FINANCIAL MARKETS

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Abstract

The purpose of this Interactive Qualifying Project is to discuss relevant topics of Modern Portfolio Theory (MPT) and illustrate a practical application of the concept. I will review MPT history and definitions before entering more in-depth in the theory. After a holistic explanation of MPT, I will show my work and results obtained, and extract conclusions from them. Finally, I will expose some weaknesses and criticism towards the theory, propose future next steps to extend my work and provide a synthesis of the project as final words.

Relevant history for this project

Before the invention of Modern Portfolio Theory, around the decade of 1930s, investors used to invest and trade using simple paper-and-pencil methods. The primary objective of investors was to find the best stock possible (or good enough) and acquire at the most profitable price (Beattie, 2018). Difficulties abounded; from slow information transmission to a still generalized perception of "gambling" on financial investing among the general public.

In this turmoil, finance professionals started to take part in more advanced analysis techniques by getting more accurate and relevant data, and extrapolating results for making better investment decisions. These advancements kickstarted the beginning of "Fundamental Analysis"; however, the motivation was to find good companies on a bargained price. Nobody

focused on risk-related metrics until the advent of Harry Markowitz and his Modern Portfolio Theory (Graham & Dodd, 1934).

Harry Markowitz was a graduate student in operations research, searching for a topic for his PHD thesis. After having a conversation with a stockbroker, he decided to focus on developing a technique for analyzing financial risk and in 1952, he published “Portfolio Selection”, an article that proved two axioms: “nothing ventured, nothing gained” , and “don’t put all your eggs in one basket”, which was used as the basis for his doctoral thesis as well and later became known as “Modern Portfolio Theory” in the field of finance. Eventually, Markowitz was awarded the Nobel Prize in Economic Sciences in 1990 for this contribution. The topic was so novel that Nobel laureate Milton Friedman reportedly argued that the thesis didn’t tackle a topic in the field of Economics.

Another important person that contributed to the development of Modern Portfolio Theory was William F. Sharpe. In the decade of the 1960s, he developed the Capital Asset Pricing Model (CAPM), which describes the relationship between specific risk and expected returns, with the notable axiom: “the higher the risk, the higher the return”. He also created the Sharpe Ratio, a metric used to measure a risk/reward relationship of a given investment. In 1990, he was awarded the Nobel Prize in Economics, along with Harry Markowitz, for the development of the Modern Portfolio Theory.

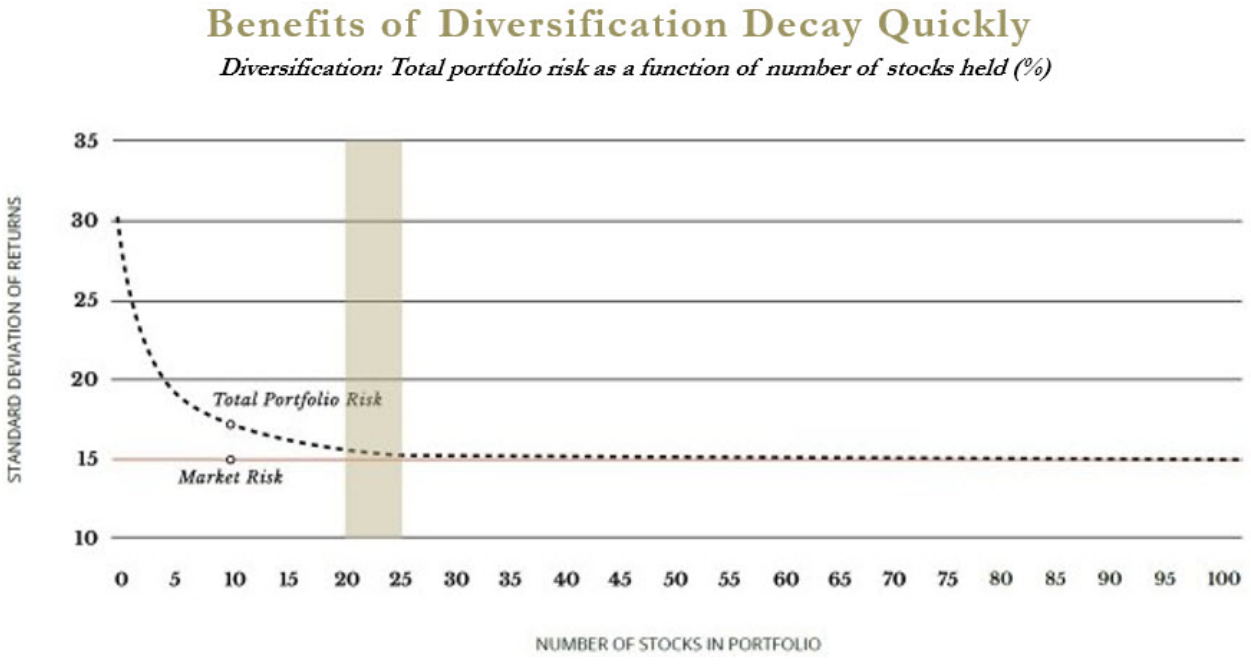
Two additional figures in Finance and economics that had great economic impact in the security investing and trading area were Eugene Fama and Robert Shiller. Fama is best known for his work on portfolio theory, asset pricing and the efficient-market hypothesis and was awarded the Nobel Memorial Prize in Economics Science in 2013. Shiller is best known for his behavioral analysis of asset prices and was also awarded the Nobel Memorial Prize in Economics Science in 2013. Both personalities worked in overlapping areas of study, made huge impacts in Finance and Economics and are highly regarded within academia. However, they have opposite views regarding market theories. Fama supports the efficient-market hypothesis, which states that all goods and services within a market are correctly priced and reflect all available information (Fox, 2013). In contrast, Shiller says that markets are inefficient; people process and react to the market's information in different ways, some rational and some irrational (Fox, 2013). Both views are currently very debated among pundits in the subject matter, also having big repercussions in the political arena.

