INTERNATIONAL HELLENIC UNIVERSITY

IHU UCIPS
Department of Science & Technology

MSc in Energy and Finance

RISK MANAGEMENT

Energy Business and Financial Markets

- Analogies and key concepts
- Trading, Investing and Risk Analytics
- Portfolio Optimization Techniques

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Contents - Summary

The energy industry faces ongoing challenges in balancing traditional energy sources with the increasing demand for sustainable, clean energy.

Transitioning toward renewables while managing legacy assets poses financial, regulatory, and technological challenges. And risks. On top of that, the evolving geopolitical landscape, climate change concerns, and the need for decarbonization add layers of complexity to this industry and line of business.

Completing the image, Risk Management has its own “desk in the office”.

In the future, successful Risk Management in the energy sector will hinge on agility, adaptability, and a proactive approach to embracing emerging technologies and regulatory shifts while maintaining a robust risk mitigation framework.

The fully detailed four-page table of contents, describes in depth the structure and contents of this document, that attempts to illustrate the evolvement in energy business and also to draw the connecting lines between energy and the (long ago well defined) financial markets.

Many lessons to be learnt from finance, on business and risk analytic practices that are duplicated in energy sector, but most importantly, the fine tuning that needs to be done, are (among many more topics), issues that will be explored in the next chapters.

(... among some clarifications in many risk concepts and misconceptions that seem to puzzle the market participants ...)

Preface

Risk Management in energy markets

A bird's eye view

Energy market companies face a variety of uncertainties, from physical risks to climate change – they (must) adapt to these challenges with the assistance and active participation of their Risk Managers.

In brief, energy market Risk Managers, borrow concepts and models from the financial industry, adapting them to their particular needs. Driven by the fact that trading and investing in the (relatively new) energy sector is always facing a number of new risks and challenges, there is a constant pressure on traditional Risk Management practices. As such, Risk Managers will need to be more flexible, adaptable, and innovative in order to address the challenges of the future.

A short history and a glimpse in the future

The past: The energy industry has a long history of Risk Management. In 1978, the New York Mercantile Exchange (NYMEX) launched the No. 2 heating oil contract, which was the first futures contract for a physical commodity. This helped to reduce the risk of price volatility for energy companies.

The present: The energy sector is undergoing a period of rapid transformation, driven by factors such as climate change, technological innovation, and geopolitical tensions. These changes are creating new risks and challenges for energy market participants, and they are also putting pressure on traditional Risk Management practices. Meeting these requirements is essential.

The future: The future of Risk Management in energy markets is uncertain (...), but it is clear that Risk Managers will play a critical role in ensuring the security and stability of the energy sector. No other entity can solve this puzzle.

The energy industry and market

The energy business, is a complex and dynamic sector that plays a pivotal role in global economic development. Encompassing assets from traditional fossil fuels (oil, natural gas) to electricity and the recent renewable sources such as solar, wind, and hydroelectric power, this industry operates within a multifaceted landscape marked by geopolitical uncertainties, market fluctuations, regulatory changes, and technological disruptions.

As such, Risk Management has become increasingly important for energy companies in recent years. For many reasons.

The [4x4] aspects of Risk Management

In brief, the purpose of Risk Management is to identify, assess, and prioritize risks so that they can be managed effectively.

There are a number of different Risk Management frameworks that can be used, but they all share the same goal: help companies to make informed decisions about how to best manage their risks.

Risk Management is a complex and challenging task, essential for energy companies to protect their businesses and ensure their long-term success.

The key aspects of Risk Management are (in order) as follows:

1. **Risk identification**
   What are the potential risks that a company faces? How can we identify all of them? Truly challenging task, as there are many known different types of risks, and new risks can arise all the time – known and unknowns.

2. **Risk assessment**
   Let's evaluate the probability and impact of each risk.
   What is the likelihood that the risk will occur, and what is the impact of the consequences if the risk does occur?

3. **Risk Prioritisation**
   Let's rank the risks, according to their probability and impact. Let's focus on the top ones, knowingly.

4. **Risk Management, by ...**

4.1. Avoiding altogether
Let's not enter this activity, transaction, market, trade, ...

4.2. Reduction
Let's enter it and hedge it, or optimize the risk reward.

4.3. Transferring it "elsewhere"
Let's transfer the risk to another counterparty.
For example, "assign it" to an insurance company, sell it to the market through a listed exchange or an otc transaction with a counterparty, ...

4.4. Entering in it and owning it
Let's undertake the risk – we know what we do and why.

Key Risk types particular to Energy Companies

Risk has many forms and peculiarities. The financial firms "pioneered" it, in its professional approach and management. Energy firms however, face their own risk types, with a varying degree of similarity to financial firms.

Market Risk (Price Volatility)

Risks that arise from price fluctuations in markets. Energy markets are highly sensitive to price fluctuations influenced by geopolitical tensions, supply-demand dynamics, and economic factors. Energy Companies, face exposure to many sudden price shifts impacting revenue and profitability.

Geopolitical Factors

Risks that arise from political instability, conflicts, terrorism, wars, geopolitical instability, trade disputes, sanctions, and political unrest especially in key producing regions can disrupt supply chains, impacting energy prices.

Regulatory Compliance

Risks that arise from changes in government regulations, for example in environmental regulations, safety regulations, and energy efficiency standards. The energy industry operates under stringent regulations aimed at ensuring safety, environmental sustainability, and fair competition. Failure to comply can lead to penalties, reputational damage, and operational disruptions.

Technological Changes

Advancements in technology, including renewable energy sources, energy storage solutions, and digitalization, introduce both opportunities and risks. Adapting to new information technologies while managing potential cybersecurity threats is crucial.

Operational Risks

Risks that arise from the day-to-day operations of the company. Examples include equipment failures, accidents, environmental incidents, natural disasters, and supply chain disruptions – all pose significant operational risks. Ensuring robust infrastructure and emergency response plans is vital.

Risk Management Strategies - Energy Companies

Again, many similarities with financial companies and many unique features.

Diversification

Energy companies often hedge their risks by diversifying their portfolios across different energy sources and geographic regions. This helps mitigate the impact of price fluctuations and geopolitical uncertainties.

Data Analytics and Forecasting

Utilizing advanced data analytics and predictive modelling, assists in anticipating market trends, optimizing trading strategies, and making informed investment decisions.

Risk Hedging financial instruments

Entering transactions in futures, options, and swaps to hedge against price volatility, they try to minimize exposures to sudden market changes.

Strategic Partnerships and Alliances

Collaborations with governments, other industry players, and technology firms can provide access to resources, expertise, and shared Risk Management strategies. This is not at all a common practice in financial companies.

Robust Compliance Measures

Implementing robust compliance and risk assessment frameworks ensures adherence to stringent regulatory standards, minimizing legal and operational risks.

Continual Innovation and Adaptation

Embracing all technological advancements, investing in research and development, and fostering a culture of innovation helps companies stay agile and competitive in a rapidly evolving landscape. Again, in a different order of magnitude than financial companies.

Benefits of Effective Risk Management

Whenever companies Implement a robust Risk Management framework, it offers a multitude of benefits to them, including:

Enhanced Financial Stability

By identifying and mitigating financial risks, companies can protect their profitability and safeguard their assets from potential losses.

Improved Operational Efficiency

Effective Risk Management helps companies identify and address operational risks, reducing the likelihood of disruptions, accidents, and environmental incidents.

Strengthened Reputation

Proactive Risk Management demonstrates a company's commitment to safety, environmental responsibility, and corporate governance, enhancing its reputation among stakeholders.

Informed Decision-Making

A comprehensive understanding of risks enables companies to make informed decisions about investments, operations, and risk transfer strategies.

Enhanced Resilience

By proactively managing risks, companies can build resilience and adapt to changing market conditions, regulatory environments, and technological advancements.

Comparing Financial with Energy Risks

An attempt to portray the correlation (or covariance, as we shall elaborate on that topic in the next chapters...) is summarized on the table below.

Again, note that energy companies "follow the trend" and are continuously "trained" on the "tricks of the trade" from financial companies.

Risk types

Risk Category	Financial Companies	Energy Companies
Market Risk	Exposure to fluctuations in interest rates, currency exchange rates, and equity prices	Exposure to fluctuations in energy prices, supply and demand imbalances, and geopolitical events
Credit Risk	Default risk of borrowers, counterparties, and other financial institutions	Credit risk of customers, suppliers, and other energy market participants
Operational Risk	Failures in information systems, fraud, and human error	Equipment failures, accidents, and environmental incidents
Regulatory Risk	Changes in financial regulations, accounting standards, and capital requirements	Changes in environmental regulations, safety standards, and energy efficiency standards
Reputational Risk	Negative publicity, scandals, and product recalls	Environmental damage, safety incidents, and corporate governance failures

Comparing Financial with Energy Risks

Risk Techniques

Technique	Financial Companies	Energy Companies
Diversification	Investing in a variety of asset classes to reduce exposure to specific risks	Diversifying energy sources and geographic operations to reduce exposure to supply and demand fluctuations
Hedging	Using derivatives financial instruments, such as options and futures contracts, to offset potential losses from market risk	Using advanced derivatives financial instruments, such as price caps and collars, to hedge against fluctuations in energy prices
Credit Risk Assessment	Evaluating the creditworthiness of borrowers and counterparties to mitigate default risk	Evaluating the creditworthiness of customers and suppliers to mitigate credit risk
Internal Controls	Implementing strong internal controls to prevent fraud and operational risks	Implementing strong operational controls to prevent equipment failures and accidents
Compliance Monitoring	Continuously monitoring compliance with regulations and standards to minimize regulatory risk	Continuously monitoring compliance with environmental regulations and safety standards to minimize regulatory risk
Reputation Management	Proactively managing public relations and corporate governance practices to protect reputation	Proactively managing environmental and social impacts, as well as corporate governance practices, to protect reputation

Trading (and investing) in energy markets

What are the main **differences** and **distinctive** characteristics that challenge an experienced financial trader/investor, while entering the energy market?

- Energy trading involves commodities that are challenging to transport and store, making physical delivery a crucial aspect. This complexity on its own, sets it many miles apart from other traded goods. Being thus way more intricate than financial trades, these physical transactions also yield potentially higher financial benefits.
- Certain energy products like electricity and heat can't be easily stored and must be created when needed. Transmitting them over long distances is expensive, so they're usually generated close to consumers. This divides the energy market into spot markets for immediate needs and forward markets for future expectations. Unlike stocks or bonds, energy spot and forward markets aren't closely connected because electricity for example can't be stored for later use.
- Energy trading involves complex spot markets governed by local regulations and physical constraints, contrasting with more liquid forward financial markets. While it might seem easier to focus on financial markets, understanding the physical markets is crucial due to their influence on various financial features. The complexity of these physical spot markets defines energy trading, with numerous distinct issues to manage.
- The energy market comprises several products related to producing and delivering electricity and heat, with natural gas and electricity being the most crucial. Other commodities like coal, carbon emissions, and alternative energy are secondary, while oil's significance lies more in powering vehicles than generating electricity and heat. However, oil's immense economic impact makes it pivotal across all aspects of energy trading. Oil seems to be “the one ring to rule them all” in energy markets while there is no such other “ring” in money or capital markets. The open interest in oil futures vs global actual production, proves it.
- In the energy market, traders, investors, and marketers play vital roles. Financial trading complements physical trading, requiring substantial capital for exploration or new plants, often sourced from investors. Local utilities utilize financial contracts to ensure steady fuel and electricity supply, while power plants engage in fuel purchase and electricity sale. Financial firms engage in power price speculation.
- Energy and Finance: Two interconnected worlds apart.

Key Risk concepts

Definitions of Risk / Manager / Management

Risk

The impact / effect / consequence of the uncertainty on our goals / objectives.

Risk Manager

The individual that monitors the financial stability of the company.

Risk Management

The art (science included) of decision making in an uncertain world.

The first steps

All organizations

- face risk and
- they [have to] deal with its results.

All these results

- are usually depicted in a form of a deviation from an expected result
- can face, create or lead to opportunities and threats
- are usually expressed as a function of sources, events, consequences and quantified with their respective probabilities.

The Risk Manager introduces coordinated activities to guide and control the organization with respect to risk.

Risk is no danger or uncertainty. Repeat.

Very common misconception. Difficult to grasp! How to explain it? To start, danger is always negative while risk is either positive or negative.

Furthermore, as risk we perceive any variability that can be quantified with probabilities. If it can't be quantified, it is simply called uncertainty. Easy. Now.

For example when we state that an investment has a 50% chance of a revenue of 100 €, a 40% chance of a loss of 30 €, and a 10% chance of losing 300 €, this is totally quantified, this is not at all uncertain, this has a calculated risk.

A day in the life of a Risk Manager

The Risk Manager has to deal with three main risk categories in a typical day.

Morning: Market Risk

Market analysis. This is a first priority, everything else can wait.

What market movements are we expecting today in the markets? How can these movements affect everyone's portfolios? Are we prepared? For everything? Really, prepared for everything? No. Let's do it then.

The Risk Manager has already produced the relevant reports from yesterday with all contingencies and probabilities - updating the report, is the first thing to do however, especially if there has been a big movement in some markets. With all these in his arsenal, the RM is confident that everything will proceed "as expected" - but also knows what must be done if black swan events occur.

