	MRO	ED	T	VZ	NEM
# of Shares (billions)	6.938	0.858	6.456	3.080	3.682	0.770	0.332	5.468	3.899	0.578

We will use a factor model to explain our observed rates of return. Therefore, we must calculate the expected excess returns and covariance matrix through this factor model. The factor model selected for this project is the Fama–French three-factor model (Fama and French, 1993), which is shown below

$$r_i - R_f = \alpha_i + \beta_{im}(f_m - R_f) + \beta_{is}SMB + \beta_{iv}HML + \varepsilon_i$$

where r_i is the asset return, R_f is the risk-free rate of return, α_i is the intercept from regression, β_{im} is the market factor loading, $(f_m - R_f)$ is the excess market return factor, β_{is} is the size factor loading, SMB is the size factor, β_{iv} is the value factor loading, HML is the value factor, and ε_i is the residual from regression. The factor data have been provided as part of the project (French, 2016), including the weekly risk-free rate. We must perform the ordinary least-squares regression to estimate the regression parameters, and then use these to estimate the relevant MVO parameters.

We will construct three portfolios based on the optimization models described. The portfolios must be rebalanced every six months at the start of every January and July. The investment horizon ranges from the start of 2013 to the end of 2015, for a total of six investment periods. We must use one year of data to calibrate the regression model and to estimate the optimization parameters. The calibration period should immediately precede the start of the investment period. Once an investment period is over, we will re-calibrate our parameters using the most recent one-year window available. The MATLAB template already includes the code to select the appropriate windows for in-sample calibration and out-of-sample testing.

For this project we do not need to incorporate transaction costs into the optimization models. We assume we have a separate cash account that will pay for all of our transaction fees. However, we must record our transaction costs every time we rebalance the portfolio. The cost of buying or selling an asset is 0.5% of the traded volume. This means that if a stock is currently quoted at \$25 and the investor must buy 10 additional shares, then the transaction fee will be equal to $0.005 \times 25 \times 10 = \$1.25$. Please note that, for the sake of simplicity, we are allowed to buy, sell, and hold fractions of stocks (e.g., we are allowed to hold 82.57 shares of a stock). There is no cost associated with the construction of the starting portfolios (i.e., we only need to start measuring the transaction costs during our first portfolio rebalance).

At the end of the experiment, we must analyze our results and compare the three investment models. We should plot the portfolio value through time to see what strategy was dominant and during which periods they did better or worse. We can also use an area plot to show the changes per period in the composition of our portfolios (i.e. to see how our optimal weights changed every time we rebalanced a portfolio). This will show if our portfolios were concentrated or well-diversified. Moreover, we can also compare our incurred transaction costs between the three portfolios. Finally, we should also compute performance metrics, such as the average rate of return, or our portfolio standard deviation (as a measure of risk). You are welcome to compute any other additional performance or risk metric to further compare our portfolios.

3 Deliverables

3.1 Report (70%)

Prepare a formal project report. The report should introduce the purpose of this project, explain your methodology, show a summary of your computational results, and present an analysis of these results. You should also discuss the drawbacks you can observe from your investment models, and describe possible improvements.

The report should show your understanding of factor models and your understanding of the three portfolio optimization models. Your analysis of the computational experiment should also reflect your knowledge of the material we have seen in class. The discussion of drawbacks and possible improvements should show any insights you are able to derive from the results.

The report should have a minimum of one plot to illustrate the weekly value of your portfolio, three plots to show your portfolio weights per investment period (one plot per portfolio), and a table to show the rest of your performance and/or risk metrics. You are welcome to include any additional plots or other material if you wish to illustrate any other results or insights.
The report is worth 70% of the total. The distribution is the following

- Formal report structure and presentation: 5%
- Description / understanding of the three investment models: 25%
- Analyzing your results: 25%
- Discussion of drawbacks and potential improvements: 15%

3.2 MATLAB program (30%)

Prepare a MATLAB program to perform the computational experiments. Try to use the template provided and fill your code in the sections indicated. However, you are allowed to modify the template as you see fit. Be sure to properly comment on your code to briefly explain what you are doing. Your code should be easy to read and it should run, printing any relevant parameters to the console (the TA will not debug your code and should not have to search for the results within the code).

Prepare three MATLAB functions to implement your three investment strategies. Templates for these three functions are already provided. As with your program, please be clear and (briefly) comment on your code to explain your procedure.

References

Fama, E. F. and French, K. R. (1993). Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics*, 33(1):3–56.

French, K. R. (2016). Data library. `http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html`. [Online; accessed 20-Sep-2017].

Idzorek, T. (2007). A step-by-step guide to the black-litterman model: Incorporating user-specified confidence levels. In *Forecasting expected returns in the financial markets*, pages 17–38. Elsevier.

Quandl.com (2017). Wiki – various end-of-day stock prices. `https://www.quandl.com/product/WIKIP/usage/export`. [Online; accessed 07-Nov-2017].