Finance Theory and Data-Driven Finance

1121AIFQA05
MBA, IM, NTPU (M5276) (Fall 2023)
Tue 2, 3, 4 (9:10-12:00) (B3F17)

https://meet.google.com/paj-zhhj-mya

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Institute of Information Management, National Taipei University
https://web.ntpu.edu.tw/~myday

2023-10-24

Syllabus

Week Date Subject/Topics

1 2023/09/12 Introduction to Artificial Intelligence in Finance and Quantitative Analysis

2 2023/09/19 AI in FinTech: Metaverse, Web3, DeFi, NFT, Financial Services Innovation and Applications

3 2023/09/26 Investing Psychology and Behavioral Finance

4 2023/10/03 Event Studies in Finance

5 2023/10/10 National Day (Day off)

6 2023/10/17 Case Study on AI in Finance and Quantitative Analysis I

Syllabus

Week Date Subject/Topics

7 2023/10/24 Finance Theory and Data-Driven Finance

8 2023/10/31 Midterm Project Report

9 2023/11/07 Financial Econometrics

10 2023/11/14 AI-First Finance

11 2023/11/21 Industry Practices of AI in Finance and Quantitative Analysis

12 2023/11/28 Case Study on AI in Finance and Quantitative Analysis II

Syllabus

Week	Date	Subject/Topics
13	2023/12/05	Deep Learning in Finance; Reinforcement Learning in Finance
14	2023/12/12	Algorithmic Trading; Risk Management; Trading Bot and Event-Based Backtesting
15	2023/12/19	Final Project Report I
16	2023/12/26	Final Project Report II

Financial Theories
and
Data-Driven Finance

Financial Theories and Data-Driven Finance

- Financial Theories
  - Uncertainty and Risk
  - Expected Utility Theory (EUT)
  - Mean-Variance Portfolio Theory (MVPT)
  - Capital Asset Pricing Model (CAPM)
  - Arbitrage Pricing Theory (APT)
- Data-Driven Finance
  - Scientific Method
  - Financial Econometrics and Regression
  - Data Availability

Financial Theories

Financial Theories

- Uncertainty and Risk
- Expected Utility Theory (EUT)
- Mean-Variance Portfolio Theory (MVPT)
- Capital Asset Pricing Model (CAPM)
- Arbitrage Pricing Theory (APT)

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Major Normative Financial Theories and Models

- Normative Theory
  - Based on assumptions (mathematically, axioms) and derives insights, results, and more from the set of relevant assumptions.
- Positive theory
  - Based on observation, experiments, data, relationships, and the like and describes phenomena given the insights gained from the available information and the derived results.

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Normative Finance

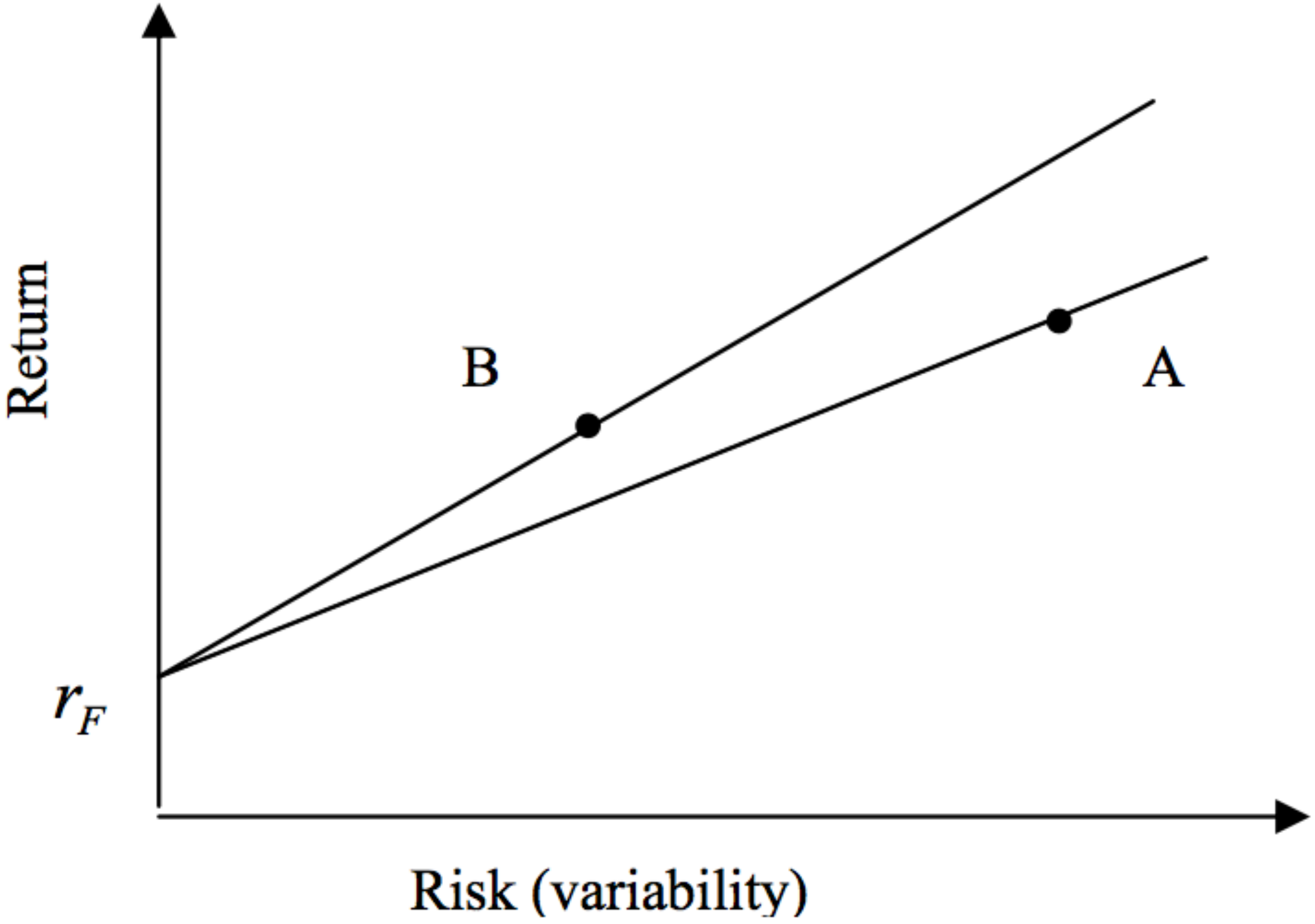
- The CAPM is based on many unrealistic assumptions.
  - The assumption that investors care only about the mean and variance of one-period portfolio returns is extreme.
    (Eugene Fama and Kenneth French, 2004)

Uncertainty and Risk

- Financial theory deals with investment, trading, and valuation in the presence of **uncertainty** and **risk**.
- The focus is on fundamental concepts from **probability theory** that build the backbone of **quantitative finance**.

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Risk and Return



Source: Bacon, Carl. "How sharp is the Sharpe-ratio?-Risk-adjusted Performance Measures." *Statpro White Paper* (2000).

Sharpe Ratio

$$\textbf{Sharpe Ratio} = \frac{Portofolio\ Return - Risk\ Free\ Return}{Portofolio\ Risk}$$

Source: Bacon, Carl. "How sharp is the Sharpe-ratio?-Risk-adjusted Performance Measures." *Statpro White Paper* (2000).

Sharpe Ratio

$$\textbf{Sharpe Ratio } SR = \frac{r_P - r_F}{\sigma_P}$$

Where

r_P = portfolio return

r_F = risk free rate

σ_P = portfolio risk

(variability, standard deviation of return)

Source: Bacon, Carl. "How sharp is the Sharpe-ratio?-Risk-adjusted Performance Measures." *Statpro White Paper* (2000).

Sortino Ratio

$$\textbf{Sortino Ratio} = \frac{r_P - r_T}{\sigma_D}$$

Where

r_P = portfolio return

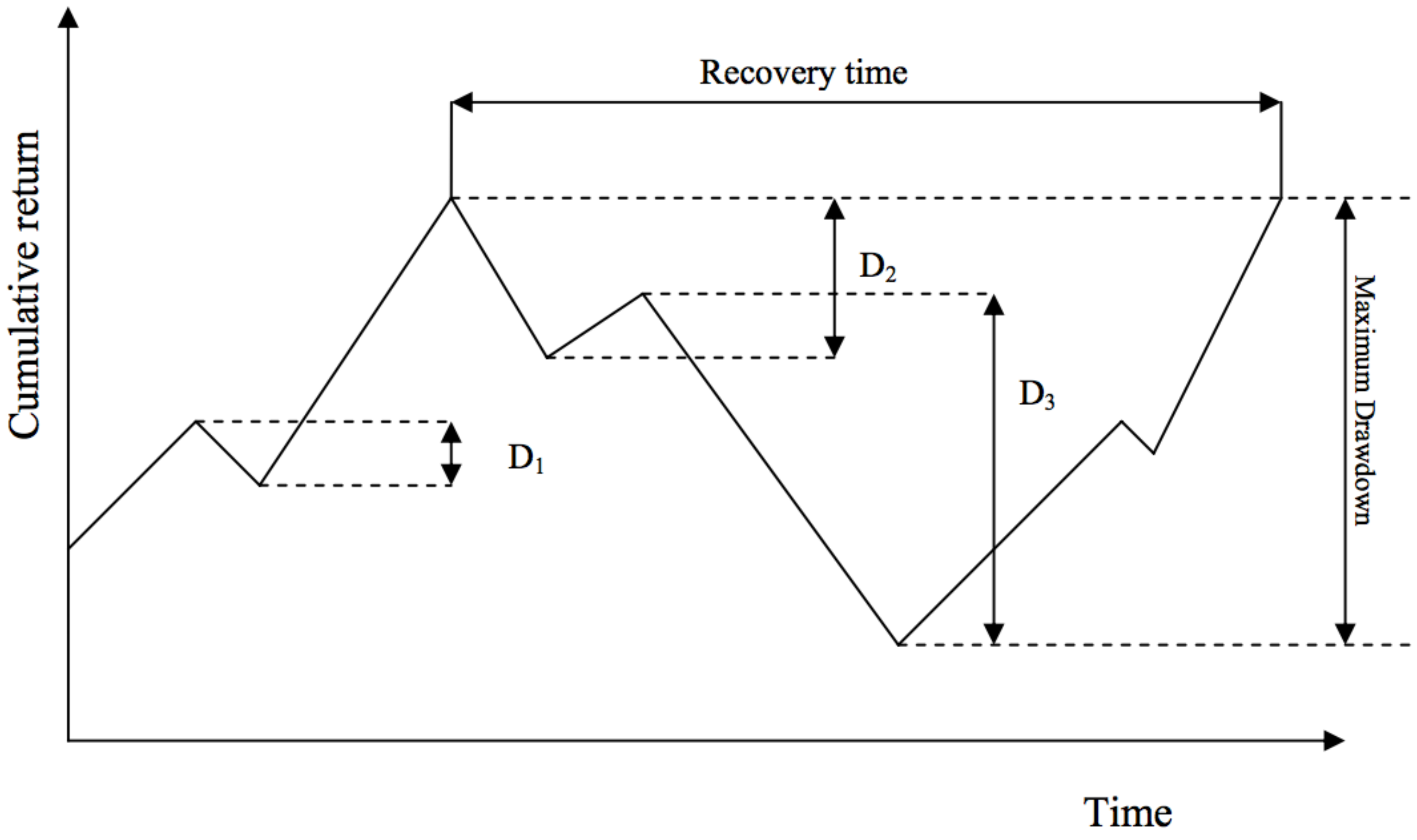
r_T = Minimum Target Return

σ_D = Downside Risk

$$\textbf{Downside Risk } \sigma_D = \sqrt{\sum_{i=1}^{n} \frac{\min[(r_i - rT), 0]^2}{n}}$$

Source: Bacon, Carl. "How sharp is the Sharpe-ratio?-Risk-adjusted Performance Measures." *Statpro White Paper* (2000).

Max Drawdown



Source: Bacon, Carl. "How sharp is the Sharpe-ratio?-Risk-adjusted Performance Measures." *Statpro White Paper* (2000).

Traded Assets

- In the economy, **two assets** are traded.
  - The first is a **risky asset**, the **stock**, with a certain price today of $S_0 = 10$ and an uncertain payoff tomorrow.
  - The second is a **risk-less asset**, the **bond**, with a certain price today of $B_0 = 10$ and a certain payoff tomorrow.

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Arbitrage Pricing

- Deriving the fair value of a European call option on the stock with a strike price of $K = 14.5$
- Arbitrage pricing theory can be considered one of the strongest financial theories with some of the most robust mathematical results, such as the fundamental theorem of asset pricing (FTAP).

Expected Utility Theory (EUT)

- Expected utility theory (EUT)
  - 1940s
  - cornerstone of financial theory
  - One of the central paradigms for **modeling decision making under uncertainty**

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Expected Utility Theory

- **Expected utility theory (EUT)**
  - **EUT is an axiomatic theory**
    - von Neumann and Morgenstern (1944)
  - **Axiomatic**
    - Major results of the theory can be deduced from a small number of axioms only
- **Axioms and normative theory**
  - **An axiom is a proposition regarded as self-evidently true without proof.**

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Preferences of an Agent

- Assume an agent with preferences $\succeq$ is faced with the problem of investing in the two traded assets of the model economy $\mathcal{M}^2$.
- One possible set of axioms leading to EUT
  - Completeness
  - Transitivity
  - Continuity
  - Independence
  - Dominance

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Utility functions

- A **utility function** is a way to represent the **preferences $\succeq$ of an agent** in a mathematical and numerical way in that such a function assigns a numerical value to a certain payoff.

Expected Utility Functions

- **Von Neumann and Morgenstern (1944) show that if the preferences of an agent $\succeq$ satisfy the preceding five axioms, then there exists an expected utility function.**

Risk aversion

- In finance, the concept of risk aversion is important.
- The most commonly used measure of risk aversion is the Arrow-Pratt measure of absolute risk aversion (ARA) (Pratt, 1964).
  - ARA(x) > 0, risk-averse
  - ARA(x) = 0, risk-neutral
  - ARA(x) < 0, risk-loving

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Mean-Variance Portfolio Theory (MVPT)

- **Mean-variance portfolio (MVP) theory**
  - **Markowitz (1952)**
  - **cornerstone in financial theory**
- **One of the first theories of investment under uncertainty that focused on statistical measures only for the construction of stock investment portfolios.**
- **MVP completely abstracts from fundamentals of a company that might drive its stock performance or assumptions about the future competitiveness of a company that might be important for the growth prospects of a company.**

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Mean-Variance Portfolio Theory (MVPT)

- **The only input data that counts is the time series of share prices and statistics derived therefrom, such as the (historical) annualized mean return and the (historical) annualized variance of the returns.**
- **The central assumption of MVP, according to Markowitz (1952), is that investors only care about expected returns and the variance of these returns.**

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Mean-Variance Portfolio Theory (MVPT)

- **Portfolio statistics**
  - **returns vector**
  - **expected return**
  - **vector of expected returns**
  - **expected return of the portfolio**
  - **covariance matrix**
  - **expected variance of the portfolio**
  - **expected volatility of the portfolio**

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

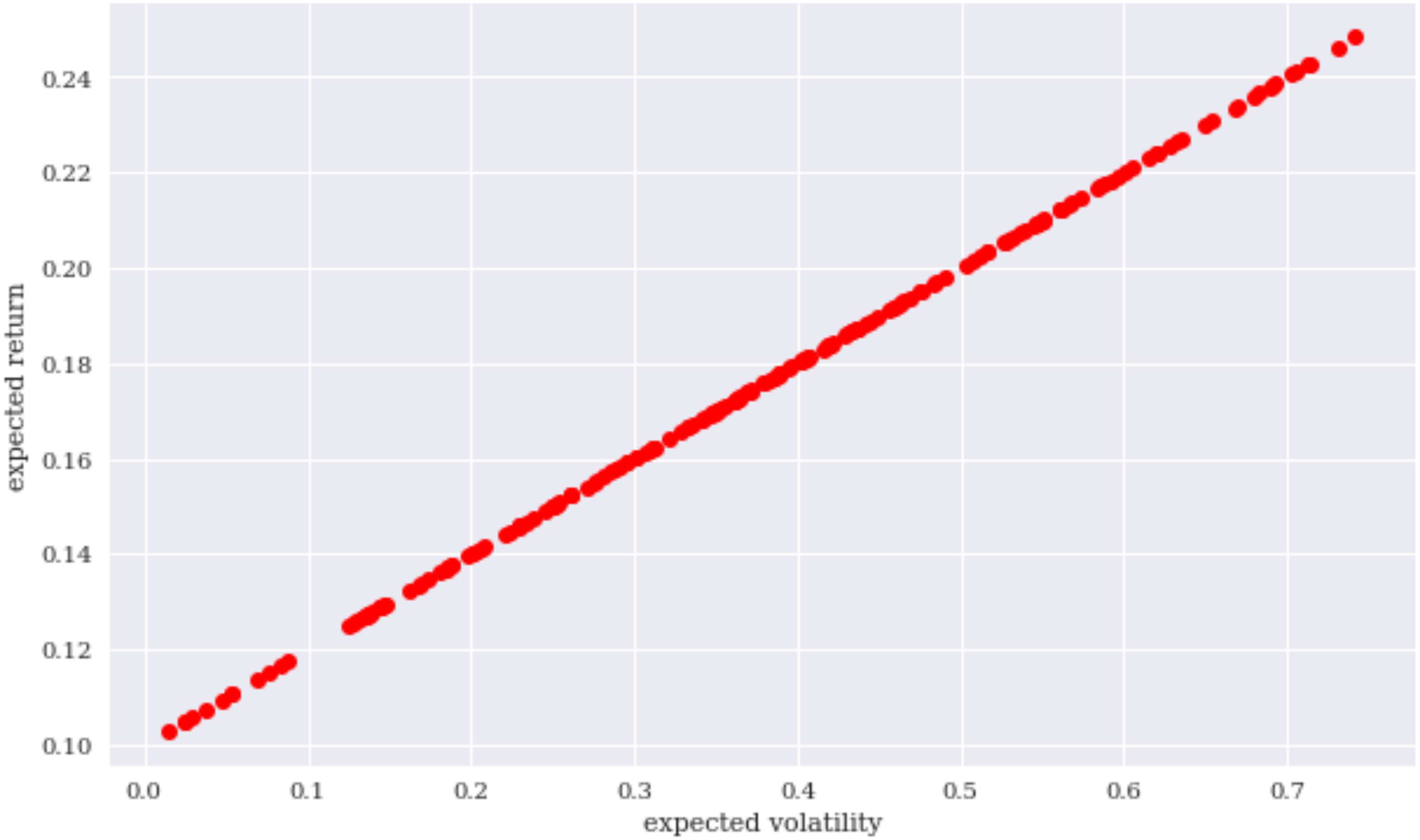
Sharpe ratio

- **Sharpe (1966) introduces a measure to judge the risk-adjusted performance of mutual funds and other portfolios, or even single risky assets.**
- **It relates the (expected, realized) return of a portfolio to its (expected, realized) volatility.**
  - **Sharpe ratio** $\pi = \frac{\mu}{\sigma}$
- **If r represents the risk-less short rate, the risk premium or excess return of a portfolio phi over a risk-free alternative is defined by** $\mu^{phi} - r$
  - **Sharpe ratio** $\pi = \frac{\mu - r}{\sigma}$

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Investment Opportunity Set

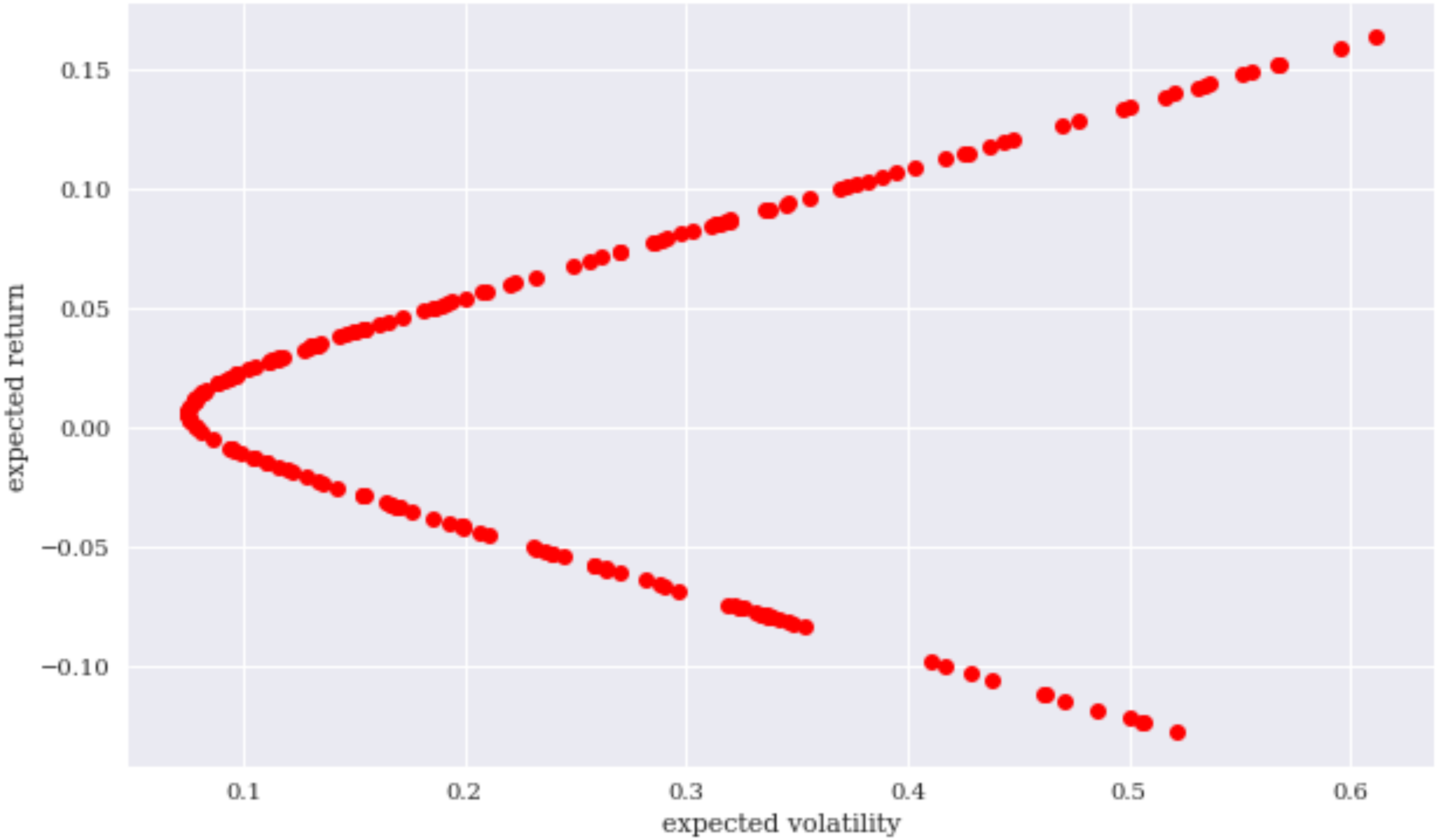
Simulated expected portfolio volatility and return (one risky asset)



Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

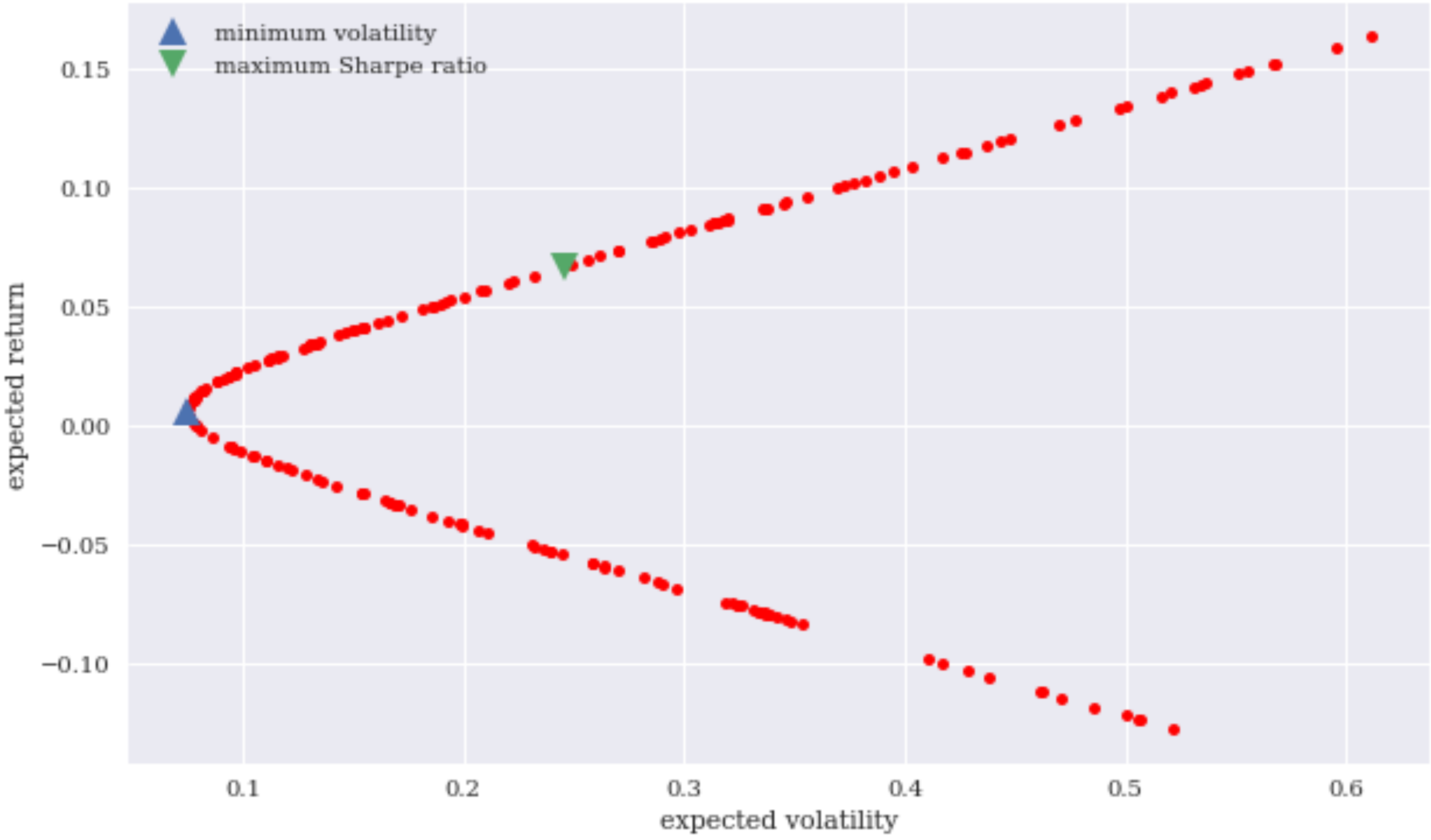
Investment Opportunity Set

Simulated expected portfolio volatility and return (two risky assets)



Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O’Reilly Media.

Minimum volatility and maximum Sharpe ratio portfolios



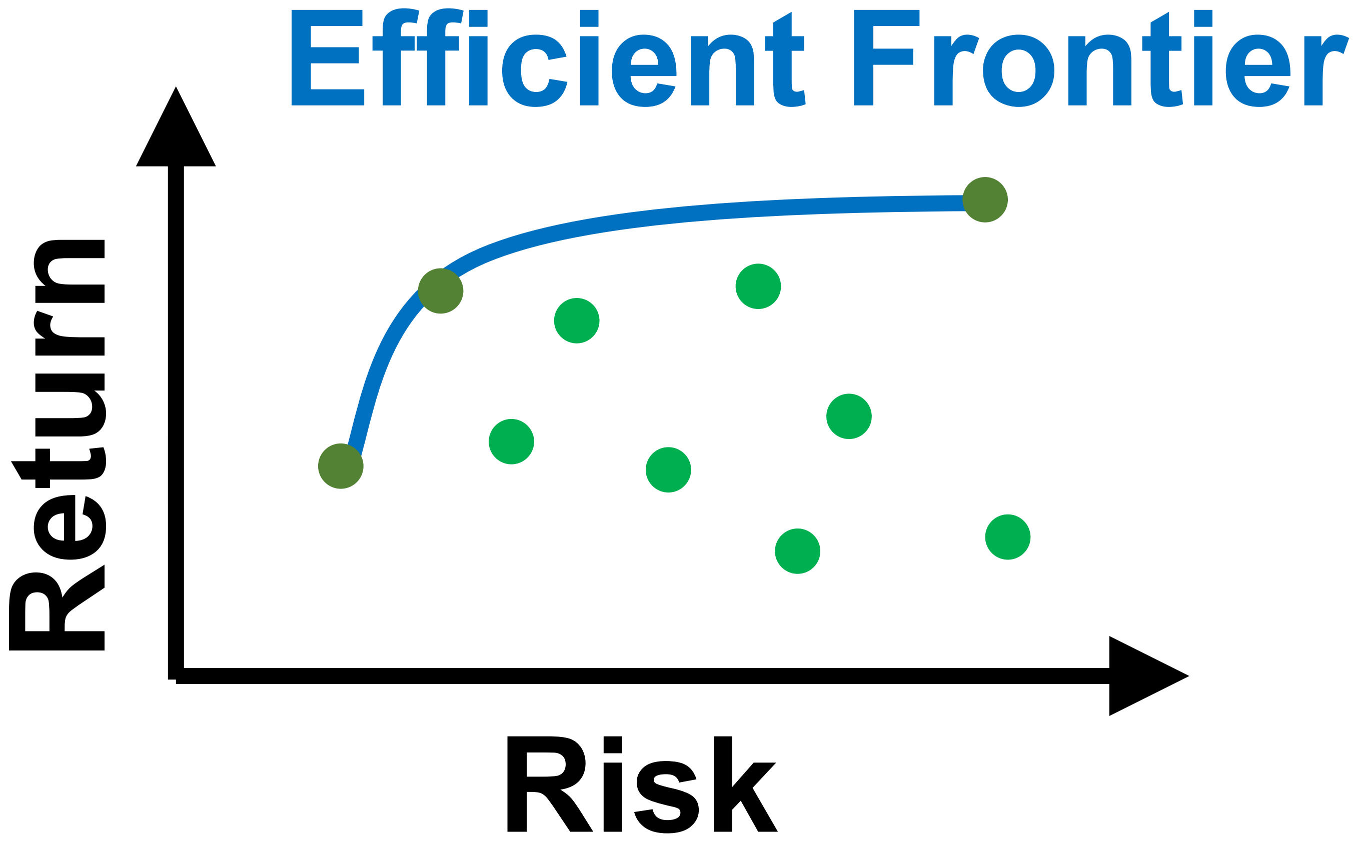
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Efficient Frontier

- An efficient portfolio
  - has a maximum expected return (risk) given its expected risk (return)
- All those portfolios that have a lower expected return than the minimum risk portfolio are inefficient.
- Efficient frontier
  - The set of all efficient portfolios
  - Agents will only choose a portfolio that lies on the efficient frontier

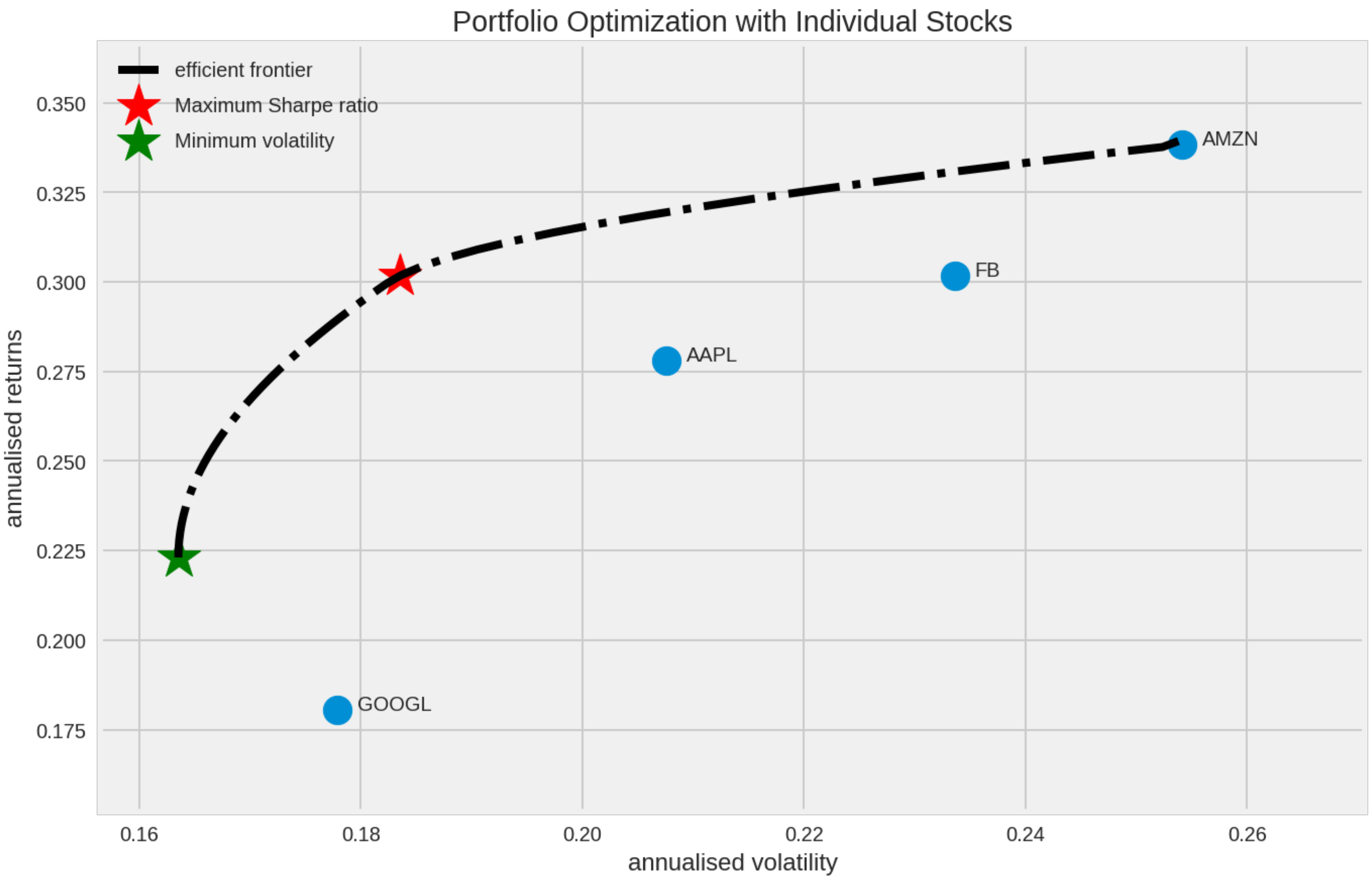
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Portfolio Optimization
Efficient Frontier



Source: Tucker Balch (2012), Investment Science: Portfolio Optimization, https://www.youtube.com/watch?v=5qbMhXXq0vI

Portfolio Optimization
Efficient Frontier



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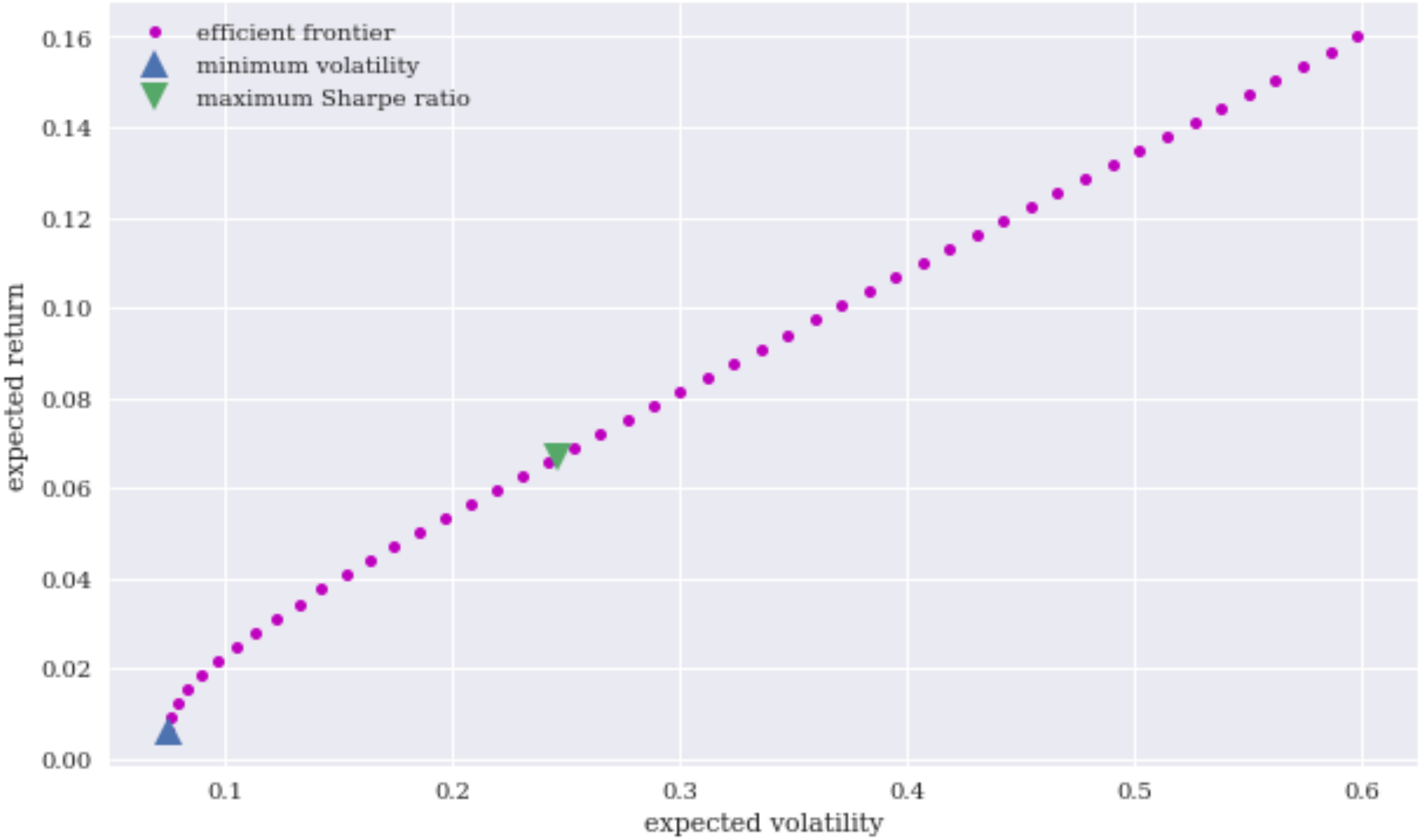
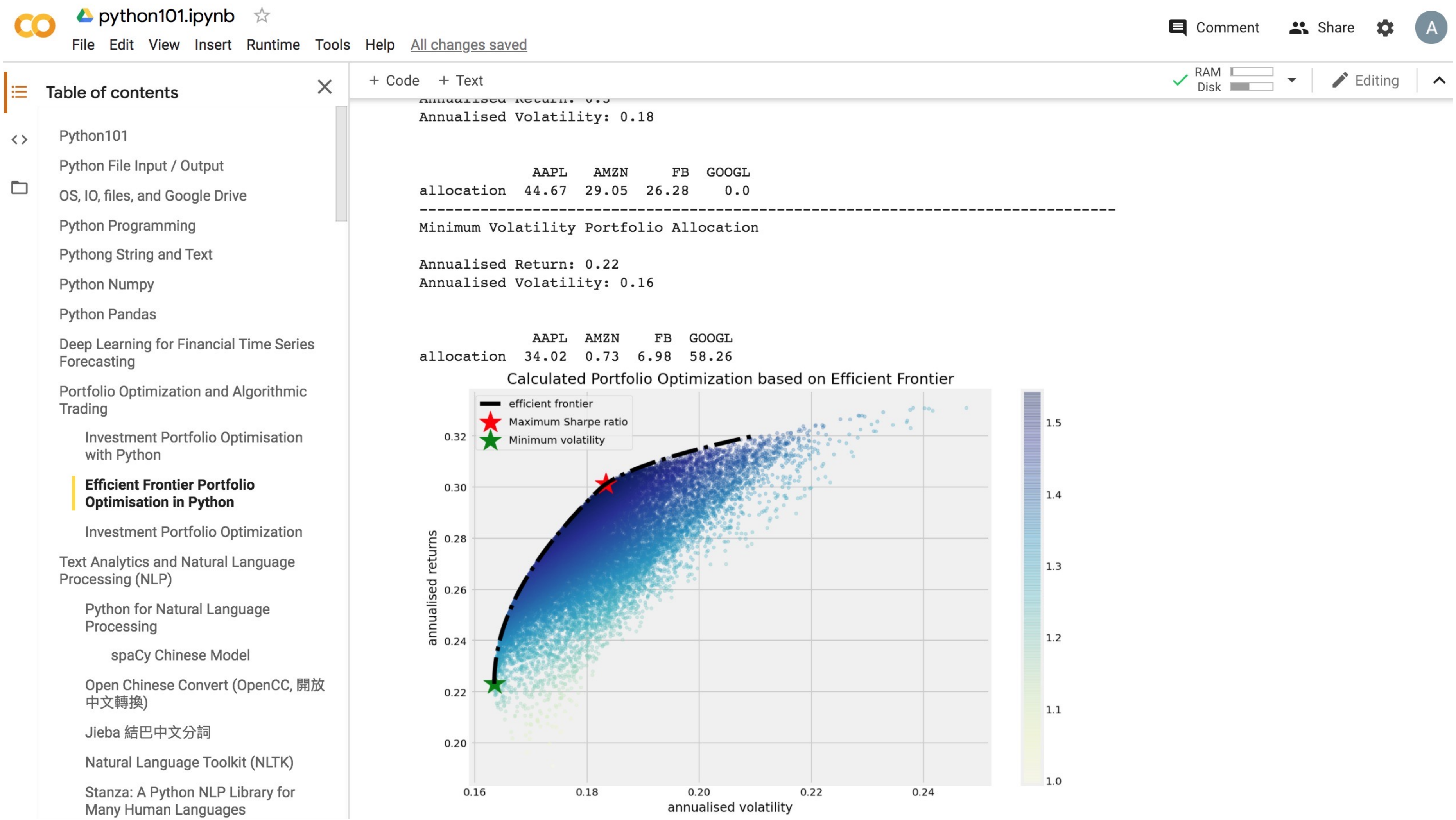
Efficient Frontier



Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O’Reilly Media.

Portfolio Optimization and Algorithmic Trading

https://colab.research.google.com/drive/1FEG6DnGvwfUbeo4zJ1zTunjMqf2RkCrT



Capital Asset Pricing Model (CAPM)

- Capital Asset Pricing Model (CAPM)
  - One of the most widely documented and applied models in finance
  - It relates in linear fashion the expected return for a single stock to the expected return of the market portfolio, usually approximated by a broad stock index such as the S&P 500.
  - Sharpe (1964) and Lintner (1965)

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Capital Asset Pricing Model (CAPM)

Capital asset prices: A theory of market equilibrium under conditions of risk
WF Sharpe - The journal of finance, 1964 - Wiley Online Library

ONE OF THE PROBLEMS which has plagued those attempting to predict the behavior of capital markets is the absence of a body of positive microeconomic theory dealing with conditions of risk. Although many useful insights can be obtained from the traditional models of investment under conditions of certainty, the pervasive influence of risk in financial transactions has forced those working in this area to adopt models of price behavior which are little more than assertions. A typical classroom explanation of the determination of …

Cite Cited by 30490 Related articles All 26 versions

Source: Sharpe, William F. "Capital asset prices: A theory of market equilibrium under conditions of risk." *The journal of finance* 19, no. 3 (1964): 425-442.