Noon: Credit Risk

Credit risk assessment. What about the stability of the entities that we have exposure as lenders? What can affect them? How are their guarantees valued? Are there any new [credit] requests that need special handling?

Afternoon: Operational Risk

Operational supervision. Any operational issues somewhere? Was there a malfunction in our processes, in our systems (mainly IT but also in everything else), in our operations in general? How many of the mistakes (and errors) made, were not mistakes but were "mistakes"? What customer complaints do we have and, MOST IMPORTANT, what do we learn from them?

End of day: Reporting

With simple, comprehensible, all-inclusive, wide-ranging and "actionable reports" (more on that later), everyone (Board of Directors, management, general managers, department managers, executives, employees, supervisory authorities, ... everyone!) is notified and updated on everything of matter to them. Nothing else matters.

The relevant information is produced in drill-down-mode reports, scheduled, pre-planned or ad hoc. Everyone can analyze information in the level that concerns them, when they want, in exactly the format and data that suits them.

The information, flows continuously and in an escalated manner. No barriers or any obstacles intervene in any place of the organizational chart.

A brief history in Risk

The feeling that “something is missing”

Four factors contributed to establishing in the minds of managements and owners/shareholders the need to do something in the form of Risk Management – at first, not knowing exactly what, but “something” ...

1. Awareness

Companies have for many years realized that their performance is affected both by (a) the main sources / forms of risk (market, operational, credit) and (b) by newer forms that are constantly added, as a direct function of their activity. For many of them, the spot-on management of their risks was their "secret" strategic advantage. But what exactly is "spot-on" management?

2. Need from the market itself

The high volatility in the local and international markets, the increased supervisory requirements and the continuous international black-swan events, lead to the need for the creation of high-level Risk Management Unit (RMU) and departments that assist the management in its work and responsibilities. Since the impacts of the above events were minor in companies that employed a functioning Risk Management Unit, it was a "no-brainer" what had to be done.

3. Regulation

In the past, RMUs were established as a plain vanilla "response" to the regulatory environment and its requirements, among others, for the existence of a "Risk Management department that is independent of operational functions and has sufficient powers, authority, resources and access to the governing body". Many companies with active RMUs witnessed their operational advantages – as such, RMUs gained active roles in management.

4. Derivatives (... “the D word”)

Companies, buy, sell and create (the financial ones), derivative products with which they hedge against (or speculate on) financial risks. The first years were in many ways very "didactic". The educational method? “Learn by mistakes”!

With “what?” and “how did this happen?” being heard more than many times, everybody realized that the use of derivatives, without proper Risk Management, should simply be prohibited. Derivatives speculation and even the "simple" hedging should be prevented, where there was no proper RMU.

A definition of the three main risk categories

Market risk

Market risk is the risk of loss of value of financial instruments resulting from

- changes in market factors
- the volatility of these factors, and
- the correlations between market factors.

These factors and parameters, mainly include, but are not limited to, exchange rates, interest rates, the price of securities (stocks or bonds), commodities, derivatives and the value of other assets.

Credit risk

Counterparty credit risk is the risk of losses arising from market operations in the event that a counterparty defaults on its payment obligations. The future market value of the exposure and the credit quality of the counterparty are uncertain and may vary over time as fundamental / key market factors change.

Operational risk

Operational risk is the risk of losses arising from inadequacies or failures in processes, personnel or information systems, or from external events. Examples include: commercial litigation, disputes with authorities, errors in pricing or risk assessment (including risk modeling), trade execution errors, fraud and other criminal activities, fraudulent transactions, loss of operational resources, IT system outages, etc

An important note about the risk context

We have seen that depending on the context and the goal(s), the above definitions may change. For example, in a fund that tracks an index, the goal is zero tracking error and not any loss of value (as is the “common” definition of risk). This is the market risk for this fund – and it is called basis risk.

The future of Risk Management

No one can predict the role and requirements of the Risk Management function in the next ten years. As a proof, let's remember the markets ten years ago: no one could predict today's needs and requirements.

However, certain needs and trends are guaranteed to continue to dominate the industry, as well as the need to create more and more new needs and trends!

In a nutshell we expect (in all types of companies) more demand for:

- Comprehensive and understandable-by-all risk measurement reports
- Clear quantification models and dashboard reports
- Creation of new procedures for mitigating and handling risk events when they occur, "including" what we learn from experience
- Creation of all business policies and procedures with "embedded" or "integrated" Risk Management instructions, procedures, directives and guidelines. This, on its own, will disrupt all business processes.
- Intelligent navigation (big data analytics, AI) whether it is in stock prices, customer transactions, or sales data of our products to identify any "hidden" risk issues. Easier said than done, this will be the new competitive advantage of those who know how to harness its power.

Focusing on Energy Software to be used, we expect a huge growth in this category of software, aiming to support energy trading and Risk Management activities. Commonly referred to as energy trading, transaction, and Risk Management (ETRM) software, the new generations of these software packages will try to match and respond on the energy business complexities.

Current Risk Management software packages and toolsets, originate and were developed for the financial industry. They price risks and perform stress tests, but fail to deal with the physical side of the business for example in terms of measuring asset volume, storage or deliverability risk (to name some).

A typical configuration will connect these classic "islands" below, but with a much (much!) more different, revised and updated method!

- Front office – Execution and deal capture of physical and/or financial contracts
- Middle office – Risk Management
- Back office – Trade settlement and clearing

A brief history of the Energy Market

The evolvement

Energy Risk Management began when the New York Mercantile Exchange (NYMEX) launched the "**No. 2 heating oil**" contract in 1978. It was indeed a significant development in energy trading, particularly for heating oil, and played a key role in the evolution of energy Risk Management.

In April 1990, NYMEX played again a pivotal role by introducing the Henry Hub Natural Gas futures.

Environmental Risk Management began in 1995 with the launch of sulfur dioxide (SO2) emissions trading in the USA.

It may be argued that Risk Management existed before these dates in various forms, including regulatory measures, corporate initiatives, and environmental impact assessments in industries. However, organized markets with active participants, always signal the "real" Risk Management.

With these exchange-traded assets, the energy market transformed into a highly competitive, efficient, and liquid marketplace due to deregulation. The result was the expansion of the pool of market participants, leading to a highly competitive and efficient wholesale market, enhancing price discovery and the subsequent Risk Management applications in day-to-day business.

This evolvement had a little "secret" to its success though ...

What we learned from this evolvement?

The organized energy market usage and adaptation, is a perfect story to teach as a real-world-applied-answer to market requirements of the (futures) contracts for real trading needs. As is the case with all listed futures contracts, they offer price discovery (and price expectations) across time. These contracts however, differ from the money market or capital market contracts – the latter "include" only the simple time value of money and dividends in their pricing. The former, include "all the door-to-door business", namely transportation costs, warehousing costs, regional market price change conditions, etc. transforming them to a genuine price discovery mechanism.

Why and when did this happen? It took many years - the tipping point was when the energy producers were encouraged to support the futures contracts by providing liquidity, i.e. by actively participating in this market.

The key point of energy Risk Management

We know that in any market, especially listed derivatives, we need professional participants to "jump-start it". For example, we have a spot market for stocks. If we want a market of stock futures and options, we need market makers to quote prices on these stock derivatives. If there are no professional participants ("market makers") the derivatives market will not prosper.

These prices (derivative prices on money and capital market instrument) are very easy, intuitive and uncomplicated[1] to create. Stock futures prices, for example, equal spot stock price, increased by interest rate and decreased by dividends. A market maker, able to quote a futures and options price in a single stock, can quote all prices in all stocks. All it needed is a one page spreadsheet.

Commodities and energy products, require a different approach. An equity market maker would certainly fail trying to quote derivatives on Natural Gas or Electricity with the same formulas used for equity derivatives. Why? The door-to-door business of energy instruments pricing is many orders of magnitude more complicated that the money and capital markets' assets. We have not yet added the snags of their expiry date physical settlement complications ...

In conclusion, the key point is the need for presence of active players from the Energy Industry as trade participants in the organized Energy Derivatives Market.

We saw it in Henry Hub: the gas industry made the contract work. Period.

Conclusion

It is certain that Energy Risk Management, borrows its theory from the Financial Markets Risk Management, but it requires the continuous active participation of players from the energy industry. We witnessed the evolvement in organized derivatives Markets and Risk Management of Oil, Gas, Electric Power, Weather derivatives[2]), Emissions (SO2, CO2) and so

[1] A personal note here: I believe (and will happily debate any time with supporters of the concept that derivatives are dangerous, difficult and obfuscated instruments) that calculating the fair price of any stock future and option, is tremendously easier than calculating the fair price on the stock itself.

[2] Rather peculiar usage of "derivatives" word in weather, because there is no spot market in weather, so where is the price derived from? And on what do we hedge or speculate?

on. All grew to various degree of success, in direct correlation with their respective active market industry participants.

To summarize, all of these successful markets share one common "secret" principle: the active participation of real world, industry subject matter experts, trading and investing among hedgers and speculators both from the industry and outside it.

Bring Risk (with maths and statistics) In!

We compared earlier on the "Comparing Financial with Energy Risks" chapter the vis-à-vis application of risk types and techniques employed in these fields.

A big percentage of the Risk Analytics theory and Financial Engineering principles, is the same in Energy and Financial markets products used for Risk Management. (How could it differ?)

Prices in both "worlds", are daily quoted, and as such they have volatility which the key ingredient of option pricing. Volatility models are used to estimate the probability of future price movements, which are then incorporated into derivatives pricing formulas. This process allows market participants to hedge against potential price risks and speculate on future price directions.

Both markets, employ concepts such as probability theory, statistical analysis, and portfolio optimization techniques to assess and manage risks associated with price fluctuations. These principles are applied to develop pricing models, hedging strategies, and Risk Management frameworks that are tailored to the specific characteristics of each market.

The constant need for actionable risk reports must be continuously answered.

Finally, the expedition of "Seeking Risk vs Reward", is exactly the same trek in our daily journeys in all markets ...

In next chapters, we will focus on exactly these topics.

We will use examples for these concepts from the simplest (in a math way) market of all, the one with the less idiosyncrasies and quirks in its instruments: the equity market.

Market Risk Measurement

Statistics

Statistics is one way to describe and quantify the market. As we analyze prices, and their returns, we are interested to communicate our findings to others.

Single asset study – Variance and Standard Deviation

Let's borrow terms and theory from statistics as we study a single asset. A stock for example. What do we want to know about our stock?

- Did it go up or down?
- At what rate did it do it?
- How smoothly did it do it?
- How "predictable" is its path?

The way we calculate them is:

- We calculate the daily returns of a stock (Xi in the table →).
- We compute their average.
- For each daily return we calculate its difference from the AVG.
- We square this difference.
- We calc the average of the above – this is the Variance
- We take the square root of the above – this is the Deviation

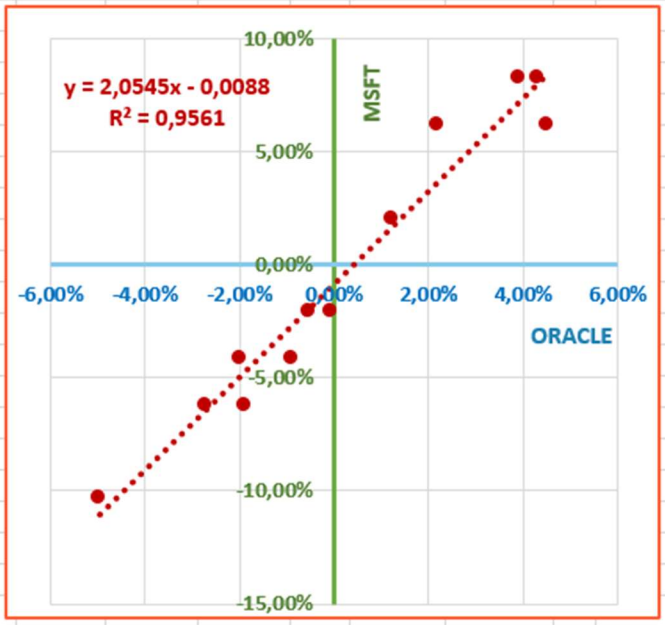
	IBM		
	Xi	Xi-AVG	(Xi-AVG)^2
	1,55%	1,21%	0,00015
	1,91%	1,56%	0,00024
	2,47%	2,12%	0,00045
	2,75%	2,41%	0,00058
	-4,86%	-5,20%	0,00270
	-0,12%	-0,46%	0,00002
	0,62%	0,27%	0,00001
	3,46%	3,12%	0,00097
	-0,42%	-0,76%	0,00006
	-1,29%	-1,63%	0,00027
	-0,96%	-1,30%	0,00017
	-0,99%	-1,33%	0,00018
AVERAGE	0,34%	Variance	0,00048
STDEV.P	2,20%	SQRT	2,20%

In this example, IBM has an average daily return of 0,34%, a Variance of 0,00048, and a Standard Deviation of 2,20%.

NOTE: The Standard Deviation has the same units as the original values it measures (eg daily return here), while Variance has squared values and units (ie here it is daily-return-squared. What?). And this is very hard to understand intuitively). And this is exactly the reason why we use Standard Deviation instead of Variance: it's easier to interpret.

