Czech University of Life Sciences Prague

Faculty of Economics and Management

Department of Economic Theories

Bachelor Thesis

DESIGN AND ASSESSMENT OF PERFORMANCE OF AN OPTIMAL DIVIDEND PORTFOLIO

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CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Economics and Management

BACHELOR THESIS ASSIGNMENT

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Design and assessment of performance of an optimal dividend portfolio

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Objectives of thesis

The main objective of this thesis is to create an optimal dividend portfolio consisting of capital markets instruments (stocks, bonds and cash) using efficient frontier, assess its performance with different metrics (Sharpe ratio, VaR) and predict price movements of each asset within portfolio using Monte Carlo simulation.

Methodology

This research is conducted with the use of $1 mil for creation of an optimal dividend portfolio.

Asset allocation of the portfolio is based on Modern Portfolio Theory with the mention of its limitations. Investment decision is made by using fundamental analysis that allows to choose which stocks and bonds suit best to the portfolio. Portfolio performance is evaluated by using specific metrics (Sharpe ratio) as well as for risk measurement (VaR). Monte Carlo simulation is used to forecast the movement of prices and to understand how asset prices might behave in the future.

The proposed extent of the thesis

30-40

Keywords

Portfolio management, Modern Portfolio Theory, Portfolio optimization, Optimal dividend portfolio, Asset allocation, Sharpe ratio, Efficient frontier, Diversification

Recommended information sources

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Declaration

I declare that I have worked on my bachelor thesis titled "Design and assessment of performance of an optimal dividend portfolio" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break copyrights of any person.

In Prague on 01.03.2022 ______________________________

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Design and assessment of performance of an optimal dividend portfolio

Abstract

This thesis is intended to show the possibility of creating an investment portfolio consisting of stocks, bonds and cash and assessing its overall performance by using Modern Portfolio Theory, as proposed by Nobel prize winner Harry Markowitz in 1952. The concept of Mean Variance optimization which is used in this research shows an optimal asset allocation within a portfolio. Financial instrument due diligence is conducted by using fundamental analysis. Risk minimization is one of the most important concepts, which has to be taken into account while considering any investment options. Value at risk model helps quantify risk and identify possible financial losses within the portfolio for a certain period of time. Sharpe ratio would be helpful to evaluate the overall portfolio performance, whether it is a good portfolio with a constant growth or it is a poor one with a huge risk taken and a respectively small expected return. Moreover, prediction of price movement is not the least important thing when it comes to portfolio performance assessment and Monte Carlo simulation is the exact tool that helps to understand how asset prices might behave themselves in the future. This thesis is written for scientific purposes only and should not be considered as a financial advice.

Keywords: Portfolio management, Modern Portfolio Theory, Portfolio optimization, Optimal dividend portfolio, Asset allocation, Sharpe ratio, Efficient frontier, Diversification

Návrh a posouzení výkonnosti optimálního dividendového portfolia

Abstrakt

Tato práce má ukázat možnost vytvoření investičního portfolia složeného z akcií, dluhopisů a hotovosti a posouzení jeho celkové výkonnosti pomocí moderní teorie portfolia, jak ji navrhl nositel Nobelovy ceny Harry Markowitz v roce 1952. Koncept optimalizace střední odchylky, který je použit v tomto výzkumu, ukazuje optimální alokaci aktiv v rámci portfolia. Výběr finančních nástrojů se provádí pomocí fundamentální analýzy. Minimalizace rizik je jedním z nejdůležitějších konceptů, který je třeba vzít v úvahu při zvažování jakýchkoli investičních možností. Model Value at risk pomáhá kvantifikovat riziko a identifikovat možné finanční ztráty v rámci portfolia za určité časové období. Sharpe ratio by pomohlo zhodnotit celkovou výkonnost portfolia, ať už se jedná o dobré portfolio s konstantním růstem nebo špatné s velkým rizikem a malým očekávaným výnosem. Navíc predikce pohybu cen není tou nejméně důležitou věcí, pokud jde o hodnocení výkonnosti portfolia a simulace Monte Carlo je přesným nástrojem, který pomáhá pochopit, jak by se ceny aktiv mohly v budoucnu chovat. Tato práce je napsána pouze pro vědecké účely a neměla by být považována za finanční poradenství.

Klíčová slova: Řízení portfolia, Moderní teorie portfolia, Optimalizace portfolia, Optimální dividendové portfolio, Alokace aktiv, Sharpe ratio, Efektivní Hranice portfolia, Diverzifikace

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List of abbreviations

MPT = Modern Portfolio Theory

MV = Mean/Variance optimization

VaR = Value at Risk model

ROI = Return on Investment ratio

ROE = Return on Equity ratio

P/E = Price to Earnings ratio

D/E = Debt to Equity ratio

DDM = Dividend Discount Model

DCF = Discounted Cash Flows model

GGM = Gordon Growth Model

VC = Variance – Covariance method

MC = Monte Carlo simulation

1 Introduction

Finance is one of the most essential fields nowadays that affects people's lives. Everyone around is talking about money, savings and investments. The financial sector is growing extremely fast as is people's demand for investments. Investment portfolios have become quite popular these days, however not all the people who are interested in finance know how to design a portfolio and assess its performance. Large institutions such as investment companies, hedge funds, investment banks as well as retail investors do manage their own portfolios consisting of diverse number of different financial instruments. At the same time there are lots of qualified financial advisers who provide professional service in order to help people design and manage their own portfolios based on clients' risk and return preferences. However, it is also possible to create an investment portfolio yourself without any extraordinary knowledge by using publicly available sources and scientific papers. Thus the whole process would be presented and explained deeply in this thesis.

2 Objectives and methodology

2.1 Objectives

The main objective of this thesis is to create an optimal dividend portfolio consisting of capital markets instruments (stocks, bonds and cash) using efficient frontier, assess its performance with different metrics (Sharpe ratio, VaR) and predict price movements of each asset within portfolio using Monte Carlo simulation.

2.2 Methodology

For this research $1 million is given to construct an optimal dividend portfolio. Historical prices and other fundamental data are downloaded from 'yahoo finance' and 'finviz' websites respectively to perform all the models which appear in this thesis (supplementary data is provided in UIS in the form of excel spreadsheet). Portfolio would consist of stocks from health care, energy, technology, industrials and financial sectors, US treasury notes and cash (dollars). Stock screening procedure is conducted by using 3 stage filtering process based on financial indicators and relative valuation method including such criteria as sector, dividends, capitalization, beta coefficient, ROI, P/E, D/E and ROE ratios. An initial portfolio with equally weighted assets would be formed in order to further optimize it by applying 2 methods of mean-variance optimization for the matter of their performance comparison. Sharpe ratio, historical Value at Risk model and Monte Carlo simulation are used for performance estimation. Expected returns are calculated as simple returns. Correlation matrix is used to show the strength of relationship between assets. Normal distribution is applied to mathematical models for simplicity of calculations within the research. Additionally, another more realistic example is presented using stable Paretian distribution to explain the distribution of stock returns in the real world. The limitations of MPT, MV optimization, VaR and Sharpe ratio are also mentioned in the thesis. Additional costs such as commissions and taxes are not included.

3 Literature Review

3.1 Modern Portfolio Theory

The foundation for the whole portfolio creation is based on Markowitz's outstanding Modern Portfolio Theory (Markowitz, 1952). Later these notes were extended into the book "*Portfolio selection: Efficient Diversification*". Lots of research papers were written with the goal of reviewing the theory in practice, to identify its major pros and cons.

According to Mangram (2013) , MPT is an investment framework for the selection and construction of investment portfolios based on the maximization of expected returns of the portfolio and the simultaneous minimization of investment risk. Expected returns and investment risk are the key components of MPT, where a constructed portfolio strives to increase the expected return of the whole portfolio and decrease all the possible risks involved. Some of the options of the returns maximization are the overall portfolio appreciation, meaning the financial instruments increase in price, income from stock dividends, coupon payments on bonds and appreciation of currency rates. The risk in general can be mitigated, as Markowitz proposed in his theory, by the concept of diversification, meaning the risk can be minimized by investing in a collection of assets (preferably different asset classes), rather than investing in an individual asset or a single asset class. As Mangram highlights in his research, MPT is a collective theory and refers to the mean-variance analysis, where 'mean' is the average or expected return and 'variance' is denoted as a potential risk.

However, none of the theories are perfect, each has its own limitations. MPT includes various assumptions regarding markets and investors. Some of them are presented below:

- Investors are rational (they strive to maximize the return and minimize risk exposure)
- Investors are willing to accept higher risk in case they will be rewarded with higher returns
- Investors are price takers, meaning they cannot affect the price of an instrument
- Markets are efficient

- Markets do not include transactional costs and taxes

In the context of financial risk within a portfolio, it's generally divided into 2 categories: **systematic risk** (also called market risk) and **unsystematic risk** (known as diversifiable risk), the concepts of which were proposed by Sharpe in 1964 in his expanded research to the original work of Markowitz (Sharpe, 1964). Sharpe also introduced the idea of beta coefficient (also known as a risk measurement) and linear relationship between beta of the portfolio and expected returns.

Systematic risk is the risk associated with the economic conditions such as inflation, interest rates, unemployment levels and exchange rates (Mangram, 2013). At some degree all of these components have their own impact on securities. Besides, systematic risk cannot be avoided or eliminated by diversification.

Unsystematic risk is a specific form of risk , where risk factors affect just an individual asset or a small group of assets. For instance, a law firm starts a lawsuit against a company, because they think the company violated the law towards its investors and company's stock tumbles 10% as soon as the news become official. In comparison with the systematic risk, unsystematic risk can be easily diversified by investing in different asset classes with opposite correlations. However, most of the assets are correlated at least at some degree, therefore it is impossible to fully eliminate this type of risk.