Burton Malkiel, author of the 1973 book "Random Walk Down Wall Street" which was based on Eugene Fama's Random Walk Hypothesis published in 1965, showed that as securities are added to a portfolio, the portfolio's volatility declines. In this context, volatility refers to the standard deviation of the periodical growth in value related to each security. Standard deviation is a measure of the amount of variation or dispersion between the values that are being analyzed (Beattie, 2018). According to the data, however, there is a point where diminishing returns start to kick in at full throttle and the risk-reducing effect of adding a marginal security to the portfolio becomes negligible; in sum, the capacity of the portfolio to

outperform the market starts to fade as well as the number of securities in the portfolio increases due to low allocation of resources to winning securities. According to Fama, the optimal number of held securities, in order to maximize the probabilities of outperforming the market but also minimize the portfolio's volatility, is between 20 and 25 (Stannard-Stockton, 2019. See Figure 1).

Figure 1

Benefits of Diversification (Stannard-Stockton, 2019)



Overview

The stock market investing landscape is a complex, no-silver-bullet area that can be extremely dynamic and ever-evolving. However, investors who allocate their time and energy to learn the basic concepts are good candidates for developing an edge over other investors. In this section, we expose some of these basic concepts that are pivotal for advancing one's endeavors in the stock market.

A stock market or stock exchange is a digital or physical medium where existing buyers and sellers come together to invest and trade securities, or assets. Prices within the stock market are set by supply and demand in the market as buyers and sellers place orders. Order flow and bid-ask spreads (buy offers and sell offers) are often maintained by specialists or market creators to ensure a competitive market. Two of the biggest stock markets are the NASDAQ and the New York Stock Exchange (NYSE), both based in the United States (Merrill, 2010).

Asset classes are important concepts in stock market investing. These are groupings of investments with similar characteristics and subjected to the same regulations, and usually investors try to create a portfolio with different types of asset classes for diversification purposes. One of the main asset classes are Stocks or Equities; shares of ownership issued by organizations trading in a stock market. Another important asset class are Bonds, fixed-

income securities that pay a rate of return in the form of interest. Other relevant asset classes are Cash or Cash Equivalents, Real Estate, Futures and Financial Derivatives (Ganti, 2020).

Another important concept for stock market investors is the concept of investment styles: what approach, or algorithm type, is used to select and position securities in a portfolio. There are two main investment styles: Value investing and Growth investing. The value investing style promotes investing in low-priced securities relative to their fundamental value but with strong fundamentals, and is a particularly good strategy for bear markets since prices, the main metric that investors use for directing their investments in value investment, are in general lower than usual or "on sale", meaning that opportunities can become even more profitable than in a bull market. On the other hand, growth investing style promotes the acquisition of securities that have recently demonstrated higher-than-average earnings and are expected to continue with this trend, or simply demonstrate potential for growth in earnings but lack a record of overperforming in such metric. This style is good for bull markets because interest rates are low and company earnings are high in general, since there are more resources available for investment in the economy and thus, the economic vehicles for scaling are more easily available, as well. There is also Growth at a Reasonable Price (GARP), a mixed investment style that was born out of the fusion of value investing and growth investing, that seeks to acquire securities that are achieving high earnings or display high earnings-growth potential but at the same time excluding securities with high valuation (Merrill, 2010).