Two assets study – Covariance and Correlation

	ORACLE			MSFT		
	Xi	Xi-AVG	(Xi-AVG)^2	Yi	Yi-AVG	(Yi-AVG)^2
	-1,98%	-2,24%	0,00050	-4,13%	-3,79%	0,0014
	-1,90%	-2,16%	0,00047	-6,20%	-5,85%	0,0034
	1,23%	0,97%	0,00009	2,07%	2,41%	0,0006
	4,32%	4,06%	0,00165	8,27%	8,61%	0,0074
	3,91%	3,65%	0,00133	8,27%	8,61%	0,0074
	4,50%	4,25%	0,00180	6,20%	6,54%	0,0043
	-0,53%	-0,79%	0,00006	-2,07%	-1,72%	0,0003
	-0,88%	-1,14%	0,00013	-4,13%	-3,79%	0,0014
	-2,71%	-2,97%	0,00088	-6,20%	-5,85%	0,0034
	2,18%	1,93%	0,00037	6,20%	6,54%	0,0043
	-4,96%	-5,22%	0,00273	-10,33%	-9,99%	0,0100
	-0,07%	-0,33%	0,00001	-2,07%	-1,72%	0,0003
AVERAGE	0,26%	Variance	0,00084	-0,34%	Variance	0,00369
STDEV.P	2,89%	SQRT	2,89%	6,07%	SQRT	6,07%
CORRELATION (X, Y)		0,97780				
COVARIANCE		0,00172				



Let's study two stocks: ORACLE and MICROSOFT.

Statistics tells us that

- Microsoft has a Standard Deviation of 6,07%
- Oracle has a Standard Deviation of 2,89%
- Their Correlation is 0,97780 and their Covariance is 0,00172
- A linear regression shows that MSFT has a beta (β) of 2,05 agains ORACLE with an R^2 of 95,61%.
- Alpha is -0,0088 (or -0,88%).

Pause!

What **exactly** do these numbers mean? All these statistics will be used in our Volatility, and Risk vs Return analytics trek in the next paragraphs.

For the time being, lets note some very important characteristics, easy to baffle and puzzle the market participants[1] on the above concepts.

Moving together is the same with correlated?

Requiring to describe how exactly do these two stocks "move together", involves to find in practice:

- The degree that the two variables move "jointly" (direction, intensity)

[1] Another personal note here: "Been there, done that, got the T-shirt".

- How can this relationship be expressed in a mathematical formula, that is, if we are able to find an equation/function that relates the two variables.

Let's dive deeper – the many red highlights demonstrate the areas of confusion.

Correlation

Correlation measures the direction and strength of the relationship between two sets of observations (e.g., daily changes of asset prices).

The sign of the correlation determines the direction: If it is...

- positive, it means that above-average values of one variable tend to "pair" with above-average values of the other.
- negative, it means that the above-average values of one variable tend to "pair" with the below-average values of the other.

The magnitude of the correlation measures the strength of the association, or better, it measures the strength of the linear relationship between the two variables. If the correlation is perfect, this means that all the points (Xi, Yi) are falling exactly on a straight line!

The correlation ranges between -1 and +1 and is unit free! Highly desirable qualities, both of them.

Covariance

The covariance between two variables is a number that shows how much the two variables "intertwine". If the number is

- large and positive, it shows us that the i's whose Xi values are greater than the average value of the Xi's coincide with those whose Yi's are greater than the average value of the Yi's.
- large and negative, it shows us that the i's whose Xi values are greater than the average value of the Xi's coincide with those whose Yi's are less than the average value of the Yi's.
- small, it is of no use for many reasons. (More, later).

Variance, Covariance, Correlation: Fun Facts.

Harder than it looks, terms like deviation and correlation have a specific meaning which is not open to personal interpretation. The Risk Manager needs to understand those terms and to be able to communicate and explain them again and again to all interested colleagues.

We present some “if only I knew it before” type remarks, mostly from common mistakes in these concepts from market participants.

- Covariance has a “disadvantage” or “flaw” by definition: It does not have a normal scale, nor can we tell by looking at it whether it is small or large.
- As such, as we will often encounter tables with asset covariances, it is comforting to keep in mind that what we are ultimately interested in comparing the relative numbers with each other (with a heatmap for example) and NOT the absolute numbers as such.
- Correlation and covariance have the same sign. Easy.
- Correlation is normalized covariance (in the interval -1...1). Easy.
- Correlation zero. What does this mean? It does not mean that there is no relationship between the two variables. (What?) It means that there is no linear relationship between them (WHAT?!?!). For example, if the changes in an equity index are -2%, -1%, 0, 1%, 2% and the stock is the same values squared, or the same positive values (absolute value) then the correlation is zero while there is a clear relationship between them. (Try it in a spreadsheet).
- The covariance of a variable with itself is equal to the variance of that variable: cov(x, x) = variance(x).
- We reiterate: High covariance says nothing about the correlation between the two variables. If, for example, one asset represents measurements from very large (numerical) numbers and the other has very small, then they will have high covariance even though they are "unrelated" series. Kilometers with centimeters. Kilos with grammars. This is one reason (among others of course) that in financial engineering we examine equity returns and not equity prices. Easy. (Now).
- Correlation has nothing to do with beta – i.e. it says nothing about how one variable will move in relation to the other. We will dive in it later. For the moment, note a common mistake “IBM has beta 2, hence it is very nervous, hence it has big volatility (deviation)”. Wrong. Wrong. Wrong.
- Deviation has nothing to do with the trend of the stock. Nothing.

Variance, Covariance, Correlation: a cheat sheet

Variance (σ^2)

- Is the mean squared distance from the mean value.
- Measures the spread of prices around it.

Standard deviation (σ) - stdev

- Is the square root of variance.
- Measures volatility ie the average "degree" that each value differs (is away) from the mean value.

Covariance

- Is the directional relationship between two variables.
- Measures the covariance (that is, their relationship as they "move" together) between two random variables.

Correlation (Correlation coefficient, better)

- The normalized version of the covariance.
- It measures to what extent (or, "the force with which") the two variables move relative to each other.
- It is a number between -1 (moving oppositely) and +1 (moving the same).
- If it is 0, it means that they move independently, that is, if one goes up, the other has a 50% chance of going up. Or down!!!

Risk Adjusted Performance & Analytics

What are we looking for?

In any portfolio analysis we are ultimately concerned about three factors.

- Performance — The return is only half the picture, however ...
- Comparison — ... use a benchmark to completes the picture a bit, but ...
- Risk — ... how much risk did we assume to achieve this return?

[Lucky?] — The unspoken factor.[1] How can we prove if [our] performance was skill and not pure luck?

These three (…) factors, grow to an exponential number of questions – let's prove it with an example: we analyse two portfolios, A and B with returns of 12% and 15%.

"HOMEWORK"

If you want to *really* appreciate the concepts and the significance of the remaining paragraph, **pause** on this page and write down as many questions as **you** would ask a financial advisor, while you discuss about choosing to invest **your** money on a portfolio A or a portfolio B. Compare afterwards your list with ours.

Help:

- What questions should you ask as an investor?
- What topics should a risk manager address in presenting these portfolios to an investing committee?
- What questions did the financial advisor prefer to remain hidden and why?

[1] The fourth factor, is known among the market wizards as "You-Know-Who" in tandem with "He-Who-Must-Not-Be-Named" in Hogwarts School of Witchcraft and Wizardry...

How many questions did you create? On what topics?

A sample of the questions that [should] arise on the A, B comparison are:

Performance Comparison

- Is portfolio B a better investment than portfolio A? Better on what?
- How does the historical performance of the portfolios compare to each other and to the overall market?
- Which portfolio is more consistent in its performance over time (in different market cycles) and how does this consistency impact long-term returns?
- Under what market conditions would one portfolio perform better than the other? How probable are these conditions?

Risk Assessment

- If we assumed twice the risk in portfolio B, are we happy with its potential returns? What is the break-even risk level?
- How can we determine if portfolio B's performance is due to skill or luck?
- What percentage of the portfolio's return variance can be attributed to market factors (equity prices) versus manager-specific factors?
- How would changes in other factors (foreign exchange or interest rates) affect the performance of each equity portfolio?
- Sector risk: Considering the sectoral diversification between A and B, how does this factor into their risk profiles and potential for returns?
- How does the diversification of each portfolio affect their risk profiles?
- How do we measure and quantify the diversifications above?
- How do the standard deviations of returns for portfolios A and B compare over the same timeframes? In various timeframes, that is.

Investment Decisions

- How do the transaction costs, liquidity, and alignment with investment goals compare between the portfolios?
- How would we rebalance the portfolios to maintain the desired asset allocation? How often do I [have to] recalculate these balances?
- How liquid are the holdings of each portfolio? How might this impact decision-making for short-term cash needs?

Risk Adjusted Performance & Analytics

- We have fresh cash to invest. Where is it worth to invest? We of course want to get the most return per unit of risk we assume, consequently ...
- We need fresh cash for a land purchase. From which portfolio is it better to get this cash, from A, from B, or (what percentage) from both?

Risk-Adjusted Performance

- What are the potential capital gains or losses associated with each portfolio?
- What are the potential tail risks associated with each portfolio?
- Which are the risk-adjusted returns of portfolios A and B?
- How exactly does the correlation of their assets affect the overall risk of each portfolio?
- How does sector risk and the presence of outlier events affect the assessment of risk and return in both portfolios? Is it clear?
- What percentage of the portfolio's return variance can be attributed to market factors (beta) versus manager-specific factors (alpha)?
- If Portfolio A has higher historical returns but lower diversification, how does this influence the perception of its risk-adjusted performance compared to Portfolio B? (This is a tough nut to crack)
- If Portfolio A outperformed the benchmark in a bull market but underperformed during market downturns, how does this influence the assessment of skill versus luck in managing risk? (Another tough nut).
- If Portfolio B demonstrates higher volatility but also includes low-correlated assets, how does this affect the evaluation of its risk compared to Portfolio A? (The tougher nut, so far).
- Which portfolio, A or B, is more consistent in its performance over time?

Skill vs. Luck

- How can we measure our absolute performance and compare it to a benchmark to determine whether our portfolio management is skilful or lucky? In clear numbers.
- How does the performance of each portfolio compare to a simple buy-and-hold strategy? (The simplest eye opener, many times, for skill vs luck).
- How does the performance of the portfolios in different market cycles influence the assessment of skill versus luck?
- Can we conduct a regression analysis to isolate the impact of skilful stock selection, market timing, and luck on the returns of each portfolio? If yes, how, if no why?

Additional Factors

- What level of active management is required for each portfolio? How does the effort and time commitment differ between managing portfolio A versus portfolio B?
- How do the standard deviations of returns for the portfolios compare? Single timeframe, the whole period.
- How does the consistency of performance in different market cycles impact long-term returns?
- Have the portfolios' returns been statistically different from those of a randomly selected portfolio? ("What happens if this turns true?")
- How much diversification does each portfolio offer? Quantify in numbers.
- Which portfolio is more aligned with my overall investment goals and risk tolerance? Chart all of them.

ESG Considerations

- How do the portfolios incorporate ESG (Environmental, Social, and Governance) principles into their investment strategies?

Now, this is a good time (and proper place) to stop generating questions. You get the idea; the list is endless. The opening of the ESG door is just a sample of what more can be requested. A good Risk Manager opens more doors.

A Risk Manager has this list in its shelf, prepares and evaluates all of these topics automatically, quantifies them, and presents every time the top 10 that differ more that the average or the perception, or the top three from each category.

We do not flood the reader with info.

Never.

Cherry pick is the name of the game.

Risk analytics in practice

First Look: Diversification and Market Sensitivity

Two indicators will concern us here, beta (b) and R2. Both of these indicators show the degree that a portfolio's changes/returns are due to the movements of the broader market, commonly expressed with an index.

Beta

Beta is used to assess a portfolio's “responsiveness” to market changes. It tells us how a portfolio's returns might fluctuate relative to a chosen benchmark, usually a market index such as the S&P 500.

Beta (b) = Cov(Rp, Rm) / Var(Rm)

- Rp = Portfolio's return
- Rm = Market's return
- Cov(Rp, Rm) = Covariance between Rp and Rm
- Var(Rm) = Variance of Rm

Use and interpretation of b

Suppose ACME stock's b is 1.2 relative to the S&P500. This means that ACME moves 20% "more" than the S%P500, meaning if the S&P500 goes up 2%, then ACME will go up 2.4%.

b (SLOPE function in EXCEL) is just that: the slope of the line relating the stock's return to the market's return. For every 1% movement on the x-axis (market) we will have 1.2% movement on the y-axis (stock).

In practice

- If b > 1 or b < -1, then the stock is aggressive (it has greater volatility than the market)
- If -1 < b < 1 then the stock has lower volatility
- If b = 1 then the stock moves like the market.
- If b = 0 then the stock moves unaffected by the market.
- If b = -1 then the stock moves exactly opposite to the market.

- All of the above apply to stocks that tend to move "close" to the market and we want to compare them to the market. For example, there is no point in interpreting beta if it is, say, 5 and/or if R^2 is too small. This means that this stock is simply moving very nervously. Period.
- b on its own tells nothing, we must also examine R^2.

R^2

It shows the extent to which the variance of one variable (the asset) explains the variance of the second variable (the reference index). It is a number between 0 and 1 and is expressed as a percentage.