In his research , Markowitz equalizes the terms of 'risk' and 'volatility', where the higher volatility means the higher risk of a portfolio. But what does volatility generally mean?
Simply speaking, volatility is "a day – to – day movement in prices" of financial instruments (Shiller, 1992). There are basically 2 measures of volatility on the market, standard deviation and variance. "Standard deviation is the most frequently used estimate of variability. It is the average amount each individual score differs from the mean" (Newman and Newman, 1994). Variance has more or less the same meaning, however the difference is that variance is the average squared deviations from the mean (measured in squared units), while standard deviation is the square root of this number (measured in the same units as the mean).

As it was mentioned before, every theory has its own limitations, which affect the overall comprehension of the theory itself. MPT is not an exception, it was criticized a lot and there are many contradicted research papers written to prove the ineffectiveness of MPT in the real world. Some of the major critics are:

- **Irrationality of investors** – considering that all investors are rational doesn't really make any sense, because every person has his/her own preferences especially regarding their personal finances. Investors are subject to manipulations on the market, so that they may be influenced by their own emotions.
- **Flawless information** – one of the MPT assumptions is that the information is perfectly complete and relevant. However, it's nothing like this in the real world. From the quantitative perspective, for instance, streaming market data might usually be defected with gaps or sometimes it happens that information is not relevant to the particular investment at all , that's exactly how manipulations on the market occur.
- **Efficient markets** – Markowitz' theory is based on the assumption that markets are efficient. It doesn't take into account the anomalies and externalities of the market including bubbles, booms, crisis and information defection, which makes it more doubtful to still believe in efficiency of the markets.
- **No costs and taxes** – MPT doesn't rely on taxes and additional transaction costs , which actually sounds unrealistic, whereas in practice most of the investments fall under the taxation and none of the deals happen for free, meaning brokers' commissions and other maintaining costs.

3.2 Mean/Variance optimization

Another paper written by Richard O. Michaud identifies what MV optimization is and reveals the benefits and limitations of the MV optimization (Michaud, 1998). As the author proposes, MV optimization is a standard theoretical model of normative investment behavior. 'Most modern finance textbooks consider mean-variance efficiency the method of choice for optimal portfolio construction and asset allocation and as a means for rationalizing the value of diversification'. Simply speaking, MV optimization is the analysis of the mean and variance of returns of securities, where the main idea is to select the most 'optimal' mix of financial instruments in respect to mean-variance components that would maximize the return (mean) and minimize the risk (variance). Speaking further, on the one hand, he considers the major benefits of the analysis as:

- **Satisfaction of client's objectives:**
  'Portfolio optimizers provide a convenient framework for integrating a wide variety of simple but important client constraint and objectives with portfolio structure', meaning that efficient frontier suits to both risk averse and non-risk averse investors
- **Control of portfolio risk exposure:**
  'Portfolio optimizers can be used to control the portfolio's exposure to various components of risk', meaning that risk is a regulated component and is kept under control within the whole optimization process
- **Timely portfolio changes:**
  'Portfolio optimizers can process large amounts of information quickly, a particularly important benefit for a large institution, which needs to determine the impact of new information on all its portfolios quickly and conveniently', meaning that MV optimization allows users to process data fast and in a more convenient way

On the other hand , the limitations of such optimization are quite crucial and Michaud emphasizes them as:

- **Estimation error maximization:**
  'Risk and return estimates are inevitably subject to estimation error. MV optimization significantly overweighs those securities that have large estimated returns , negative correlations and small variances. These securities are, of course, the ones most likely to have large estimation errors'.
  Proceeding on what Michaud writes about, he provides an example of how Jobson and Korkie 'quantified the magnitude of the error maximization characteristics of MV optimizers in certain cases'. As Michaud mentions, they found an optimal portfolio identified as a portfolio on the efficient frontier with the max. Sharpe ratio, using a known distribution of monthly returns for 20 stocks. Then they evaluated the

expected returns and variances for these 20 stocks over a 60-month period and computed the 'optimal' portfolio for each set of estimates by using Monte Carlo simulation. Eventually, they compared the true Sharpe ratios of the average of the simulated optimal portfolios, the optimal portfolio derived from the known distribution of returns and an equally weighted portfolio of the 20 stocks. Final results were 0.08, 0.34 and 0.27 respectively, which confirm the error maximization hypothesis.

- **Missing factors:**
  'MV optimization often ignores factors that are fundamentally important investment management considerations. One of the most important of these factors is liquidity , or the percentage of a company's market capitalization represented by portfolio holdings. A portfolio of a large bank trust department or a portfolio of small-cap stocks , for example, may hold a significant percentage of a security's market capitalization. A 1 percent change in the portfolio may thus represent a very substantial amount of the total value of the firm'.

As MV optimization is mostly used for asset allocation within this research, it's important to mention the pros and cons regarding the MV analysis particularly for asset allocation. According to Michaud, the benefit of the optimization is its reliability based on the small number of estimates required. 'The character of the 'optimal' allocation may consequently be anticipated, and errors created by the input estimates more easily controlled'. The issue as a negative side of the analysis is its non - uniqueness. 'A reliable optimal asset mix recommendation requires a more than casual understanding of the characteristics of the confidence region associated with the input estimates'. Confidence region is defined by Michaud as a set of 'optimally equivalent' portfolios to that one on the efficient frontier line and assumed optimal.

3.3 Security selection

This section is dedicated to the selection of financial instruments particularly individual dividend stocks. In his book '*The Intelligent Investor*', Benjamin Graham reveals some of the methods for 'intelligent' stock picking (Graham, Buffett and Zweig, 2013) . Since the book was written, it became quite popular to use fundamental analysis for researching stocks based on the analysis of companies' financial statements and diverse financial ratios. Following Graham, first of all, it is important to look at the **market value** of a company. The whole process of choosing what stock to invest in is pretty subjective and depends strictly on the investor's preferences and needs. For instance , Graham provides an example of a defensive investor, who would less likely include small cap companies (risky) in his portfolio and may focus on companies with a bit less than $2 billion market value. As an option he also recommends taking a look at index funds such as Vanguard, however it's not the case for this thesis.

Secondly, Graham emphasizes **strong financial conditions**, what sounds quite logical and almost obvious. 'If you build a diversified basket of stocks whose current assets are at least double their current liabilities, and whose long term debt does not exceed working capital, you should end up with a group of conservatively financed companies with plenty of staying power'. Although there are lots of financial metrics that are used in fundamental analysis, some of them are extremely important to look at such as current assets and current liabilities, which are mentioned above, non-current assets and non-current liabilities, revenue, net profit, EBIT, retained earnings, etc.

Earnings stability is another factor playing an important role while considering securities to invest in. Graham insisted that earnings for common stocks should be stable in each of the past ten years. It is still a valid way to identify 'winners' and 'losers' on the market nowadays, but it is not the only decisive factor to rely on.

Dividend records are an important attribute to look at while evaluating companies performance. A company with stable dividend payments, which pays out steady dividend every predetermined date during a long period of time, is supposed to have strong financial performance including constant (temporarily) long term earnings. Earnings are basically the main factor dividends are dependent on. If the company shows stability in earnings , then potential dividends could be paid out, depending on the decision of a board of directors.

One of the metrics investors use to compare the price of stock and its earnings per share and figure out whether a company is overvalued or underrated is **P/E ratio**. The way it works is to take several companies (competitors) within one industry/sector, divide the price of each company's stock to its earnings per share and compare them. The higher the ratio the more overvalued a company is , the lower the value the more undervalued the company is. In his book, Graham recommends limiting yourself to stocks whose current price is no more than 15 times average earnings over the past three years.

Besides the diversity of stocks existing on the market, there is a various number of bonds as a potentially defensive alternative to stocks. A **bond** is a fixed income instrument that represents a loan made by an investor to a borrower and could be thought of as an I.O.U. that includes the details of the loan and its payments (J. Fernando,2021). Bonds are as different as stocks including short and long term bonds, company, municipal, government bonds, taxable and non-taxable bonds, convertible and non-convertible bonds, etc. However, for the sake of simplicity of this research, US 10-years treasury notes are used as a low-risk component of the investment portfolio.

It is also worth mentioning that other methods of stock evaluation exist such as valuation methods which include DDM (dividend discount model), DCF (discount cash flows model), etc.

Dividend discount model represents the value of a stock that is considered the present value of expected dividends on it. 'The rationale for the model lies in the present value rule- the value of any asset is the present value of expected future cash flows discounted at a rate appropriate to the riskiness of the cash flows.' (Damodaran). There are different types of DDM, however within this research only Gordon Growth Model is covered. This model can be applied to value firms that are growing steadily and sustainably. GGM requires 3 major inputs such as **expected dividends per share, cost of equity** and **expected dividend growth**. Several assumptions also have to be taken into account when considering the use of GGM. First and foremost is that a company has to grow at a 'constant' rate which is quite difficult to achieve in reality, especially when the volatility of earnings is involved. Model's sensitivity might have a huge impact on the anticipated outcome. It could lead to absolute nonsense results, if used inappropriately. Here comes the second limitation regarding relationship between required rate of return and a dividend growth rate. The result would be **negative**, if the rate of return is less than the dividend growth rate. Moreover, if the cost of equity (same as RRR) is equal to growth rate, the intrinsic value would **head to infinity**. Despite all of these issues, different versions of DDM are widely used in valuation analysis. The main idea is that if every input satisfies the requirements of getting correct output, the intrinsic value shall further be compared to market price of the instrument. The lower the calculated value in comparison to market price, the more overvalued the instrument is at the moment. But if an intrinsic value is larger than the market price, the more underrated the instrument which might then be assumed as a potential investment is.