Capital Asset Pricing Model (CAPM)

The Journal of FINANCE

VOL. XIX SEPTEMBER 1964 No. 3

CAPITAL ASSET PRICES: A THEORY OF MARKET EQUILIBRIUM UNDER CONDITIONS OF RISK*

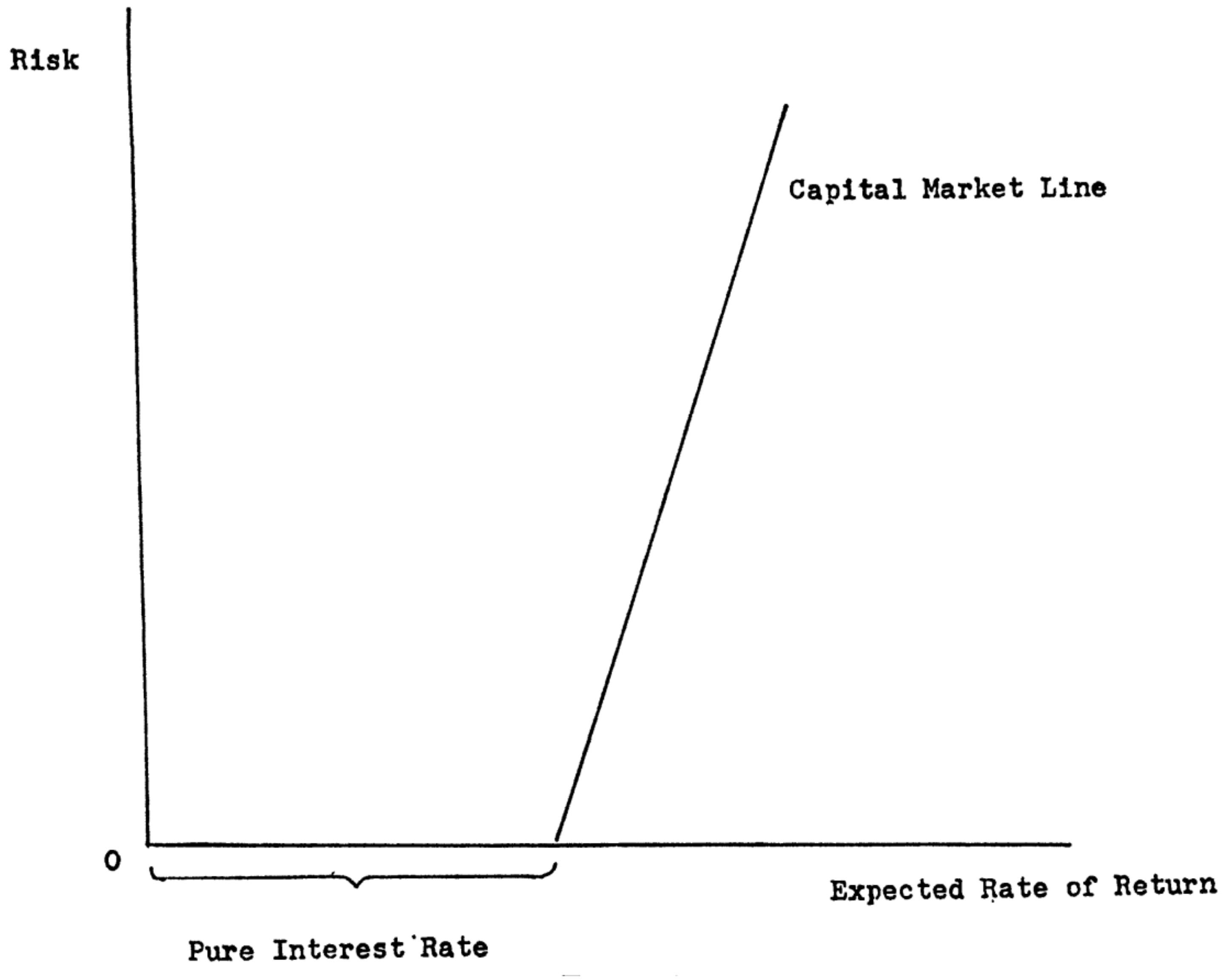
WILLIAM F. SHARPE†

I. INTRODUCTION

ONE OF THE PROBLEMS which has plagued those attempting to predict the behavior of capital markets is the absence of a body of positive microeconomic theory dealing with conditions of risk. Although many useful insights can be obtained from the traditional models of investment under conditions of certainty, the pervasive influence of risk in financial transactions has forced those working in this area to adopt models of price behavior which are little more than assertions. A typical classroom explanation of the determination of capital asset prices, for example, usually begins with a careful and relatively rigorous description of the process through which individual preferences and physical relationships interact to determine an equilibrium pure interest rate. This is generally followed by the assertion that somehow a market risk-premium is also determined, with the prices of assets adjusting accordingly to account for differences in their risk.

Source: Sharpe, William F. "Capital asset prices: A theory of market equilibrium under conditions of risk." *The journal of finance* 19, no. 3 (1964): 425-442.

Capital Asset Pricing Model (CAPM)



Source: Sharpe, William F. "Capital asset prices: A theory of market equilibrium under conditions of risk." *The journal of finance* 19, no. 3 (1964): 425-442.

Capital Asset Pricing Model (CAPM)

Journal of Economic Perspectives—Volume 18, Number 3—Summer 2004—Pages 25–46

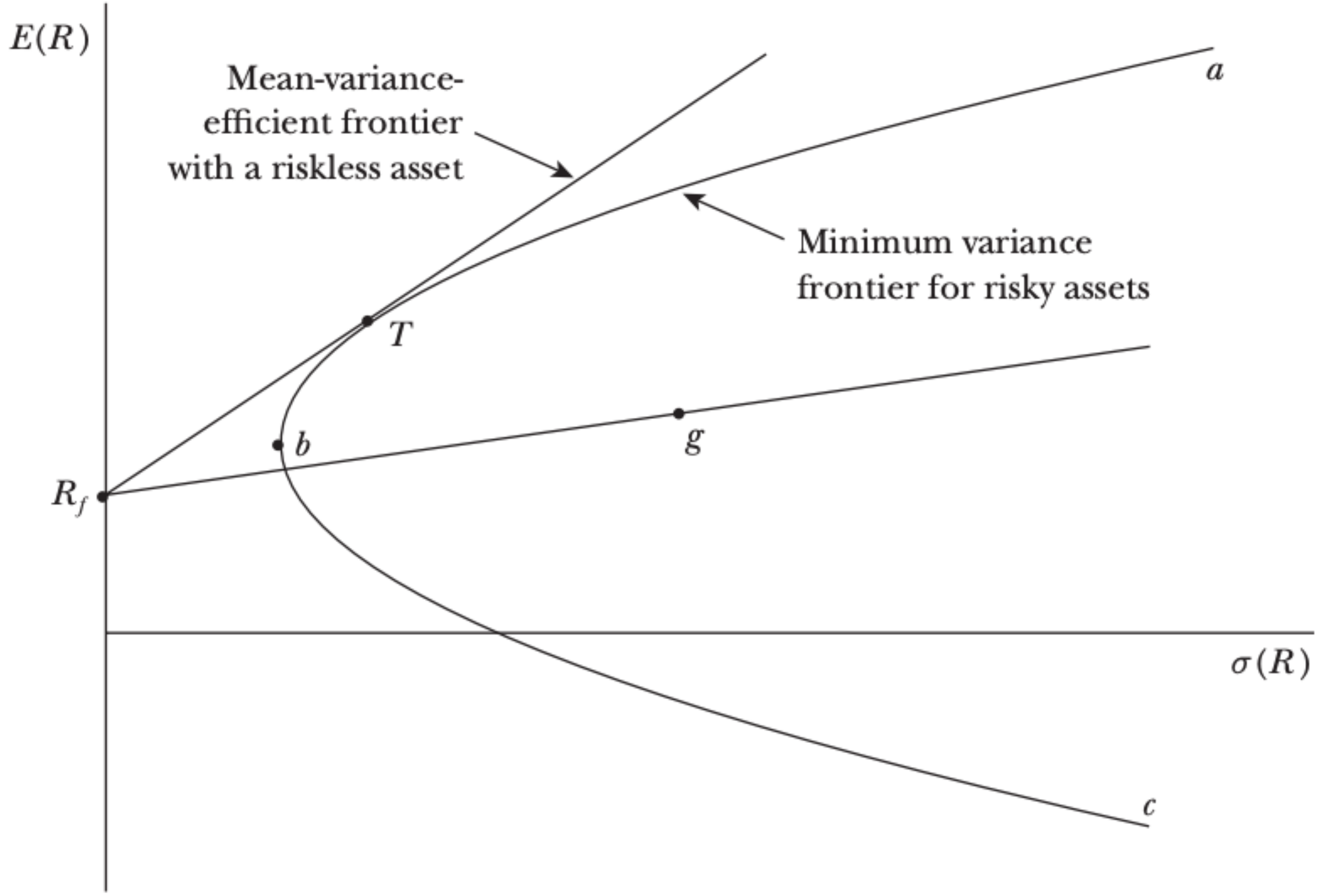
The Capital Asset Pricing Model: Theory and Evidence

Eugene F. Fama and Kenneth R. French

The capital asset pricing model (CAPM) of William Sharpe (1964) and John Lintner (1965) marks the birth of asset pricing theory (resulting in a Nobel Prize for Sharpe in 1990). Four decades later, the CAPM is still widely used in applications, such as estimating the cost of capital for firms and evaluating the performance of managed portfolios. It is the centerpiece of MBA investment courses. Indeed, it is often the only asset pricing model taught in these courses.[1]

Source: Fama, Eugene F., and Kenneth R. French. "The capital asset pricing model: Theory and evidence." Journal of economic perspectives 18, no. 3 (2004): 25-46.

Investment Opportunities



Source: Fama, Eugene F., and Kenneth R. French. "The capital asset pricing model: Theory and evidence." Journal of economic perspectives 18, no. 3 (2004): 25-46.

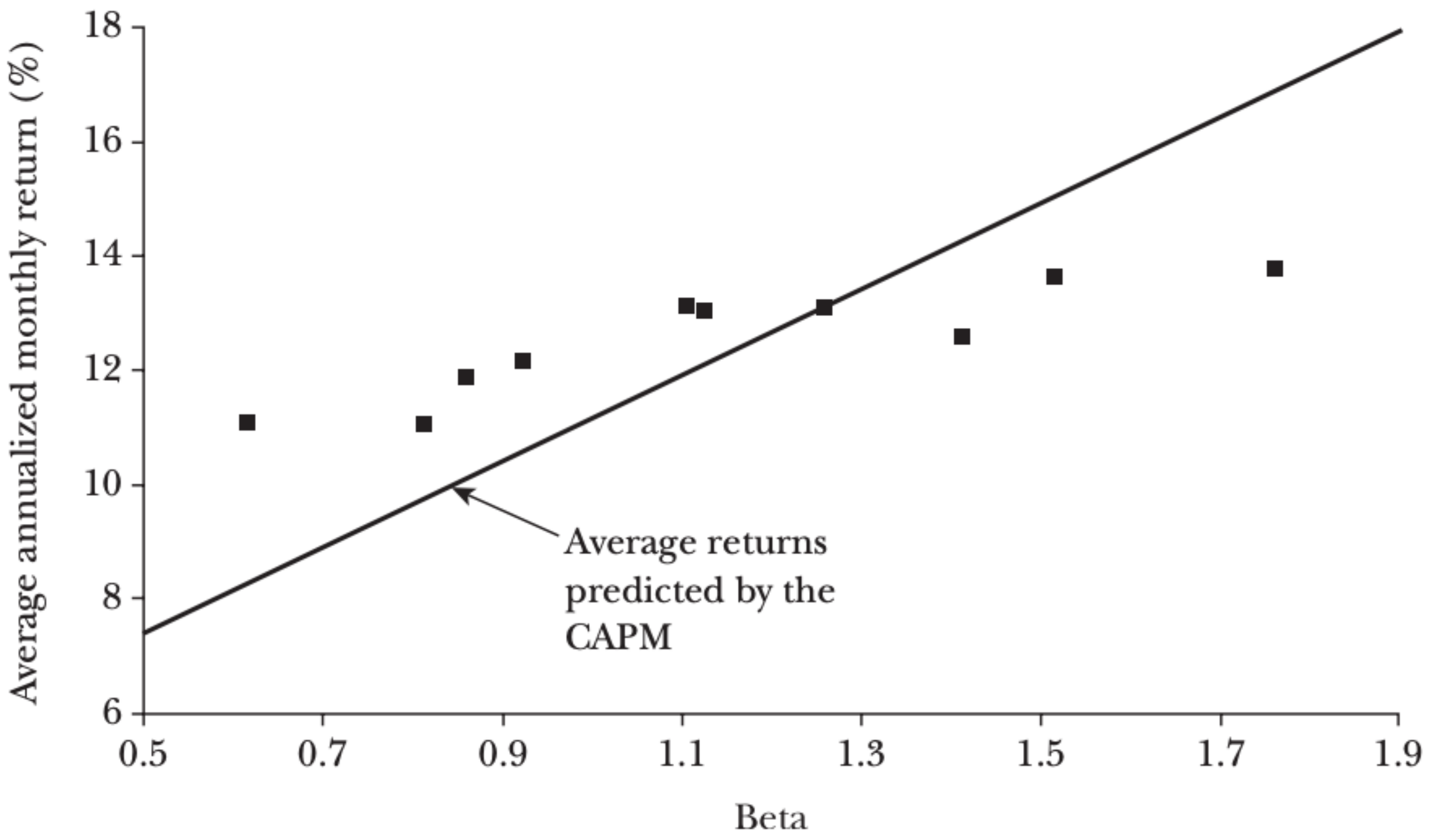
Capital Asset Pricing Model (CAPM)

$$E(R_i) = R_f + \beta_{iM} [E(R_M) - R_f]$$

The expected return on any asset i
is the risk-free interest rate, R_f, plus a risk premium,
which is the asset's market beta, β_{iM} ,
times the premium per unit of beta risk, $E(R_M)-R_f$

Source: Fama, Eugene F., and Kenneth R. French. "The capital asset pricing model: Theory and evidence." Journal of economic perspectives 18, no. 3 (2004): 25-46.

Capital Asset Pricing Model (CAPM)



Average Annualized Monthly Return versus Beta for Value Weight Portfolios Formed on Prior Beta, 1928–2003

Source: Fama, Eugene F., and Kenneth R. French. "The capital asset pricing model: Theory and evidence." Journal of economic perspectives 18, no. 3 (2004): 25-46.

Capital Asset Pricing Model (CAPM)

- **Capital market theory** is a **positive theory** in that it hypothesizes how investors do behave rather than how investors should behave, as in the case of **modern portfolio theory (MVP)**
  - It is reasonable to view capital market theory as an extension of portfolio theory, but it is important to understand that MVP is not based on the **validity**, or lack thereof, of capital market theory.

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Capital Asset Pricing Model (CAPM)

- The specific equilibrium model of interest to many investors is known as the capital asset pricing model, typically referred to as the CAPM.
  - It allows us to assess the relevant risk of an individual security as well as to assess the relationship between risk and the returns expected from investing.
  - The CAPM is attractive as an equilibrium model because of its simplicity and its implications.

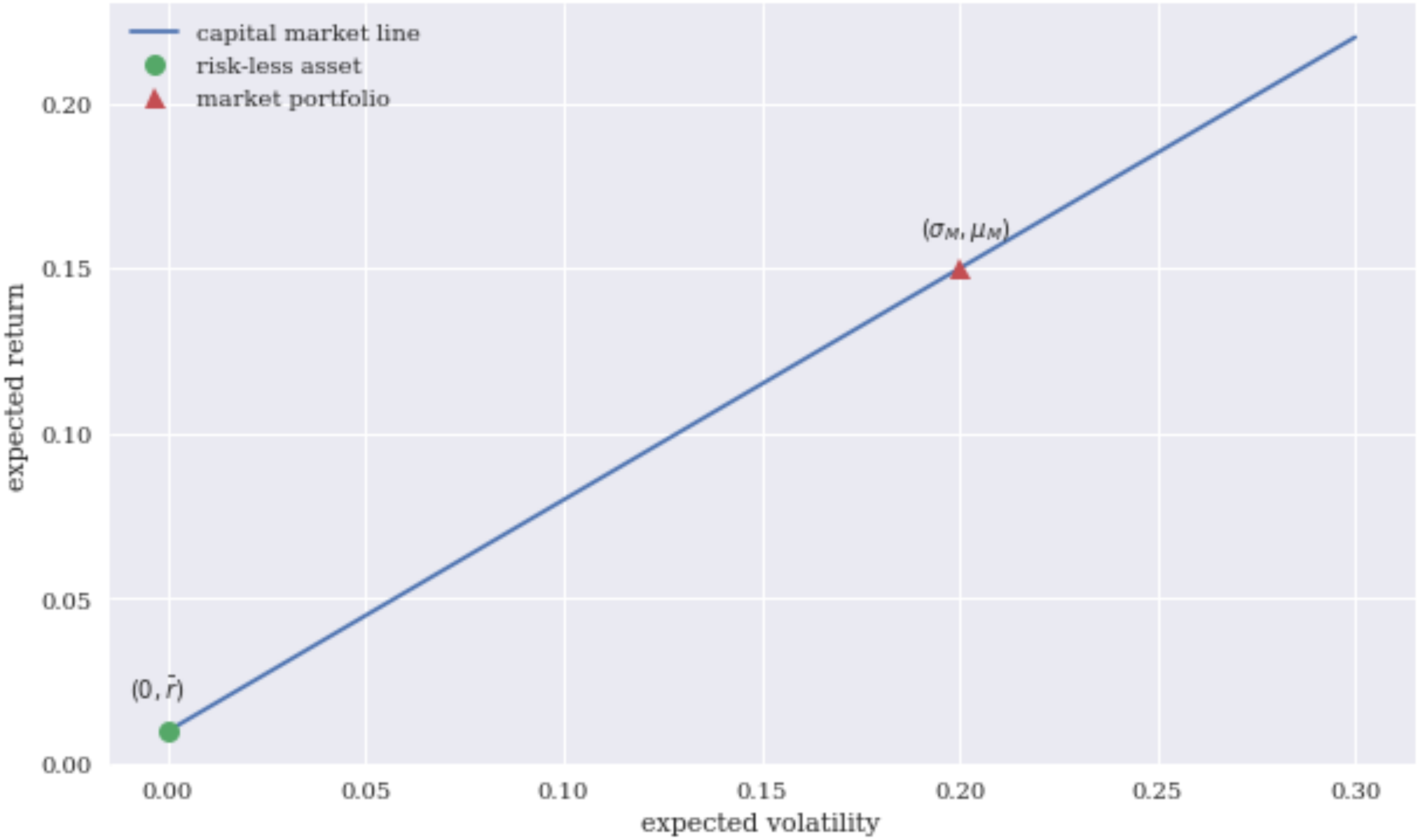
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Capital Asset Pricing Model (CAPM)

- In the CAPM, agents are assumed to invest according to MVP, caring only about the risk and return statistics of risky assets over one period.
- In a capital market equilibrium, all available assets are held by all agents and the markets clear.
- Market portfolio (set of tradable assets) must lie on the efficient frontier.
- Two fund separation theorem
  - Every agent will hold a combination of the market portfolio and the risk-free asset in equilibrium.
  - The set of all such portfolios is called the Capital Market Line (CML).

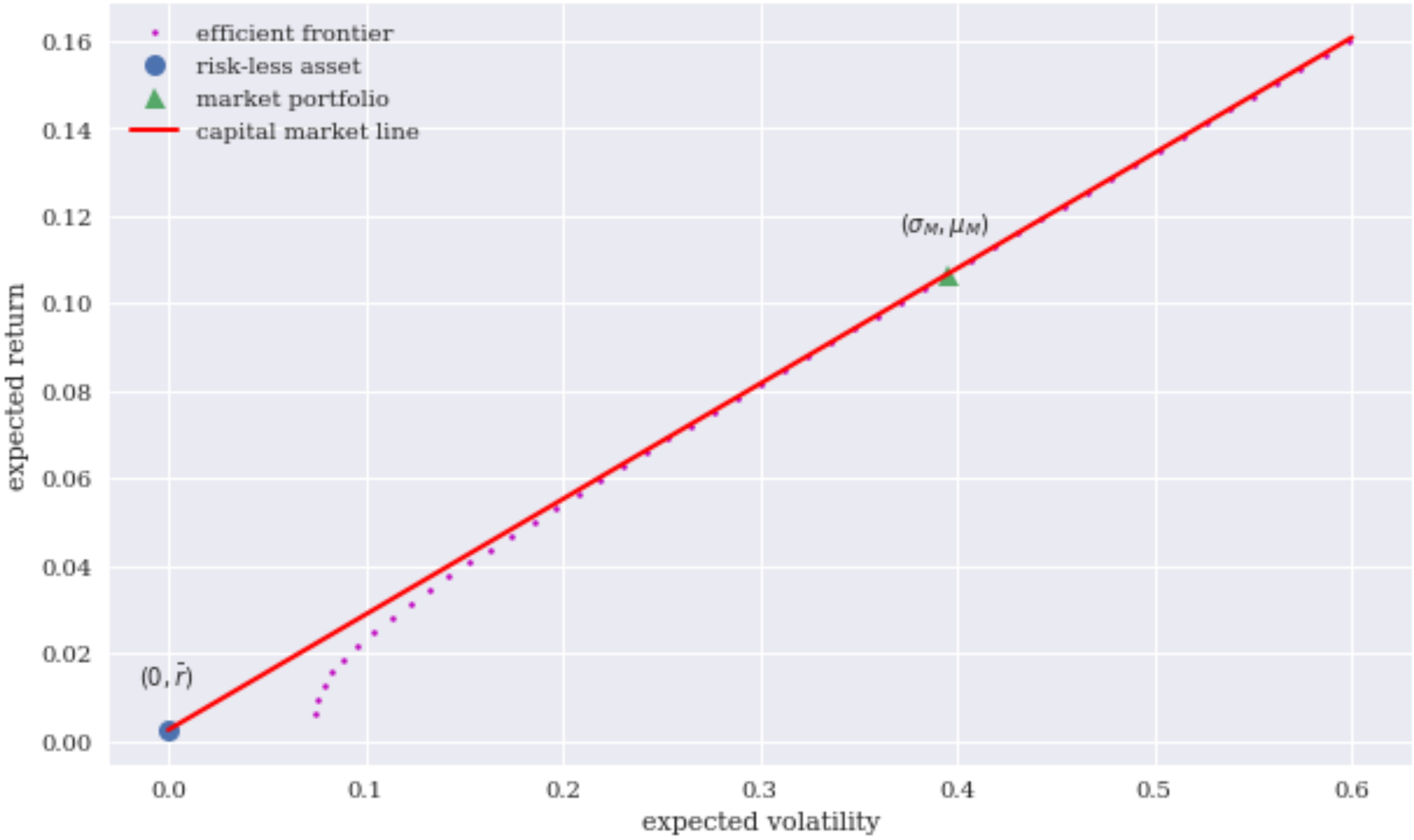
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Capital Market Line (CML)