$R^2 = [Cov(Rp, Rm)^2] / [Var(Rp) * Var(Rm)]$

- Rp = Portfolio's return
- Rm = Market's return
- Cov(Rp, Rm) = Covariance between Rp and Rm
- Var(Rp) = Variance of Rp
- Var(Rm) = Variance of Rm

Use and interpretation of R^2

- R^2 tells us how much of the change in our dependent variable (stock, y-axis) is explained by changes in the independent x variable (market).
- If R^2 is 57%, this means that 57% of our portfolio movements are explained by b.
- If R^2 is 15%, this means that 85% of the changes in the portfolio are purely due to its constituent stocks and not the market.

Practical use of b and R^2 in combination: Suppose ACME has a previous year b=1.2 and R^2 = 30%. This means that 30% of its fluctuations can be explained by market movements, where then for every 1% market movement, ACME moved 1.2%, while the remaining 70% were exclusively its own moves.

Second Look: Portfolio Performance metrics

Alpha (Jensen's Alpha)

It is equal to the difference of the stock return from the return explained by the market model (CAPM).

$A = Rp - [Rf + b (Rm - Rf)]$

- Rp = Portfolio's expected return
- Rf = Risk-free rate
- b = Beta (systematic risk of portfolio)
- Rm = Market's expected return

Practically, it tells us whether a stock's returns are above or below market returns.

Example

- The fund QQQ has a return of 12%, the market has a return of 7%, the risk free rate is 3% and the beta of the fund is 1.2
- a = 12% - [3% + 1.2 * (7% - 3%)] => a = +4.2 %

Practical issues

- Alpha is limited to comparing portfolios with similar beta.
- It makes no sense to compare "dissimilarly behaved" portfolios with alpha.
- In the end, it does expose the "talent" of each fund manager. Skill vs luck, remember?
- Like all risk analytics ..
  - there is no one-size-fits-all concept.
  - there has been a lot of "gaming" in the markets with pseudo-scientific articles in the form of "seeking alpha" which further mislead investors.

Third look: Risk metrics

We arrive now - finally - at the heart of risk measurement.

Standard deviation

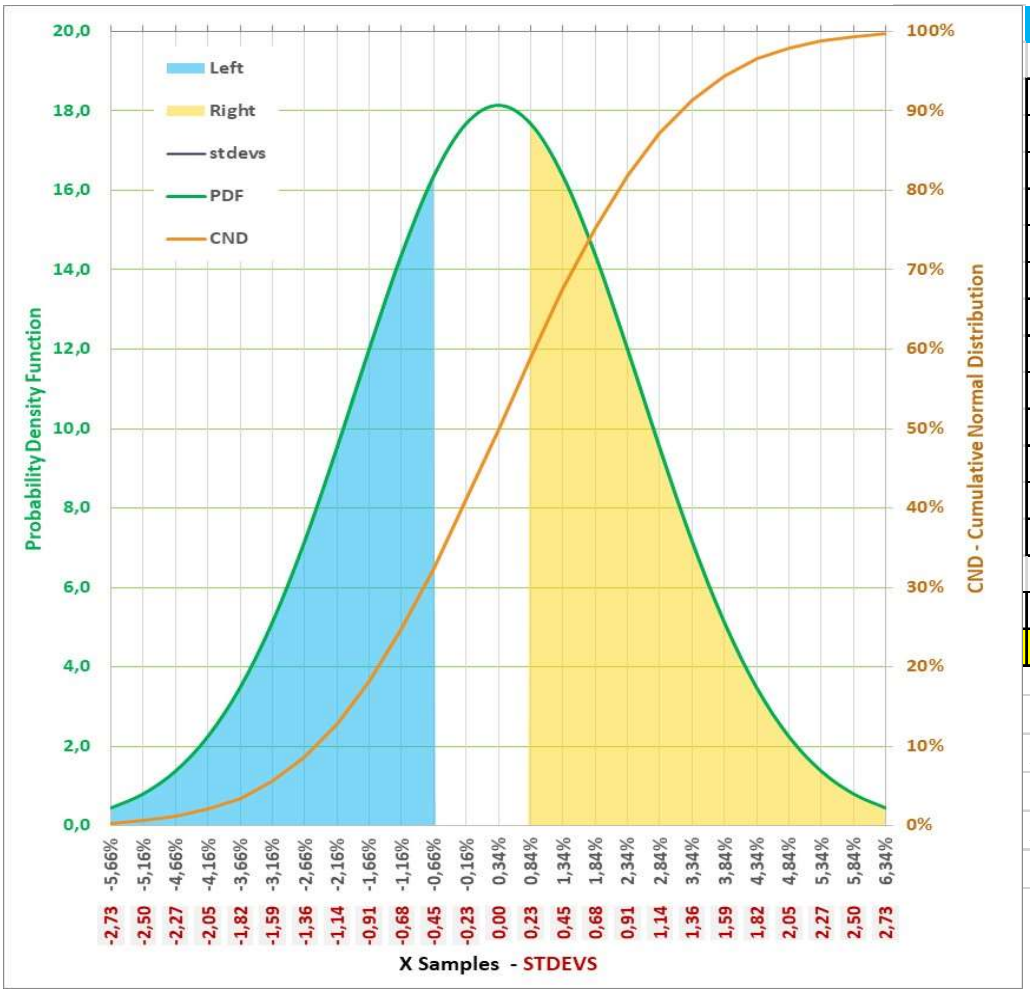
It is the "hardest easy" topic to understand deeply and truly. It requires a lot of attention and it would be good not to "overcome" it but to understand it, so that concepts like σ and σ^2 don't confuse us either!

The standard deviation quantifies the extent to which a set of data deviates from its mean and thus depicts their dispersion. (Repeat).

$$(\sigma) = \sqrt{[\Sigma (Xi - \mu)^2 / N]}$$

- Xi = each individual price (eg daily stock return)
- μ = the average value of our values
- N = the number of the data

Example



IBM		
Xi	Xi-AVG	(Xi-AVG)^2
1,55%	1,21%	0,00015
1,91%	1,56%	0,00024
2,47%	2,12%	0,00045
2,75%	2,41%	0,00058
-4,86%	-5,20%	0,00270
-0,12%	-0,46%	0,00002
0,62%	0,27%	0,00001
3,46%	3,12%	0,00097
-0,42%	-0,76%	0,00006
-1,29%	-1,63%	0,00027
-0,96%	-1,30%	0,00017
-0,99%	-1,33%	0,00018
0,34%	Variance	0,00048
2,20%	SQRT	2,20%

		Probability	stdevs
X1 <=	-0,50%	35,13%	-0,38
between		17,77%	
X2 >=	0,50%	47,10%	0,07
		100,00%	

Let Xi be the daily returns of IBM for a period of 7 days. The mean return is 0,34% and the standard deviation is 2,20%. If we assume that IBM's returns follow a normal distribution, then we know (statistics) the probability that the daily return will be in a certain range of values, expressed as standard deviations from the mean (68,3% +- 1 σ // 95,4% +- 2 σ // 99,7% +- 3 σ) or equal to a certain value. For example, IBM has

- a probability of 17,77% to trade in the range of -0,50% and +0,50%
- a probability of 35,13% to trade below -0,50%
- a probability of 47,10% to trade above +0,50%

We will see that this range, translated as a distance from the mean, is a key issue for the VaR risk measure.

FUN FACT: Volatility IS NOT Standard Deviation. But it is!

Standard deviation is a statistic, it measures dispersion across a data set and it is calculated by a formula.

Volatility is how much something tends to move. We may choose to measure volatility in a stock by the low-high range, for example.

However, **market participants choose standard deviation to measure volatility**. In an equity for example, volatility is the (annualized) standard deviation of its continuously compounded returns and it measures the likely dispersion of prices between two periods of time.

It is clear now that volatility is not the same with standard deviation, and why it is often considered to be.

Note that volatility has nothing to do with the profit or loss of a stock path. We may have one-year period, ten stock returns with the same volatility, with the annual returns ranging from -20% to +20%, all with the same volatility of 16%.

Final look: Risk adjusted performance metrics

We've seen that we don't "care" as Risk Managers about the return on our investment, but how we got there (ie what risk we assumed, both in systemic and also in specific risk).

To keep it simple, we are also ultimately interested in the following: ...

... (will) we have more return if we assume more risk?

In other words, and this is the key point.

... are we being rewarded enough for the additional risk we assume?

Sharpe ratio

The Sharpe ratio measures the excess return that an investment generates for each unit of risk assumed, relative to a risk-free investment (Risk free rate).

Risk is related to the risk (standard deviation) of the portfolio itself.

Sharpe Ratio = (Rp – Rf) / σp

- Rp = Return of portfolio
- Rf = Return of risk-free rate
- σp = standard deviation of the portfolio

Treynor ratio

The Treynor ratio measures the excess return that an investment generates for each unit of risk assumed, relative to a risk-free investment (Risk free rate).

The risk is related to the systemic risk of the portfolio (ie against the market), expressed by b.

Treynor ratio = (Rp – Rf) / b

- Rp = Return of portfolio
- Rf = Return of risk free rate
- b = beta (systemic risk of the portfolio) against a benchmark index

Practical notes on Sharpe and Treynor ratios

- Treynor Ratio and Sharpe Ratio are similar – both are effective return for risk. HOWEVER, they use "different" risks:
  - the Sharpe Ratio is divided by the risk of the asset
  - the Treynor Ratio divided by beta (the risk inherent in the market)
- The Sharpe ratio is used to measure performance (and is meaningful) for all portfolios, while the Treynor ratio is only for well-diversified portfolios. In practice, we ignore the Treynor ratio if the portfolio is not diversified.
- The Treynor ratio helps us compare portfolios with similar risk profiles.
- If the portfolio is well diversified, then it will have a Sharpe ratio close to that of the market.
- The Sharpe ratio shows us a better “picture” of the past and the Treynor ratio "predicts" the future better.
- Well-diversified portfolios tend to have high Sharpe and Treynor ratios, while poorly diversified portfolios tend to have low Sharpe and Treynor ratios. This is why diversification is an important principle of portfolio management. By diversifying their portfolios, investors can reduce their risk and improve their risk-adjusted returns.

Numerical example and interpretation

Suppose a portfolio has

- expected return 10%
- the Risk Free rate is 3%
- the standard deviation σ of portfolio returns is 12%
- the beta of the portfolio is 1.3.

We have

- Sharpe ratio = (10% - 3%) / 12% = 0.5833
- Treynor ratio = (10% - 3%) / 1.3 = 0.0538

Interpretation

- Sharpe: for each unit of risk (σ), the portfolio creates 0.5833 units above the risk free rate.
- Treynor: for each unit of systemic risk (b), the portfolio generates 0.0538 units above the risk free rate.

Risk adjusted return on Capital

We have five traders that invested € 1 mio each, choosing one stock each. After one year, the results were as follows:

	AAPL	MSFT	AMZN	GOOG	TSLA
RETURN	17,60%	2,60%	-3,72%	-0,79%	23,74%

	Trader 1	Trader 2	Trader 3	Trader 4	Trader 5
Start Capital	1.000.000	1.000.000	1.000.000	1.000.000	1.000.000
End Capital	1.175.985	1.026.040	962.804	992.068	1.237.383
End PL	175.985	26.040	-37.196	-7.932	237.383

The question is: the TESLA trader made the more money, but was he the better of the five? What is the criterion for the “better?” As risk managers, we put the stdev in the picture.

	AAPL	MSFT	AMZN	GOOG	TSLA
RETURN	17,60%	2,60%	-3,72%	-0,79%	23,74%
STDEV	1,73%	1,58%	1,87%	1,63%	4,42%
RETURN/STDEV	1015,58%	165,16%	-199,08%	-48,59%	537,51%

It seems now that AAPL is better choice. Double better? What is the RETURN/STDEV meaning intuitively?

Normalizing the risks above, we calculate the € positions that all traders must have, under the assumption that all positions have the same risk of € 20000.

Risk Adjusted Capital	17.328	15.767	18.685	16.325	44.163
	AAPL	MSFT	AMZN	GOOG	TSLA
Equal Risk, Adjusted Start Capital	1.154.172	1.268.510	1.070.403	1.225.125	452.868
End Adjusted Capital PL	203.117	33.032	-39.815	-9.717	107.503

If management allocates these "Adjusted Start Capital" in these traders, then all traders will have positions with equal risk.

Note that their final returns, are exactly proportional for each of the five stocks to the respective return / stdev ratio. Check the heatmap as well. This quantifies and depicts in the best way the return / stdev sharpe ratio.

Bonus time

Time for a bonus of € 100.000 – a fair allotment would be on trader #1, #2 and #5, of € 59.105, € 9.612 and € 31.282 respectively.

Efficient frontier

We know that diversification of investments creates a portfolio with reduced risk and higher sharpe ratios that the individual assets' risk and risk/return.

