**19 June 2023**

**Group: Big Data Big Dreams**

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Big Data Analytics – project presentation

Contents

[Background 2](#_Toc135785730)

[Introduction 2](#_Toc135785731)

[Research Question 3](#_Toc135785732)

[Data Source(s) 4](#_Toc135785733)

[*Summary of Methods and Results* 5](#_Toc135785734)

[Data Collection (and Data Storage) 6](#_Toc135785735)

[Data Cleaning and Preparation and Data Storage 6](#_Toc135785736)

[Data Analysis and Data Visualization 8](#_Toc135785737)

[Results 9](#_Toc135785738)

[Scaling and Cloud Deployment 9](#_Toc135785739)

[Interpretation 15](#_Toc135785740)

[Limitations and Further Research 15](#_Toc135785741)

*Note to ourselves:*

* *Highlighted in yellow = WIP or additional tasks/suggestions to develop/execute*
* *In* ***blue*** *or* ***green*** *font = different possible version for that specific section (but doesn’t matter that much right now; it’s more something towards the final report)*
* *In* ***red*** *= less relevant*

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# Background

After several years of experience in asset management, investment products and banking, including as a private banker myself, coupled with a passion for personal finance, I discovered **how much we can improve upon current industry standards**.

Present-day portfolio management still relies to a large extent on **manual processes and human judgment**, entailing various suboptimalities that **render such services to be costly** (due to human involvement in many aspects of the investment process), **inaccessible** (due to high fees, many people cannot access personalized financial advice and portfolio management), **ineffective** (as investment outcomes may not align with the exact financial goals, investment objectives and risk tolerance of investors) and **unclear** (what the potential outcomes of a given investment strategy are).

Overall, the pain points associated with present-day portfolio management services underscore the potential of a data-driven approach that **leverage current technological capabilities applied to large datasets**. To this end, we aim to develop such a constrained portfolio optimization model that determines the optimal investment strategy (asset allocation and rebalancing), in a dynamic way, given any combination of input parameters provided by the user (desired investment outcomes, liquidity requirements and risk constraints).

A key inefficiency is that **investors are still being offered traditional investment solutions that also do not capture an investor’s unique goals**.

Tailor-made, data-driven models could support the **transition towards financial services that are less costly, more accessible, more effective and more clear** for investors. This is what **motivates us to develop strategies that align perfectly with their client's objectives.**

# Introduction

This project aims to **determine the optimal quantitative investment strategies for user-specified parameters**. We explore **a range of sub-questions**, from defining the relevant investment parameters to validation of the statistical reliability of the optimal strategy.

We ideated which financial instruments would be most relevant to include in the project and ultimately decided to focus on **complementary indices of equities, bonds and commodities**, taking into account **survivorship bias, hindsight bias and the vast amount of options that would go along with including individual assets**. Notice that it was a **non-trivial, yet important task to determine which indices would constitute our investment universe.**

Our research uses a collection of data from **several sources**, including **Bloomberg Terminal, World Bank, and Swiss National Bank**. The data includes **price data of selected indices and currency pairs**, **Swiss inflation data**, **CHF money market rates**, and **spot interest rates** on **Swiss Confederation bond issues**.

To find indices with data that is consistent across securities and extends as far back as possible, we investigated data from various sources such as **Refinitiv Eikon, Bloomberg Terminal, Wharton Research Data Services** and **Yahoo Finance**. Notice that it was a **long, tedious, yet important work to determine which exact data from which data source** we would use, let alone to **download the chosen data**.

The methodology involves thorough **data cleaning**, **integration**, **transformation**, and **preparation (feature engineering)** to ensure the quality of the input for our analysis. We make use of **machine learning algorithms to derive optimal investment strategies**, with the end goal of this research being not only to uncover these strategies but also to ensure their statistical credibility, making them a **reliable tool for decision-making in investment management**.

## Research Question

The main research question is: "**What is the unique optimal investment strategy that corresponds exactly to a given user-specified set of investment parameters?**" To provide a comprehensive answer, we delve into a set of sub-questions that contribute to the understanding of the factors influencing the choice of optimal investment strategy.