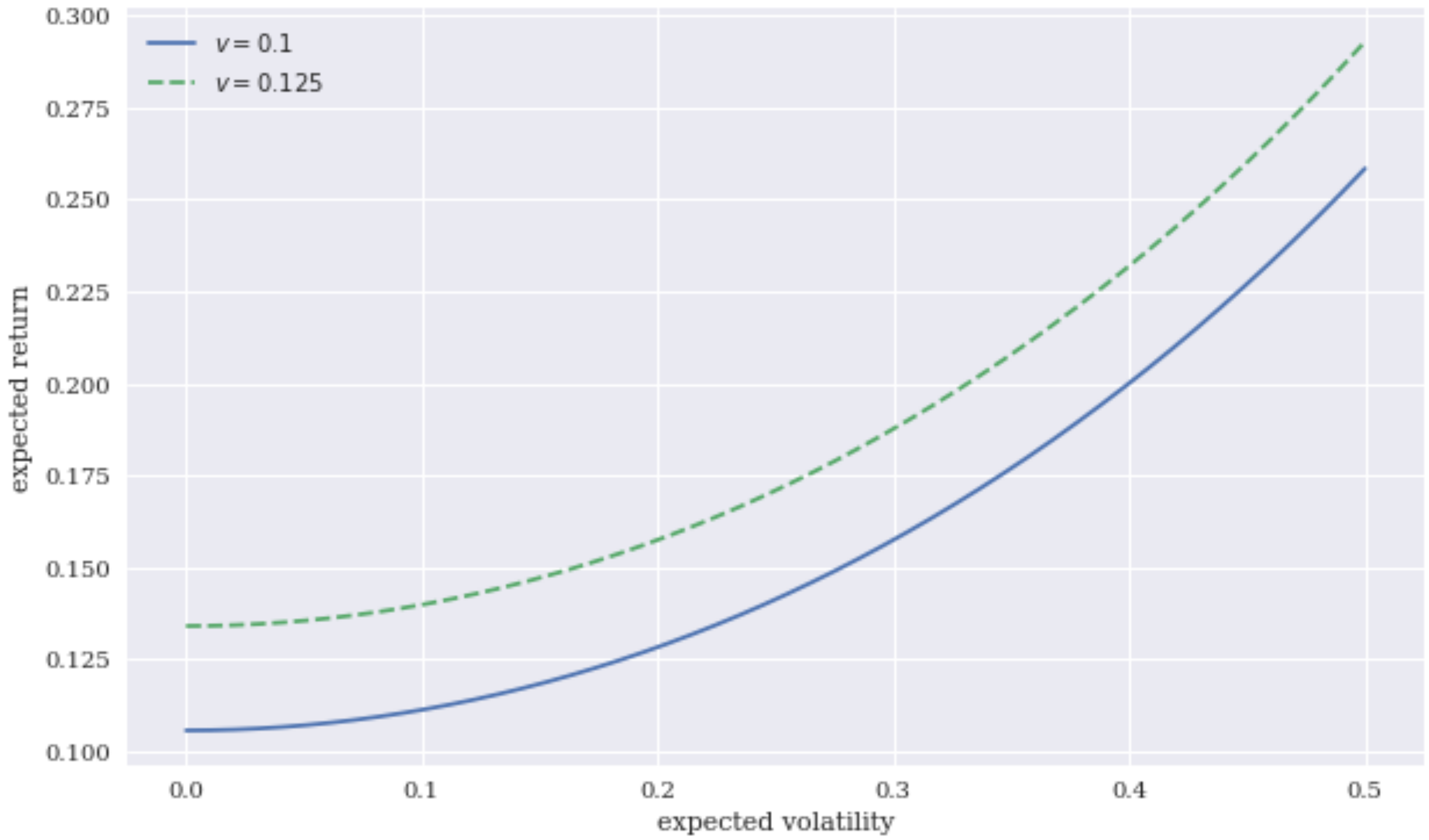
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Capital Market Line with Two Risky Assets



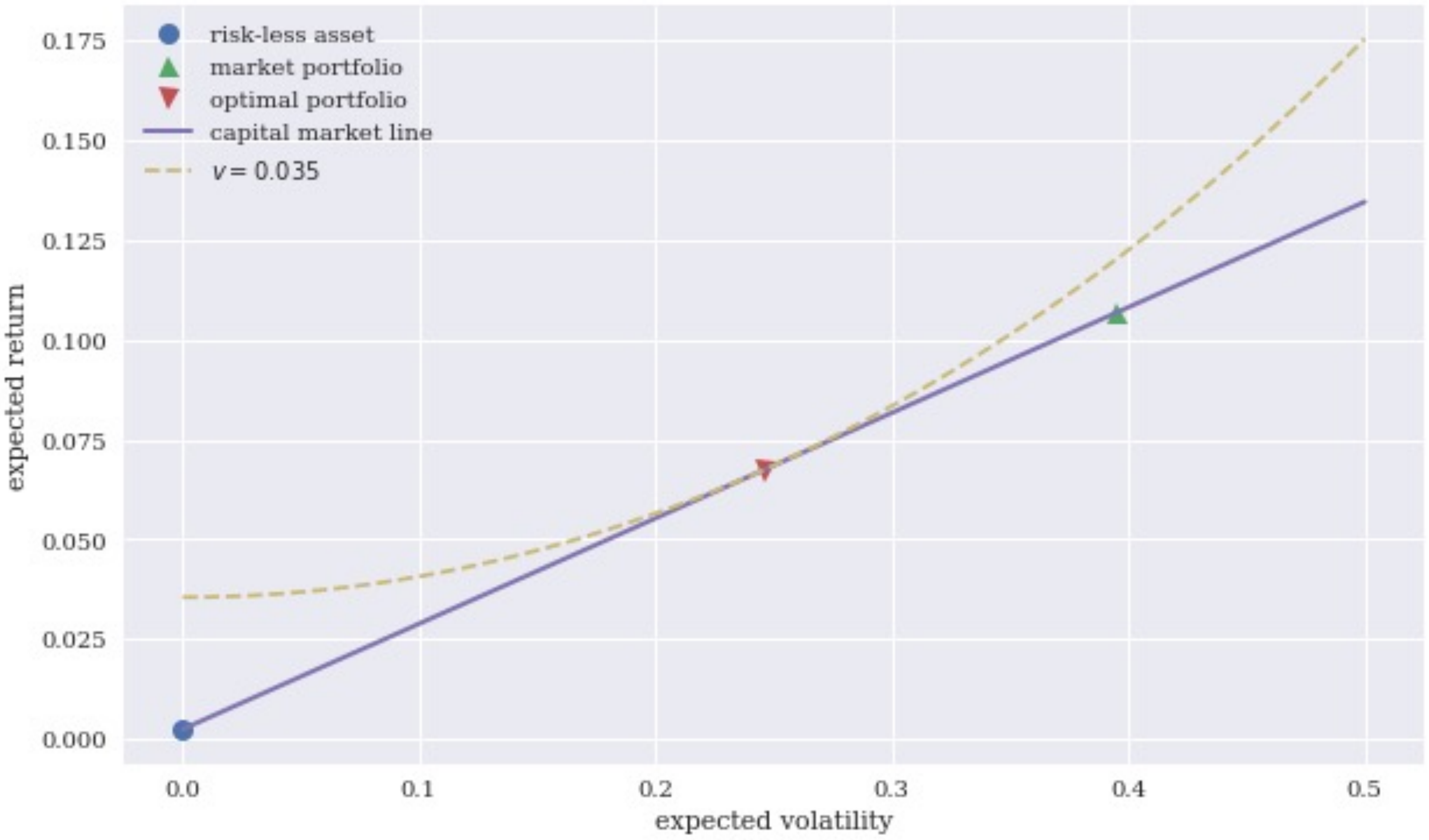
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Indifference curves in risk-return space



Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Optimal Portfolio on the Capital Market Line (CML)



Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Arbitrage Pricing Theory (APT)

- **Arbitrage Pricing Theory (APT)**
  - **One of the major generalizations of the Capital Asset Pricing Model (CAPM)**
  - **Ross (1971) and Ross (1976)**
  - **The purpose of this paper is to examine rigorously the arbitrage model of capital asset pricing developed in Ross (1971).**
    - The arbitrage model was proposed as an alternative to the mean variance capital asset pricing model, introduced by Sharpe, Lintner, and Treynor, that has become the major analytic tool for explaining phenomena observed in capital markets for risky assets.

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Arbitrage Pricing Theory (APT)

JOURNAL OF ECONOMIC THEORY **13**, 341–360 (1976)

The Arbitrage Theory of Capital Asset Pricing

STEPHEN A. ROSS*

Departments of Economics and Finance, University of Pennsylvania, The Wharton School, Philadelphia, Pennsylvania 19174

Received March 19, 1973; revised May 19, 1976

The purpose of this paper is to examine rigorously the arbitrage model of capital asset pricing developed in Ross [13, 14]. The arbitrage model was proposed as an alternative to the mean variance capital asset pricing model, introduced by Sharpe, Lintner, and Treynor, that has become the major analytic tool for explaining phenomena observed in capital markets for risky assets. The principal relation that emerges from the mean variance model holds that for any asset, i, its (ex ante) expected return

$$E_i = \rho + \lambda b_i \,, \qquad (1)$$

Source: Ross, Stephen A. "The arbitrage theory of capital asset pricing." Journal of Economic Theory 13, no. 3 (1976): 341-360.

Arbitrage Pricing Theory (APT)

- The APT is a generalization of the CAPM to multiple risk factors.
- APT does not assume that the market portfolio is the only relevant risk factor
  - There are rather multiple types of risk that together are assumed to drive the performance (expected returns) of a stock.
  - Such risk factors might include size, volatility, value, and momentum.

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Capital Asset Pricing Model (CAPM) Arbitrage Pricing Theory (APT)

- **Capital Asset Pricing Model (CAPM)**
  - **univariate ordinary least-squares (OLS) regression**
- **Arbitrage Pricing Theory (APT)**
  - **multivariate ordinary least-squares (OLS) regression**

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Python in Google Colab (Python101)

https://colab.research.google.com/drive/1FEG6DnGvwfUbeo4zJ1zTunjMqf2RkCrT

python101.ipynb - Colaboratory

https://colab.research.google.com/drive/1FEG6DnGvwfUbeo4zJ1zTunjMqf2RkCrT?authuser=2#scrollTo=wsh36fLxDKC3

python101.ipynb

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```python
# Future Value
pv = 100
r = 0.1
n = 7
fv = pv * ((1 + (r)) ** n)
print(round(fv, 2))
```

```
194.87
```

[11]

```python
amount = 100
interest = 10 #10% = 0.01 * 10
years = 7

future_value = amount * ((1 + (0.01 * interest)) ** years)
print(round(future_value, 2))
```

```
194.87
```

[12]

```python
# Python Function def
def getfv(pv, r, n):
    fv = pv * ((1 + (r)) ** n)
    return fv
fv = getfv(100, 0.1, 7)
print(round(fv, 2))
```

```
194.87
```

[13]

```python
# Python if else
score = 80
if score >=60 :
    print("Pass")
else:
    print("Fail")
```

```
Pass
```

https://tinyurl.com/aintpupython101

Python in Google Colab (Python101)

https://colab.research.google.com/drive/1FEG6DnGvwfUbeo4zJ1zTunjMqf2RkCrT

python101.ipynb

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Table of contents

AI in Finance

- Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O’Reilly Media.
- Github: https://github.com/yhilpisch/aiif/

Normative Finance and Financial Theories

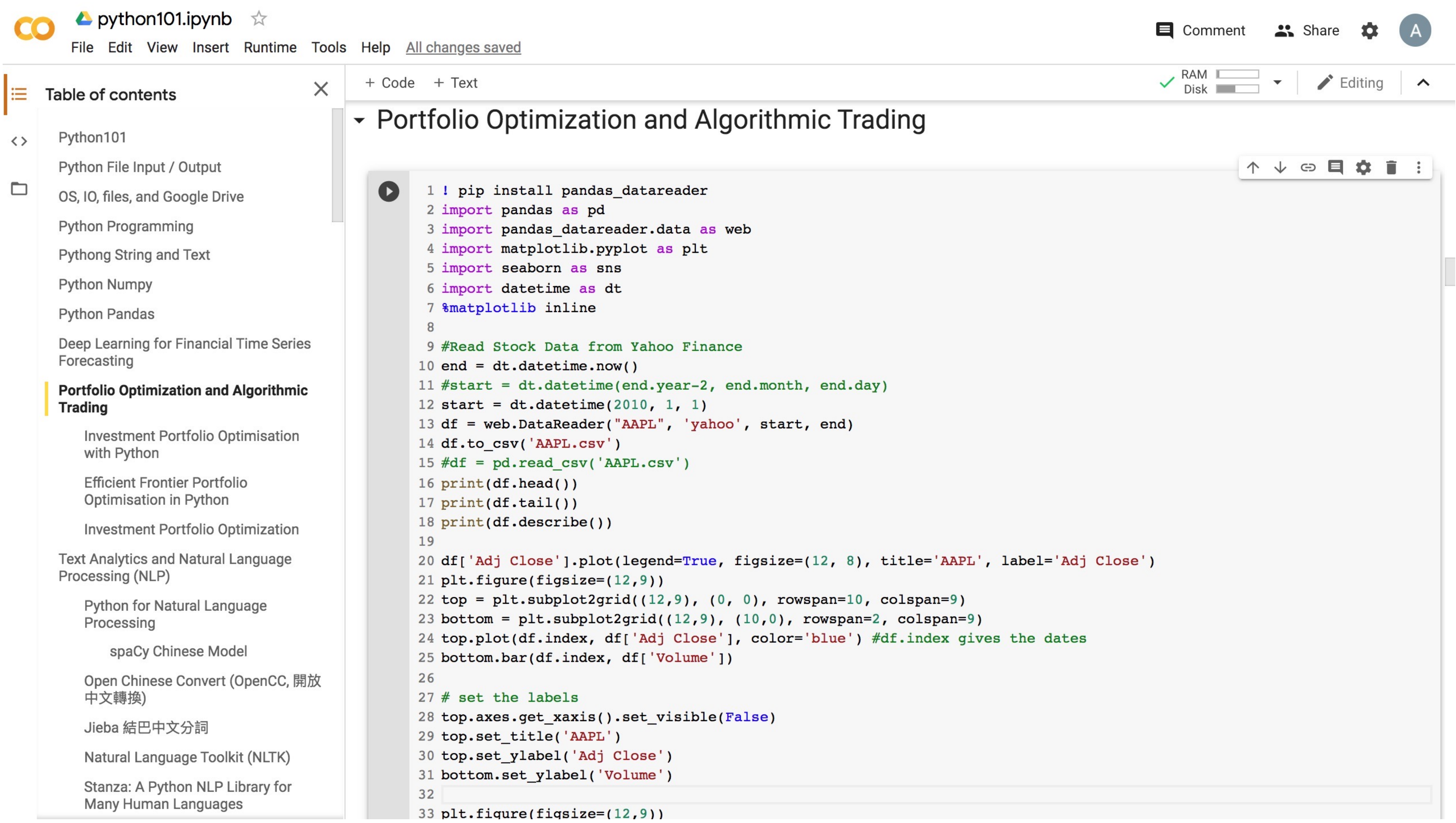
Uncertainty and Risk

```
import numpy as np

#The prices of the stock and bond today.
S0 = 10
B0 = 10
print('S0', S0)
print('S0', S0)

#The uncertain payoff of the stock and bond tomorrow.
S1 = np.array((20, 5))
B1 = np.array((11, 11))
print('S1', S1)
print('B1', B1)

#The market price vector
M0 = np.array((S0, B0))
```

https://tinyurl.com/aintpupython101

Python in Google Colab (Python101)

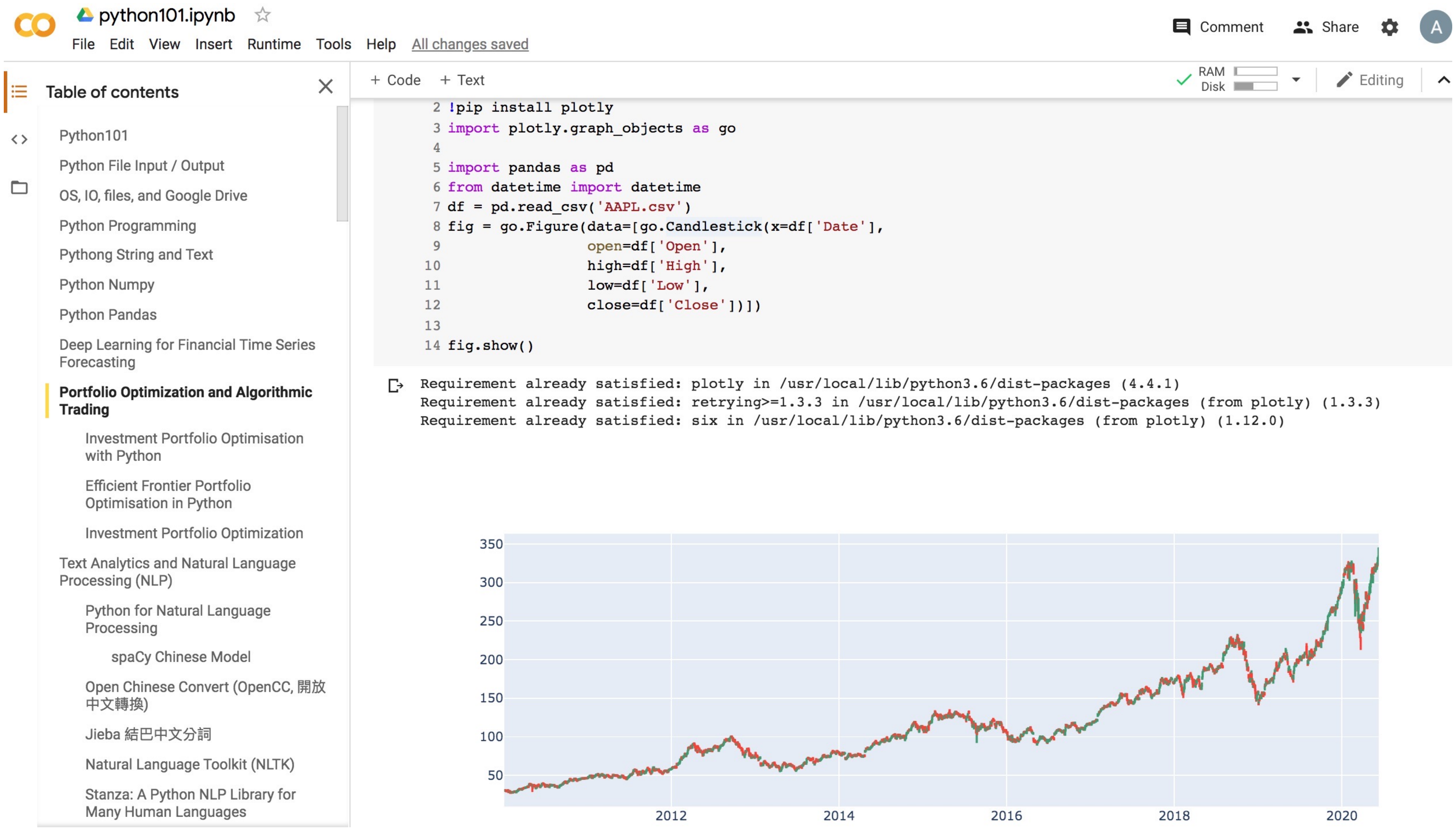
https://colab.research.google.com/drive/1FEG6DnGvwfUbeo4zJ1zTunjMqf2RkCrT



https://tinyurl.com/aintpupython101

Python in Google Colab (Python101)

https://colab.research.google.com/drive/1FEG6DnGvwfUbeo4zJ1zTunjMqf2RkCrT



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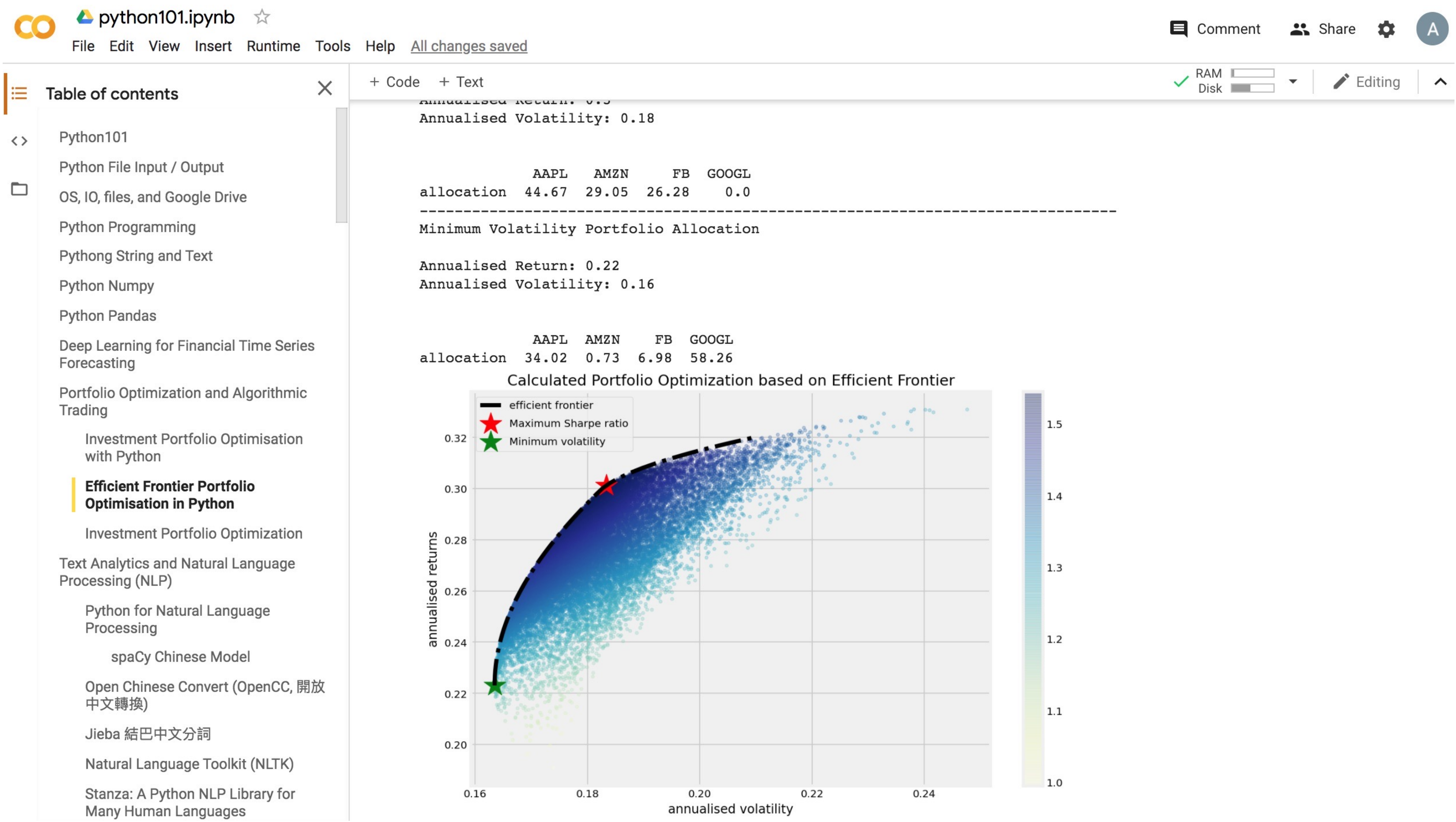

https://tinyurl.com/aintpupython101

Python in Google Colab (Python101)

https://colab.research.google.com/drive/1FEG6DnGvwfUbeo4zJ1zTunjMqf2RkCrT

Portfolio Optimization

Efficient Frontier Portfolio Optimization

python101.ipynb

File Edit View Insert Runtime Tools Help All changes saved

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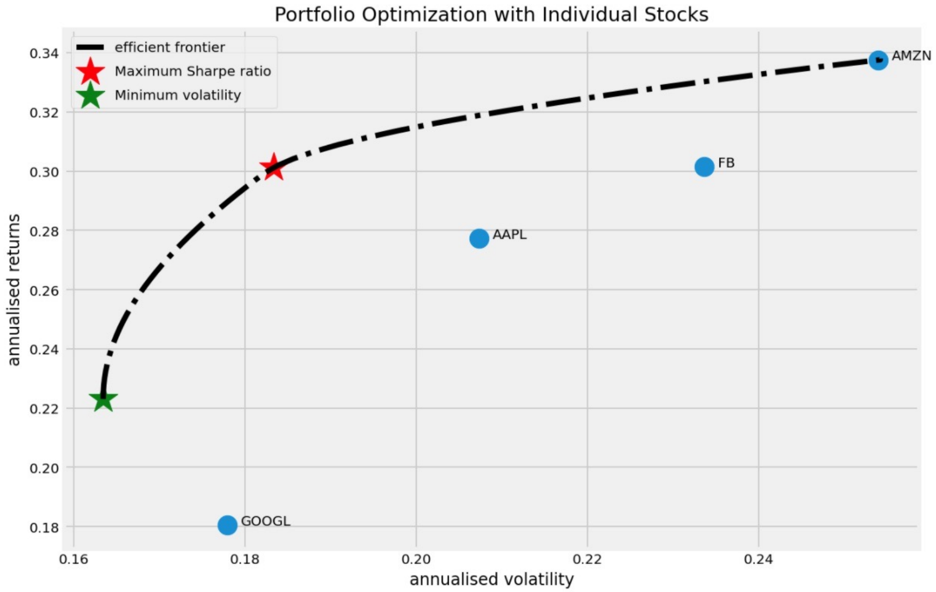
Table of contents

+ Code + Text RAM Disk Editing