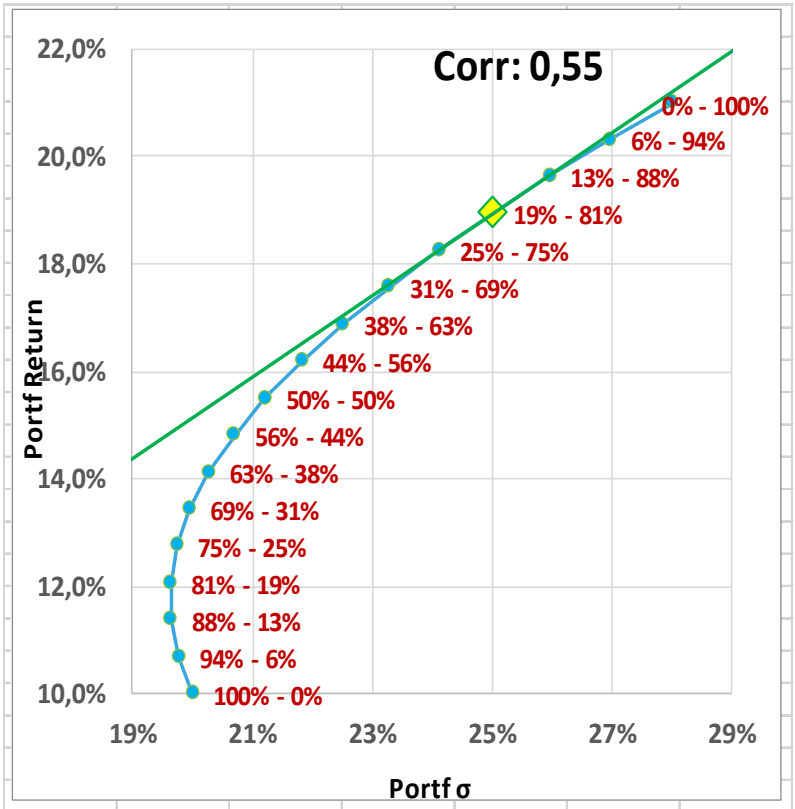
We will analyse in depth these concepts with an example of a two-asset equity portfolio, stock A (IBM, **σ** 20% and return 10%) and stock B (MSFT, σ 28% and return 21%). The stocks have a correlation of 0,55%

From this data only, we produce the following efficient frontier chart.

Each point in the efficient frontier curve represents a portfolio that offers the highest expected return for a given level of risk. In other words, it represents the best possible trade-off between risk and return.

With correlation 0,55 the efficient frontier curve is a left bending curve. It starts on (20,10) and ends to (28,21).

The optimum sharpe ratio is 0,7573 and lies on 20,50 - 79.50 weights with a portfolio σ of 24,75% and return 18,74%



	σ	Return
IBM	20,00%	10,00%

	σ	Return
MSFT	28,00%	21,00%

The Capital Market Line which is the line that represents all portfolios that are composed of risk-free assets and risky assets, is tangent to the efficient frontier line, crossing it on the optimum sharpe ratio point.

Various combinations of the weights of the risky assets, produce different risk/return characteristics on our portfolio.

Efficient frontier

	σ	Return	Sharpe
IBM	20,00%	10,00%	0,50
MSFT	28,00%	21,00%	0,75

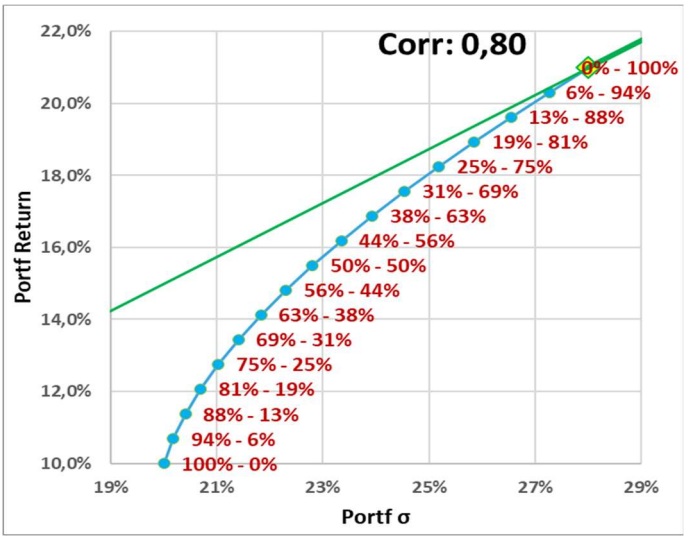
STOCK WEIGHTS		PORTFOLIO σ FOR DIFFERENT PORTFOLIO WEIGHTS AND CORRELATIONS									
IBM	MSFT	Correlation									Portfolio Return
	24,75%	-1,00	-0,75	-0,50	-0,25	0,00	0,25	0,50	0,75	1,00	
0,00%	100,00%	28,0%	28,0%	28,0%	28,0%	28,0%	28,0%	28,0%	28,0%	28,0%	21,00%
10,00%	90,00%	23,2%	23,7%	24,3%	24,8%	25,3%	25,8%	26,3%	26,7%	27,2%	19,90%
20,00%	80,00%	18,4%	19,6%	20,7%	21,7%	22,8%	23,7%	24,6%	25,5%	26,4%	18,80%
30,00%	70,00%	13,6%	15,6%	17,4%	19,0%	20,5%	21,9%	23,2%	24,4%	25,6%	17,70%
40,00%	60,00%	8,8%	12,0%	14,6%	16,7%	18,6%	20,3%	21,9%	23,4%	24,8%	16,60%
50,00%	50,00%	4,0%	9,3%	12,5%	15,0%	17,2%	19,1%	20,9%	22,5%	24,0%	15,50%
60,00%	40,00%	0,8%	8,2%	11,6%	14,2%	16,4%	18,3%	20,1%	21,7%	23,2%	14,40%
70,00%	30,00%	5,6%	9,5%	12,2%	14,4%	16,3%	18,0%	19,6%	21,0%	22,4%	13,30%
80,00%	20,00%	10,4%	12,4%	14,1%	15,6%	17,0%	18,2%	19,4%	20,5%	21,6%	12,20%
90,00%	10,00%	15,2%	16,0%	16,8%	17,5%	18,2%	18,9%	19,6%	20,2%	20,8%	11,10%
100,00%	0,00%	20,0%	20,0%	20,0%	20,0%	20,0%	20,0%	20,0%	20,0%	20,0%	10,00%

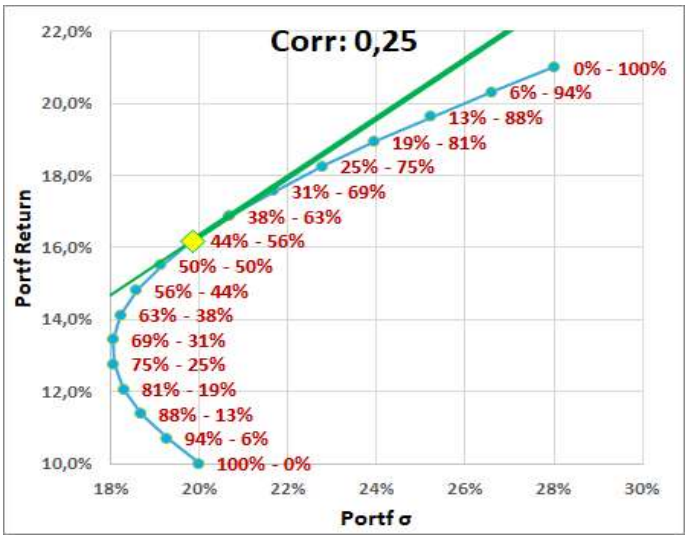
STOCK WEIGHTS		PORTFOLIO SHARPE FOR DIFFERENT PORTF WEIGHTS AND CORRELATIONS									
IBM	MSFT	Correlation									Portfolio Return
	0,76	-1,00	-0,75	-0,50	-0,25	0,00	0,25	0,50	0,75	1,00	
0,00%	100,00%	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	21,00%
10,00%	90,00%	0,86	0,84	0,82	0,80	0,79	0,77	0,76	0,74	0,73	19,90%
20,00%	80,00%	1,02	0,96	0,91	0,86	0,83	0,79	0,76	0,74	0,71	18,80%
30,00%	70,00%	1,30	1,13	1,02	0,93	0,86	0,81	0,76	0,72	0,69	17,70%
40,00%	60,00%	1,89	1,38	1,14	0,99	0,89	0,82	0,76	0,71	0,67	16,60%
50,00%	50,00%	3,88	1,67	1,24	1,03	0,90	0,81	0,74	0,69	0,65	15,50%
60,00%	40,00%	18,00	1,75	1,24	1,01	0,88	0,78	0,72	0,66	0,62	14,40%
70,00%	30,00%	2,38	1,40	1,09	0,92	0,81	0,74	0,68	0,63	0,59	13,30%
80,00%	20,00%	1,17	0,99	0,87	0,78	0,72	0,67	0,63	0,59	0,56	12,20%
90,00%	10,00%	0,73	0,69	0,66	0,63	0,61	0,59	0,57	0,55	0,53	11,10%
100,00%	0,00%	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	10,00%

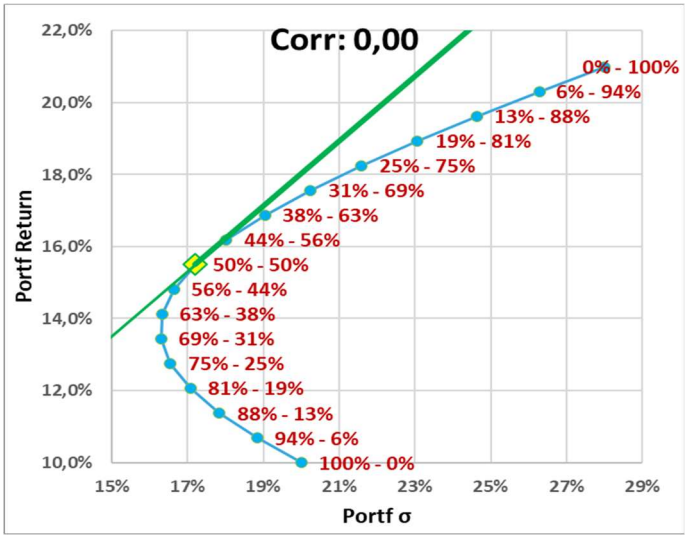
A heatmap table, wonderfully depicts all these combinations. All combinations produce a **portfolio return** from 10% to 21% (self-evidently), **σ** from 20% to 28%, curving lower as correlation decreases and **sharpe ratio** from 0,50 to 0,75, curving up as correlation decreases

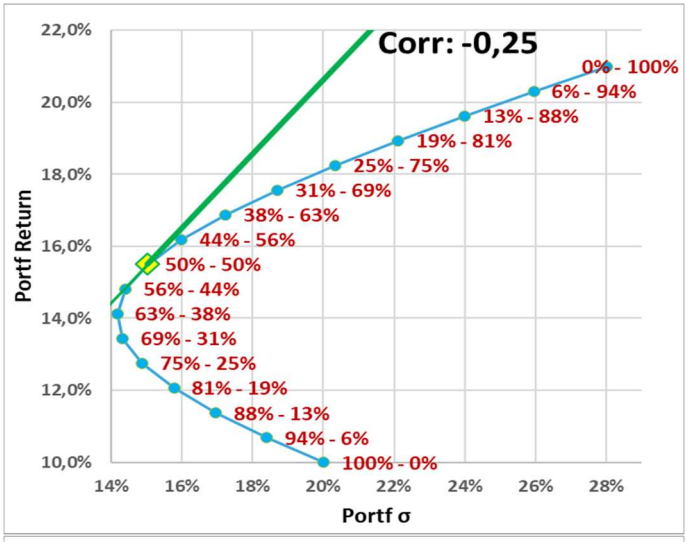
On the next page we plot the efficient frontier and capital market lines for various correlations. The lower the correlation, the higher left curve bending.