Discounted Cash Flow Model 'merely projects the anticipated cash flows from the asset and estimates the return that may be desired commensurate with the risk profile of the projected cash flows and the asset value is spontaneous' (J. P. Singh, Shigufta Hena Uzma, 2010). In other words, the concept of the model is based on the calculation of net present value of future cash flows applying discount rate. The model has its disadvantages as well as any mathematical model has. The first one stands behind the estimation of future cash flows. It is not easy to do since lots of factors may affect those cash flows such as state of economy, aggregate demand, competitions, unexpected losses, technological development, etc. The second issue might occur when determining discount rate. It is crucial to choose more or less precise discount rate, because the wrong choice may lead to high unjustified expectations and losses in profits or a company may miss out on a lucrative opportunity.

3.4 Performance

Being able to construct an investment portfolio yourself is a good thing , but it is not enough to stay satisfied. Assessment of its performance using different ratios and mathematical models is a next level. Lots of so-called KPIs exist to evaluate the performance of the portfolio and some of them are covered in this thesis. Statistics basics are essential when it comes to performance estimation, because most of the financial models are based on statistical analysis.

Correlation analysis

As it is mentioned in the book of M.A.H. Dempster, ‘correlation analysis is used in finance as a measure of dependence between different financial instruments and employ an elegant theory, which is essentially founded on an assumption of multivariate normally distributed returns, in order to arrive at an optimal portfolio selection, meaning that correlation analysis is generally approached to find the relationship between variables, in our case of a various number of securities’ (Dempster, 2002). Simply speaking, correlation is used as a measure of strength and direction of relationship between assets. Correlation of 1 means a strong positive correlation, correlation of -1 means that variables have strong negative correlation and move in more or less different direction, whereas correlation of 0 means there is no relationship between variables at all. Furthermore, in his work, Markowitz (1952) highlighted the role of correlation in portfolio management and constructing an efficient frontier to ‘avoid investing in securities with high covariances among themselves… firms in different industries , especially industries with different economic characteristics, have lower covariances than firms within an industry’.

Distribution

Diving deeper into statistics, it is clear that missing on the distribution would be a huge mistake. But why is it so important to talk about it? A distribution is a collection of data within a sample, which shows all the possible values and how often they appear, then it’s all analyzed and represented graphically as a bell shaped curve. There are some types of distributions that exist, however for this thesis only gaussian (normal) distribution is observed accompanied by additionally presented Stable Pareto distribution as a ‘more realistic example’. Normal distribution is actually considered as a distribution for real valued random variables. Lots of financial models are based on statistical analysis including analysis of stock returns , which theoretically are normally distributed. The key aspect of it is that 68% of data falls within 1 standard deviation, 95% of data falls within 2 standard deviations and 99.7% of all data falls within 3 standard deviations. Regarding stock returns it means that if all the data of stock returns falls within 99.7%, investors can be sure there is a really small probability of an extreme event to occur. However, it is never 0, meaning although there is a small chance of a huge loss, it still may happen. That is exactly, where all the arguments and critics emerge.

In his scientific paper E. Fama emphasizes the idea of a random walk theory and efficient markets, describing it as 'a market where there are large numbers of rational profit-maximizers… and where important current information is almost freely available to all participants' (Fama, 1965). In addition, he claims that future prices cannot be predicted based on the past data, because stock price changes are independent and have no memory. As far as stock returns are stated to be independent and random, it means that stock returns data is theoretically normally distributed.

Speaking further, another research was conducted by B. Mandelbrot to challenge the idea of stock returns being normally distributed. He came up with the contrary results, that price changes of speculative commodities he observed, did not fall under normal distribution, explaining it by identifying fat tails with extreme events and peaky central part of a bell shaped curve. After all, he introduced a totally new version of distribution called the Stable Paretian (Mandelbrot, 1963). According to this paper, Stable Paretian distribution by definition is 'the distribution of sums of independent , identically distributed variables' and has 2 assumptions:

- The variance of the distribution is infinite
- Empirical distribution fits best to stable Paretian family of limiting distributions

Following these assumptions some serious implications occur. If the variance is infinite within the set of data, it is meaningless to use it as a measure of data dispersion. The concept of alpha, as 'the most important for the purpose of comparing the goodness of fit' is presented , where alpha means the total probability contained in tails. The main difference between these 2 distributions is that alpha following Stable Paretian distribution can take any value between 1 and 2 , whereas alpha is strictly equal to 2 following normal distribution, meaning that Stable Paretian distribution has higher tails with more extremes in it, than those of the normal distribution, which in fact seems more likely to fit stock price changes. Fama saw this type of distribution as a prospective one and was sure that it will be improved further in the future.

Sharpe ratio

Sharpe ratio is one of the mostly used metrics while assessing the performance of a portfolio. The ratio was introduced by W. Sharpe in 1964 and nowaday it is used by many investors when it comes to comprehension of risk and return components in comparison with each other (Sharpe, 1964). Simply speaking, Sharpe ratio shows how much additional return investors are able to get by taking extra risk being different from risk-free rate. Any security with the total risk approximately equal to 0 is called risk- free security. In his work, Sharpe comes up with 2 methods of calculating the ratio: Ex ante - calculated by dividing expected differential return (excess return) by differential standard deviation (unit of risk associated with return) and Ex post also called historic Sharpe ratio 'indicates the historical average differential return per unit of historic variability of the differential return'. On the one hand, Sharpe ratio is simple to use and it is a good representation of relationship between risk and return, but, on the other hand, it has some limitations too:

- **Reliance on past data:**
  It probably may be a good idea in a relatively stable macroeconomic environment, where return and standard deviation are not extremely volatile , which is quite hard to replicate in dynamic markets nowadays.
- **Misinterpretation of variability:**
  Although some stock returns fall under normal distribution and fit the bell shaped curve, some of them do not and refer to non-gaussian distribution, which to some degree might be misleading.

Despite these limitations, it is still a valid option to assess portfolio results. As it is generally accepted, the higher the Sharpe ratio of a portfolio, the better its performance. Sometimes it happens that the ratio can be negative, meaning that the risk free rate is either greater than the actual return or the return is negative.

Value at Risk

Value at Risk, also called VaR, is a helpful mathematical model broadly used in finance and helps identify potential losses, which may occur under uncertain circumstances and extreme events. In accordance with the scientific work of Aswath Damodaran, VaR is a measure of potential loss in value of a risky asset or portfolio over a defined period for a given confidence level (Damodaran, 2019). Several methods of VaR calculations exist using different inputs:

- **Variance - Covariance method:**
  A method that uses a probability distribution to find out the probability of an asset falling in price below a certain level. The main benefits of this method are understandability and applicability. VaR is applied to various securities such as stocks, bonds, futures, options, currencies, that is why the model is used by different financial institutions such as banks in order to stay alert and allocate the risk based on the model. Despite the benefits the VC method has, it has some drawbacks too. It is hard to calculate VaR , when a portfolio is large, as long as it is necessary to calculate risk and return for each asset separately. Wrong distribution assumptions may be problematic and misleading , especially when some securities are not normally distributed.
- **Historical method:**
  This method uses historical data as a basis for calculations. As Damodaran mentions in his research , the VaR for a portfolio is estimated by creating a hypothetical time series of returns on that portfolio, obtained by running the portfolio through actual historical data and computing the changes that would have occurred in each period. The major disadvantage of this approach is reliance on past data, which might be the reason for understated VaR results.
- **Monte Carlo method:**
  Monte Carlo is another approach to calculation of VaR which is also popular nowadays. It is pretty similar to the VC method, however the crucial difference is

that instead of finding variances and covariances within portfolios, simulation techniques are used. One of the significant advantages of the MC method is that it takes into account different types of distributions other than gaussian one. Due to the ability to simulate random routes to the outcome (up to 1 mil runs), it allows to get more precise results. MC method is limited by the number of analyzed variables as well as VC VaR, because it gets harder to execute the model with hundreds of assets in the portfolio.

Overall, considering VaR as the only risk assessment tool might be risky, because, despite the fact that it is a good and simple instrument for identifying potential risk exposure in particular cases, there is a chance of being fooled by deception caused by misleading returns distribution and complications associated with large portfolio size.

Monte Carlo Simulation

Monte Carlo simulation is a powerful and pretty popular analytical tool . Statistics is not the only field where the simulation is obtained, it is also widely used in quantitative finance, which is the actual and probably essential part of this thesis. As John H. Halton reveals in his book, "Monte Carlo Simulation is defined … as a parameter of a hypothetical population, and using a random sequence of numbers to construct a sample of the population, from which statistical estimates of the parameter can be obtained" (Halton, 1970) . Simply, Monte Carlo simulation is used to conduct some sort of experiments by using random sampling from probability distribution. Following Christopher Z, the principle behind MC simulation is that the behavior of a statistic in random samples can be assessed by the empirical process of actually drawing lots of random samples and observing this behavior (Mooney, 1997) .

MC simulation as mentioned above is used in quantitative finance , for instance, for price predictions of different securities such as stock, options and etc., scenario analysis to recreate artificial economic conditions and analyze how securities would behave within different economic states, risk analysis by applying Value at Risk model to figure out the potential losses of the portfolio in specific conditions.

4 Practical part

This part is entirely dedicated to in-depth description of portfolio creation process and its performance assessment in practice. Python programming language will assist me throughout the way. Each result I get after performing a model will be followed by an explanation for deeper understanding of the whole process. All data used in the research is gathered in the form of secondary data (daily historical prices of assets and US bonds historical yield rates) for the period of 365 days or 252 trading days.