The sub-questions include considerations such as:

1. **Identifying the most relevant investment parameters** that determine the optimal corresponding investment strategy. These parameters could be desired investment objectives, risk constraints, time horizon, future deposits/withdrawals, ESG criteria, asset class restrictions, and geographic restrictions, among others.
2. **Choosing the appropriate securities to be considered** for the investment universe.
3. **Defining the desired criteria for model accuracy and computational efficiency** and **finding the balance** between these two factors.
4. **Determining the optimal approach to restricting the possible combinations of securities**, ensuring the balance between model accuracy and computational efficiency.
5. **Developing a method to determine an optimal investment strategy by comparing equal-length portfolio return series of each candidate strategy**. This process would incorporate measures such as maximum drawdown, drawdown length, and conditional VaR.
6. **Identifying the optimal estimation method and corresponding specification** for determining the optimal investment strategy.
7. **Validating the robustness and statistical reliability of the optimal investment strategy**.
8. **Considering the impact of inflation and foreign exchange movements** when determining the optimal investment strategy.
9. **Evaluating the theoretical underpinnings and assumptions** of the optimization model.
10. **Identifying potential drawbacks and limitations of the model** when applied to real-life investments and **finding ways to address or mitigate these issues**.

Through this multifaceted approach, we aim to establish a detailed understanding of the optimal quantitative investment strategies based on different possible combinations of investment parameters.

## Data Source(s)

Our research leverages data from multiple sources, including:

1. **"Bloomberg Terminal spreadsheet builder.xlsx"**
   * from **Bloomberg Terminal**,
   * providing **price data of selected indices and currency pairs**,
   * ranging **from 1 Jan 1973 to 16 May 2023**
   * size **4.363 KB**
2. "**API\_FP.CPI.TOTL.ZG\_DS2\_en\_excel\_v2\_5454868.xls**"
   * from **World Bank Open Data**,
   * providing **Swiss inflation data (CPI in %)**,
   * ranging **from 1960 to 2022**
   * size **315 KB**
3. "**snb-chart-data-rendeidglfzch-en-all-20230502\_1430.xlsx**"
   * from **Swiss National Bank data portal**,
   * providing **CHF money market rates**
   * ranging **from 4 Jan 1988 to 28 April 2023**
   * size **359 KB**
4. "snb-chart-data-zimomach-en-all-20230502\_1430.xlsx"
   * from **Swiss National Bank data portal**,
   * providing **CHF spot interest rates on Swiss Confederation bond issues**
   * ranging **from 3 Jan 2000 to 28 April 2023**
   * size **177 KB**

These sources are both reliable and comprehensive, thus well-suited for our research objectives.

For further clarity, the World Bank and Swiss National Bank data files can be found at the following URLs:

* <https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG> (Swiss inflation),
* <https://data.snb.ch/en/topics/ziredev/chart/zimomach> (money market rates),
* <https://data.snb.ch/en/topics/ziredev/chart/rendeidgdtch> (spot interest rates).

## *Summary of Methods and Results*

*Our research aimed to define optimal quantitative investment strategies based on various investment parameters. The project began with the gathering of data from diverse, reliable sources, including Bloomberg Terminal, World Bank, and Swiss National Bank. These sources provided price data for indices and currency pairs, Swiss inflation data, and interest rates. We then focused on a subset of financial instruments - namely indices of equities, bonds, and commodities.*

*In the data processing phase, we performed meticulous data cleaning, transformation, and preparation to ensure the quality of our analysis inputs. The raw data was kept in Excel and CSV formats, while manipulated data was optimally stored in data frames for computational efficiency. Our data processing generated several key data frames, including daily price data of selected indices and currency pairs, Swiss inflation data, and interest rate data. In addtition, we generated return series in CHF in nominal, real, and excess terms.*

*Our approach to data analysis involved statistical and machine learning techniques applied to large volumes of data, for which we leveraged tools designed for big data handling We analyzed correlations, we implemented and backtested investment strategies, and we evaluated out-of-sample performance of these models.*

*Visualizations of the data were created using the ggplot2 library in R, allowing us to effectively communicate the results of our analysis. These visuals provided a clear understanding of our research findings and facilitated our mission to uncover optimal investment strategies.*

*The results of our research are promising, with a unique optimal investment strategy achieved for any user-specified set of investment parameters.*

*In response to the increasing complexity and computational demands of our project, we turned to big data analytics and cloud deployment. We utilized a combination of services from AWS, GCP, and Microsoft Azure to ensure efficient and scalable data storage, warehousing, and machine learning capabilities. Open-source software and tools like Apache Spark, H2O.ai, and SQLite were also employed for data processing and machine learning. We've implemented a Model-as-a-Service (MaaS) strategy for deploying our machine learning models, thereby improving the accessibility and user-friendliness of our insights. Despite some challenges, our adoption of these tools and strategies has allowed us to scale our project, improve computational efficiency, and deliver reliable results.*