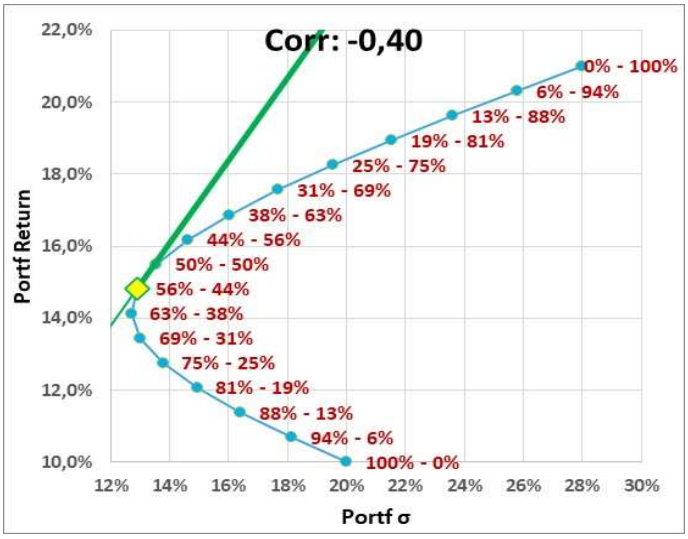
Efficient frontier

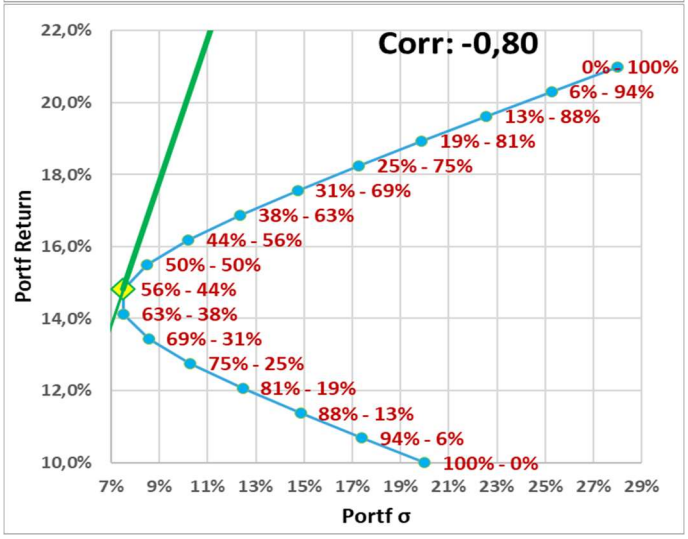




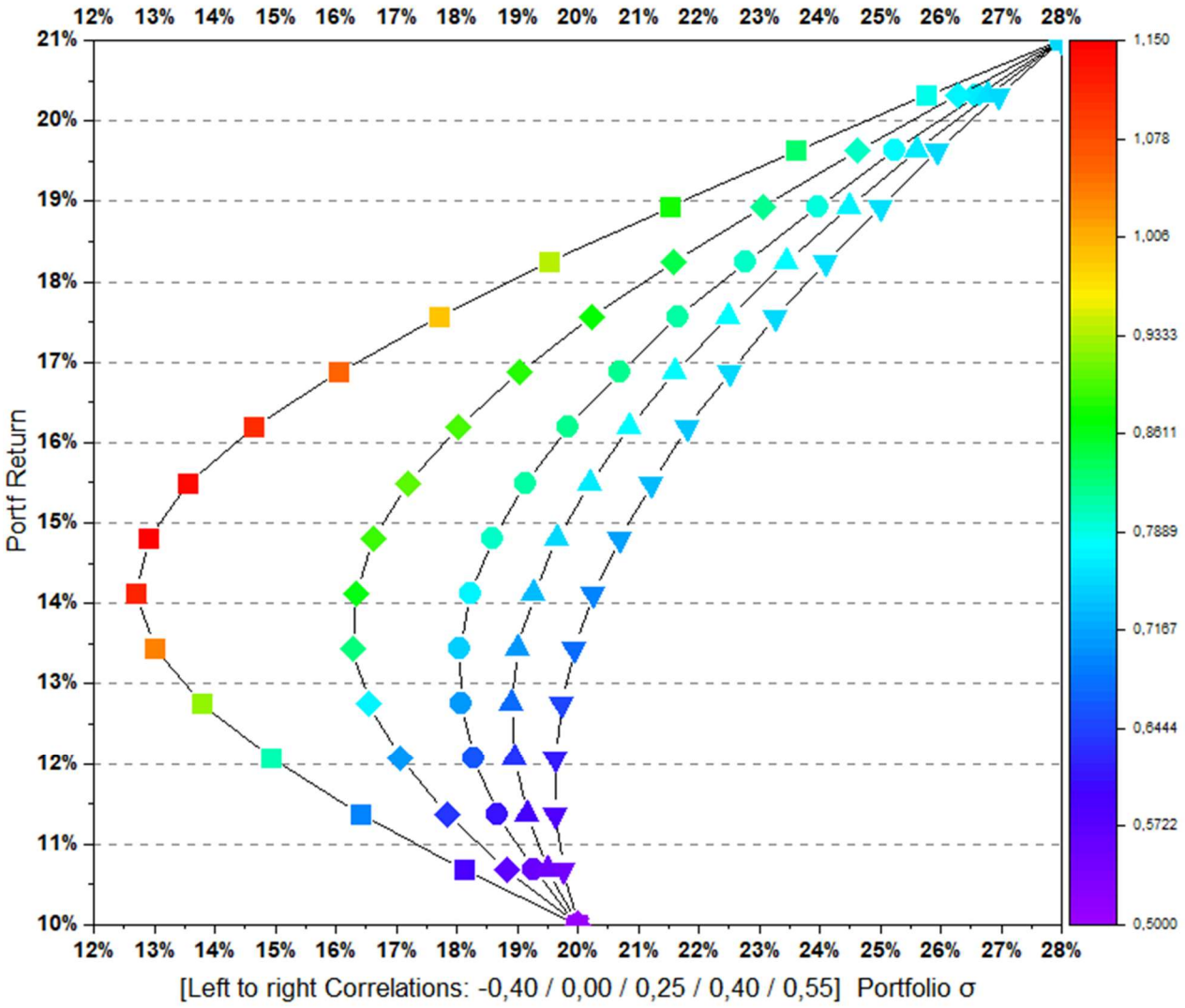








Efficient frontier



Deeper analysis of efficient frontier and sharpe ratio

This chart plots the efficient frontier curve for five different correlation factors. Each marker depicts the sharpe ratio. Each horizontal line (on y axis) has the same return, so lower σ produce higher sharpe ratios on this line.

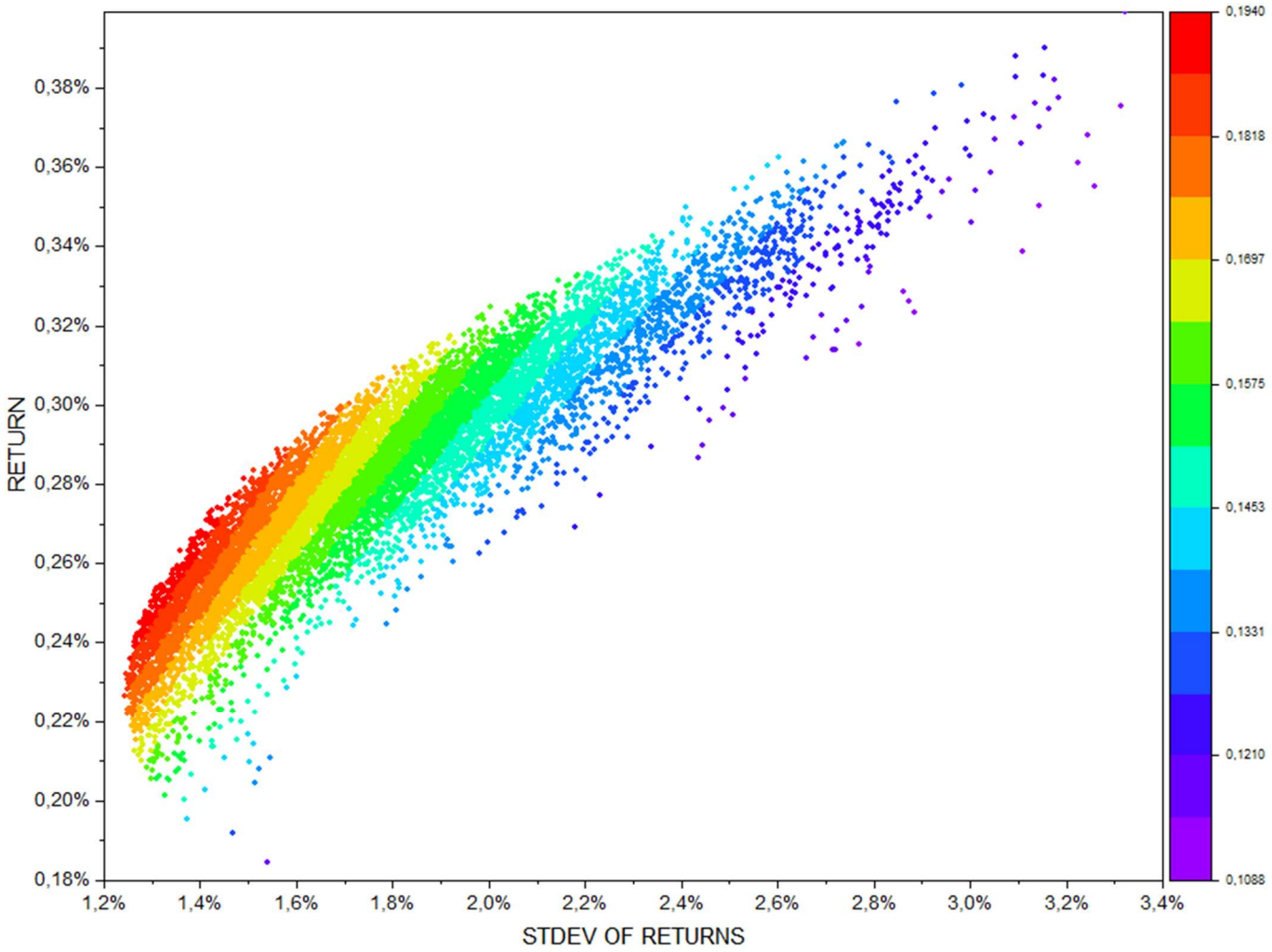
It is really eye opening to observe the progression order of the sharpe ratios on each efficient frontier line. On top of that, observe that as we move towards lower correlations, the optimum sharpe point is on higher portfolio returns.

In other words, in lower correlations we achieve a higher sharpe ratio in lower returns!

These graphs and heatmaps are in the daily arsenal of the Risk Mabager.

Efficient frontier

Efficient frontier analysis in a 5 asset portfolio



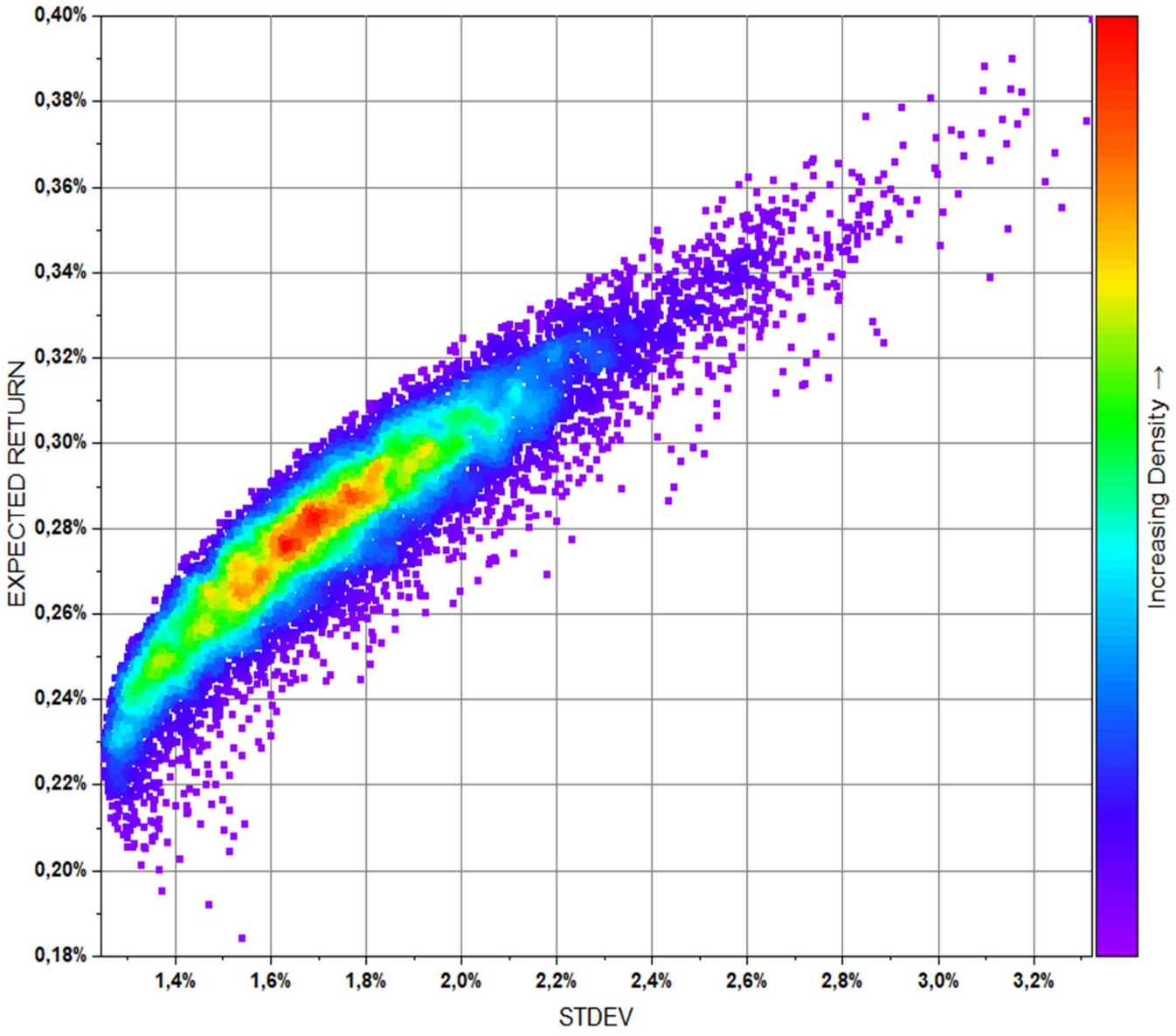
We plot stdev vs return, in a five assets portfolio, for 10000 random combinations. The scatterplot is heat-mapped on the Sharpe ratio.

Notes:

- The coordinates and (x, y) area of the optimum sharpe ratio are expected.
- The slope of the shapes resembles the slope of the capital market line.
- How about the concentration of the samples?
- Why is this concentration not uniform?

Another chart, on the way

Efficient frontier



- Same portfolio data, on a chart that shows the density of the samples ...
- Counter intuitive the 1,7 – 0,28 coordinates with the higher density.
- Either the random number generator is biased, or something else happens...
- Why do we observe these sparse areas ?
- Can we explain this phenomenon?
  (Hmm, statistics, rolling dices, density functions, distributions, ...)