Firstly, particular financial instruments will be chosen from all existing ones backed by a review on why exact stocks or bonds are included in the portfolio using various indicators and ratios to prove that it is not gambling, but a valid point based on facts. Correlation matrix is performed to show that stocks and bonds are correlated differently to some degree and to prove that diversification is effective in response to market uncertainty and unexpected swings. Initial portfolio with equally weighted assets will be formed in order to apply MV (mean / variance) optimization model for clearer understanding on how it is helpful to identify an 'optimal asset allocation'. Basically, 2 types of optimization will be used – **maximum Sharpe ratio** for risk takers and **minimum volatility** optimization for risk averse investors in order not to stand only on one side of risk scale, but to take both of them into account and by performance comparison make a decision on which optimization method would make more sense to consider. Afterall, when the portfolio is optimized, its profitability would be evaluated by using Sharpe ratio, the riskiness of portfolio is estimated by Value at Risk model, future potential movement of each stock is predicted and executed via Monte Carlo simulation.

4.1 Instrument choice

The identification of 'right' instruments for a portfolio is a tough and time consuming process which requires lots of efforts and tons of data for analysis. There are many helpful analysis models, indicators and ratios out there, but for the matter of simplicity and clearer perception I will use relative valuation method only. For this part of the research I use secondary financial historical data which is provided by 'finviz.com' website for calculations. At the first stage of filtering procedure for stock picking I am going to use 'sector' criteria. It allows me to limit stocks by 5 necessary sectors I am looking for (healthcare, technology, energy, financial and industrials). After that I use other filters to limit stocks by 'positive dividends' , ' Mid capitalization and over', 'beta over 0', 'US market' and 'positive ROI'. Each of them has its own functions:

- **Positive dividends** mean that I am looking for stocks which are profitable and pay dividends in any amount to those who purchased a stock
- **Mid Capitalization and over** filter allows me to show large companies that have their market capitalization equal to $2 billion and higher
- **Beta** coefficient is an indicator of stocks' correlation with the market. They can either have a positive beta and move in the same direction with the market or have a negative beta and move in different directions. It is considered that beta of 1 is a perfect correlation with the market. Everything above 1 would mean that a stock has more potential volatility and move more sharply than the market itself. Beta less than 1 makes it clear that an asset has lower volatility than the market and moves in a slower pace
- **Positive ROI** gives me a possibility to see only those companies that provide any rate of return investors would expect on the investment they potentially make.
- **US market** filter will reveal only those instruments that are traded on any of US exchanges

All of these filters are applied for each sector in order to show all the options available for picking. Each stock contains certain financial information starting from **Ticker**, going through **Company name, Sector, Price per share, Market Cap, Annual dividends, Beta coefficient** up to **ROI**.

Ticker	Company	Sector	Price	Market Cap	Dividends in $	Beta	ROI
A	Agilent Technologies, Inc.	Healthcare	140.37	42.59B	0.78	1.04	14.70%
ABBV	AbbVie Inc.	Healthcare	142.53	252.12B	5.20	0.80	12.70%
ABC	AmerisourceBergen Corporation	Healthcare	139.41	29.43B	1.78	0.47	24.30%
ABT	Abbott Laboratories	Healthcare	128.05	227.13B	1.80	0.73	9.70%
AMGN	Amgen Inc.	Healthcare	223.53	127.00B	7.04	0.60	19.50%
ANTM	Anthem, Inc.	Healthcare	449.43	110.43B	4.52	1.06	9.10%
BAX	Baxter International Inc.	Healthcare	86.87	43.19B	1.08	0.62	8.60%
BDX	Becton, Dickinson and Company	Healthcare	269.27	77.25B	3.36	0.68	6.00%
BRKR	Bruker Corporation	Healthcare	67.44	10.14B	0.16	1.32	10.20%
CAH	Cardinal Health, Inc.	Healthcare	52.63	14.68B	1.47	0.94	9.30%

Figure 1. Example of stocks in Healthcare sector

Source: own elaboration. Data source: finviz and Yahoo finance

The second stage of filtering process has led to the following results:

- 43 companies in Healthcare sector
- 60 companies in Technology sector
- 21 companies in Energy sector
- 138 companies in Industrials sector
- 186 companies in Financial sector

Next step is to filter these companies manually by using relative valuation method which includes the comparison of ratios calculated individually for each company and to choose those that have the most reliable and sustainable results. The ratios I am using for comparison are **Price-to-earnings ratio** (taken from finviz.com directly) to find overvalued stocks in case of P/E ratio being higher than 15 and underrated stocks with P/E ratio being lower than 15 (Carnevale, 2019). **Debt-to-equity ratio** (calculated by dividing company's total liabilities by total equity) to figure out how much leverage companies use. For the purpose of clearer understating maximum value of 2 is used which means that companies are leveraged 2 times its equity at maximum and less. **Return-on-equity** (calculated by dividing company's net income by total equity) to look at those companies that generate positive returns on investors equity (those companies that contained negative numbers for any metric were dropped as well). There is a particular threshold which cannot be exceeded or fallen below. For instance, I limit a number of companies by P/E ratio no more than 15, D/E in range (0;2}, ROE should be a in range of (0;+inf). Those instruments that contained missing or negative values were dropped as well.

Here is how a source code looks like:

```python
# Calculating RoE
df['ROE'] = np.round(df['netIncome']/df['totalEquity'],2)

# Calculating Debt-to-equity ratio
df['D/E'] = np.round(df['totalLiab']/df['totalEquity'],2)

# Dropping missing and negative values
df = df.loc[(df['ROE'] != '-') & (df['P/E']!= '-')]
df = df.loc[(df['netIncome']>0) & (df['totalEquity']>0) & (df['D/E']>0) & (df['EPS']>0) & (df['ROE']>0)]

# Limiting a number of companies under certain conditions: P/E <= 15 , D/E = (0;2} , ROE = (0;+inf)
df = df.loc[(df['D/E'] <= 2) & (df['P/E'] <= 15)]
df[['Company','Sector','Price','Market Cap','Beta','P/E','D/E','ROE']].dropna()
```

Figure 2. Source code for stock picking based on data downloaded from finviz and yahoo finance websites

Source: own elaboration. Data source: finviz and Yahoo finance

Final filtering stage of stock picking procedure resulted in **3** companies that met the screening criteria in Healthcare, **9** companies in Technology sector, **1** company in Energy sector, **11** companies in Industrials sector and **13** companies in Financial sector which would then be considered as potential investments at the optimization stage.

Ticker	Company	Sector	Price	Market Cap	Dividends in $	Beta	P/E	D/E	ROE
COO	The Cooper Companies, Inc.	Healthcare	394.00	19.53B	0.06	0.87	6.65	0.38	0.42
DGX	Quest Diagnostics Incorporated	Healthcare	132.37	16.51B	2.42	1.10	8.51	1.06	0.22
UHS	Universal Health Services, Inc.	Healthcare	132.59	10.79B	0.80	1.11	10.68	1.12	0.15

Figure 3. Final list of stocks in Healthcare sector

Source: own elaboration. Data source: finviz and Yahoo finance

Ticker	Company	Sector	Price	Market Cap	Dividends in $	Beta	P/E	D/E	ROE
AMKR	Amkor Technology, Inc.	Technology	20.90	5.16B	0.17	1.54	9.26	1.15	0.15
AVT	Avnet, Inc.	Technology	40.63	4.13B	0.91	1.50	8.98	1.19	0.05
DOX	Amdocs Limited	Technology	79.32	9.87B	1.44	0.76	11.88	0.80	0.19
HPE	Hewlett Packard Enterprise Company	Technology	17.20	22.26B	0.48	1.18	6.70	1.89	0.17
INTC	Intel Corporation	Technology	47.63	194.99B	1.39	0.54	9.80	0.89	0.26
MKSI	MKS Instruments, Inc.	Technology	144.98	8.12B	0.86	1.47	14.64	0.65	0.15
MU	Micron Technology, Inc.	Technology	89.76	101.50B	0.10	1.21	13.88	0.34	0.13
SWKS	Skyworks Solutions, Inc.	Technology	133.13	22.76B	2.12	1.11	14.84	0.62	0.28
VSH	Vishay Intertechnology, Inc.	Technology	19.78	2.85B	0.38	1.35	9.62	1.00	0.08

Figure 4. Final list of stocks in Technology sector

Source: own elaboration. Data source: finviz and Yahoo finance

Ticker	Company	Sector	Price	Market Cap	Dividends in $	Beta	P/E	D/E	ROE
EPD	Enterprise Products Partners L.P.	Energy	24.68	53.61B	1.8	1.23	13.91	1.59	0.16

Figure 5. Final list of stocks in Energy sector

Source: own elaboration. Data source: finviz and Yahoo finance

Ticker	Company	Sector	Price	Market Cap	Dividends in $	Beta	P/E	D/E	ROE
AGCO	AGCO Corporation	Industrials	128.12	9.67B	4.76	1.30	12.95	1.84	0.14
KFY	Korn Ferry	Industrials	67.14	3.66B	0.46	1.52	13.70	1.24	0.08
KNX	Knight-Swift Transportation Holdings Inc.	Industrials	55.33	9.34B	0.38	1.30	12.45	0.44	0.07
LPX	Louisiana-Pacific Corporation	Industrials	68.04	6.05B	0.68	1.75	4.82	0.68	0.40
MLI	Mueller Industries, Inc.	Industrials	57.93	3.35B	0.52	1.25	7.03	0.94	0.18
MOG-A	Moog Inc.	Industrials	75.96	2.43B	1.00	1.42	14.80	1.45	0.11
RCII	Rent-A-Center, Inc.	Industrials	38.94	2.61B	1.27	1.56	13.60	1.96	0.35
SNA	Snap-on Incorporated	Industrials	208.92	11.34B	5.11	1.21	13.99	0.71	0.17
TKR	The Timken Company	Industrials	66.11	5.09B	1.19	1.66	13.81	1.31	0.14
WERN	Werner Enterprises, Inc.	Industrials	43.58	2.94B	0.34	0.80	12.27	0.80	0.14
WIRE	Encore Wire Corporation	Industrials	110.81	2.26B	0.06	1.21	5.41	0.15	0.09