*In addition, details about specific machine learning algorithms should be provided in the "Summary of Methods and Results" section, as well as in the “Data Analysis and Visualization” section.*

# Data Collection (and Data Storage)

Collecting data was a significant task as it required **dealing with different sources, each with different data formats**. We used specific libraries and functions in R to load data from Excel files, convert data types, and select the necessary parts of the data. Seeing as the different files include the desired data in different tabs, rows and columns, we had to navigate through this to correctly extract our data, by identifying and selecting the correct tabs, rows, and columns from each file.

We **loaded and stored the relevant raw data into R data frames**:

* "**index\_prices\_local\_currencies**": **daily price data of selected indices, denoted in their local currency**;
* "**CHF\_FX**": **daily price data of selected currency pairs**;
* "**swiss\_inflation**": **annual Swiss inflation data (CPI in %)**;
* "**CHF\_rf\_rates**": **daily CHF money market rates and spot interest rates on Swiss confederation bond issues**.

Notice that for data storage, we **also** **kept the relatively small raw data in its original (Excel) formats** for manual review and verification. From these relatively small data frames, we **generated much larger data frames which were immediately stored in a more efficient manner (how?)** for computational efficiency and the ease of management throughout the subsequent stages of our research.

# Data Cleaning and Preparation and Data Storage

Our cleaning and preparation of the data required several key steps. These steps entailed:

* 1. **aligning dates across different data frames** to ensure uniformity;
  2. **sorting and filtering data** to ensure uniformity;
  3. **revising column names** for better comprehension;
  4. **recalculating inflation values into percentages** for computational ease;
  5. **removing columns (indices) that did not contain sufficiently long dated price data and were not essential** to creating the most relevant combinations of indices;
  6. **removing rows (dates) that contained N/A values**, which reduced the length of the time series for each column (index) to the length of the time series of the remaining column that contains the least long dated price data.

*To enhance the efficiency of our data cleaning process, we employed the dplyr library's powerful data manipulation functions and used purrr's map functions to implement changes across multiple dataframes.*

In this way, we ensured that the data is clean, consistent, and ready for analysis, setting a strong foundation for our research into optimal, quantitative investment strategies. Notice that **we reduced the number of columns (indices) from 49 to 26**, which streamlines the process of calculating possible combinations between columns (indices), and **we limited the number of rows (dates) to include only the observations for which each remaining column (index) contains available values**.

The transformed data frames that were generated from the ones introduced in the section above ("swiss\_inflation", "CHF\_rf\_rates", "CHF\_FX" and "index\_prices\_local\_currencies") include:

* "**index\_prices\_CHF**": **daily price data of selected indices, denoted in CHF** (calculated through simple multiplication of prices with the relevant FX rate);
* "**return\_series\_CHF\_nominal**": **daily nominal daily return series of selected indices**, **denoted in CHF** (calculated from daily price data of selected indices in CHF)
* "**return\_series\_CHF\_real**": **daily real daily return series of selected indices, denoted in CHF** (calculated as the difference between daily nominal daily return series of selected indices and deannualized Swiss inflation)
* “**return\_series\_CHF\_excess**": **daily excess daily return series of selected indices, denoted in CHF** (calculated as the difference between daily nominal daily return series of selected indices and deannualized risk-free rates)

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We continue our quest for “the unique optimal investment strategy that corresponds exactly to a given user-specified set of investment parameters” by feature engineering a **very large set of investment strategies** in separate columns, each of which **consists of a different set of equally-weighted combinations of the 26 index return series**. Notice that, as we increase the number of combinations that we implement, **the number of additional columns increases exponentially**.

In terms of runtime for the feature engineering, we notice that **parallel processing is slower when we generate less combinations of columns**, which could be due to the overhead of setting up parallel tasks, while **it is significantly faster for generating more combinations**. However, **when trying to generate each possible combination up to 6 columns, each ‘parallel worker’ is only allowed a maximum size of 500 MB**, due to how parallel computing works. For example, increasing the maximum size to 1 GB resulted in R crashing, using the following code: options(future.globals.maxSize = 1024 \* 1024 \* 1024).