This is (a small part of) the real function of the Risk Manager.

Key formulas for optimum portfolio weights

The formulas that implement the statistics and optimum portfolio analytics on an asset A and asset B example are given below

Portfolio σ

= SQRT(σA^2*WA^2+σB^2*WB^2+2*WA*WB*σA*σB*corrAB) = 24,75%

Minimum σ

The weight in stock A is given by the formula
=(σB^2-σA*σB*corrAB)/(σA^2+σB^2-2*σA*σB*corrAB)
→ 83,80%

Maximum Sharpe ratio

The weight in stock A is given by the formula
=((RA*σB^2)-(RB*covAB))/((RA*σB^2)+(RB*σA^2)-((RA+RB))*covAB)
→ 20.5%

Covariance (A, B) = corrAB * σB * σA

→ 0,031

If the portfolio has more than two assets, then the closed end formulas are “exponentially” more difficult to produce and other numerical optimization algorithms and methods are used.

VaR – Value at Risk

Introduction

Risk Managers

- are focusing in the probability of events and
- are concerned about the possibility of adverse events.

The VaR (Value at Risk) of an investment is

- an important measure of risk that focuses on adverse events and their likelihood
- a function of two parameters
  - the time horizon
  - the confidence interval

Definition of VaR

VaR is the maximum loss we expect to occur over a certain time horizon and confidence interval.

Characteristics of VaR

- VaR is a statistical "approach" to the quantification of risk.
- We sustain three parameters in "balance" – any two produce the third!
- VaR, is commonly used to depict the maximum loss of our investment for a given day horizon and probability.

Example:

With 99% probability, in the next 1 day we will lose less than 10,000 euros.
With 95% probability, in the next 5 days we will lose less than 23,000 euros.

As a market practice, common probabilities are 99%, 95%, and regular days used are 1, 5, and 10. Each day, or ad hoc, we calculate the new potential loss.

Note: The concept of risk is often confused with VaR. VaR is just the quantification of risk and its translation into money. Just remember the confusion of volatility vs standard deviation...

ES - Expected shortfall

The problem with VaR is that it tells us nothing about how big the potential loss will be if the VaR level is exceeded.

The Expected Shortfall (aka Conditional VaR) captures exactly this loss.

Volatility

The volatility of a security is measured by the standard deviation of its returns and refers to a time period equal to the return interval.

For example, if we measure daily returns, then the volatility will be for one day. To scale the volatility over different time intervals, we multiply (or divide) with the square root of time.

Usually volatility is reported annualized, so to convert it to daily we divide by the square root of 252. Also, to calculate, for example, ten-day volatility having the daily volatility, we multiply it by the square root of 10.

Quantifying volatility

On the previous chapters we have laid out the foundations of the formulas used in quantifying VaR.

The standard deviation is used to measure volatility. Simple as that!

For example, we have already seen IBM has an average of 0,34% and a standard deviation of 2,20% in its daily returns.

From these two numbers only, we will produce all the required VaR numbers.

Suppose we want the VaR and Expected shortfall of a position of 100.000 € in IBM. We are interested in a 1 day and 5 day period for a confidence level of 99% and 95%. Let's produce the full array with all combinations of days and probabilities.

	IBM		
	Xi	Xi-AVG	(Xi-AVG)^2
	1,55%	1,21%	0,00015
	1,91%	1,56%	0,00024
	2,47%	2,12%	0,00045
	2,75%	2,41%	0,00058
	-4,86%	-5,20%	0,00270
	-0,12%	-0,46%	0,00002
	0,62%	0,27%	0,00001
	3,46%	3,12%	0,00097
	-0,42%	-0,76%	0,00006
	-1,29%	-1,63%	0,00027
	-0,96%	-1,30%	0,00017
	-0,99%	-1,33%	0,00018
AVERAGE	0,34%	Variance	0,00048
STDEV.P	2,20%	SQRT	2,20%

		Probability	stdevs
X1 <=	-0,50%	35,13%	-0,38
between		17,77%	
X2 >=	0,50%	47,10%	0,07
		100,00%	

All we have to do is to translate the 1% and 5% to a z-score. We want one z-score for VaR and another one for Expected Shortfall.

The daily VaR in € is equal to z-score * Notional * volatility

The 5 days VaR is Equal to daily VaR * sqrt(5).

The daily Expected Shortfall in € is calculated exactly as before, computing its new z-score.

The 5 days ES is one day ES * sqrt (5).

€ @ RISK !!! --> z-score, VaR and ES			
	Asset	IBM	
	Notional	100.000	
	Volatility	2,20%	Daily
	Confidence	1,00%	5,00%
VaR (parametric, mean-variance)			
z-score (scaling factor)		-2,326	-1,645
	VaR in Euro	-5.118	-3.619
5	days	-11.444	-8.092
EXPECTED SHORTFALL			
z-score (scaling factor) *		-2,665	-2,063
	VaR in Euro	-5.863	-4.538
* Use of scaling factor based on fat tailed			
student's t distribution.			

Formula of VaR z-score, in EXCEL

=NORM.S.INV(Confidence)

Formula of z-score for Expected Shortfall

=-(1/(Confidence))*NORM.S.DIST(NORM.S.INV(Confidence);FALSE)

Note: How about the 0,34% average return? Shouldn't we use it in the volatility calculations?

VaR, standard deviations and ignoring the average return

The average return is not used in calculating VaR with the parametric variance covariance method because it is not necessary and can introduce bias.

Even if it seems more accurate to do so, in the distribution plot, we do not use it! VaR is defined as the quantile of the portfolio return distribution at a given confidence level. The quantile can be calculated directly without needing to know the mean of the distribution. As such, using the average return in the VaR calculation would actually be counterproductive, as it would introduce a past data bias into the VaR estimate, and past data may not be representative of future performance.

Moreover, the parametric variance covariance method, is based on the assumption that the portfolio return distribution is stationary, meaning that its characteristics do not change over time. This assumption is more likely to be valid than the assumption that the average return will remain constant.

In addition to the above, the parametric variance covariance method is more efficient than any method that would require as input in the calculations the average return. This is because the stdev can be calculated from a relatively small amount of data, while the average return requires a much larger sample size to be estimated accurately.

On top of that, sort the daily returns of IBM ascending and descending. All have the same stdev and average with IBM. One is clearly rising, one is dropping, and one is random. Does the average produce any new knowledge on the volatility of the asset?

The reasons above are more than enough.

How accurate is the normal distribution in practice?

Real world (and math) proves that

- If we describing a distribution by the mean and standard deviation and then we assume a normal distribution, it is very probable to underestimate the likelihood of extreme events.
- The standard deviation of a distribution, although a useful measure in many situations, does not describe the tails of a probability distribution.

There are a number of ways to measure the tails of a distribution.

One common method is to use the interquartile range (IQR - the difference between the 75th percentile and the 25th percentile of the distribution). Another common method is to use the kurtosis of the distribution. A distribution with high kurtosis has a lot of weight in the tails, while a distribution with low kurtosis has a lot of weight in the center.

Methods of calculating VaR

We work with what we have. We have daily returns of the assets. We calculate the correlations (and covariances) and we calculate the VaR. Straightforward.

We always focus on the idea that the value at risk (VaR) measure, is essentially just a quantile on a loss distribution.

Simple: Calculate the losses, rank them. cut the quantile, and here is the VaR!

The three popular methods

With this in mind we describe in brief the three methods.

Parametric VaR, Historic or back simulation, and Monte Carlo simulation.

Parametric VaR

(a.k.a. RiskMetrics, Variance/Covariance method, Analytic method)

This method is based on assumptions about the particular form of the loss distribution (normal, lognormal, etc.). We then correspond/match the relevant curve and use a formula to obtain the VaR with a quantile equation matching our distribution and parameter estimates.

The method in practice

- Uses Mean-Variance analysis, assuming that future returns follow a normal distribution around the mean (we use 0, this assumption does not always hold but we have explained why market uses zero mean).
- Practically, because -2.33 standard deviations is in 1% of the standard normal distribution, the (required eg) 99% VaR equals (in money) 2.33 standard deviations. Simple as that. Z-score (1%) = 2,33. End of story.
- VaR is derived similarly for other probabilities and day tenors.

However, as elegant and simple as it is, it has a problem and specifically the need to assume that the distribution of returns on our assets is symmetric (normal). This is not the case for non-linear asset returns, like options or short-term bonds. Thus, the need for additional models arises.

Historic approach (a.k.a. back simulation)

This is the simplest method of all, and easier to explain.

- We rank the historical returns, sorting them from lowest to highest.

Methods of calculating VaR

- VaR is the k^{th} largest observation, inline with our required quantile again!
- There is need for any hypothesis about the shape of the distribution of returns, nor calculation of correlations is needed, nor assumptions about the linearity or not in the return of the assets.

Monte Carlo Simulation

We generate thousands of new price/return time series scenarios, with returns similar to the probability distribution that occurred in the real recent past.

We specify the stochastic process, calibrate the model factors to fit the parameters of our asset (volatility and sometimes drift), and then run a large number of simulations that construct thousands of hypothetical paths by drawing a set of random variables that determine the asset prices.

Each path produces a return, mostly (end-start)/start. We rank the returns, cut the quantile and this is the VaR.

Note that this method handles non-linear assets quite well.

Using Risk in active Portfolio Management

RISK REPORTS IN A PORTFOLIO OF ASSETS

We analyze a portfolio with assets (for example equities) and among others we want to pinpoint all its characteristics regarding its risk reward attributes.

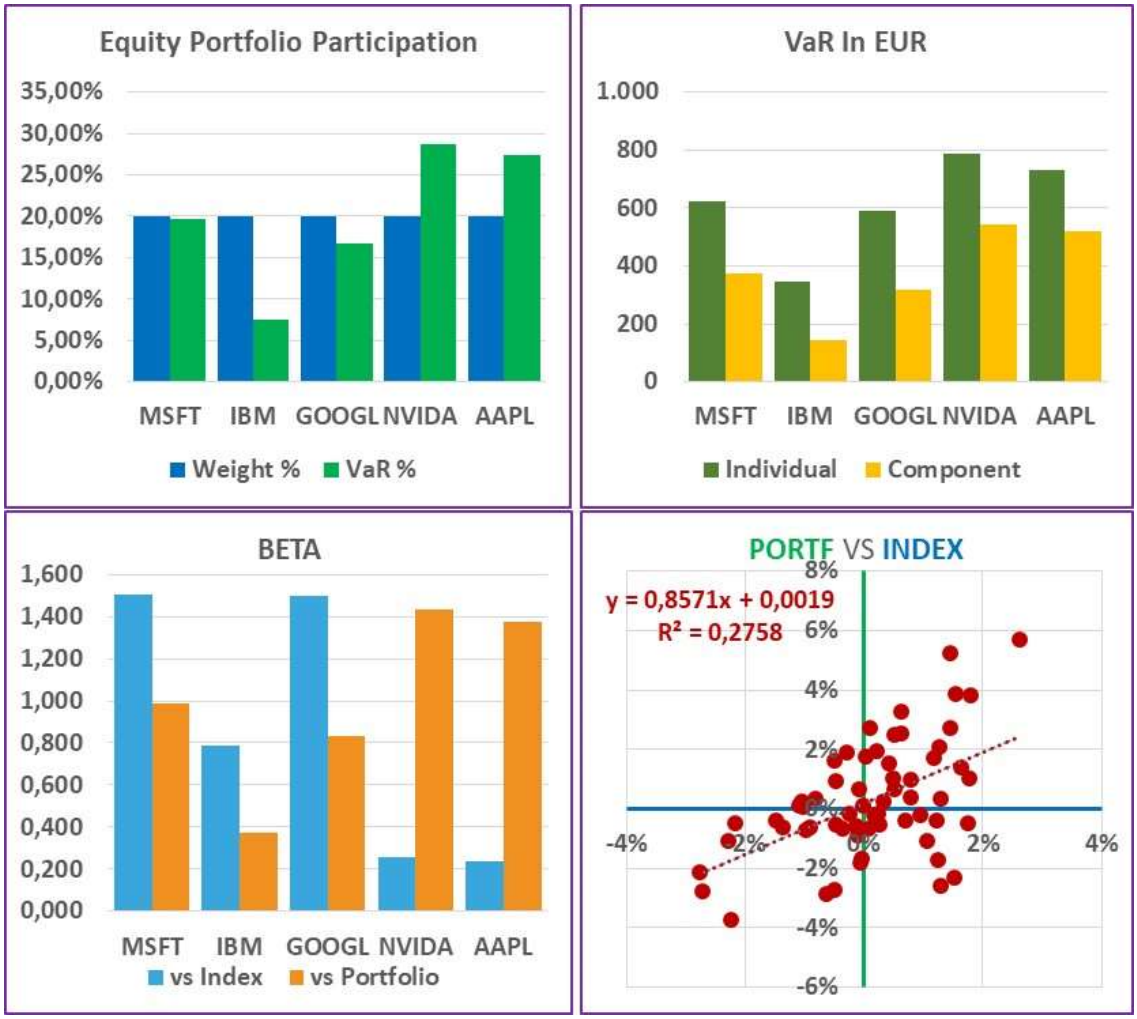
Applying the risk analytics concepts we learned so far