```
Annualised Return: 0.22
Annualised Volatility: 0.16


              AAPL  AMZN    FB  GOOGL
allocation   34.02  0.73  6.98  58.26
--------------------------------------------------------------------------------
Individual Stock Returns and Volatility

AAPL : annuaised return 0.28 , annualised volatility: 0.21
AMZN : annuaised return 0.34 , annualised volatility: 0.25
FB : annuaised return 0.3 , annualised volatility: 0.23
GOOGL : annuaised return 0.18 , annualised volatility: 0.18
--------------------------------------------------------------------------------
```



https://tinyurl.com/aintpupython101

Summary

- Uncertainty and Risk
- Expected Utility Theory (EUT)
- Mean-Variance Portfolio Theory (MVPT)
- Capital Asset Pricing Model (CAPM)
- Arbitrage Pricing Theory (APT)

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Data-Driven Finance

Data-Driven Finance

- Scientific Method
- Financial Econometrics and Regression
- Data Availability
- Normative Theories Revisited
- Debunking Central Assumptions in Finance

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Data-driven finance

- **Financial context (theory, model, application) that is primarily driven by and based on insights gained from data.**

Data-driven finance

Robin Wigglesworth (2019)

- Nowadays, analysts sift through non-traditional information such as satellite imagery and credit card data, or use artificial intelligence techniques such as machine learning and natural language processing to glean fresh insights from traditional sources such as economic data and earnings-call transcripts.

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Scientific Method

- Generally accepted principles that should guide scientific effort
- The scientific method is an empirical method of acquiring knowledge that has characterized the development of science
- It involves careful observation, applying rigorous skepticism about what is observed, given that cognitive assumptions can distort how one interprets the observation.

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Scientific Method

- It involves formulating hypotheses, via induction, based on such observations; experimental and measurement-based testing of deductions drawn from the hypotheses; and refinement (or elimination) of the hypotheses based on the experimental findings

Normative Finance and Scientific Method

- **Normative financial theories** mostly rely on assumptions and axioms in combination with deduction as the major analytical method to arrive at their central results.
  - **Expected utility theory (EUT)** assumes that agents have the same utility function no matter what state of the world unfolds and that they maximize expected utility under conditions of uncertainty.
  - **Mean-variance portfolio (MVP)** theory describes how investors should invest under conditions of uncertainty assuming that only the expected return and the expected volatility of a portfolio over one period count.

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Normative Finance and Scientific Method

- The capital asset pricing model (CAPM) assumes that only the nondiversifiable market risk explains the expected return and the expected volatility of a stock over one period.
- Arbitrage pricing theory (APT) assumes that a number of identifiable risk factors explains the expected return and the expected volatility of a stock over time; admittedly, compared to the other theories, the formulation of APT is rather broad and allows for wide-ranging interpretations.

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Financial Econometrics and Regression

- [Financial] econometrics is the quantitative application of statistical and mathematical models using [financial] data to develop financial theories or test existing hypotheses in finance and to forecast future trends from historical data.
- It subjects real-world [financial] data to statistical trials and then compares and contrasts the results against the [financial] theory or theories being tested.

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Financial Econometrics and Regression

- One of the major tools in **financial econometrics** is **regression**, in both its univariate and multivariate forms
- **Regression** is also a central tool in **statistical learning** in general

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Data Availability

- **Types of (financial) data**
  - **Financial econometrics is driven by statistical methods, such as regression, and the availability of financial data**
  - **Theoretical and empirical financial research was mainly driven by relatively small data sets and was mostly comprised of end-of-day (EOD) data**
  - **Types of financial and other data available in ever increasing granularity, quantity, and velocity.**
- **Quality and quantity via programmatic APIs**
  - **Finance professionals have relied on data terminals from Refinitiv or Bloomberg**
  - **Major breakthrough in data-driven finance via programmatic APIs**

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Relevant types of financial data

Time	Structured data	Unstructured data	Alternative data
Historical	Prices, fundamentals	News, texts	Web, social media, satellites
Streaming	Prices, volumes	News, filings	Web, social media, satellites, Internet of Things

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Yahoo Finance World Indices

https://finance.yahoo.com/world-indices/

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U.S. markets closed

S&P 500	Dow 30	Nasdaq	Russell 2000	Crude Oil
4,217.04	32,936.41	13,018.33	1,665.88	86.04
-7.12 (-0.17%)	-190.87 (-0.58%)	+34.52 (+0.27%)	-14.91 (-0.89%)	+0.55 (+0.64%)

World Indices

Symbol	Name	Last Price	Change	% Change	Volume	Intraday High/Low		52 Week Range		Day Chart
^GSPC	S&P 500	4,217.04	-7.12	-0.17%	2.455B	4,189.22	4,255.84	3,698.15	4,607.07	
^DJI	Dow Jones Industrial Average	32,936.41	-190.87	-0.58%	345.435M	32,892.19	33,234.85	31,161.41	35,679.13	
^IXIC	NASDAQ Composite	13,018.33	+34.52	+0.27%	4.075B	12,848.83	13,143.23	10,207.47	14,446.55	
^NYA	NYSE COMPOSITE (DJ)	14,946.01	-87.30	-0.58%	0	14,916.63	15,082.62	14,085.42	16,458.89	
^XAX	NYSE AMEX COMPOSITE INDEX	4,518.31	-63.56	-1.39%	0	4,501.20	4,581.87	3,824.21	4,723.96	
^BUK100P	Cboe UK 100	736.03	-2.71	-0.37%	0	732.56	738.73	690.72	805.30	
^RUT	Russell 2000	1,665.88	-14.91	-0.89%	0	1,662.64	1,687.74	1,662.64	2,007.31	
^VIX	CBOE Volatility Index	20.37	-1.34	-6.17%	0	19.48	23.08	15.53	35.05	
^FTSE	FTSE 100	7,374.83	-27.31	-0.37%	0	7,338.59	7,402.20	6,914.70	8,047.10	
^GDAXI	DAX PERFORMANCE-INDEX	14,800.72	+2.25	+0.02%	0	14,630.21	14,838.01	12,747.38	16,528.97	

World Indices

```
import io
import requests
import pandas as pd
response = requests.get('https://finance.yahoo.com/world-indices/')
df = pd.read_html(io.StringIO(response.text))
worldidx = df[0]
worldidx.to_csv('world_indices.csv')
worldidx
```

Symbol	Name	Last Price	Change	% Change	Volume
^GSPC	S&P 500	3,797.34	+44.59	+1.19%	2.589B
^DJI	Dow Jones Industrial Average	31,499.62	+417.06	+1.34%	345.036M
^IXIC	NASDAQ Composite	10,952.61	+92.90	+0.86%	4.063B
^NYA	NYSE COMPOSITE (DJ)	14,226.11	+82.05	+0.58%	0
^XAX	NYSE AMEX COMPOSITE INDEX	4,295.57	-106.83	-2.43%	0
^BUK100P	Cboe UK 100	701.69	+5.39	+0.77%	0
^RUT	Russell 2000	1,748.40	+6.16	+0.35%	0
^VIX	Vix	29.85	+0.16	+0.54%	0

ffn: Financial Functions for Python

```
#^GSPC S&P 500
#^DJI Dow 30
#^IXIC Nasdaq
!pip install ffn
import ffn
%pylab inline
df = ffn.get('^gspc, ^dji, ^ixic', start='2010-01-01', end='2022-01-01')
print(df.head())
print(df.tail())
print(df.describe())
ax = df.plot(figsize=(12,9))
```

```
2021-12-29  4793.060059  36488.628906  15766.219727
2021-12-30  4778.729980  36398.078125  15741.559570
2021-12-31  4766.180176  36338.300781  15644.969727
              gspc           dji          ixic
count  3021.000000   3021.000000   3021.000000
mean   2260.488112  19756.317518   6004.283709
std     890.501675   6927.100147   3438.840186
min    1022.580017   9686.480469   2091.790039
25%    1461.400024  13557.000000   3131.489990
50%    2088.479980  17851.509766   4984.620117
75%    2798.360107  25332.179688   7669.169922
max    4793.060059  36488.628906  16057.440430
```

^GSPC: S&P 500, ^DJI: Dow 30, ^IXIC: Nasdaq

```
df = ffn.get('^gspc, ^dji, ^ixic', start='2010-01-01', end='2022-01-01')
ax = df.plot(figsize=(12,9))
```

ffn: Financial Functions for Python

```
!pip install ffn
import ffn
%pylab inline
df = ffn.get('^gspc, ^dji, ^ixic', start='2010-01-01', end='2022-01-01')
print(df.head())
print(df.tail())
print(df.describe())
ax = df.plot(figsize=(12,9))

returns = df.to_returns().dropna()
ax = returns.hist(figsize=(14, 10))
returns.corr().as_format('.2f')
returns.plot_corr_heatmap()
ax = df.plot(figsize=(14,10))

perf = df.calc_stats()
perf.plot(figsize=(14, 10))

print(perf.display())
```

CoinGeckoAPI(): Cryptocurrency Data API

```
from pycoingecko import CoinGeckoAPI
import pandas as pd
from datetime import datetime

start_date_obj = datetime.strptime('2020-01-01', '%Y-%m-%d')
end_date_obj = datetime.strptime('2022-12-31', '%Y-%m-%d’)

cg = CoinGeckoAPI()

data = cg.get_coin_market_chart_range_by_id(id='bitcoin',
vs_currency='usd', from_timestamp=start_date_obj.timestamp(),
to_timestamp=end_date_obj.timestamp())