Investor's mindsets also play a huge role in the world of stock market investing and impact greatly how people allocate resources. Generally, the psychology of investors varies between the following risk-based spectrum: Risk-averse mindset and Risk-seeking mindset. An investor is considered Risk-averse when he tends to choose the preservation of capital over the potential for a higher-than-average return. Bonds, large cap stocks and certificate deposits (CDs) are often securities picked by risk-averse investors. In the other hand, the Risk-seeking mindset represents the acceptance from investors to accumulate volatility in their portfolio in exchange of relatively high probabilities of achieving higher-than-normal returns. Examples of securities that risk-seeking investors pursue are growth stocks, futures and options.

Modern Portfolio Theory

Modern Portfolio Theory, or MPT for short, is a theory created by Harry Markowitz on how investors can construct portfolios to maximize expected returns based on a given level of market risk. It is also the first formal analysis to gain general acceptance from academia and professionals alike that focused exclusively on risk metrics. The main argument of MPT is that an investment's risk and return should not be contemplated in isolation, but they should be evaluated based on how it impacts the overall portfolio of investments' risk and return. For doing this, the theory provides investors tools to construct a portfolio of multiple securities that will maximize return at any given level of risk taken, or vice versa, using diversification as the main vehicle for accomplishing so. A key assumption that MPT makes is that investors are

risk averse, meaning that they prefer a less risky portfolio instead of a riskier one for any given level of return. It also helps investors understand that as risks go up, returns go up as well.

Modern Portfolio Theory has many benefits to offer. It shows how investors can optimize the amount of resources allocated to each portfolio's component, including the feature of greatly reducing risk by allocating a fraction of their portfolios into risk-free assets, such as the US treasury bills. These assets are considered "risk-free" because the entities in charge of the creation and management of these assets (the US government, the Federal Reserve, etc.) have the authority to simply create or print money, so there is virtually no risk that those who lend money to the government will not receive their interest and principal payments when due. Based on these, investors can extrapolate realistically ideal levels of risk and return, tailored to any point of the spectrum in the risk-reward mindset (Chen, 2020).

The theory is not exempt of shortcomings, either. For example, MPT measures risk based on historical data, which might or might not come to happen. The theory also assumes that risk is symmetric; according to the theory, fluctuations in rate of return affect investors in the same way regarding of the direction of the fluctuations. In other words, overperforming rate of returns and underperforming rate of returns are treated equally, which is not how fluctuations affect investors in the real world since downward fluctuations (underperforming rate of returns) affect investors more negatively than upward fluctuations (overperforming rate of returns), meaning risk is asymmetric in nature. Another weakness of the theory is that it assumes that securities with negligible (or convenient) correlations can be readily found and

persist within a portfolio. This is a big problem in practice since, aside from the fact that MPT doesn't give a tool for analyzing correlations within one's portfolio by itself, in times of market stress securities tend to behave as if they are correlated, irrespective of results from previous correlation analysis.

Two main shortcomings of Modern Portfolio Theory are the absence of systematic guidance for selecting securities, a very important decision for investors to make, and the fragility of the analysis when data inputs are modified, which makes the analysis less robust and practical.

MPT theory explained

In this section, I explain key definitions and concepts for understanding how Modern Portfolio Theory works.

Return: one of the main metrics we are trying to maximize is Return. Return is considered to be the price appreciation for each acquired security.

Risk/Standard deviation: another main metric that has to be tracked in order to optimize a portfolio, only that in this case we try to minimize it. It is considered to be the average price fluctuations, or standard deviation, for each held security.

Variance: another measurement of the spread between numbers in a data set. It is used for calculating the standard deviation.

Covariance: measures the directional relationship between the returns of two assets. A positive covariance means that asset returns move together while a negative covariance means they move inversely.