Figure 6. Final list of stocks in Industrial sector

Source: own elaboration. Data source: finviz and Yahoo finance

Ticker	Company	Sector	Price	Market Cap	Dividends in $	Beta	P/E	D/E	ROE
AMG	Affiliated Managers Group, Inc.	Financial	142.48	5.69B	0.04	1.35	12.71	1.40	0.15
BEN	Franklin Resources, Inc.	Financial	30.63	15.30B	1.13	1.16	8.09	1.02	0.19
CINF	Cincinnati Financial Corporation	Financial	121.14	19.33B	2.52	0.65	7.79	1.55	0.11
FAF	First American Financial Corporation	Financial	70.37	7.79B	1.94	1.22	6.23	1.60	0.14
FHI	Federated Hermes, Inc.	Financial	33.21	3.17B	1.08	1.13	10.70	0.60	0.30
GSBD	Goldman Sachs BDC, Inc.	Financial	20.19	2.06B	1.95	1.39	6.05	1.05	0.11
MAIN	Main Street Capital Corporation	Financial	42.39	2.92B	2.58	1.40	9.18	0.83	0.02
MC	Moelis & Company	Financial	51.25	3.36B	6.80	1.24	8.72	1.57	0.46
MTG	MGIC Investment Corporation	Financial	15.72	5.04B	0.28	1.63	8.53	0.57	0.09
PIPR	Piper Sandler Companies	Financial	148.44	2.62B	6.80	1.44	12.19	1.29	0.06
RDN	Radian Group Inc.	Financial	23.89	4.25B	0.55	1.35	8.32	0.86	0.09
TROW	T. Rowe Price Group, Inc.	Financial	144.25	32.26B	5.16	1.29	10.99	0.18	0.33
VCTR	Victory Capital Holdings, Inc.	Financial	34.47	2.28B	0.21	1.11	9.68	1.45	0.30

Figure 7. Final list of stocks in Financial sector

Source: own elaboration. Data source: finviz and Yahoo finance

It is also important to emphasize the reasons of why other valuation models such as Gordon Growth Model and Discounted Cash Flows model were not applied in the research. First things first, Gordon Growth Model has its limitations in a way that certain inputs are quite sensitive and sophisticated by nature therefore it is a pretty complex task to perform the model for over 400 companies and get appropriate outcome simultaneously. The main issue of getting inappropriate output is that dividend growth was larger than rate of return what actually makes the model vulnerable to distorted results. There are some examples of intrinsic values derived from GGM with the current market price next to it for a quick comparison. Frankly speaking, the outcome is an absolute nonsense, meaning that in my case this kind of model cannot truly define and refer to companies' intrinsic value.

Ticker	Sector	Price	GGM
AAPL	Technology	168.64	-3.685216
ADI	Technology	153.90	19.721626
AMAT	Technology	132.49	-10.692583
AMKR	Technology	20.90	3.796785
APH	Technology	75.18	5.256864

Ticker	Sector	Price	GGM
AB	Financial	49.14	2.671235
ABCB	Financial	50.41	8.303164
ADS	Financial	71.16	22.125086
AFG	Financial	136.57	-0.719753
AFL	Financial	65.31	16.749159

Ticker	Sector	Price	GGM
A	Healthcare	137.20	17.043578
ABBV	Healthcare	142.01	14.610975
ABC	Healthcare	140.24	-2.892058
ABT	Healthcare	125.49	13.942230
AMGN	Healthcare	228.20	9.232118

Figure 8. Examples of calculated intrinsic values by applying GGM

Source: own elaboration. Data source: finviz and Yahoo finance

Furthermore, Discounted Cash Flows model is not implemented in the research, because it requires much more efforts to employ the model properly since future cash flows shall be estimated as precisely as possible for all of the companies with refined individual approach, which is not actually my case as I have to go through all 400+ companies at the second filtering stage.

Regarding the choice of bonds, I prefer to limit the list of all the bonds available on the market by using only 10 - years US treasury notes, because they are assumed to be low risk investments since they are backed by the US government debt. In this case the default risk is at its minimum, because those bonds would default if only US government would go bankrupt, what actually seems improbable.

4.2 Mean/Variance optimization

Some assumptions about mean/variance optimization worthlessness exist claiming that it does not represent appropriate results since returns are considered normally distributed, however it is still widely used nowadays by large institutions as well as retail investors due to its simplicity of use.

Generally, I will apply two types of mean/variance optimization – **Maximum Sharpe ratio** which will optimize a portfolio by determining maximum return for a certain level of risk and **Minimum Volatility** which is intended to minimize variance (risk) within the portfolio corresponding to a certain level of return – and plot an efficient frontier which will show a number of randomly generated portfolios with the only one which will lie on the efficient frontier curve and represent the most ‘optimal’ combination of assets in the portfolio depending on optimization method.

Firstly, I need to create an initial portfolio consisting of equally weighted instruments I emphasized previously and consequently calculate further inputs for the optimization model. The exact inputs for optimization are **asset weights** which are equally distributed in the portfolio and in total have to be equal to 1**. Daily adjusted close prices** for stocks and **historical yield rates** for bonds for the time horizon of 1 year starting from 1st of January 2021 up to 1st of January 2022. Unfortunately, a lookback period of 1 year is not enough to follow the long term tendency of risk and return distribution, therefore it does not fully represent the reality of risk and return relationship, but it is still deliberately used for demonstrative purposes. **Daily returns** calculated by using percent change of daily close prices for stocks and yield rates for bonds**. Annual covariance matrix** is calculated by finding covariance of daily returns and multiplying it by 252 trading days in a year. Afterall, I would like to know the performance results of the initial portfolio, which includes portfolio expected annual return and its volatility**. Portfolio variance** is estimated by multiplication of squared weights and variance of each asset. The interim results are then added by the number of assets in the portfolio multiplied by the weight of every asset and the covariance of all assets. **Volatility of the portfolio** is considered its standard deviation and evaluated by taking a square root of portfolio’s variance. Whereas the **portfolio annual return** is measured by the sum of mean returns multiplied by weights of assets and then the result is also multiplied by 252 trading days.

```
# Collecting tickers
tickers= ['COO','DGX','UHS','AMKR','AVT','DOX','HPE','INTC','MKSI','MU','SWKS',
          'VSH','EPD','AGCO','^TNX','KFY','KNX','LPX','MLI','MOG-A','RCII','SNA',
          'TKR','WERN','WIRE','AMG','BEN','CINF','FAF','FHI','GSBD','MAIN','MC',
          'MTG','PIPR','RDN','TROW','VCTR']

# Setting their weights within the portfolio
weights = np.array([1 / len(tickers)]*len(tickers))

# Download historical prices of each instrument
stocks = yf.download(tickers= tickers, start="2021-01-01", end="2022-01-01")
df = pd.DataFrame(stocks['Adj Close'])

# Caluculating returns of each instrument
returns = df.pct_change()

# Constructing annual covariance matrix
cov_matrix_annual = returns.cov()*252

# Calculating portfolio variance
portforlio_variance = np.dot(weights.T,np.dot(cov_matrix_annual,weights))

# Calculating portfolio volatility (standard deviation) based on portfolio variance
portfolio_volatility = np.sqrt(portforlio_variance)

# Calculating portfolio simple annual returns
portfolio_simple_annual_return = np.sum(returns.mean()*weights)*252
```

Figure 9. Initial portfolio construction and optimization inputs calculations

Source: own elaboration. Data source: finviz and Yahoo finance

As all inputs are calculated, I move on to assessment of initial portfolio basic metrics – risk and return. At the first glimpse, the output is rather promising: overall portfolio volatility of 19% and expected return of 36%. What it says is basically that expected return on the initial equally weighted portfolio is almost as twice as higher than volatility (1.89x to be exact) which is a quite good result in terms of return, assuming that the portfolio consisting of 38 assets is diversified, but still not good enough in terms of risk taken.

4.3 Maximum Sharpe Ratio and Minimum Volatility optimization methods

The way optimization works is that it takes certain inputs and creates random portfolios around efficient frontier curve by correlating risk and return of each asset. Combination that, using historical records, generated as high return for the lowest possible risk in case of

Maximum Sharpe ratio optimization and higher return for a minimum variance in case of Minimum Volatility optimization lies directly on the curve and indicates the most optimal portfolio among them all. Other portfolios outside the curve are impossible to achieve whereas those that are below the frontier are not really optimal, because it is possible to obtain higher return with lower risk elsewhere. Model implementation is realized via using python third party libraries and particularly requires **expected return** calculated as **annualized mean daily historical return** and **annualized sample covariance matrix** as major inputs.