processed_data = [ {'date': datetime.utcfromtimestamp(price[0] /
1000).date(), 'price': price[1]} for price in data.get('prices', [])]
df = pd.DataFrame(processed_data)
df.to_csv('btcusd.csv')
```

Source: https://www.coingecko.com/en/api

Carbon Credits: Carbon Prices Today

CARBON CREDITS .com

CARBON PRICES STOCKS NEWS EDUCATION FEATURED

Home › Live Carbon Prices Today

(+17.50%) | KEUA • 29.31 D −0.30 (−1.00%) | KCCA • 28.65 D +0.03 (+0.10%) | SMOG • 95.18 D +0.27 (+0.28%)

Live Carbon Prices Today

Trending Right Now

US DOE's $7B Clean Hydrogen Hub Grant: The 7 Chosen Ones

greenlines

Startup Revolutionizes Mobility Sector with World's First Carbon Credit Patent

CarbonCredits.com Live Carbon Prices	Last	Change	YTD
Compliance Markets			
European Union	€80.30	-6.30 %	+0.37 %
UK	£41.49	-3.17 %	-43.36 %
California	$29.41	-	+1.17 %
Australia (AUD)	$31.00	-0.80 %	-8.28 %
New Zealand (NZD)	$69.50	-	-9.06 %
South Korea	$8.78	-	-26.25 %
China	$11.13	-0.29 %	+40.88 %
Voluntary Markets			
Aviation Industry Offset	$0.75	+1.35 %	-80.47 %
Nature Based Offset	$1.57	-1.26 %	-65.87 %
Tech Based Offset	$0.82	-	-28.07 %

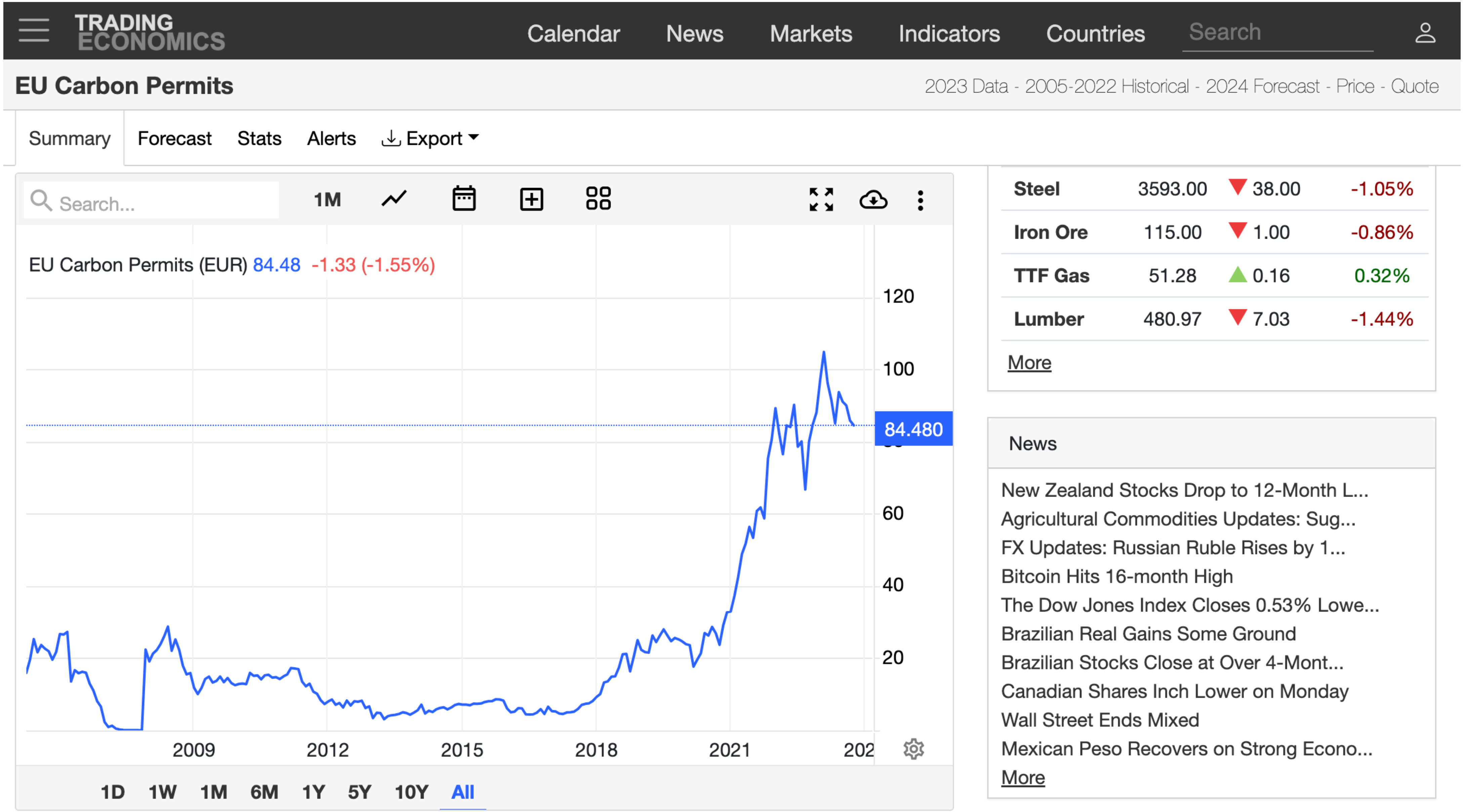
CarbonCredits.com Real-time Pricing

Click here to learn how carbon credits are priced.

Opportunity

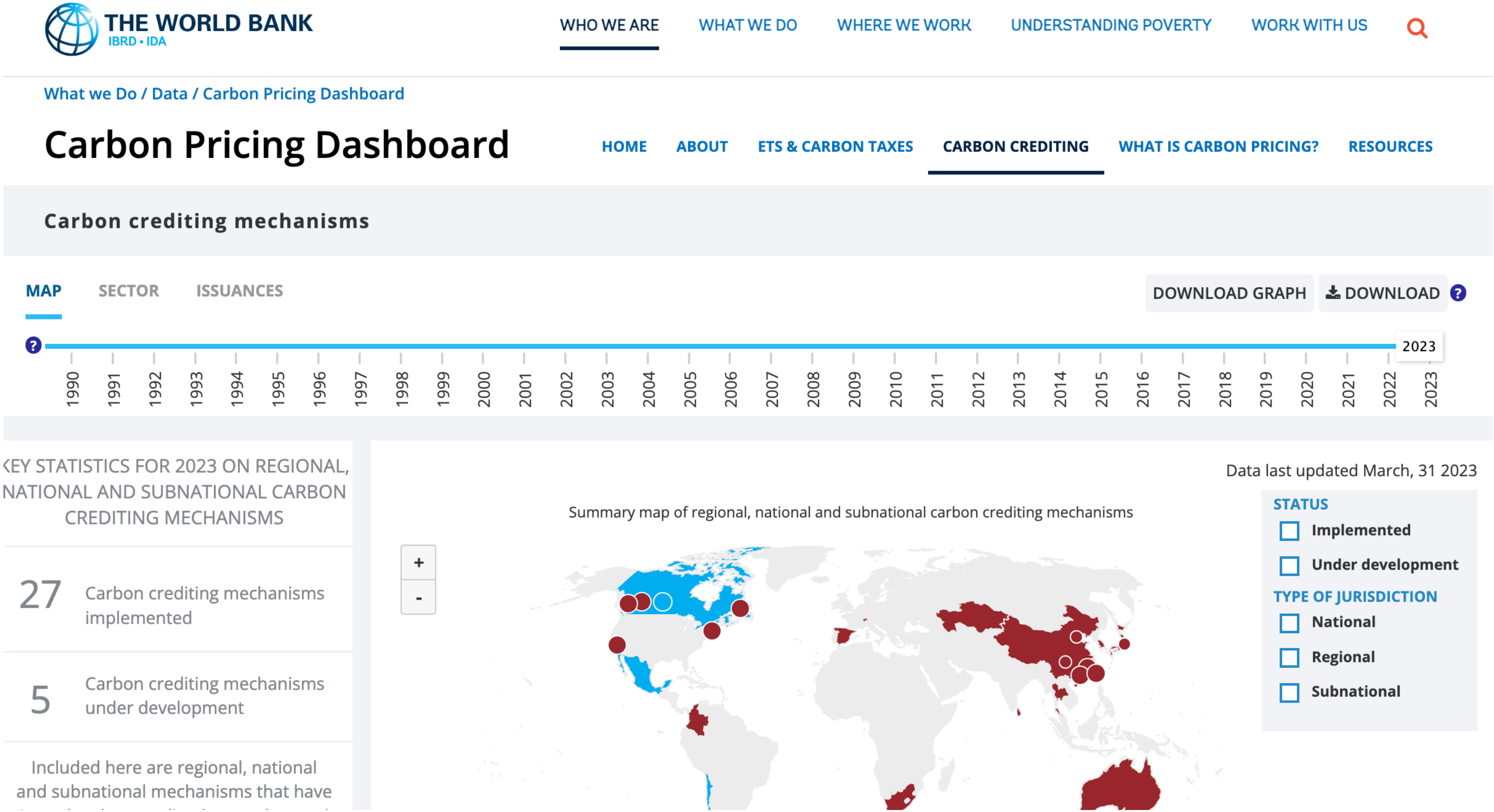
Source: https://carboncredits.com/carbon-prices-today/

TradingEconomics: Commodity Carbon



Source: https://tradingeconomics.com/commodity/carbon

The World Bank: Carbon Credit



Source: https://carbonpricingdashboard.worldbank.org/carbon_crediting

Normative Theories Revisited

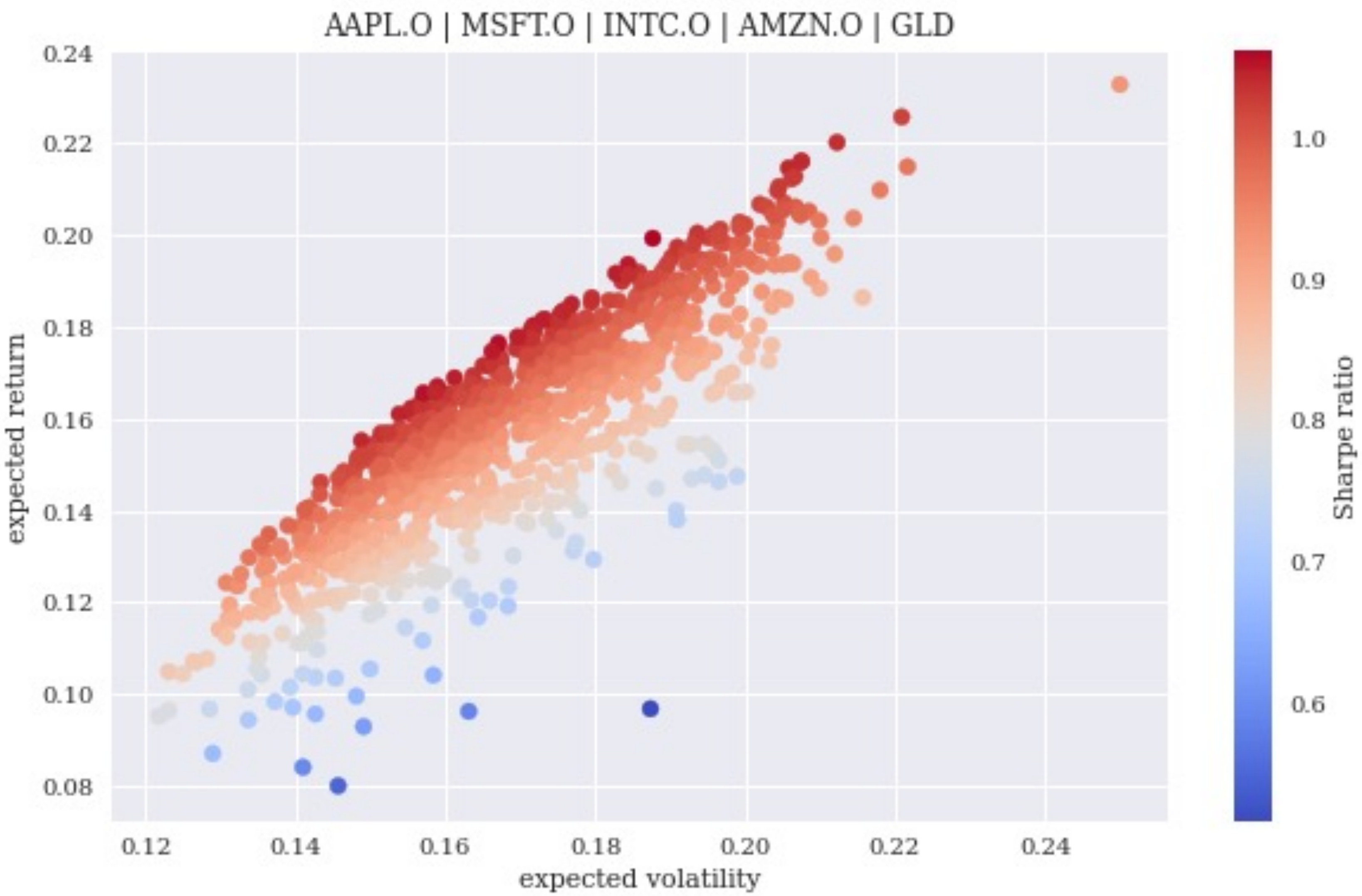
- Revisits the normative theories and analyzes them based on real financial time series data
- Expected Utility and Reality
- Mean-Variance Portfolio Theory (MVPT)
- Capital Asset Pricing Model (CAPM)
- Arbitrage Pricing Theory (APT)

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Normalized financial time series data

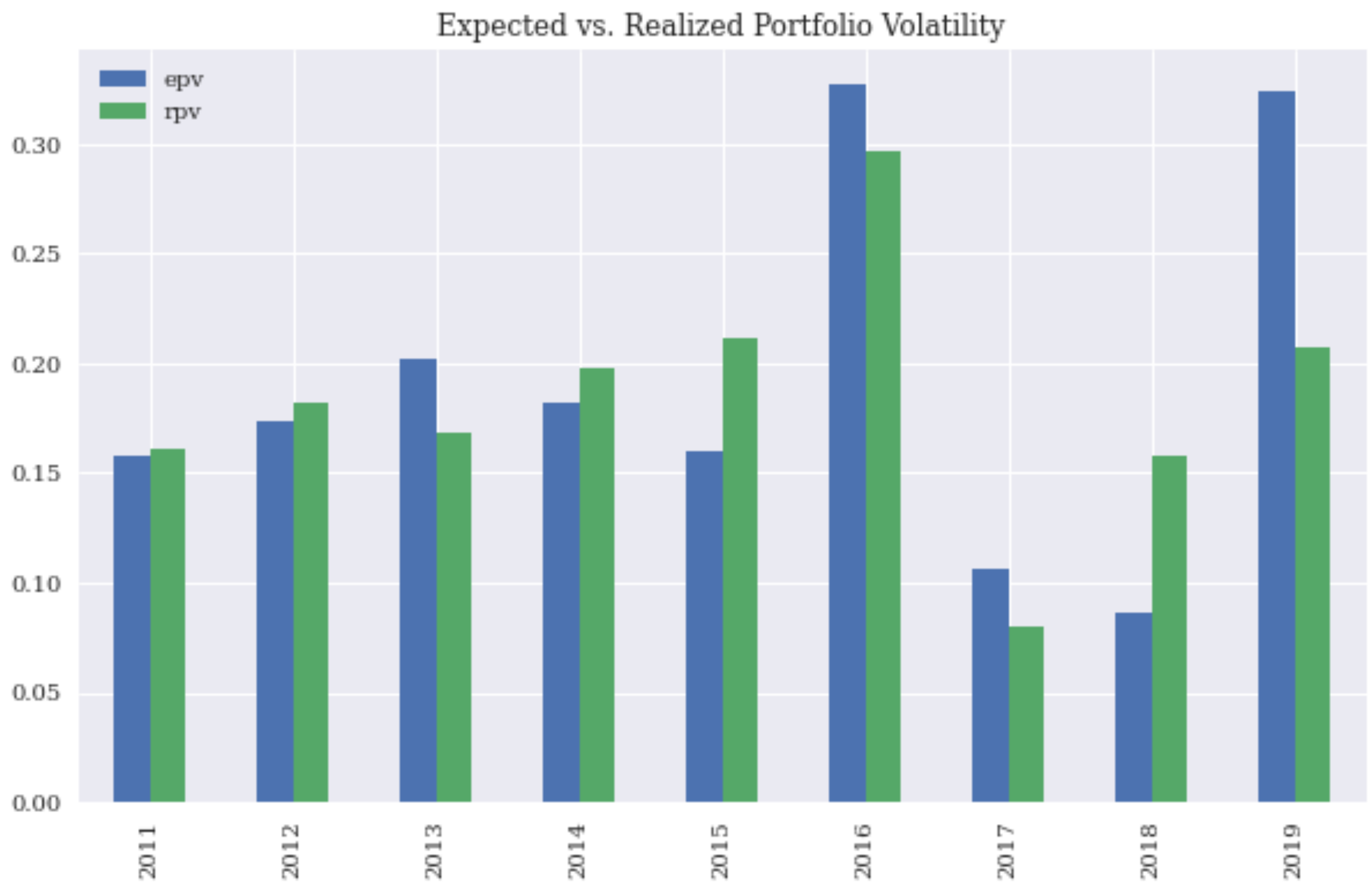
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Simulated portfolio volatilities, returns, and Sharpe ratios



Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Expected versus realized portfolio volatilities



Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

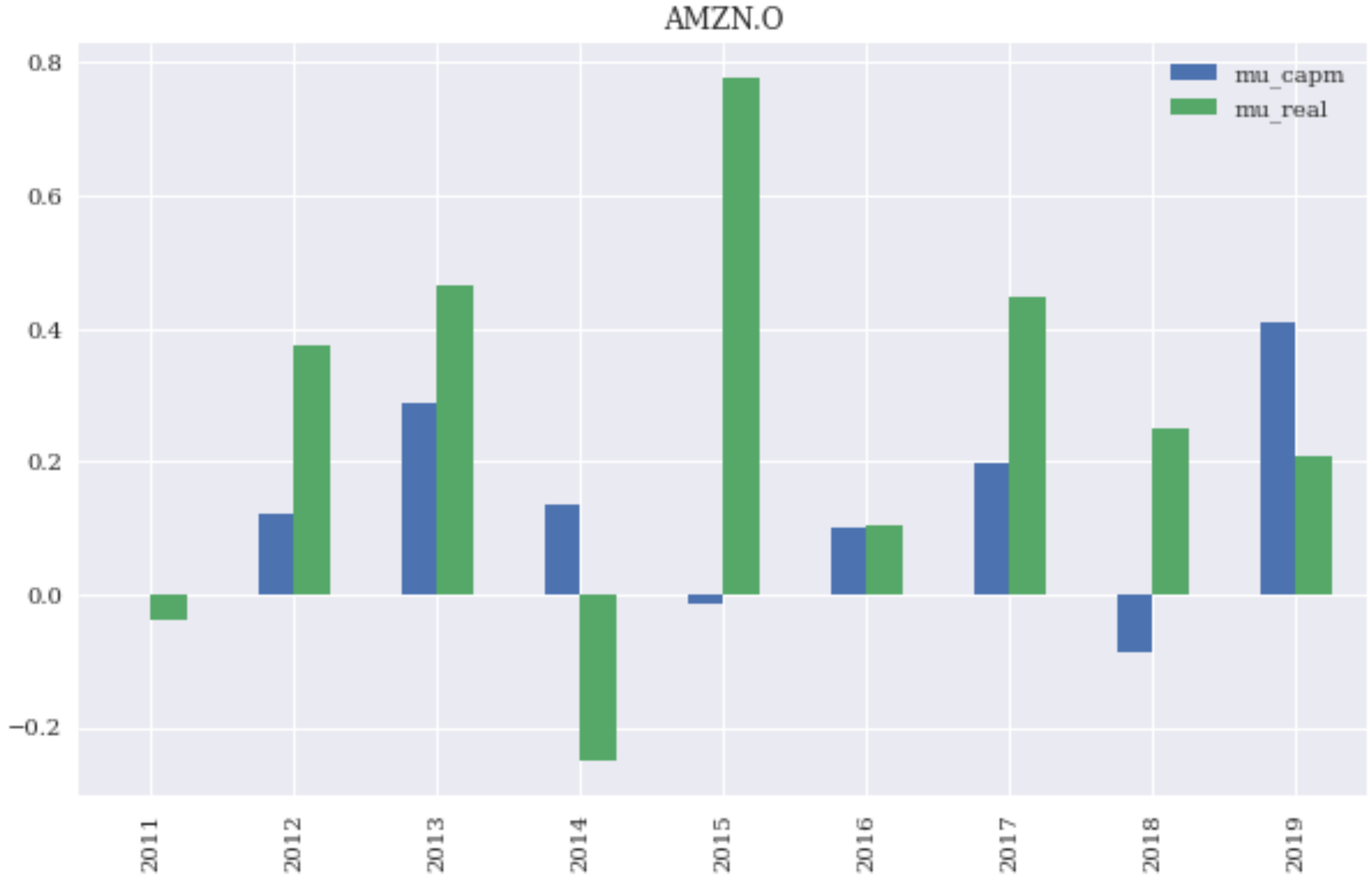
Expected versus realized portfolio returns

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Expected versus realized portfolio Sharpe ratios

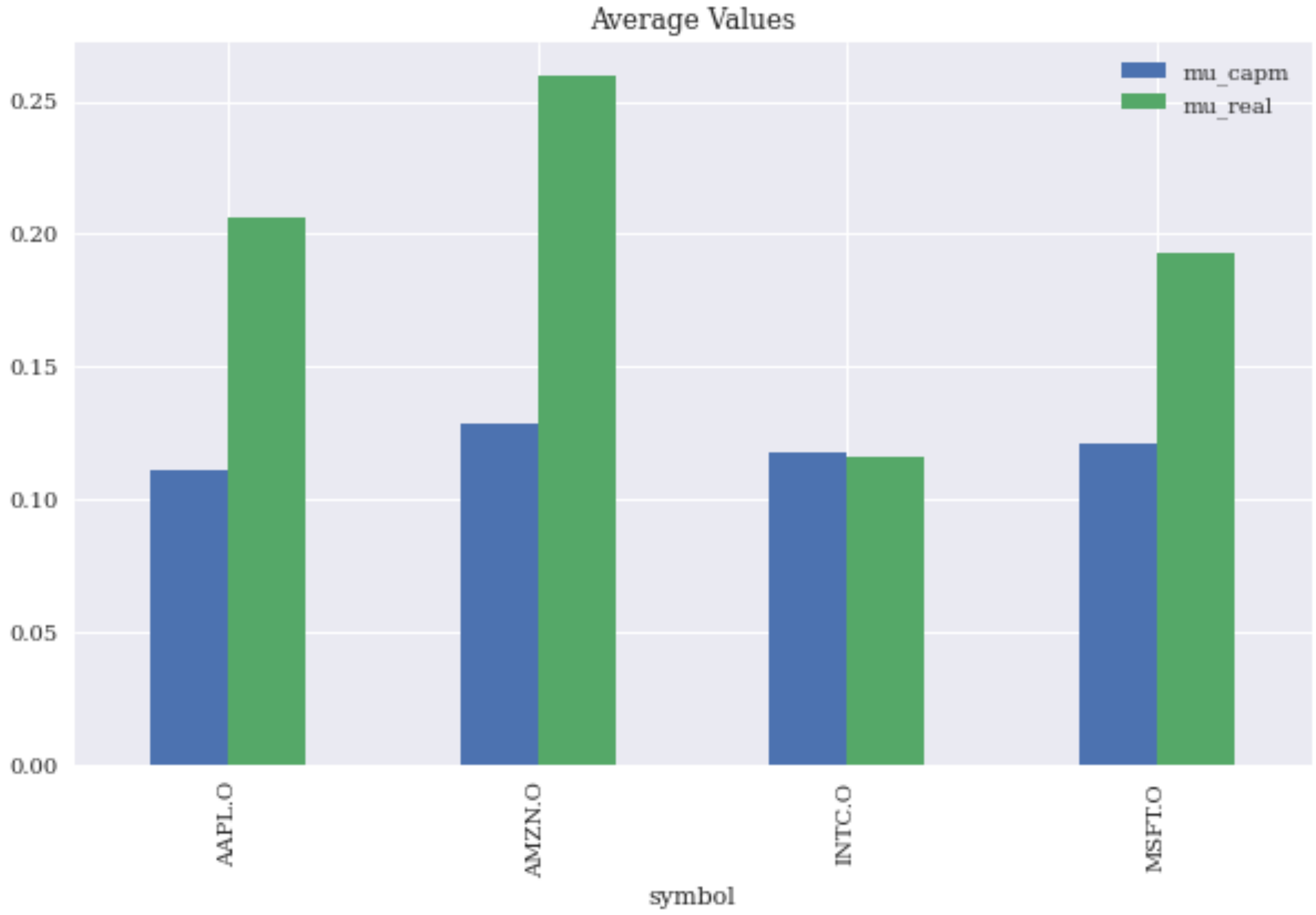
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

CAPM-predicted versus realized stock returns for a single stock



Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Average CAPM-predicted versus average realized stock returns for multiple stocks



Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Arbitrage Pricing Theory (APT)

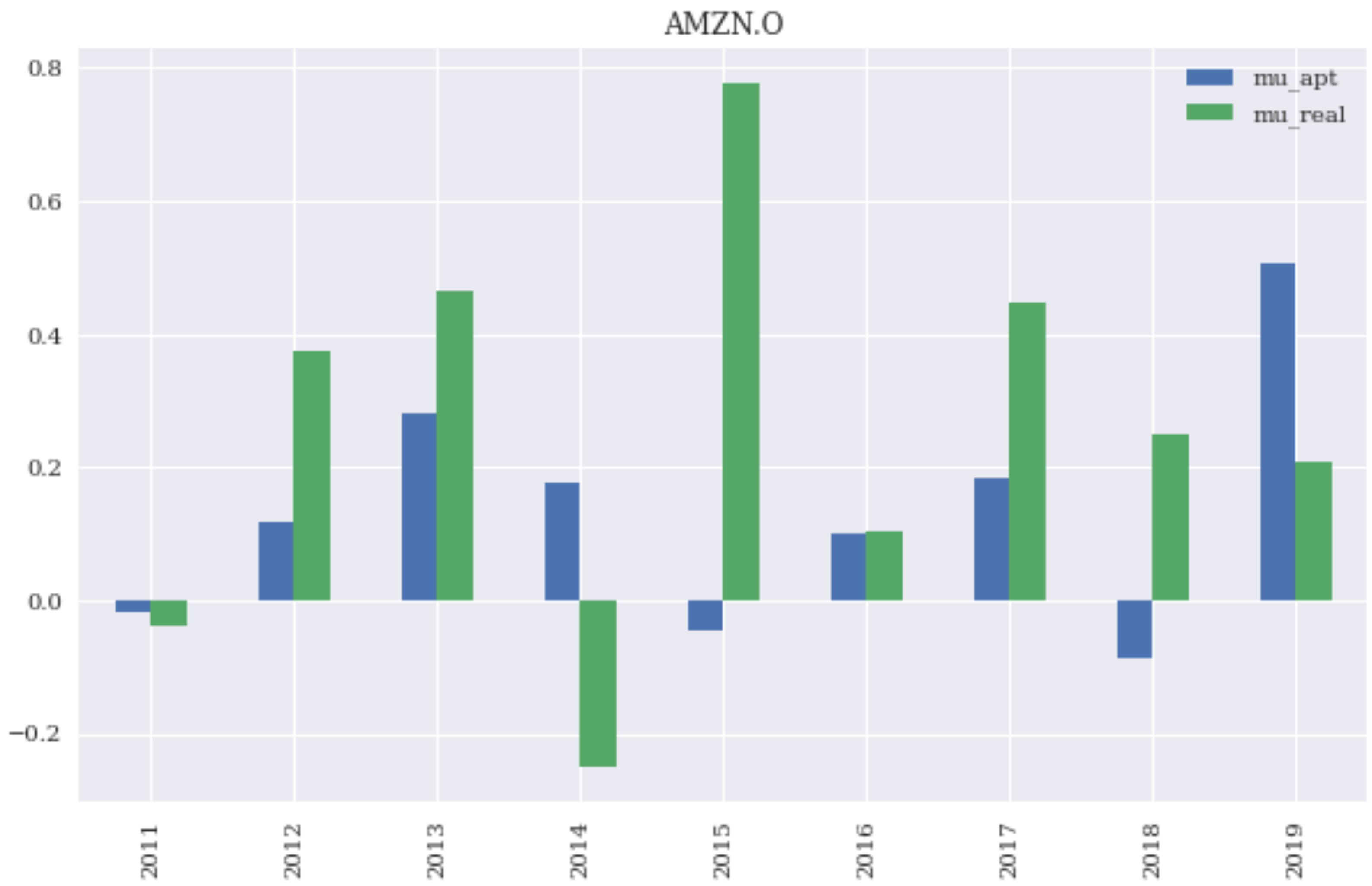
Relevant types of financial data

Factor	Description
Market	MSCI World Gross Return Daily USD (PUS = Price Return)
Size	MSCI World Equal Weight Price Net Index EOD
Volatility	MSCI World Minimum Volatility Net Return
Value	MSCI World Value Weighted Gross (NUS for Net)
Risk	MSCI World Risk Weighted Gross USD EOD
Growth	MSCI World Quality Net Return USD
Momentum	MSCI World Momentum Gross Index USD EOD