Correlation Coefficient: measures the degree to which two securities move in relation to each other. It is a sort of a normalized covariance but not sensitive to the unit of measurements. In contrast, covariance shows the net variations that occur between variables taking into account the unit of measurements. Figure 2 displays the Correlation Coefficient Matrix, a method for calculating the correlation coefficient (Radzicki, 2017), which I have used for calculations within my MPT model. The method calculates de correlation between each stock by using the correlation function in Excel (CORREL). Weights are assigned to the securities, which are then multiplied by their respective correlation coefficients and added together. Finally, the Excel Solver feature is used for optimizing the weights and thus minimizing the correlation coefficient of the portfolio.

Figure 2.

Correlation Coefficient Matrix

Correlation Matrix														
	MMM	BAC	XOM	MCD	PFE	WMT			BAC	XOM	MCD	PFE	WMT	Sum
MMM	1.0000	0.2115	0.1632	0.3463	-0.0032	0.2114		MMM	0.00000	0.00090	0.00045	-0.00001	0.00166	0.00300
BAC	0.2115	1.0000	0.1679	0.4923	0.0899	0.2333		BAC		0.00000	0.00000	0.00000	0.00000	0.00000
XOM	0.1632	0.1679	1.0000	0.2571	0.1233	0.5810		XOM			0.00465	0.00419	0.06305	0.07189
MCD	0.3463	0.4923	0.2571	1.0000	0.0544	0.2900		MCD				0.00044	0.00751	0.00795
PFE	-0.0032	0.0899	0.1233	0.0544	1.0000	-0.0340		PFE					-0.00166	-0.00166
WMT	0.2114	0.2333	0.5810	0.2900	-0.0340	1.0000		WMT						
													Sum =	0.16237
Weights	0.1412	0.0000	0.2752	0.0657	0.1236	0.3943								
	0.0199	0.0000	0.0757	0.0043	0.0153	0.1555	Sum =	0.2707						
							1 - Sum =	0.7293						
								Average Portfolio Correlation						
								0.4453						

Portfolio weights: the percentage of resources allocated to a particular security, based on the totality of resources available.

Modern Portfolio Theory attempts to optimize portfolio performance by maximizing return for any given level of risk or by minimizing risk for any given level of return. For doing this, Microsoft Excel offers an optimization engine called “Solver” that minimizes or maximizes a variable by inputting parameters, depending on the user’s objective.

One of the pillars of Modern Portfolio Theory is Diversification. This is a risk management strategy that mixes different investment types within a portfolio in an attempt to promote exposure to different risks associated to each security within the portfolio, instead of only a single or few risks within the portfolio, and also attempting that these different associated risks behave independently of each other (Ways2Wealth, 2015).

The efficient frontier is the set of optimal portfolios that offer the highest expected return for a defined level of risk or the lowest risk for a given level of expected return. Portfolios that lie below the efficient frontier are sub-optimal because they do not provide enough return for the given level of risk (WallStreetMojo, 2017).

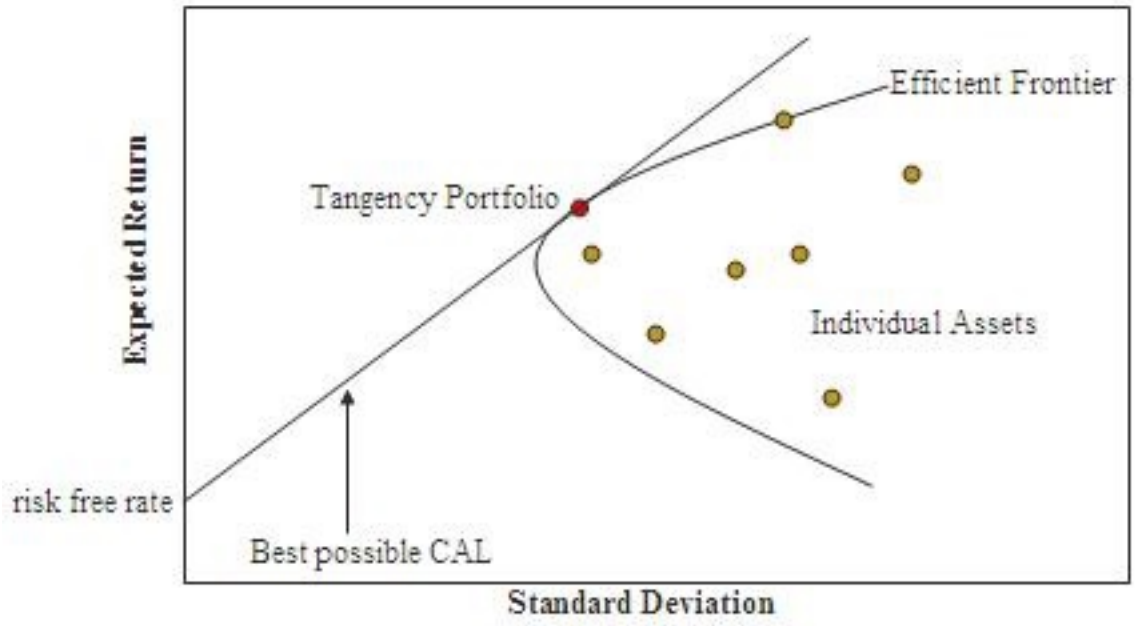
There also exists a risk-free asset, one that has a certain future return and negligible risk or possibility of loss.