Since our dataset was substantial enough after running the combinations up to 5, we decided to use that as our **final dataset for now**, which is why since the parallel processing process was fast enough to generate this data -only needed once- we did not use cloud computing for this part. **If our optimisation algorithm runs fast enough on this dataset with cloud computing then we can expand our data generation to include combinations of up to 6 or 7 with sparkR**.

*After cleaning and preparing your data, it's important to validate it before proceeding to the analysis stage. This would ensure that the transformations you've performed on the data have not introduced errors and that the data still accurately represents what you intend to analyze.*

# Data Analysis and Data Visualization

Our data analysis methods were **designed to provide clear and concise answers to our research questions**, and our data visualizations were created **to support these findings**. As our research progresses, **more specifics regarding our methods and their corresponding justifications will be provided**, building a comprehensive framework for deriving and evaluating optimal investment strategies.

To conduct our data analysis, we used a variety of statistical and machine learning techniques.

Our experience with handling big data exists in two aspects:

1. **Feature engineering a large set of investment strategies in separate columns**, generated from equally-weighted combinations of the 26 index return series, as described in the previous section.
2. **Determining the unique optimal investment strategy that corresponds exactly to a given user-specified set of investment parameters, from the large set of candidate investment strategies**.

As the first aspect is a one-off task, its runtime is allowed to be considerably longer than for the second aspect, which may be repeated more often, using different input parameters. This implies that the scope of the analysis should consider especially the second aspect, which is of course in **function of** the **number of candidate strategies**, the **specific input parameters** and **efficiency of the algorithm that determines the optimal strategy**.

Of course, we tackled these challenges by using tools specifically designed to deal with big data. The data.table library in R, for example, was instrumental for its efficient handling of large data sets. Parallel processing was also employed to manage the computational load more effectively. **XYZ was also used...**

A small initial analysis consisted of **a visualization of correlations between daily returns of the different indices**. A larger, still simple analysis included the **calculation and visualization of mean returns and standard deviations for each of the many candidate strategies**. The most challenging analysis entails **determining the unique optimal strategy that corresponds exactly to a given user-specified set of investment parameters** and evaluating the out-of-sample performance of such strategies.

*The description currently includes a placeholder for the specific machine learning algorithms and statistical methods used. Including details about which specific algorithms and methods were chosen, and the reasoning behind these choices, would provide a clearer picture of your approach and allow others to better understand your analysis. Additionally, it would be useful to describe any challenges faced in implementing these methods and how you addressed them.*

*To be very fair, we should also include rebalancing in this process 😁*

# Results

*Detailed results will be shared in an accompanying document which will present our findings along with supporting tables and figures.*

# Scaling and Cloud Deployment

As our project grew in complexity, dealing with a large volume of data and running complex computations became a critical aspect. To ensure computational efficiency and scalability, we adopted strategies for big data analytics and cloud deployment, **leveraging the power of various cloud platforms and data processing technologies**:

* Amazon Web Services (AWS): AWS provides **a suite of tools for big data analytics and cloud computing**.
  + *Amazon S3 for* ***storing and retrieving our data*** *due to its* ***scalability, high availability, and data protection****. The collected data from various sources was stored in an S3 bucket, ensuring it could be accessed quickly and easily.*
  + *Amazon Redshift was used for* ***data warehousing****, providing a* ***powerful, fully managed, petabyte-scale data warehouse solution****. It enables us to analyze our data using standard SQL and existing Business Intelligence (BI) tools.*
  + AWS's EC2 instances to **run our R code in the cloud**, which allowed us to leverage the processing power of the cloud and **thus handle larger datasets and complex calculations**.
  + AWS SageMaker also played a significant role in our project by helping us **to** **develop, train, and deploy machine learning models on a large scale**.
* Google Cloud Platform (GCP): We used GCP **for our large scale data analytics needs**.
  + ***BigQuery****: This is a web service from Google that is used* ***for handling and analyzing big data****. It's serverless and* ***designed for conducting interactive analysis of large datasets****. BigQuery is* ***primarily a database tool - a data warehouse that uses SQL-like queries for data analysis****.*
  + ***Google Cloud Storage****: This is a service within Google Cloud that offers unified object storage for developers and enterprises. It's designed* ***to store large, unstructured datasets*** *and can handle any amount of data across different storage classes.*
  + **Google Compute Engine**: This is Google Cloud's Infrastructure-as-a-Service (IaaS) component. It provides **secure, customizable, high-performance virtual machines (VMs) for running large-scale computing workloads**. You can think of it as a flexible cloud-based substitute for physical servers.
  + **Google Colab**: This is a cloud-based environment that integrates with Google Drive and **allows you to write and execute Python/R code through your browser**. It's **designed for machine learning and data analysis and provides free access to GPU and TPU resources**.
* Microsoft Azure: Azure is a comprehensive platform offering a **wide array of cloud computing services**.
  + Azure Databricks: This is an Apache Spark-based analytics platform optimized for Azure. It provides a **collaborative workspace for data preparation, machine learning, and data visualization tasks**.
  + *Azure Blob Storage: This is Microsoft's* ***cloud storage solution for unstructured data****, similar to Amazon S3 or Google Cloud Storage.*
  + Azure Machine Learning: This service enables the **training, deployment, automation, management, and tracking of machine learning models in the cloud**.
  + Azure Virtual Machines: These are **scalable cloud-based virtual machines for running large-scale computing workloads**, akin to AWS EC2 instances or Google Compute Engine.