```
factors = pd.read_csv('http://hilpisch.com/aiif_eikon_eod_factors.csv',
                      index_col=0, parse_dates=True)
```

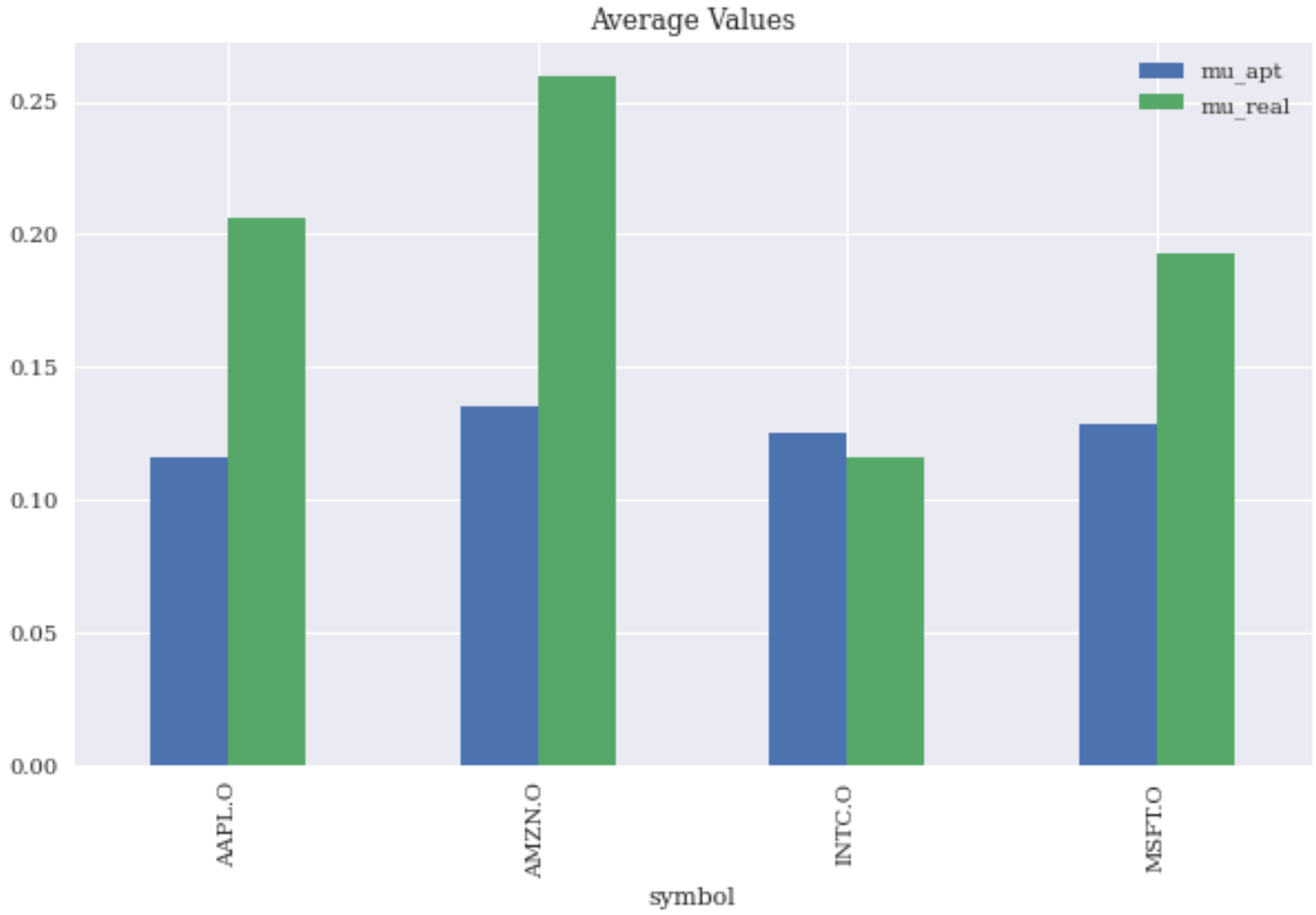
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

APT-predicted versus realized stock returns for a stock



Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Average APT-predicted versus average realized stock returns for multiple stocks

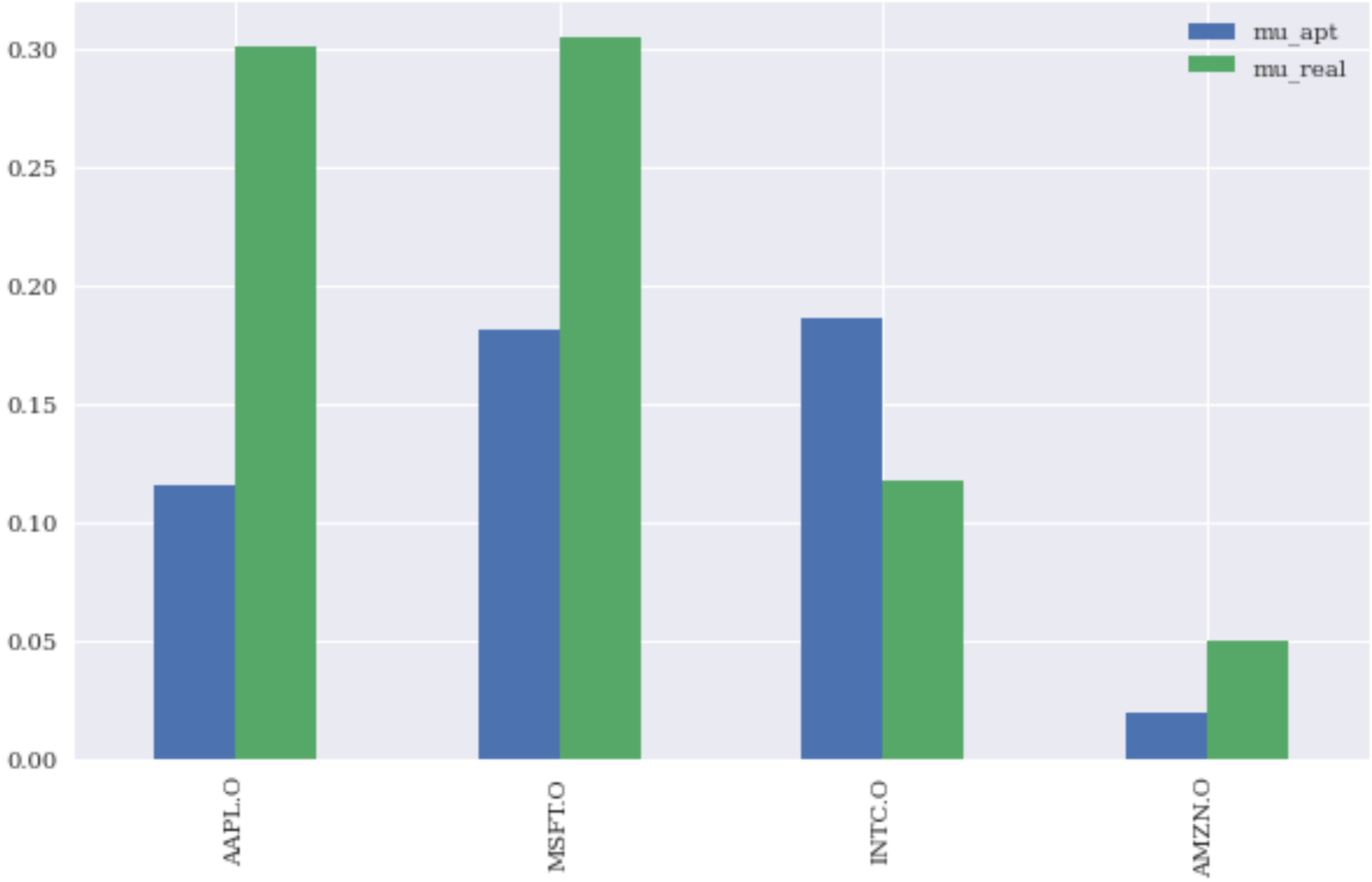


Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Normalized factors time series data

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

APT-predicted returns based on typical factors compared to realized returns



Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

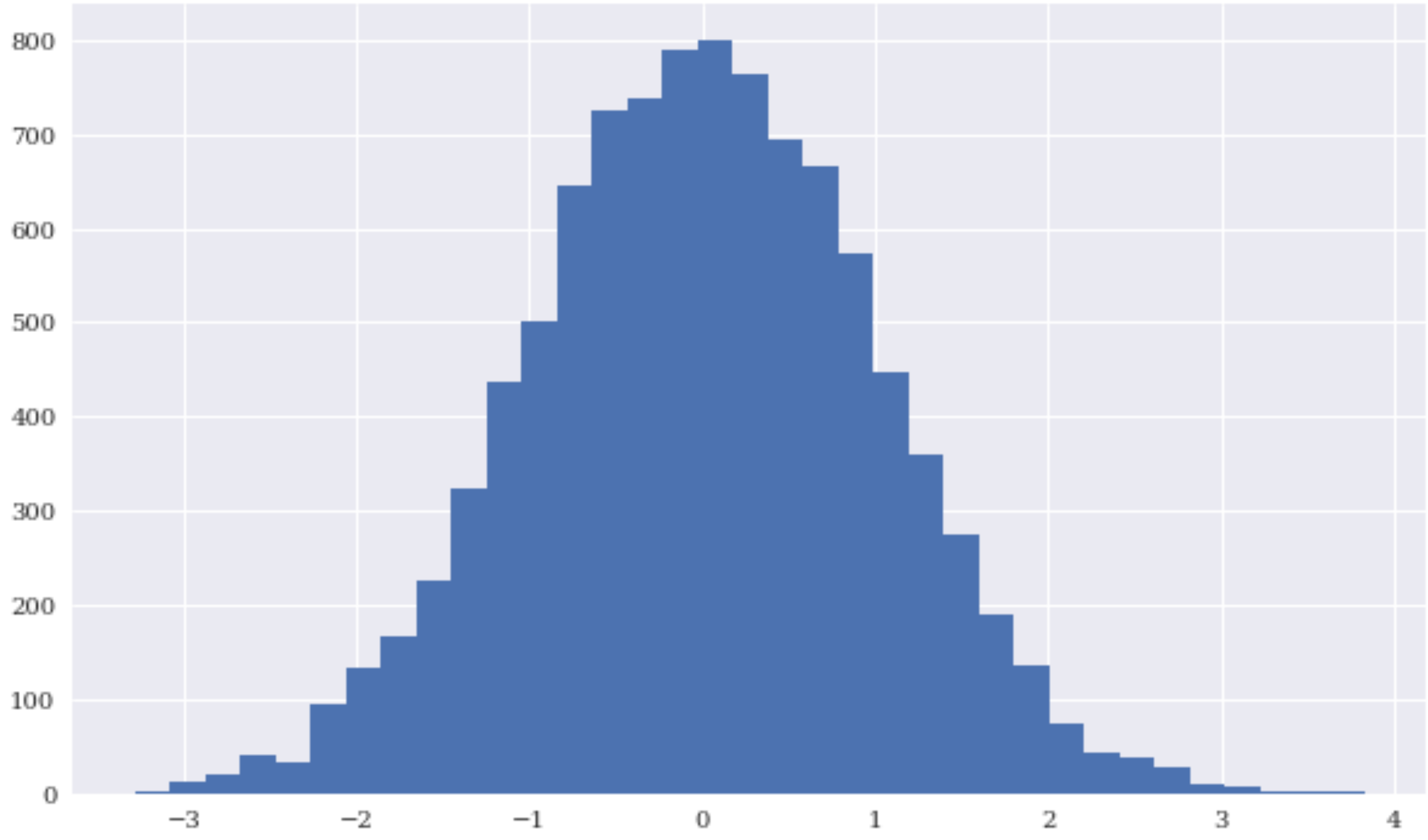
APT-predicted performance and real performance over time (gross)

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O’Reilly Media.

Debunking Central Assumptions in Finance

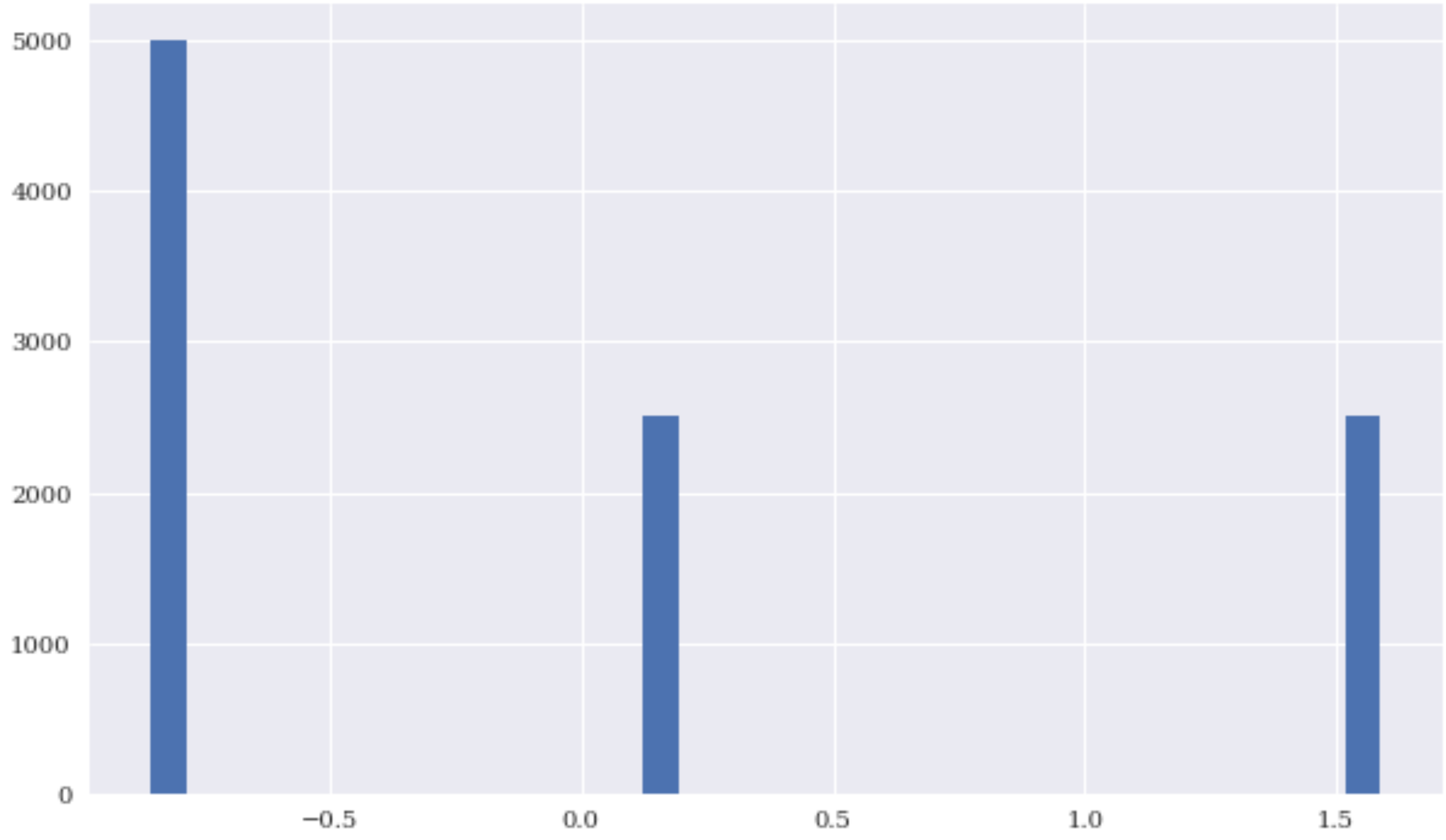
- **Debunks two of the most commonly found assumptions in financial models and theories**
  - **Normality of returns**
  - **Linear relationships**

Standard normally distributed random numbers



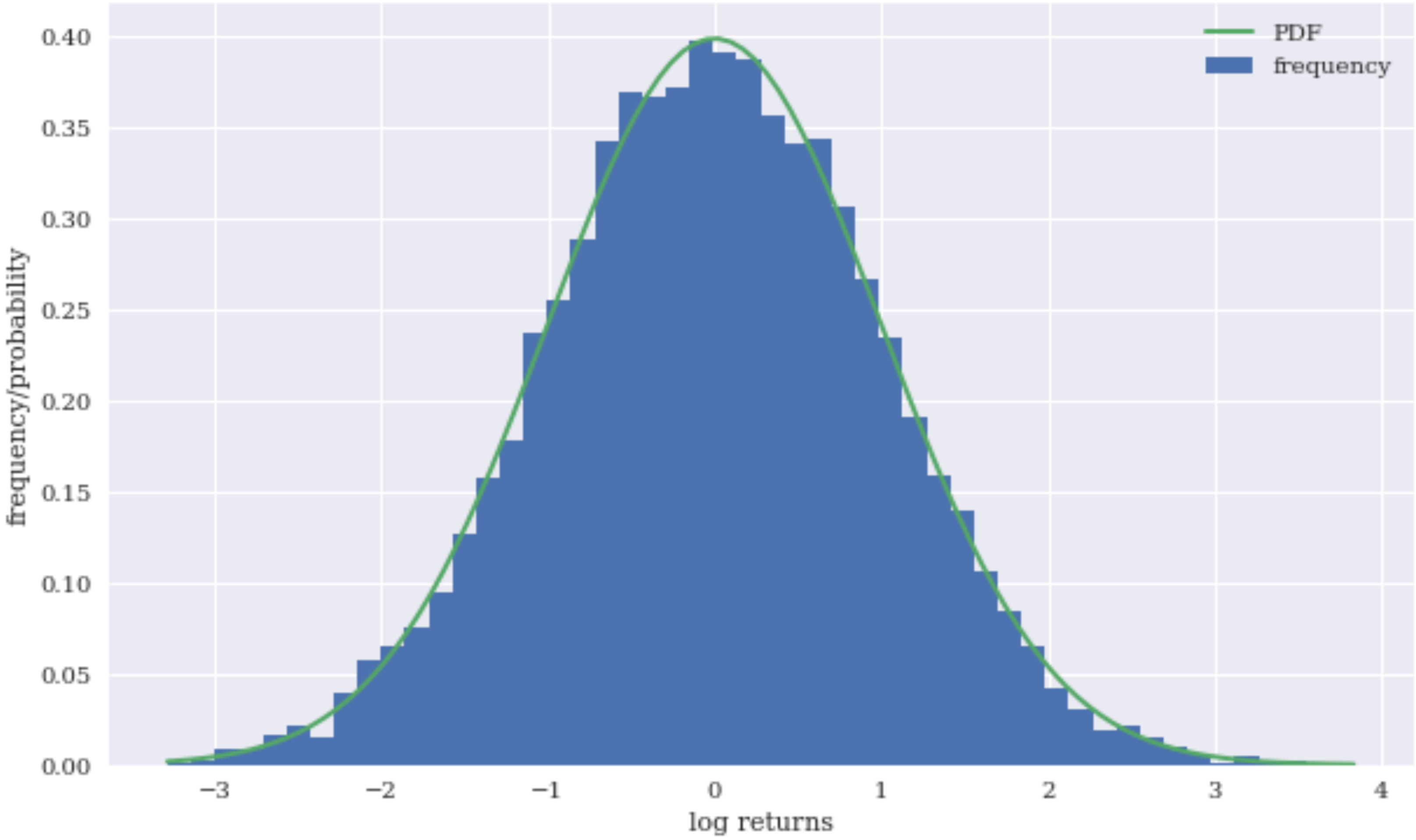
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Distribution with first and second moment of 0.0 and 1.0, respectively



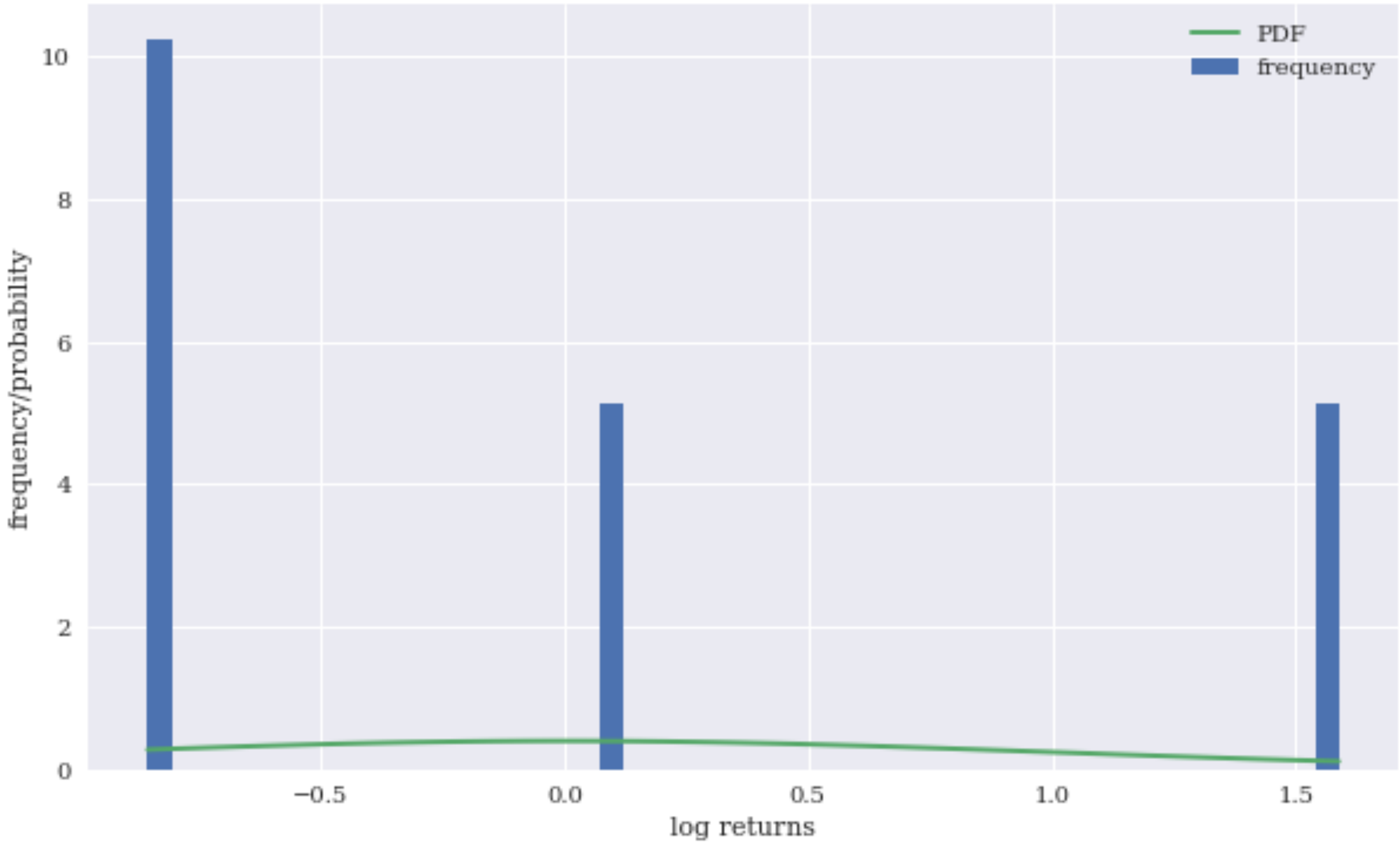
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Histogram and PDF for standard normally distributed numbers



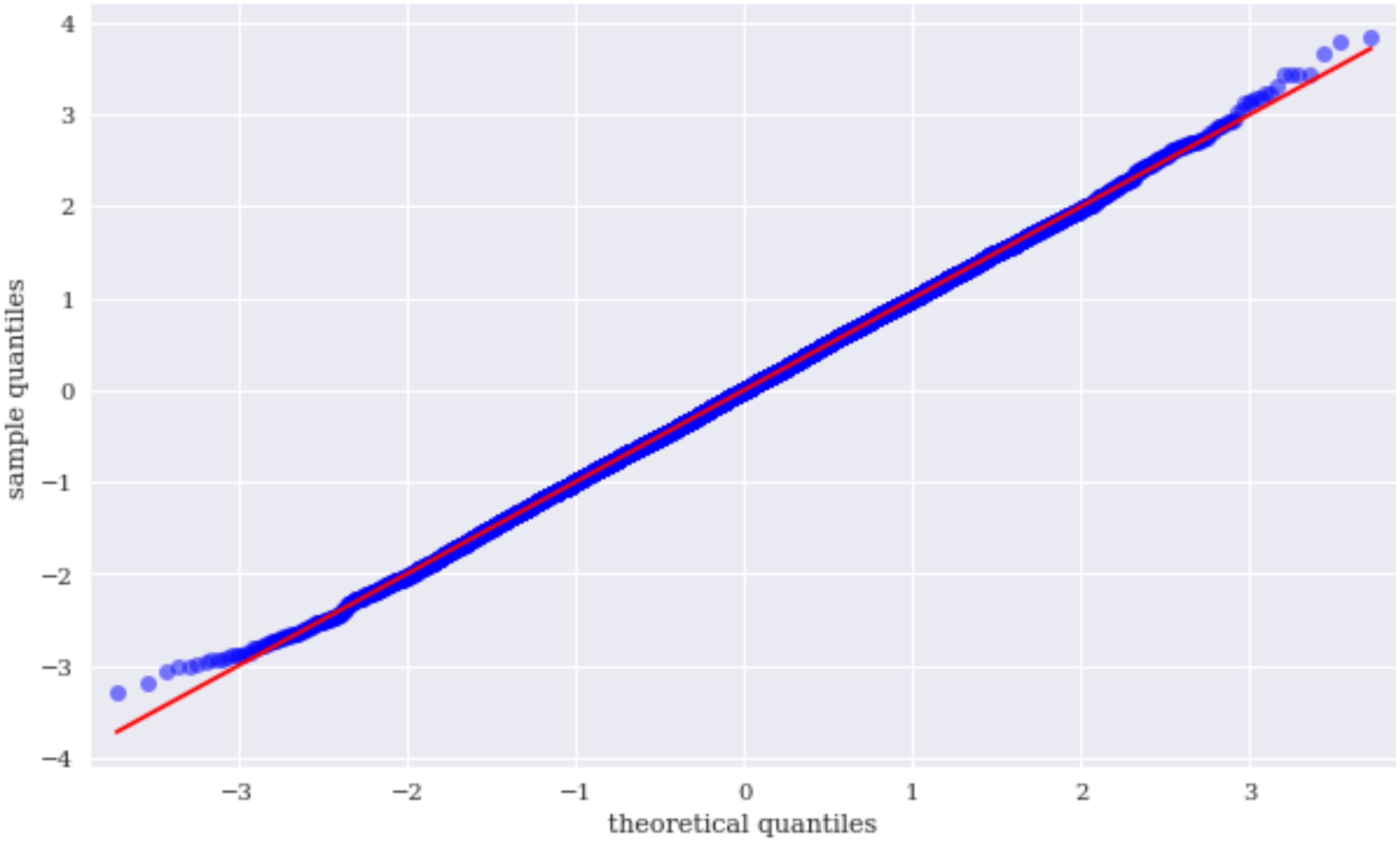
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Histogram and normal PDF for discrete numbers