The Capital Allocation Line (CAL) is a line created on a graph of all possible combinations of risk-free and risky assets. The graph displays the return investors might possibly earn by assuming a certain level of risk with their investment. It also aids investors in choosing how much to invest in a risk-free asset and one or more risky assets (WallStreetMojo, 2017).

Theta (Sharpe Ratio) represents the optimal amount of return that an investor receives per unit of increase in risk (WallStreetMojo, 2017). A portfolio optimized for maximum Sharpe Ratio is called “Tangency Portfolio”. Figure 2 presents a visual presentation of these concepts.

Figure 3.

Capital Allocation Line (WallStreetMojo, 2017).



Work & Results

Data

I started by searching and selecting data for the securities that would be analyzed in the scope of the project. Using Yahoo Finance, I ended up with monthly prices for 6 company stocks; Stratasys (SSYS), Disney (DIS), Itau (ITUB), Fedex (FDX), Bosch (BOSCHLTD.NS) and Petrobras (PBR). I chose these stocks because I believe the companies related to each of them

are positioned in sectors that have potential for growth or are engaging in novel technology applications. Stratasys is working with additive manufacturing technology, a type of technology that I think will be pivotal in the future of manufacturing because it eliminates the need to engage in economies of scale for producing goods at competitive prices; Disney is dabbling in on-demand digital entertainment services, which in my opinion is the future of mass-entertainment; Itau, Fedex and Petrobras are leaders in prominent sectors (financial, logistics and energy, in that order) in emerging markets, such as Latin America, that promise high and steady growth in the next couple of years; Bosch is a well-stablished company within the automotive sector that might be able to supply the next demand wave for new types of auto parts related to electric and connected vehicles, a trend that I think will intensify in the near future.

I used monthly data because it represents the behavior of the securities' prices more accurately than quarterly or yearly data due to higher quantity of data points.

Then, I calculated the monthly price differences for each selected stock relative to their past month's prices, in percentage form. Using this data set, I created a transverse data set with the same data points from the monthly price differences for calculation purposes.

Analysis

Client profiling: In this subsection, I focused on establishing an objective for the expected return of my portfolio. I aimed for an annual percentage in expected returns between 10% and 15% and a standard deviation (i.e. risk) between 5% and 10%.

Market analysis: In this subsection, I analyzed the macroeconomic environment at which securities are existing. Using the US GDP, I have found that the overall economy is in contraction and a bear market is currently ongoing; using a rule of thumb, I concluded that we are in a favorable environment for using fundamental analysis for selecting stocks that might be undervalued, since the main metric for this type of analysis (securities' prices) are lower than usual and thus a greater profitability could be achieved.

Preselection: I selected 7 securities based in 2 broad classification criteria and 1 way in which securities within the portfolio interact, with the aims of diversifying the holding positions and thus diminishing the overall correlation of the portfolio, and also reflecting the risk and return preferences of the investor: by sector, by type and by portfolio style.
Regarding the sector criteria, I looked for at least 3 stocks of different sectors, accomplishing by selecting SSYS (technology), ITUB (financial) and PBR (energy).
Regarding the type of security criteria, I looked for two different types of securities; stocks and bonds (risk-free asset).

Regarding portfolio style, I looked for overall expected returns of 10%-15% when the securities were added together in the portfolio. This was accomplished by selecting mainly

stocks between 5% to 15% in expected returns, picking up stocks in the lower end of the mentioned range due to their low volatility (standard deviation of expected returns). The exception to this selection method is the risk-free asset, in this case the 3-months US treasury bill, which was selected based solely on its beneficial impact in terms of volatility.