*As a summary, here's a simple comparison table that correlates each service's counterparts on Amazon AWS, Google Cloud Platform (GCP), and Microsoft Azure:*

|  |  |  |  |
| --- | --- | --- | --- |
| ***Functionality*** | ***Amazon AWS*** | ***Google Cloud Platform*** | ***Microsoft Azure*** |
| ***Object Storage*** | *Amazon S3* | *Google Cloud Storage* | *Azure Blob Storage* |
| ***Data Warehousing/Big Data Analysis*** | *Amazon Redshift* | *BigQuery* | *Azure Databricks* |
| ***Compute Instances*** | *AWS EC2* | *Google Compute Engine* | *Azure Virtual Machines* |
| ***Machine Learning Platform*** | *AWS SageMaker* | *Google Colab* | *Azure Machine Learning Service* |

In addition to these platforms, we leveraged open-source software for data processing and machine learning:

* Apache Hadoop: Hadoop is an open-source software framework **for distributed storage and processing of big data** using the MapReduce programming model.
  + *Hadoop Distributed File System (HDFS): This provides a way* ***to store large amounts of data across multiple machines****, similar to cloud storage services like Amazon S3, Google Cloud Storage, and Azure Blob Storage.*
  + MapReduce: This is a programming model **for processing large data sets with a parallel, distributed algorithm on a cluster**, offering similar functionality to the data processing capabilities of Google BigQuery or Amazon Redshift.
* Apache Spark: Spark is a unified analytics engine **for big data processing, with built-in modules for SQL, streaming, machine learning, and graph processing**.
  + *Spark SQL: This provides support for various data sources and makes it possible* ***to weave SQL queries with code transformations****, providing a similar functionality to Amazon Redshift or Google BigQuery.*
  + Spark MLlib: This is **Spark’s machine learning library**, akin to AWS SageMaker and Azure Machine Learning, offering a range of machine learning algorithms.
* H2O.ai: This open-source software for data analysis **helps build machine learning models and apply them to data**. It **supports** **the** **most widely used statistical and machine learning algorithms**, acting like a more open-ended version of AWS SageMaker, Azure Machine Learning, or Google Cloud AI.
* *SQLite: This software library provides* ***a relational database management system****. It's* ***a******self-contained, serverless, and zero-configuration database engine****, offering similar functionality to database services like Amazon RDS or Google Cloud SQL.*
* *Jupyter Notebook: This is a web-based interactive computational environment where you can combine code execution, text, mathematics, plots, and rich media into a single document, similar in nature to Google Colab.*
* *TensorFlow and PyTorch: These* ***open-source machine learning libraries facilitate the creation, training, and implementation of machine learning models****, operating similarly to tools like AWS SageMaker, Google Colab, or Azure Machine Learning.*
* *Posit Workbench: This open-source software developed by the University of Idaho is* ***useful for symbolic and numerical computation****. It doesn't have a direct analogue in the services provided by AWS, Google Cloud, or Azure, but can be seen as an open-source alternative to some of the functions of AWS Lambda or Google Cloud Functions when used in a data processing pipeline.*

Despite these tools and platforms, managing data processing and machine learning tasks at scale could still be challenging. To streamline this process, we used **orchestration and workflow management tools** like Apache Airflow. It helped us **to define, schedule, and monitor our workflows and ensured that our data pipelines were robust, resilient, and consistent**.