	Weights
COO	0.12
DGX	0.25
DOX	0.06
EPD	0.03
FAF	0.05
GSBD	0.28
INTC	0.01
MAIN	0.12
WERN	0.04
^TNX	0.04

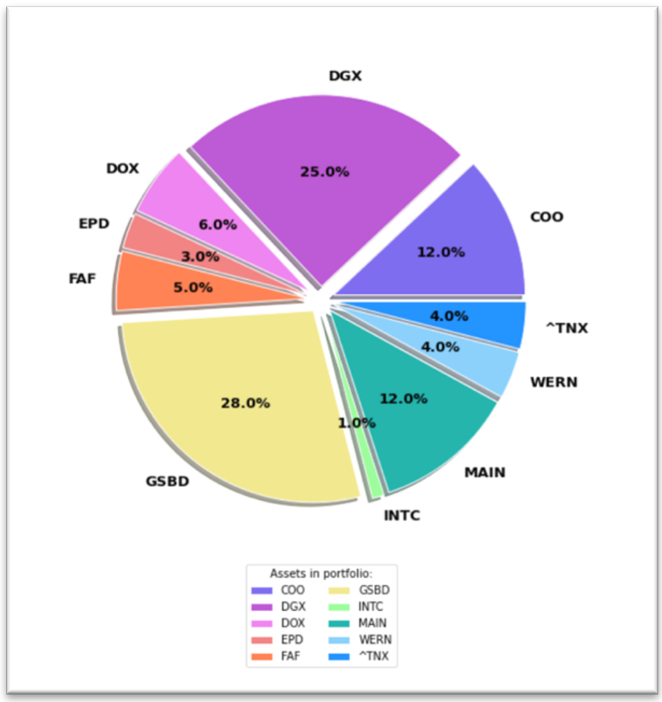

Figure 10. Interpretation of Min. Volatility optimization results in tabular and pie chart form

Source: own elaboration. Data source: finviz and Yahoo finance

	Weights
DGX	0.29
FAF	0.04
KNX	0.01
LPX	0.04
MAIN	0.29
WIRE	0.28
^TNX	0.05

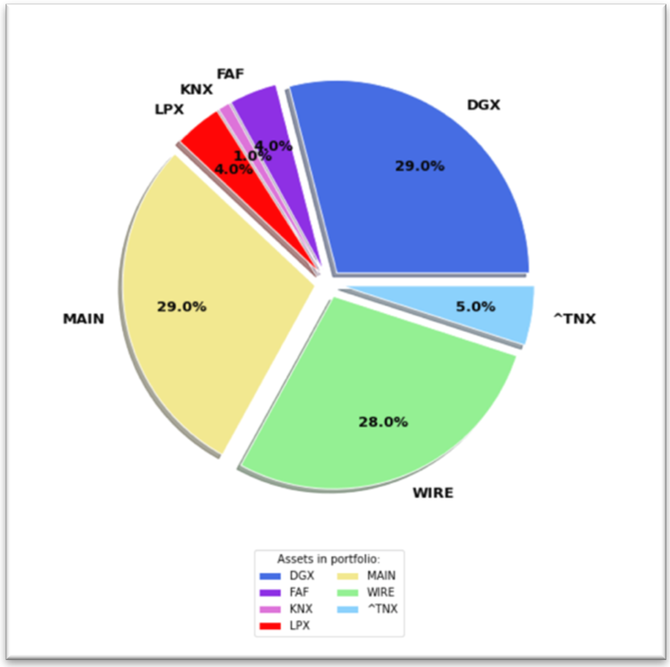

Figure 11. Interpretation of Max. Sharpe ratio optimization results in tabular and pie chart form

Source: own elaboration. Data source: finviz and Yahoo finance

If we follow the results of both optimizations, we notice that there are less assets obtained in the Maximum Sharpe ratio portfolio than in the portfolio which was generated by using Minimum volatility optimization. The reason for that is a relatively small number of volatile instruments in comparison to those with lower standard deviations which were chosen by relative valuation method. Since most companies that pay dividends are profitable and considered stable to some extent, standard deviation of such companies is lower comparing to those that do not generate any income yet. Besides, volatility of companies' share prices also might depend on the sector they are operating in. Enterprises operating in Technology sector have higher volatility than those operating , for instance, in industrials sector.

As weights of each asset within portfolios are known, it is possible to calculate a number of shares that would be allocated with a budget of $1 million. But for the sake of diversification, I decided that 10% of the total budget would be carried as cash for any unexpected and unforeseen situations, meaning that overall there are $900.000 left for stocks and bonds allocation. Final result of total number of shares for each company and total number of US treasury notes (^TNX) within both portfolios are provided below:

Tickers	Shares
COO	268
DGX	1280
DOX	675
EPD	1445
FAF	550
GSBD	13265
HPE	20
INTC	177
MAIN	2461
WERN	715
^TNX	360

Tickers	Shares
DGX	1538
FAF	449
KNX	221
LPX	452
MAIN	5793
WIRE	1735
^TNX	459

Figure 12. Shares & bonds in Min. Volatility and Max. Sharpe portfolios respectively

Source: own elaboration. Data source: finviz and Yahoo finance

It is pretty noticeable that some assets contain more shares than the others. This fact is self-explanatory by correspondence of stock prices and their weights in the portfolio which are in turn based on the type of applied optimization either on low volatility or high return. Eventually, as I have all the components gathered, I would like to move on to assessment of performance of both portfolios and figure out which one would have better results.

4.4 Performance assessment

Assessment of portfolio performance is one of the most vital and fascinating parts of the whole portfolio creation procedure. Different mathematical models are widely used nowadays in financial field by large institutions as well as retail investors for risk management. This research is not an exception, therefore I will introduce some models that I use for risk management, overall performance evaluation and future price movement prediction.

Primarily, I would like to know how much excessive return I may get for the amount of risk taken. Sharpe ratio is a tool that will help to figure it out. It indicates how much extra return I may anticipate to get on additional amount of risk taken. The higher the ratio, the better. The ratio less than 1 is considered bad, whereas the ratio higher than 1 is thought to be good enough to earn at least above- average return. However, the ratio above 2-3 is rated as excellent (Maverick, 2021).

Performance outcome from both optimization methods is shown down below:

```
Expected annual return: 31.1%
Annual volatility: 10.7%
Sharpe Ratio: 2.72
```

```
Expected annual return: 79.4%
Annual volatility: 16.0%
Sharpe Ratio: 4.84
```

Figure 13. Min. Volatility and Max. Sharpe portfolios performance respectively

Source: own elaboration. Data source: finviz and Yahoo finance

The way each metric is calculated is as follows:

- **Expected annual return** for optimal portfolios is measured the same way as for initial equally weighted portfolio by the sum of mean returns multiplied by weights of assets and further multiplied by 252 trading days.
- **Annual volatility** of optimal portfolios is simply estimated as a square root of optimal portfolio variance.
- Calculation of **Sharpe ratio** is entirely based on a division of expected annual return less risk free rate by annual volatility. In this case risk free rate is considered an asset with 'no risk' and 3 month Treasury bills are widely used for risk free rate interpretation.

Additionally, graphs below represent all possible combinations of optimal and suboptimal portfolios around efficient frontier curve and takes into account the inputs of annual expected return and annual volatility of portfolios. All the portfolios which are below the curve are considered sub-optimal and there is only one optimal portfolio settled right on the curve. The boundaries of both axis are determined by the highest and lowest values of expected return each asset is able to generate and standard deviation of each instrument in the portfolio.

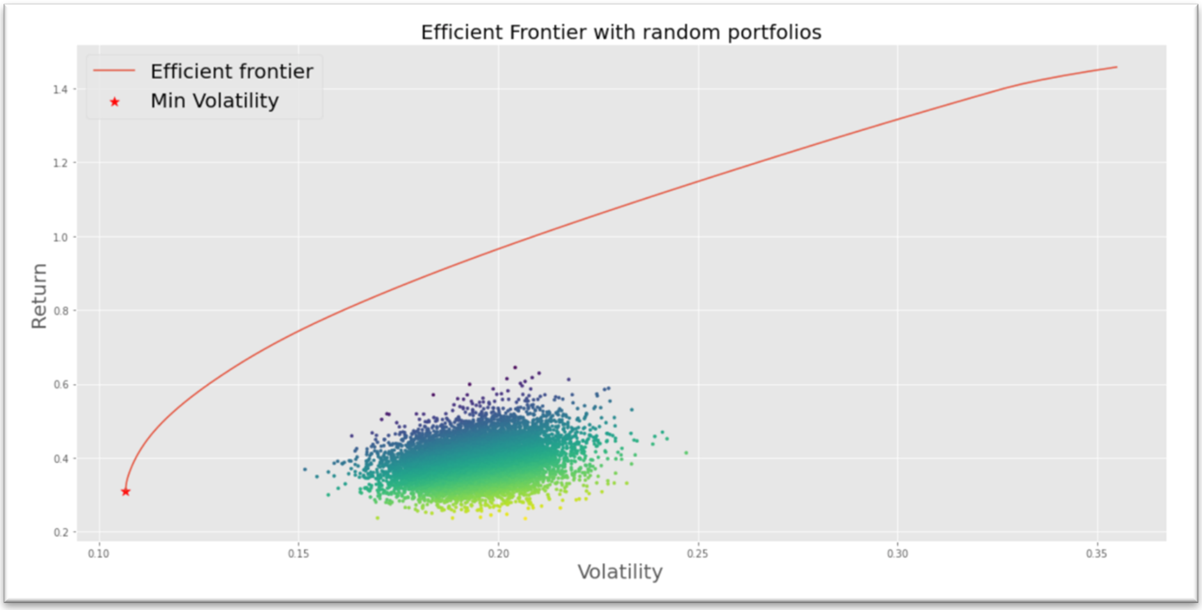

Figure 14. Efficient frontier with random portfolios for Min. Volatility optimization