Correlation: In this section, I created a correlation matrix in order to calculate and show the correlation coefficient between each stock, or the statistical measure of the strength of the relationship between the relative movements of two variables. I used correlation as a measure of how diversified the portfolio was; the less correlation between stocks there is, the more diversified the portfolio is. Using the Correlation Coefficient Matrix (Radzicki, 2017), my portfolio achieved a correlation of 0.4453, which reflects a somewhat good diversification across held positions, although there is room for improvement by selecting less correlated securities.

A caveat, however, relies on whether the calculations show a statistically significant correlation coefficient metric or not, since a Hypothesis Test (T-Test, specifically) was not employed and thus it's impossible to say so. Applying a T-Test for discovering whether calculations provide a statistically significant correlation coefficient or not can be a useful direction for future work on this Interactive Qualifying Project.

Fundamental analysis: I looked for securities with strong fundamentals, with the goal of selecting securities that might be resilient and keep a healthy growth rate in the future, and that might also be currently undervalued. I used the following metrics:

Earnings/share ratio: As this ratio goes up, the cash available for usage in the organizations associated with the measured security goes up, and the probabilities of the securities being resilient through difficult external economic and internal financial scenarios, and maintaining a healthy growth rate, goes up as well (Wilkins, 2020).

Price/earnings ratio. As this ratio goes down, the lower the price that one must pay for every dollar of profits gained by holding a position on the security. This is a good metric for trying to pick undervalued securities (Wilkins, 2020).

Table 1 presents the results for the fundamental analysis of each security:

Table 1.

Fundamental Analysis Ratios

SSYS		
	Earnings/Share	8.81
	Price/Earnings	18.54
DIS		

	Earnings/Share	2.08
	Price/Earnings	12.95
ITUB		
	Earnings/Share	1.68
	Price/Earnings	26.78
FDX		
	Earnings/Share	6.33
	Price/Earnings	32.4
BOSCHLTD.NS		
	Earnings/Share	2.53
	Price/Earnings	14.96
PBR		
	Earnings/Share	5.26
	Price/Earnings	24.76

Security labels and Analysis metrics: In this section, we can find basic metrics for each acquired stock; average returns and standard deviations of returns. For calculating both metrics, we used the price differences for each stock relative to their past month performance calculated in the Data section. We can also find the correlation matrix, a covariance matrix and the portfolio weights.

Efficient frontier: In this section, I calculated the Efficient Frontier with the help of Excel Solver by using monthly expected returns ranging from 0.01 to 0.016, resulting in calculations of minimum standard deviations for any given monthly expected return.

Global Minimum Variance Portfolio (GMV): In this portfolio, the weights were optimized with the Excel Solver for minimizing the average standard deviation of the portfolio, achieving a standard deviation of 0.0455 and expected return of 0.0133. We accomplished the following weights: 0.0191 for SSYS, 0.4304 for DIS, 0.0390 for ITUB, 0.1714 for FDX, 0.3312 for BOSCHLTD.NS and 0.0089 for PBR; this means that 1.91%, 43.04%, 3.90%, 17.14%, 33.12% and 0.89% of the investor's available resources (i.e. money) will be allocated to SSYS, DIS, ITUB, FDX, BOSCHLTD.NS and PBR, respectively.