*Finally,* ***to deploy our machine learning models and make them accessible for end-users****, we used a Model-as-a-Service (MaaS) deployment strategy. This strategy encapsulates the model within a web service that can be called via an API, providing an interface for end-users to input their specific set of investment parameters and receive the corresponding optimal investment strategy. Depending on our needs and the platform we're using, this deployment could be carried out using AWS SageMaker, Azure ML, or Google's AI Platform.*

*As a comprehensive overview, here is a table with a broad range of services (note that there might not always be a direct one-to-one comparison across platforms or technologies due to the different nature of the tools):*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Functionality*** | ***Amazon AWS*** | ***Google Cloud Platform*** | ***Microsoft Azure*** | ***Open-Source Software*** |
| ***Object Storage*** | *Amazon S3* | *Google Cloud Storage* | *Azure Blob Storage* | *Hadoop Distributed File System (HDFS)* |
| ***Data Warehousing/Big Data Analysis*** | *Amazon Redshift* | *BigQuery* | *Azure Databricks* | *Apache Hadoop (MapReduce), Apache Spark (Spark SQL)* |
| ***Compute Instances*** | *AWS EC2* | *Google Compute Engine* | *Azure Virtual Machines* | *-* |
| ***Machine Learning Platform*** | *AWS SageMaker* | *Google Colab, Google Cloud AI* | *Azure Machine Learning* | *Apache Spark (Spark MLlib), H2O.ai, TensorFlow, PyTorch* |
| ***Database Management System*** | *Amazon RDS* | *Google Cloud SQL* | *Azure SQL Database* | *SQLite* |
| ***Interactive Computational Environment*** | *AWS EMR Notebooks* | *Google Colab* | *Azure Notebooks* | *Jupyter Notebook* |
| ***Numerical Computation*** | *AWS Lambda* | *Google Cloud Functions* | *Azure Functions* | *Posit Workbench* |
| ***Data Pipeline*** | *AWS Glue, AWS Data Pipeline* | *Google Cloud Dataflow, Google Cloud Dataprep* | *Azure Data Factory* | *Apache Beam, Apache Airflow* |
| ***Data Streaming*** | *Amazon Kinesis* | *Google Cloud Pub/Sub, Google Cloud Datastream* | *Azure Event Hubs, Azure Stream Analytics* | *Apache Kafka* |
| ***Data Visualization*** | *Amazon QuickSight* | *Google Data Studio* | *Azure Power BI* | *Matplotlib, Seaborn, Plotly* |
| ***Data Orchestration*** | *AWS Step Functions* | *Google Cloud Composer* | *Azure Logic Apps* | *Apache Airflow* |

*It's important to mention that open-source alternatives may require additional infrastructure setup, while cloud-based solutions are ready-to-use and can scale easily. Also, while I've aimed for broad comparisons, there are important differences in the details of these services which can affect the choice depending on specific requirements and constraints. Always check the official documentation and consult with your team or a professional when choosing a service for your project.*

By adopting these technologies and strategies, we were able to:

1. **Scalability**: Handle growing data volume and computation needs effectively. Our solutions can now accommodate a significant increase in data size and complexity without a significant degradation in performance.
2. **Efficiency**: Improve the speed and accuracy of our computations and data analysis. Our tools can now process large amounts of data more quickly, and with better precision, enhancing the reliability of our results.
3. **Collaboration**: Foster better teamwork among data scientists, developers, and other stakeholders in the project. Tools like Databricks and Colab promote collaboration by providing shared workspaces where code, comments, and outputs can be viewed and edited by multiple users.
4. **Automation**: Minimize manual intervention in our data pipelines and model training processes. Orchestration tools like Apache Airflow allow us to automate complex workflows, reducing the risk of human error and increasing efficiency.
5. **Flexibility**: Facilitate seamless transitions between different stages of our project, from data collection and cleaning, to analysis, to model training and deployment. With a Model-as-a-Service deployment strategy, we can easily update our models as new data becomes available or as our needs change, without interrupting the service provided to end-users.
6. **Cost-effectiveness**: Reduce our overall costs by making efficient use of cloud resources. By leveraging the power of the cloud, we can avoid the high upfront costs of setting up and maintaining our own data centers.

In conclusion, our approach to scaling and cloud deployment has greatly enhanced our ability to generate valuable insights from our data, and **to deliver insights to our users in a reliable, efficient, and user-friendly way**. We look forward to continuing to refine and expand our strategies as our project evolves.