... and some more:

	Risk Free Rate		0,00%			Active Risk (tracking Error)	1,6209%
	Weights %		20,00%	20,00%	20,00%	20,00%	20,00%	100,00%
	Euro Notional		20.000	20.000	20.000	20.000	20.000	100.000
		SPX	MSFT	IBM	GOOGL	NVIDA	AAPL	PORTF
	Average Return	0,12%	0,26%	0,17%	0,25%	0,44%	0,35%	0,29%
	Beta vs Index	1,000	1,504	0,786	1,500	0,257	0,238	0,857
	R2 vs Index	1,000	0,315	0,275	0,348	0,006	0,006	0,276
	Beta vs Portf	0,322	0,984	0,374	0,835	1,433	1,373	1,000
	R2 vs Portf	0,276	0,360	0,166	0,287	0,477	0,504	1,000
	Alpha	0,00%	0,08%	0,07%	0,07%	0,41%	0,32%	0,19%
	Treynor Ratio	0,001	0,002	0,002	0,002	0,017	0,015	0,003
	Sharpe Ratio	0,103	0,084	0,096	0,085	0,112	0,095	0,155
	Variance (σ2)	0,013%	0,097%	0,030%	0,087%	0,155%	0,134%	0,036%
	STDEV (σ)	1,161%	3,111%	1,741%	2,952%	3,931%	3,665%	1,895%
	Residual Volatility	0,000%	2,574%	1,483%	2,384%	3,920%	3,655%	1,612%
	Individual (Gross) VaR €		622,11	348,18	590,40	786,22	732,99	3079,91
	Component VaR €		373,02	141,83	316,40	543,18	520,25	1894,67
	Marginal VaR (unitless)	[σ]	0,0303	0,0115	0,0257	0,0441	0,0423	0,0308
	Exp Ret / β (vs portf)	[sharpe]	0,0027	0,0045	0,0030	0,0031	0,0025	0,0029
	Incremental VaR € (proxy)	10,00	0,3032	0,1153	0,2572	0,4415	0,4228	0,3080

We start by using an equal weight strategy, of 20%, in each stock. All analytics are displayed here, in an easy-to-understand color coded heatmap table, adjusted for work in a fast-paced trading environment. Lets' dive deeper.

Using Risk in active Portfolio Management



Initially, each stock weighs 20% in the portfolio, with IBM having the smallest percentage contribution. This portfolio has a beta of 0,857 vs index.

"Sell the Reds"

Let's assume that we have two targets: Target [1] is to minimize portfolio VaR and target [2] is to maximize the portfolio sharpe ratio.

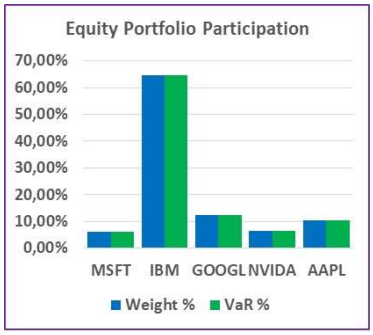
For target [1], we sell the stock with the maximum marginal VaR and we buy the stock with the minimum marginal VaR. So, we start by selling NVIDA and by buying IBM, and we keep the same strategy.

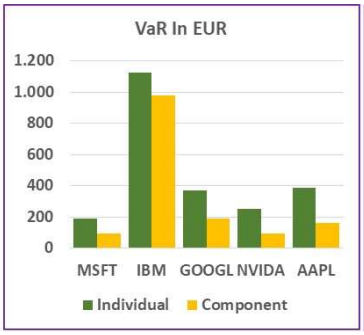
For target [2], we sell the stock with the minimum ER/b ratio and we buy the stock with the maximum ER/b ratio. So, we start by selling AAPL and by buying IBM, and we keep the same strategy. The numerical methods software is our friend and it will propose an optimal portfolio. Again.

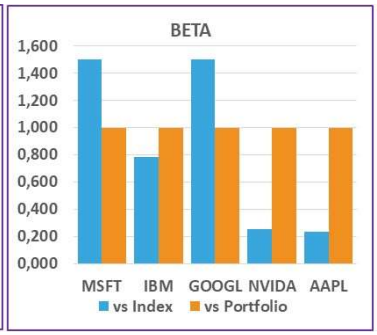
Using Risk in active Portfolio Management

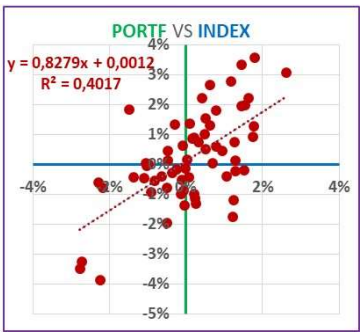
Minimize portfolio VaR

	Risk Free Rate		0,00%		Active Risk (tracking Error)			1,1898%
	Weights %		6,05%	64,63%	12,51%	6,33%	10,49%	100,00%
	Euro Notional		6.046	64.632	12.511	6.326	10.485	100.000
		SPX	MSFT	IBM	GOOGL	NVIDA	AAPL	PORTF
	Average Return	0,12%	0,26%	0,17%	0,25%	0,44%	0,35%	0,22%
	Beta vs Index	1,000	1,504	0,786	1,500	0,257	0,238	0,828
	R2 vs Index	1,000	0,315	0,275	0,348	0,006	0,006	0,402
	Beta vs Portf	0,485	1,000	1,000	1,000	1,000	1,000	1,000
	R2 vs Portf	0,402	0,238	0,759	0,264	0,149	0,171	1,000
	Alpha	0,00%	0,08%	0,07%	0,07%	0,41%	0,32%	0,12%
	Treynor Ratio	0,001	0,002	0,002	0,002	0,017	0,015	0,003
	Sharpe Ratio	0,103	0,084	0,096	0,085	0,112	0,095	0,145
	Variance (σ2)	0,013%	0,097%	0,030%	0,087%	0,155%	0,134%	0,023%
	STDEV (σ)	1,161%	3,111%	1,741%	2,952%	3,931%	3,665%	1,516%
	Residual Volatility	0,000%	2,574%	1,483%	2,384%	3,920%	3,655%	1,173%
	Individual (Gross) VaR €		188,07	1125,18	369,31	248,70	384,27	2315,54
	Component VaR €		91,68	980,04	189,70	95,93	158,99	1516,35
	Marginal VaR (unitless)	[σ]	0,0232	0,0232	0,0232	0,0232	0,0232	0,0232
	Exp Ret / β (vs portf)	[sharpe]	0,0026	0,0017	0,0025	0,0044	0,0035	0,0022
	Incremental VaR € (proxy)	10,00	0,2316	0,2316	0,2316	0,2316	0,2316	0,2316









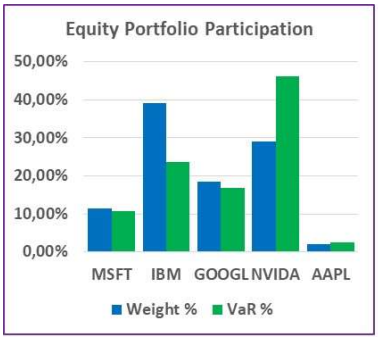
With these weights, all stocks have

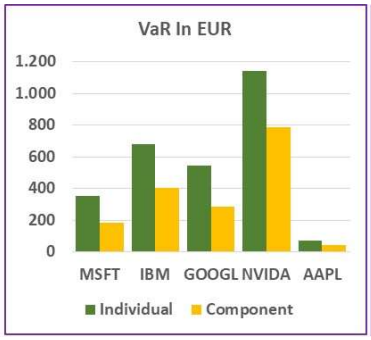
- equal Marginal VaR
- a beta of 1 vs portfolio
- weights in notional equal to their participation% in portfolio VaR.

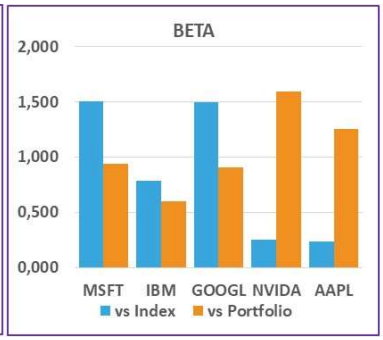
Using Risk in active Portfolio Management

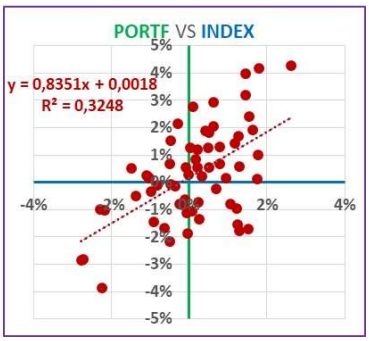
Maximize portfolio Sharpe Ratio

	Risk Free Rate	0,00%			Active Risk (tracking Error)		1,4108%
	Weights %	11,31%	39,16%	18,52%	29,05%	1,96%	100,00%
	Euro Notional	11.308	39.162	18.517	29.055	1.959	100.000
		SPX	MSFT	IBM	GOOGL	NVIDA	AAPL	PORTF
	Average Return	0,12%	0,26%	0,17%	0,25%	0,44%	0,35%	0,28%
	Beta vs Index	1,000	1,504	0,786	1,500	0,257	0,238	0,835
	R2 vs Index	1,000	0,315	0,275	0,348	0,006	0,006	0,325
	Beta vs Portf	0,389	0,945	0,605	0,912	1,593	1,254	1,000
	R2 vs Portf	0,325	0,267	0,350	0,276	0,475	0,339	1,000
	Alpha	0,00%	0,08%	0,07%	0,07%	0,41%	0,32%	0,18%
	Treynor Ratio	0,001	0,002	0,002	0,002	0,017	0,015	0,003
	Sharpe Ratio	0,103	0,084	0,096	0,085	0,112	0,095	0,163
	Variance (σ2)	0,013%	0,097%	0,030%	0,087%	0,155%	0,134%	0,029%
	STDEV (σ)	1,161%	3,111%	1,741%	2,952%	3,931%	3,665%	1,701%
	Residual Volatility	0,000%	2,574%	1,483%	2,384%	3,920%	3,655%	1,398%
	Individual (Gross) VaR €		351,73	681,77	546,63	1142,18	71,78	2794,09
	Component VaR €		181,80	403,15	287,21	787,07	41,79	1701,03
	Marginal VaR (unitless)	[σ]	0,0264	0,0169	0,0255	0,0445	0,0351	0,0279
	Exp Ret / β (vs portf)	[sharpe]	0,0028	0,0028	0,0028	0,0028	0,0028	0,0028
	Incremental VaR € (proxy)	10,00	0,2641	0,1691	0,2548	0,4450	0,3505	0,2794









These weights maximize the Sharpe ratio in the portfolio. Compare the participation weights vs the individual stock sharpe ratio. Not proportional!!! Correlation is the name of the game ....

Also note that all expected returns over beta are equal.

We can continue with any requirement (minimize active risk, maximize R2 and set beta 1, match portfolio return with index with the minimum stdev, etc)

Using Risk in active Portfolio Management

The most important paragraph of this document

Having seen the above, especially in practice, this is our conclusion.

There is never a clearly detectable obvious strategy on what to do, based on the simple analytics (return, stdev, sharpe).

For example, IBM, turns to be a perfect candidate to buy for all optimal portfolios. This cannot be seen anywhere in the first rows of analytics but only in our two yellow analytics on the bottom of the report.

The ideal software, has clear "where to look" parts, with reminder mnemonics like [σ] and [sharpe] on the yellow relevant analytics and, since we know what to do: (… we "sell the red, buy the green"...) we advise accordingly.

This is exactly what we mean by "ACTIONABLE REPORT".

An afterword on energy Risk Management

Message of the day

A clearly fascinating world, using art (skill) and science jointly, to gauge risk.

Trading, risks and the new kids in energy industry trading

TRADING

Mechanistic, trend-following strategies commonly used in other markets may not effectively translate to the intricate and physical nature of energy and environmental trading. Energy financial markets, despite using familiar terms, respond to complex supply-demand fundamentals, weather risks, and various other factors. Predicting the duration of this trend remains uncertain, as these yet uncharted territories present unique challenges never encountered before. As such, do not trade energy markets as you trade financial markets.

RISK

Quantitative modeling in energy trading involves sifting through information, focusing on key aspects while acknowledging the risks of flawed assumptions or input data. Just like financial market does. An extra attention to detail is crucial, with real-world understanding (settlement, delivery) on energy instrument differences; this is paramount for successful price changes and consequently the successful modeling of the energy market.

THE_NEW_KIDS_IN_THE_BLOCK

Everybody jumps on the energy market trading train. The market's complexity and volatility, is influenced by multifaceted factors that defy simple financial markets' algorithms. This is magnified in tandem with the recent influx of hedge funds and investment banks in energy markets. While these new entrants boost liquidity and enhance credit situations, seasoned players like multinational oil companies possess extensive knowledge and experience, dominating the field. Survival in this competitive landscape favors those deeply entrenched in energy markets and Risk Management.

Two certain things for the future of energy markets Risk Management:

1. The future of Risk Management in energy markets is fruitful and bright.
2. Risk managers will continue developing new methodologies to address the challenges of managing risk in the complex and ever-changing landscape, ensuring the security and stability of the energy sector.