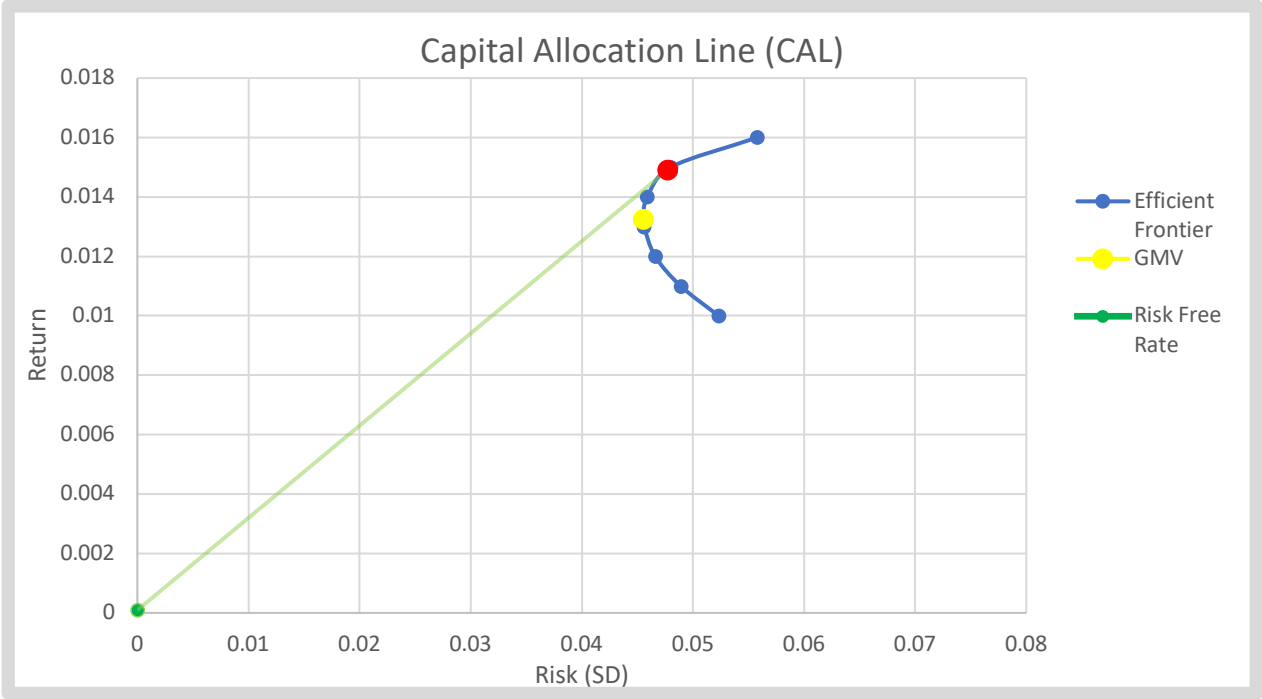
Capital Allocation Line (CAL): In this portfolio, the weights were optimized with the Excel Solver for maximizing Theta (Sharpe Ratio) of the portfolio. We used the 3-months United States Treasury Bill rate as our Risk-Free Asset, since it's one of the safest and most commonly used near-risk-free securities. The bond displays monthly expected returns of 0.000092 and of course, 0% of standard deviation for practical purposes. We achieved a Theta (Sharpe ratio) of 0.3105 with the following optimized security weights: 0.0071 for SSYS, 0.6712 for DIS, 0.0311 for ITUB, 0 for FDX, 0.2907 for BOSCHLTD.NS and 0 for PBR; this means that 0.71%, 67.12%, 3.11%, 0%, 29.07% and 0% of the investor's available resources (i.e. money) will be allocated to SSYS, DIS, ITUB, FDX, BOSCHLTD.NS and PBR, respectively.

Conclusions

For our optimized tangency portfolio with risk-free asset, we achieved an annual 17.89% in expected returns and 4.77% in standard deviation, meaning that in average we would generate a 17.89% increase in our allocated resources and also deviate from that expected return 4.77% in average; in other words, my portfolio is expected to achieve in average returns ranging from 13.12% to 22.66%. With these results, we outperformed our initial expected return objective (15% in best-case scenario) by 2.89% and our initial standard deviation objective (5% in best-case scenario) by 0.23%. Overall, we are satisfied with the overperformance of our portfolio.

Figure 4.