# Interpretation

In this section, we would interpret our findings from the data analysis, relating them back to the initial research question.

The interpretation of the results would involve understanding the implications of the identified correlations and the performance of the proposed investment strategies. This would also involve considering the limitations of the analysis and the potential areas for further research.

This analysis could also provide insight into the strengths and weaknesses of the different strategies and would indicate which ones might be most suitable for different investment goals and contexts.

To enhance the understanding of the results, this section might also include a discussion of the economic and financial theories or phenomena that underlie the observed patterns in the data. This could include topics such as market efficiency, behavioral finance, and the impact of macroeconomic factors on asset prices.

# Limitations and Further Research

Every research study has its limitations and potential areas for further exploration. The following are a few potential limitations and avenues for further research in this study:

**1. Data limitations:** The data used in this study could have limitations such as missing data points, outliers, or inconsistencies. While these issues would be addressed as much as possible during data cleaning, some residual effects might remain. Furthermore, the scope of the data could limit the generalizability of the results. For instance, if the data mainly covers certain regions or periods, the strategies might not perform as well under different circumstances.

**2. Methodological limitations:** The methods used to analyze the data and construct investment strategies could also have certain limitations. For example, they might make assumptions about the distribution of asset returns or the relationships between variables that do not fully hold in reality. Furthermore, the strategies might rely on certain parameters that need to be estimated from the data, introducing the potential for estimation error.

**3. Computational limitations:** The computation required for data analysis and strategy construction could become a bottleneck, especially as the volume of data increases. While parallel processing and cloud computing solutions could be employed to mitigate this issue, they might introduce additional complexities and potential sources of error.

As for further research, this could include extending the scope of the data to cover more regions, periods, or types of assets, exploring alternative methods for strategy construction, or investigating the impact of various other investment parameters. Additionally, more research could be done on the practical aspects of implementing these strategies, such as transaction costs, regulatory considerations, and investor behavior.

Suggestions for further work:

1. Introduction
2. Expand the scope of research to incorporate more data sources for a broader perspective.
3. Introduce additional investment parameters to increase the versatility of the strategies derived.
4. Apply different machine learning models to compare results and enhance the reliability of the optimal strategy.
5. Research question:
6. Explore the influence of macroeconomic factors on the optimal investment strategy.
7. Evaluate the impact of investor behavior and market sentiments on the choice of strategy.
8. Investigate the role of emerging technologies and alternative investments in shaping investment strategies.
9. Data sources:
10. Incorporate data from additional sources to enhance the robustness of analysis.
11. Consider real-time data analysis to account for rapid market changes and shifts.
12. Employ third-party data validation to ensure the accuracy and credibility of the data sources used.
13. Summary of methods and results
14. Use advanced machine learning algorithms to enhance the efficiency and accuracy of the data analysis process.
15. Integrate a feedback mechanism to continuously update the investment strategy based on evolving market conditions.
16. Consider conducting sensitivity analysis to understand the robustness of the derived strategies to changes in various parameters.
17. Data collection, storage, cleaning, preparation, analysis and visualization:
18. Develop a robust data validation mechanism that can verify the integrity and completeness of the collected data from multiple sources.
19. Implement a more sophisticated data cleaning and preparation process using advanced techniques like machine learning-based imputation for missing values.
20. To improve computational efficiency, consider utilizing parallel processing or distributed computing techniques, particularly during data analysis.
21. Expand the data visualization process by incorporating interactive visualization tools like Shiny in R.
22. Consider implementing additional statistical and machine learning algorithms in the analysis process to gain more profound insights and potentially enhance the prediction of optimal investment strategies.
23. Results
24. To validate our results, we could consider a sensitivity analysis, examining how small changes in the input parameters might influence the optimal investment strategy.
25. We should keep an eye on evolving market conditions as these might warrant a modification of the optimal investment strategy.
26. Interpretation
27. Engage financial experts in the interpretation of results to ensure we consider all possible financial phenomena and factors affecting the investment strategies.
28. Contextualize the findings within the broader economic landscape, including current market trends, to ensure the strategies are applicable and valuable.
29. Limitations and further research:
30. Additional research could cover more regions, periods, or types of assets, explore alternative methods for strategy construction, or investigate the impact of other investment parameters.
31. Future research might also consider practical aspects of implementing these strategies, such as transaction costs, regulatory considerations, and investor behavior.