Source: own elaboration. Data source: finviz and Yahoo finance

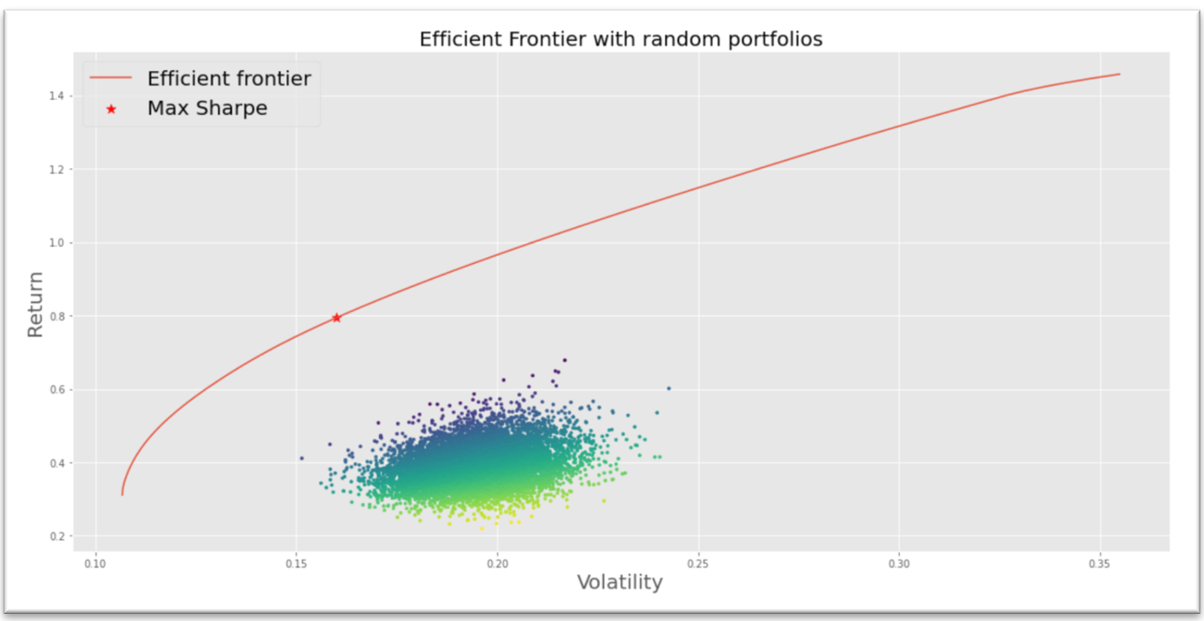

Figure 15. Efficient frontier with random portfolios for Max. Sharpe ratio optimization

Source: own elaboration. Data source: finviz and Yahoo finance

Another useful tool for relationship analysis is **correlation matrix**. There are 2 correlation matrices estimated for both portfolios:

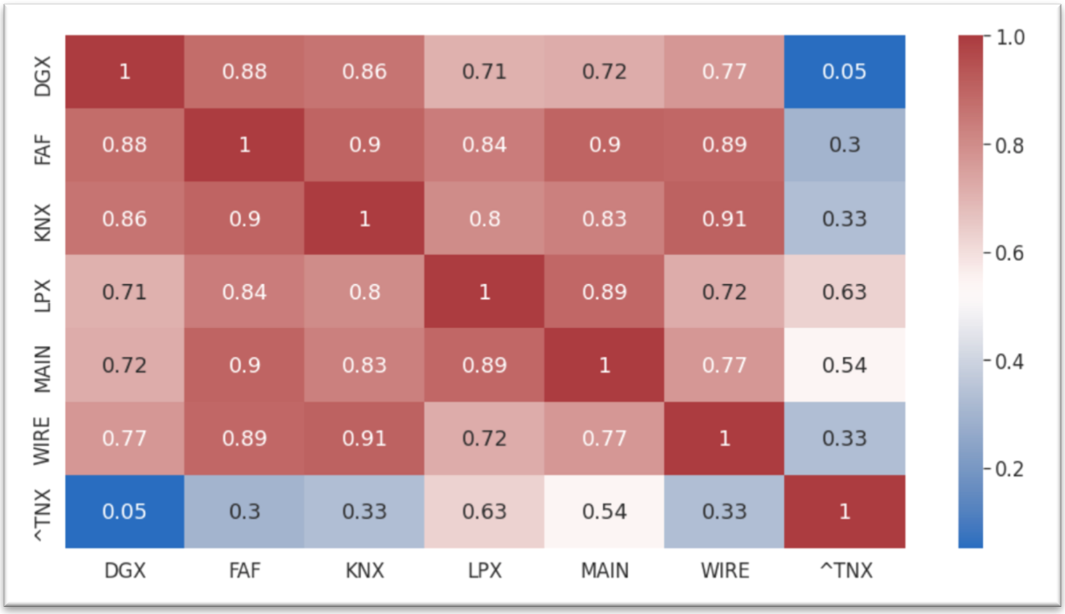

Figure 16. Correlation matrix of Max. Sharpe portfolio

Source: own elaboration. Data source: finviz and Yahoo finance

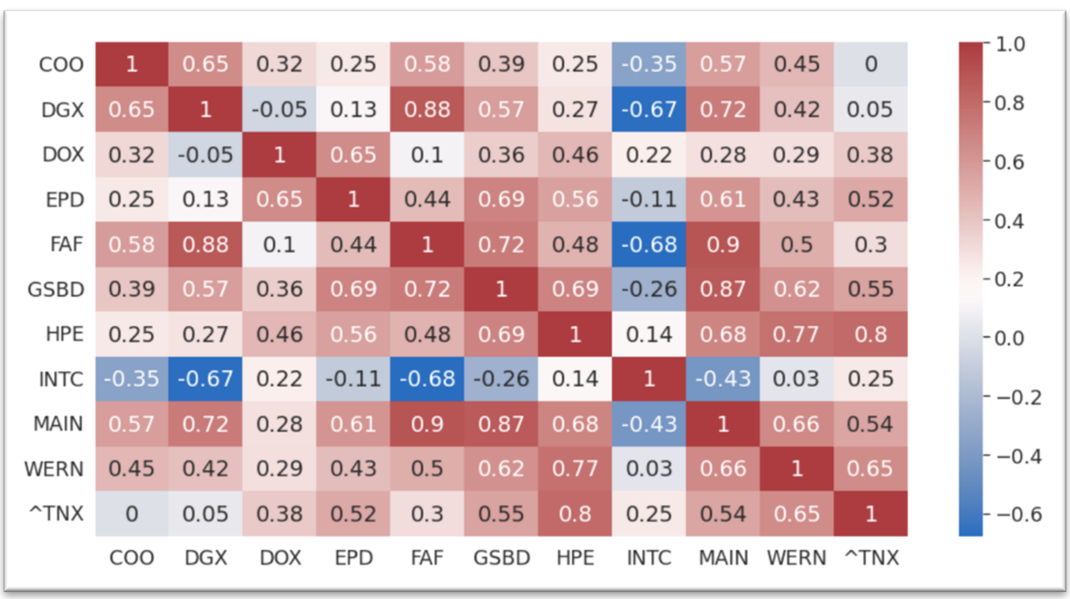

Figure 17. Correlation matrix of Min. Volatility portfolio

Source: own elaboration. Data source: finviz and Yahoo finance

Evaluation of correlations within each cell was conducted by dividing covariance by the product of standard deviations of prices of two assets. Both correlation matrices reveal the relationship between assets, whether they move together in the same direction or not. A handy scale on the right hand side indicates the strength of the relationship between assets starting from the dark red color or very strong correlation up to dark blue color or negative correlation in case of Min. Volatility portfolio and weak positive correlation in case of Max. Sharpe portfolio. Light colors or white color are determined as weak correlation or no relationship respectively within Min. Volatility portfolio.

Value at Risk model is used for risk management purposes and shows what maximum drawdown in portfolio value I can expect for a definite period of time with a certain level of confidence. For this research I use historical VaR based on historical prices with a lookback period of 1 year. The time horizon I am planning to look ahead is also 1 year with a 95% confidence level. The results I received are presented below:

```
VaR for Min.Volatility portfolio with the confidence level of 95 % is equal to 3.35 % for the next 365 days
```

Figure 18. VaR for Min. Volatility portfolio

Source: own elaboration. Data source: finviz and Yahoo finance

```
VaR for Max.Sharpe portfolio with the confidence level of 95 % is equal to 5.03 % for the next 365 days
```

Figure 19. VaR for Max. Sharpe portfolio

Source: own elaboration. Data source: finviz and Yahoo finance

Following the outcome, I can say that the maximum potential loss of the portfolio value ($900.000) I should anticipate is 3.35% or $30.150 for Minimum Volatility portfolio and 5.03% or $45.270 for Maximum Sharpe portfolio. In fact, considering the results to be precise and accurate is not quite right because of model's limitations explained in the literature review section such as reliance on past data and normal distribution of returns used as one of the inputs. Thus the outcome is purely indicative for the purposes of general comprehension of risks and further implementation of risk management strategies.

Monte Carlo simulation is an additional model that allows to generate hundreds, thousands or even millions of random simulations in order to predict assets' potential price movements in the future. It requires specific inputs for proper realization too such as number of simulations, look ahead period and a dataset of historical prices of assets. I decided to create 1000 random simulations for 1 year period by using historical prices I already used previously in this research.

	Price	Lower	Upper
COO	418.91	131.68	965.48
DGX	172.26	68.57	380.95
DOX	74.84	26.87	188.62
EPD	21.54	7.6	46.89
FAF	78.23	36.09	168.37
GSBD	19.16	9.68	38.6
HPE	15.77	4.81	50.68
INTC	51.11	12.71	165.23
MAIN	44.43	20.34	92.11
WERN	47.66	17.7	127.62
^TNX	1.51	0.19	11.18

	Price	Lower	Upper
DGX	172.26	70.17	359.89
FAF	78.23	30.06	196.14
KNX	60.94	22.46	158.38
LPX	78.35	13.47	313.93
MAIN	44.43	20.89	102.06
WIRE	143.08	32.71	498.42
^TNX	1.51	0.12	8.54

Figure 20. Monte Carlo results for Min. Volatility and Max. Sharpe portfolios respectively

Source: own elaboration. Data source: finviz and Yahoo finance

The results show the current market price of each asset and potential minimum and maximum values that might be achieved during the next 365 days. The higher the number of conducted simulations, the more accurate the result would be.