Capital Allocation Line result

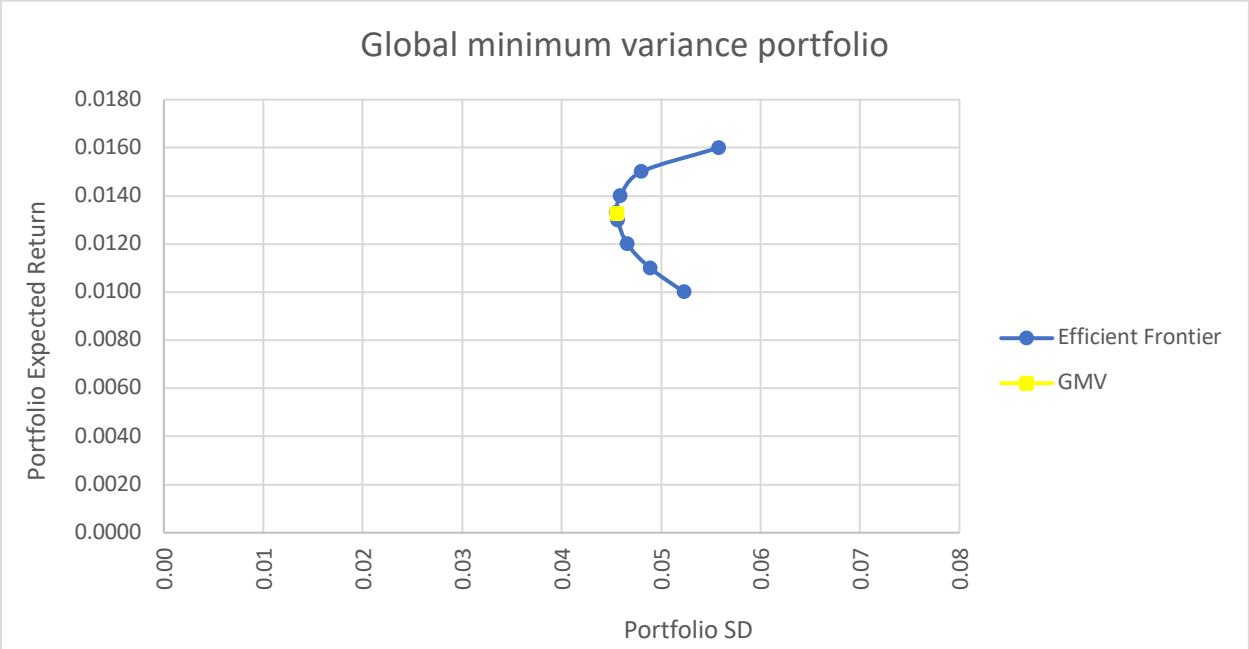


For our Global Minimum Variance portfolio (GMV), we achieved an annual 15.91% in expected returns and 4.55% in standard deviation, meaning that in average we would generate a 15.91% increase in our allocated resources and also deviate from that expected return 4.55% in average; in other words, my portfolio is expected to achieve in average returns ranging from 11.36% to 20.46%. This portfolio is better suited for risk-averse investors than the tangency portfolio due to its lower standard deviation. These differences highlight the fundamental difference between the GMV portfolio and the Tangency portfolio; the GMV portfolio minimizes the risk (standard deviation) of a given portfolio, and the Tangency portfolio maximizes the level of achieved expected return for any given level of risk.

Figure 5.

Global Minimum Variance Portfolio.

Observation: the risk-free asset was not included to Figure 3 for simplicity and for facilitating the understanding of the Global Minimum Variance Portfolio. Normally, it would be included in the GMV portfolio.



Weaknesses

A common criticism of Modern Portfolio Theory is that it is somewhat rigid if changes occur in securities' or investor's characteristics. For example, if a risk-seeking investor changes its mindset to a more conservative, risk-averse outlook, we will have to analyze again what standard deviation and expected return would fulfill the new investor's requirements and make considerable changes to the Excel model for recalculating results that reflect the new objectives. Also, if the market receives certain types of shocks within industries, previous relationships between securities that were true before the economic shock might not hold true anymore afterwards, causing our results to be inaccurate in the real world. Another criticism is that the theory assumes a normal distribution of the return on an asset within a class of assets which is proved to be wrong for individual equities as the correlations of asset class may change over the period of time (WallStreetMojo, 2017).

Next steps

One area that might need future improvement is the fundamental analysis section for a better understanding of securities' characteristics and picking them in a more robust way. Specifically, I would suggest the addition to the analysis of the following metrics: Working Capital Ratio, Quick Ratio, Debt-Equity Ratio and Return on Equity.

Another future step that might be useful for achieving more robust analysis and thus more accurate results is to add artificial intelligence algorithms for analyzing the data. Particularly, I'm interested in genetic algorithms; heuristic search methods inspired by nature, that can be used to find solutions to optimization problems where there are no good deterministic search methods. These algorithms use principles from evolutionary biology to "evolve" a population of solutions to a given problem. The main advantage of this technique is that you don't have to define all the details of a problem or create an optimal solution right away; you seek to find "good enough" solutions and mix them together, or "reproduce" them, leading to even better solutions each time this process is repeated (Roudier, 2007)

Final words

The market is hard to beat and the people who beat it are those who take on above-average risk. Modern Portfolio Theory, with its reported benefits and criticisms, might or might not prove to be the optimal strategy for allocating assets for investments. However, it indeed provides a great framework for educating and illustrating prospect investors about the importance of diversification in their investments, highlighting the importance of the quantitative characteristic of the model for giving people a better grasp of how diversification actually works and providing actual real-world examples and the capability of recreating what-if scenarios.

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