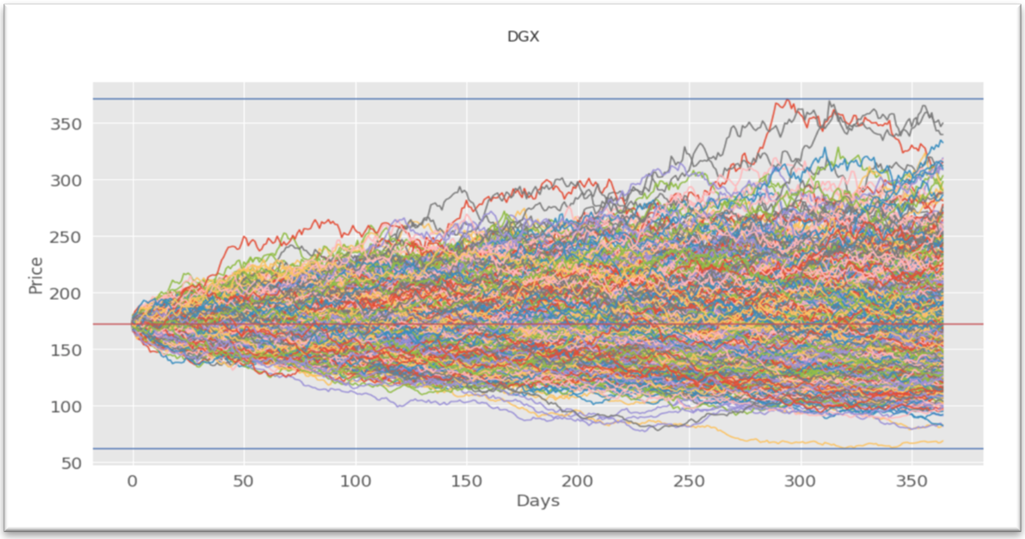

Figure 21. Example of Monte Carlo simulation for a stock price

Source: own elaboration. Data source: finviz and Yahoo finance

The graph above reveals 1000 random simulations of a certain asset price as an example for the next 365 days or 252 trading days based on 1 year of lookback period. Each curve represents one simulation generated on the basis of daily volatility of historical data taken from previous calculations of daily returns (referring to figure 9). Red line shows the current market price of an asset, whereas other 2 blue lines are the indicators of upper and lower bounds of potential maximum and minimum prices which theoretically can be achieved throughout the period of 1 year. Since the model requires daily returns which, in this research, are normally distributed, it is hard to believe in 100% accuracy of the outcome, hence the result is also indicative in order to get a general idea of what may happen in the future.

As an addition, considering the fact that both portfolios are dividend portfolios, there is also a possibility of generating income from dividends and coupon payments. The only thing I need to know is the dividend per share for the next period for stocks and coupon payment for bonds and then it is multiplied by the number of shares and bonds in the portfolio. Dividends per share for the next period are calculated by multiplying official dividends per share available for the most recent period by sustainable growth rate which in turn is calculated individually for each company by multiplying its ROE by 1 minus payout ratio.

Payout ratio is simply a division of a dividend per share by earnings per share. Consequently, the overall result is shown below:

Ticker	Total
COO	16.0
DGX	3098.0
DOX	972.0
EPD	2601.0
FAF	1067.0
GSBD	25867.0
HPE	10.0
INTC	246.0
MAIN	6337.0
WERN	243.0
^TNX	655.0
Sum	41112.0

Ticker	Total
DGX	3722.0
FAF	871.0
KNX	84.0
LPX	307.0
MAIN	14917.0
WIRE	104.0
^TNX	835.0
Sum	20840.0

Figure 22. Total income from dividends and coupon payments for Min. Volatility and Max. Sharpe portfolios respectively

Source: own elaboration. Data source: finviz and Yahoo finance

5 Results and discussion

In this part I will break down and compare the results of examined performance of initial equally weighted portfolio with other 2 optimal portfolios and interpret the output of VaR model and Monte Carlo simulation.

5.1 Risk and return (Sharpe ratio)

Estimated performance of portfolios showed that returns of all 3 portfolios do exceed the overall volatility within portfolios. Firstly, referring to figure 13 , if we compare expected returns of both optimal portfolios, on the one hand, we notice that it is almost 3x (2.55x being specific) difference between expected returns on Max. Sharpe and Min. Volatility portfolios, on the other hand, annual volatility of Max. Sharpe portfolio exceeds annual volatility of Min. Volatility portfolio only by 5.3% (~1.5x). Speaking further, Sharpe ratio of both portfolios is above 2, meaning that returns we may earn are much higher than average return, but if we take a closer look at the ratio and compare them between each other, Sharpe ratio of Max. Sharpe portfolio is almost 2 times (1.77x being precise) larger than Sharpe ratio of Min. Volatility portfolio which is pretty logical since Sharpe ratio is dependent on volatility and expected return inputs' proportionality, the higher the expected return and the lower the volatility, the larger the ratio would be, what exactly is my case. Min. Volatility and Max. Sharpe portfolios cover the taken risk and earns excessive returns of 2.72x and 4.84x respectively which seem to be a pretty high returns in both cases. There is no surprise, because MV optimization is subject to estimation error, thus received output should be considered indicative and should not be assumed as ideal. The result of 36% of expected return for 19% of volatility initial equally weighted portfolio performed does not look as attractive and 'efficient' as of other optimal portfolios. Furthermore, if we compare the initial portfolio and Min. Volatility portfolio, we will see that the expected return of Min. Volatility is less than initial portfolio's return by only 4.9%, however, whilst the risk we take in case of initial portfolio is higher by 8.9% than Min. Volatility portfolio. The idea behind it is that it is not worth wasting resources on attempts to obtain initial portfolio, because it is purely suboptimal from the perspective of risk and return relation. The comparison of initial and Max. Sharpe portfolios would not be extraordinary, since Max. Sharpe portfolio has better results in a way that it has lower volatility (around 3% less volatile) and much larger return (2.2x to be precise).

5.2 Correlations

Following figures 16 and 17, most of the assets in Maximum Sharpe portfolio have strong positive correlations above 0.8, whereas the situation is a bit different in case of Minimum Volatility portfolio where some of the assets have weak positive correlations less than 0.5 as well as a few of them have stronger correlations higher than 0.6. Besides, several instances of negative correlation or no relationship are also present in both portfolios.

Moreover, in the literature review I emphasized that stocks and bonds have different correlations and I would check whether it is true or not. As we can see, US treasury notes have lower correlations than the average among other stocks in Max. Sharpe portfolio including no correlation with DGX stock, whilst correlations between assets in Min. Volatility portfolio are more diverse. For instance, INTC stock does have both weak positive and negative correlations, meaning that it does not behave the same way as most of other stocks do. Besides, US treasury notes have no correlation with some of the assets, strong correlation with HPE stock and predominantly neither weak nor strong correlation with remaining stocks. To sum up, most of the assets are correlated at least to some extent as it was explained in the literature review, thus full elimination of unsystematic risk is impossible.

5.3 Value at Risk and Monte Carlo simulation

Both models were generally performed in order to show the behavior of assets in the future for a certain period of time. VaR indicated the maximum loss of portfolios' value by the end of the period of 365 days or 252 trading days with a confidence level of 95% which is equal to 3.35% or $30.150 of total loss in case of Min. Volatility portfolio and 5.03% or $45.270 in case of Max. Sharpe portfolio which look realistic enough to take it into account, while coming up with more advanced risk management strategies, but it is worth implementing some other risk models for higher accuracy of overall output.

Monte Carlo simulation predicted and determined possible price minimums and maximums which theoretically might be reached during 1 year period by conducting 1000 random simulations. Speaking further, the results seem surprisingly unreal and unobtainable for this period of time. Reasons for that may be a relatively short lookback period of 1 year which is not enough to truly reflect a long term tendency and a small number of simulations when, in fact, millions of simulations could have been conducted. As most of the models are limited in a way that they all rely on past data, in fact, it is not effective, since there is no confidence that historical data genuinely reflects the future behavior. It '… is not sufficient to allow the past history of the series to be used to predict the future in a way which makes expected profits greater than they would be under a naive buy-and hold model' (Fama, 1970) as well as normal distribution of returns, which is used in this thesis, does not guarantee the precision of output particularly in case of VaR and Monte Carlo simulation.

6 Conclusion

To summarize, the overall process of portfolio creation is not a rocket science, especially when you are into it and genuinely understand what to do and how to do it. The major objective of the thesis was to create an optimal dividend portfolio consisting of various financial instruments, assess its performance with different metrics and predict the price movements of assets within portfolio. Throughout the research, I broke down some of the major aspects of portfolio creation and its performance assessment. In the literature review I made an overview of Modern portfolio theory, Mean/Variance optimization and primary performance evaluation tools – Sharpe ratio, VaR and Monte Carlo simulation. I distinguished their assumptions and constraints which I should consider while constructing a portfolio with its further performance estimation as well as I determined some other important aspects such as distribution of returns and correlation analysis. Fundamental analysis was explained as the main approach to choice of financial instruments. In the practical part, firstly, I initiated a 3 stage screening procedure for stocks in order to highlight the most suitable ones based on specific criteria. Secondly, I created an initial equally weighed portfolio which then underwent an optimization procedure by using 2 methods - Minimum Volatility and Maximum Sharpe Ratio optimizations. Afterall, I measured the performance of both portfolios, applying Sharpe ratio. I estimated the maximum drawdown in portfolio value by Value at Risk model and carried out Monte Carlo simulation for asset prices prediction purposes.

The outcome is good enough, but still not flawless to fully rely on it, taking into account the limitations of all mathematical models applied in the research. It turned out that both portfolios generated satisfying results for risk averse and non-risk averse investors. Objectively, there is no right or wrong side to choose in regard to risk and return attitude. On the one hand, high return is very lucrative and attractive to pursue, however, on the other hand, with greater returns come greater risks which some people will not be able or are not willing to maintain. That is why it is all a matter of personal preferences.

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