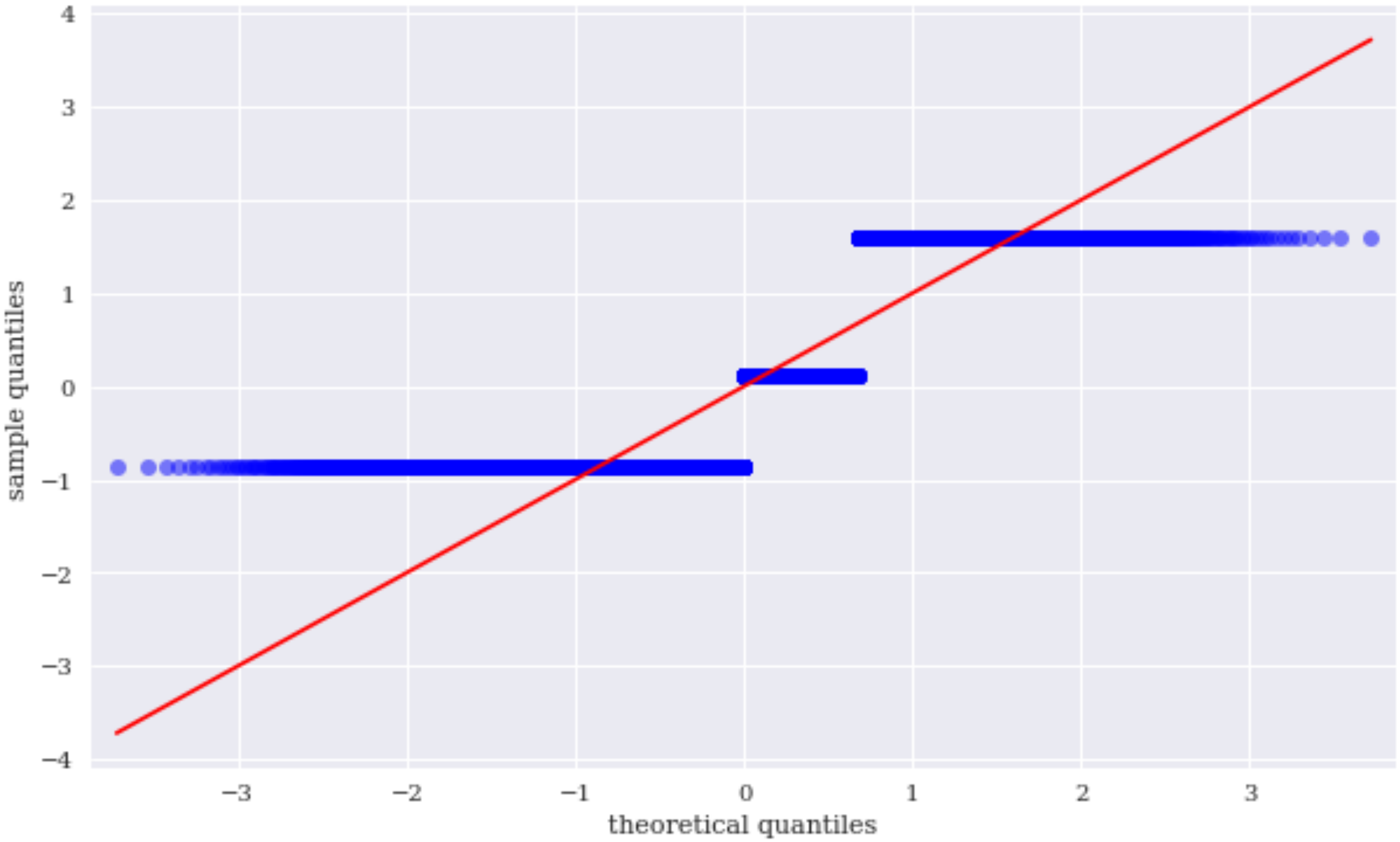
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Q-Q plot for standard normally distributed numbers



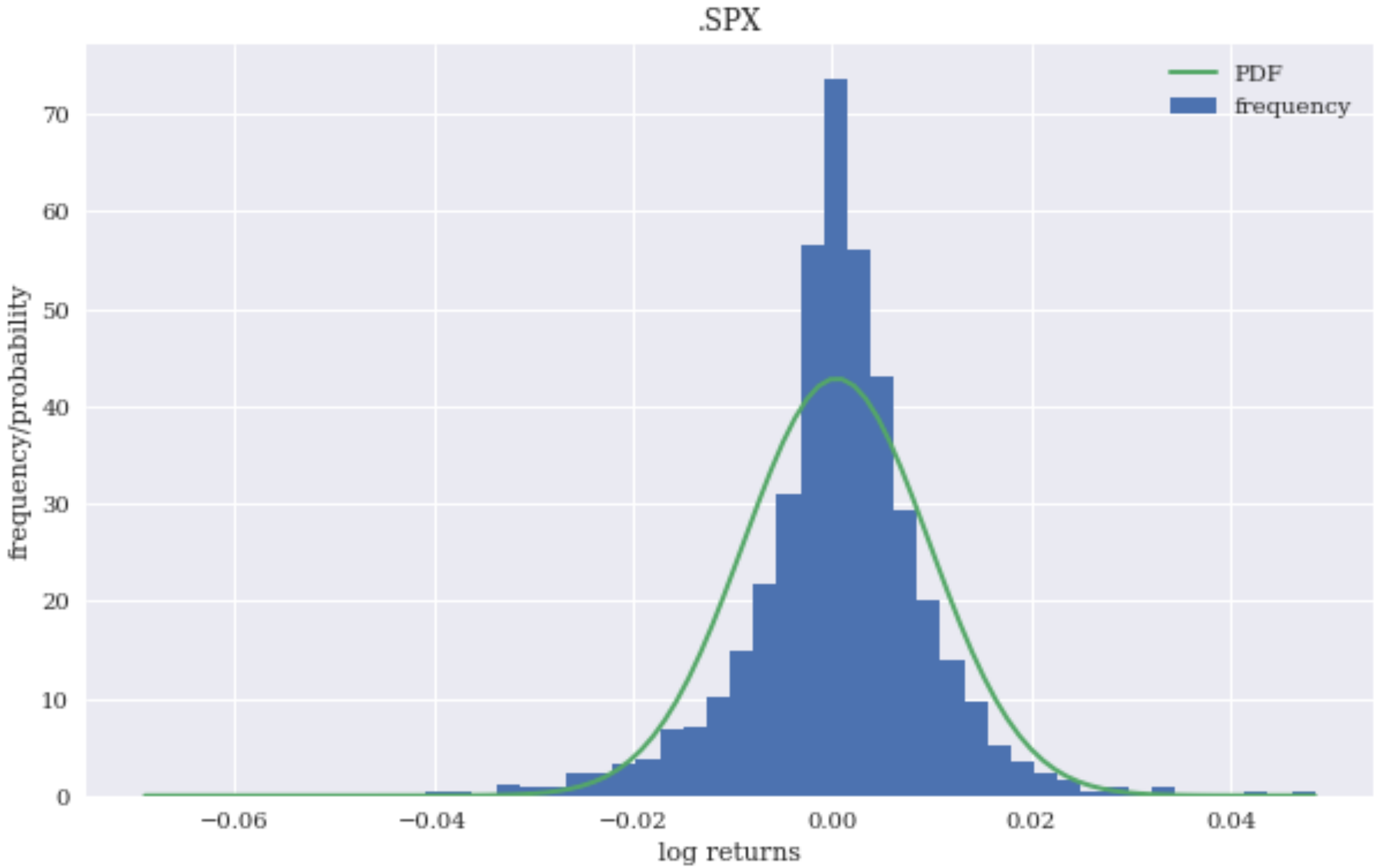
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Q-Q plot for discrete numbers



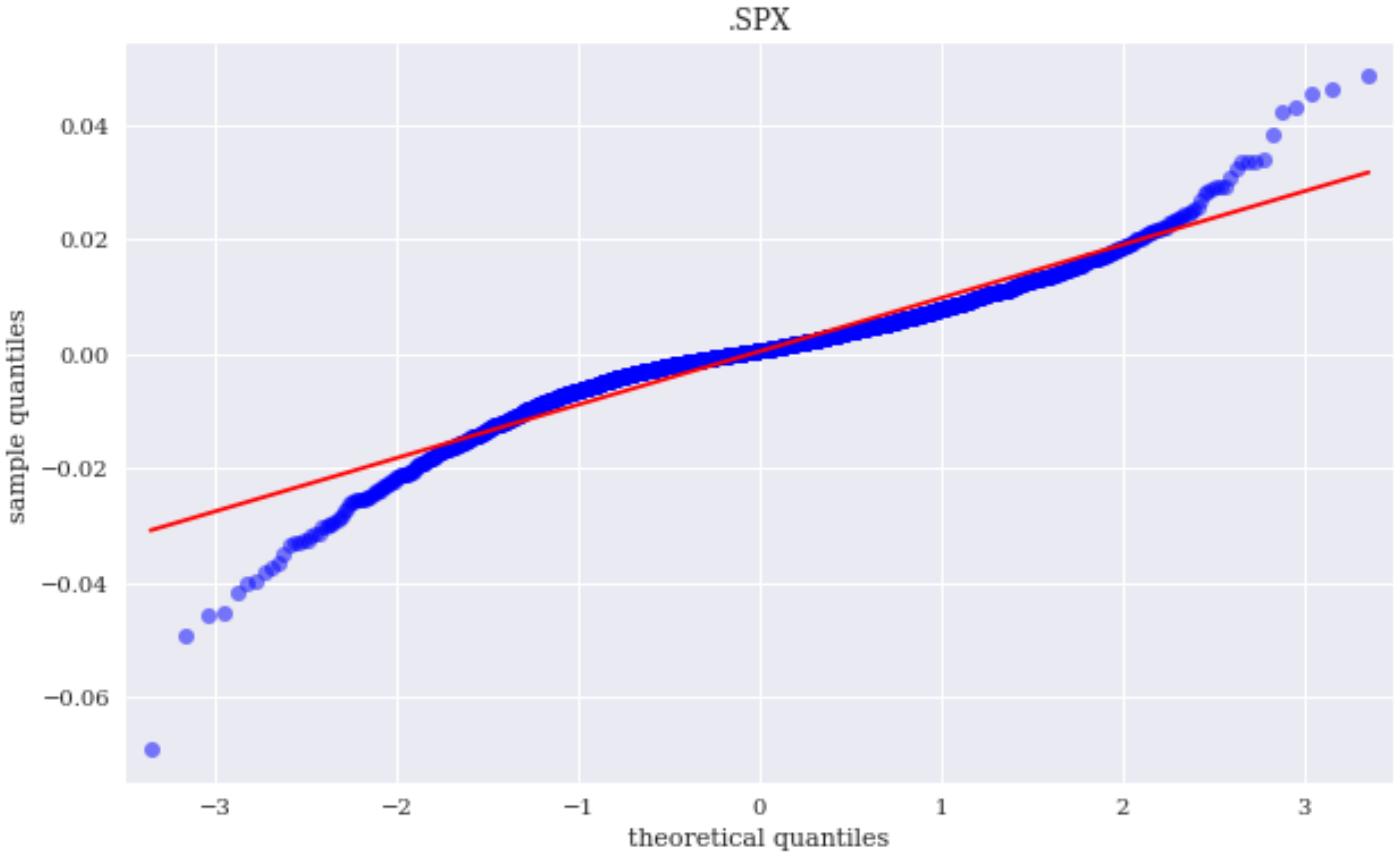
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Frequency distribution and normal PDF for S&P 500 log returns



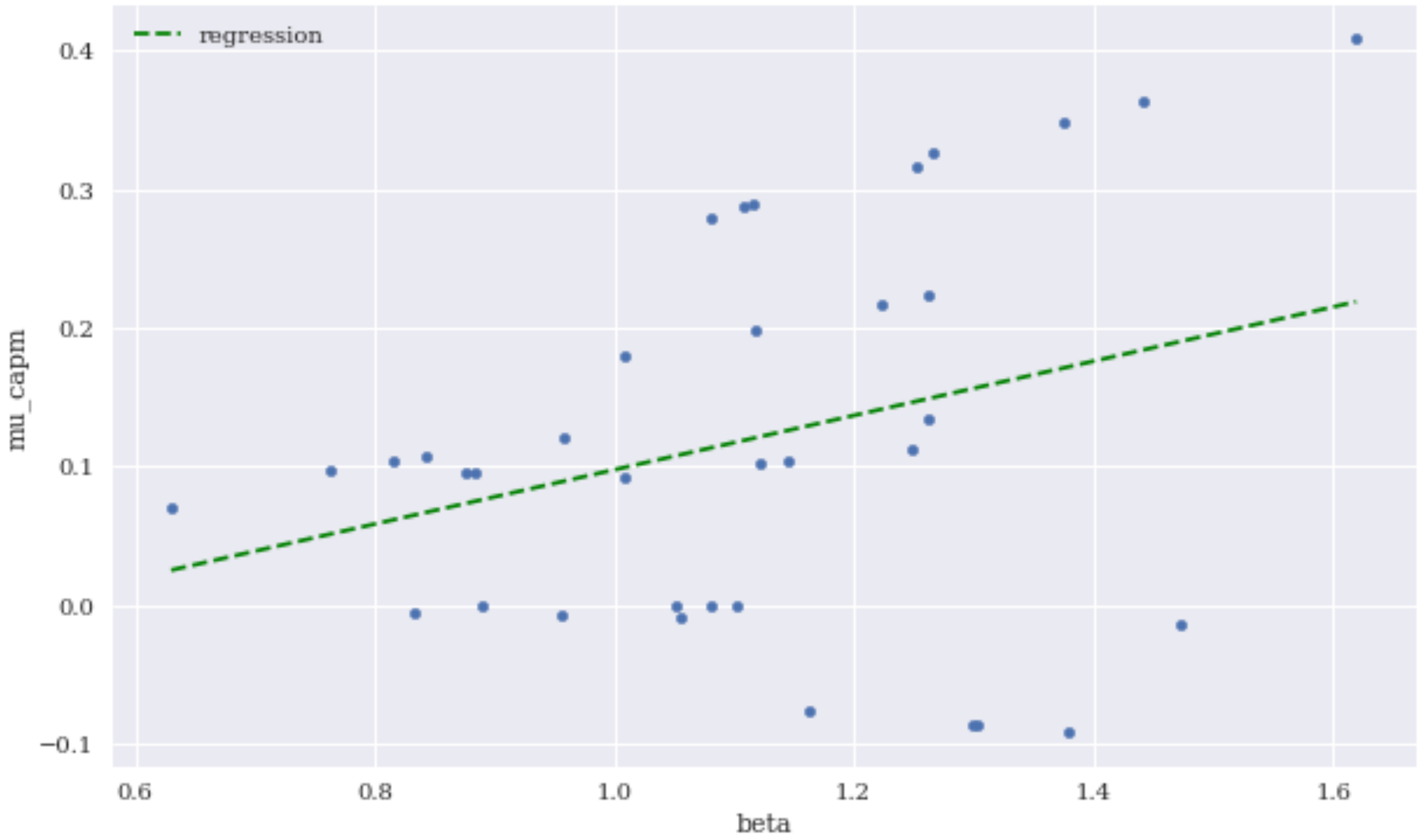
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Q-Q for S&P 500 log returns



Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Expected CAPM return versus beta (including linear regression)



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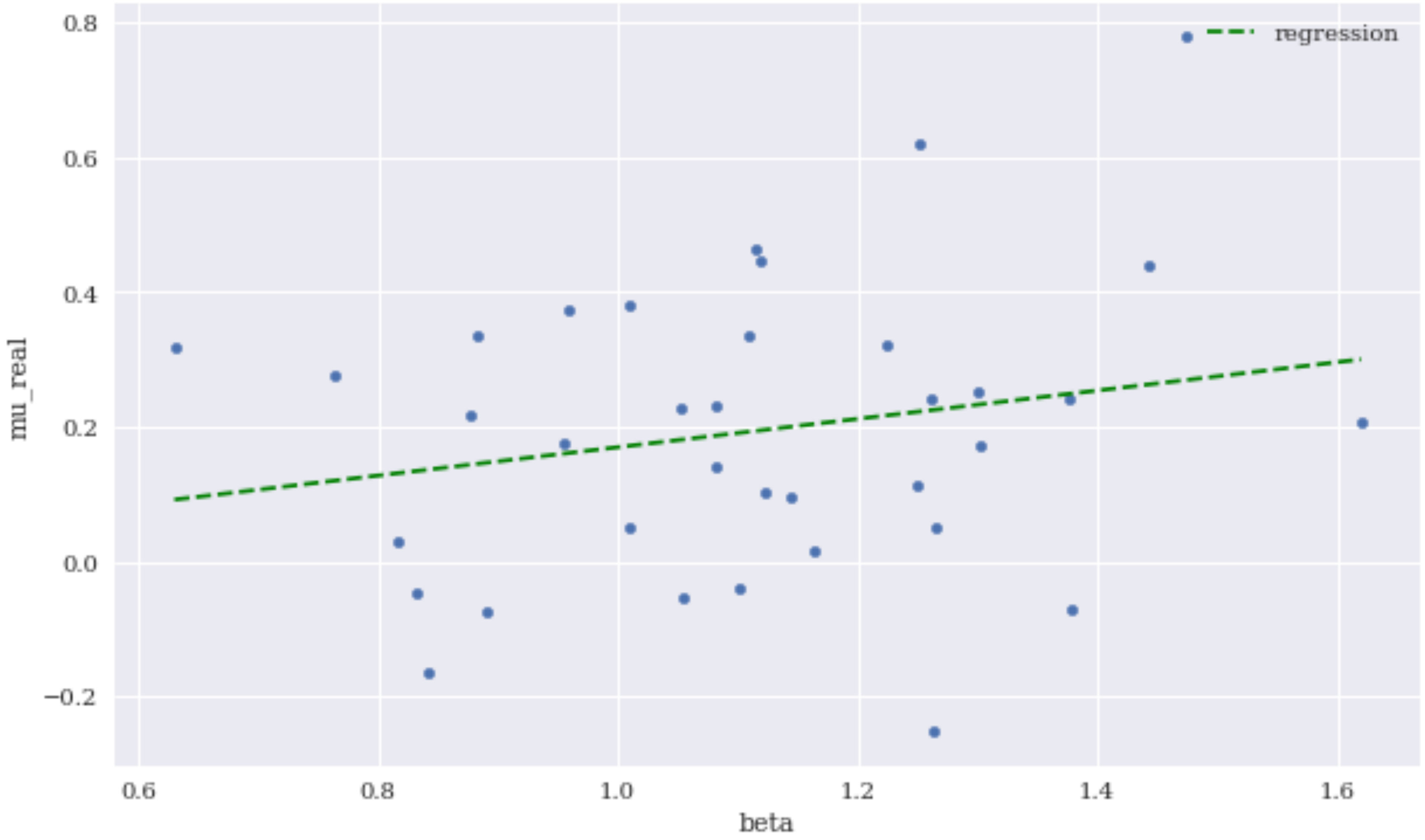
Expected CAPM return versus beta (including linear regression)



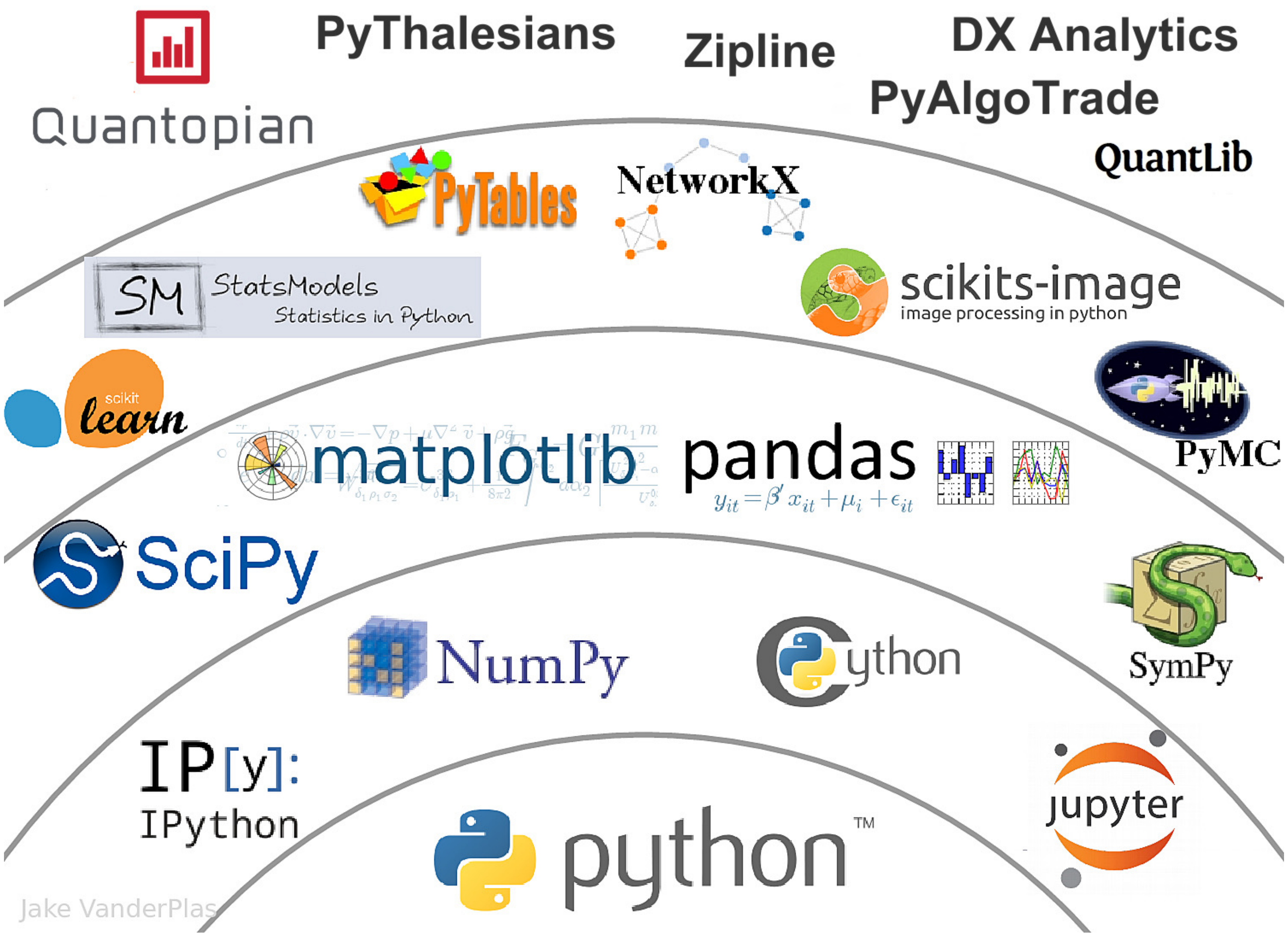
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Theory-First to Data-Driven Finance

- Finance used to be characterized by normative theories based on simplified mathematical models of the financial markets, relying on assumptions such as normality of returns and linear relationships.
- The almost universal and comprehensive availability of (financial) data has led to a shift in focus from a theory-first approach to data-driven finance.
- Several examples based on real financial data illustrate that many popular financial models and theories cannot survive a confrontation with financial market realities.
- Although elegant, they might be too simplistic to capture the complexities, changing nature, and nonlinearities of financial markets.

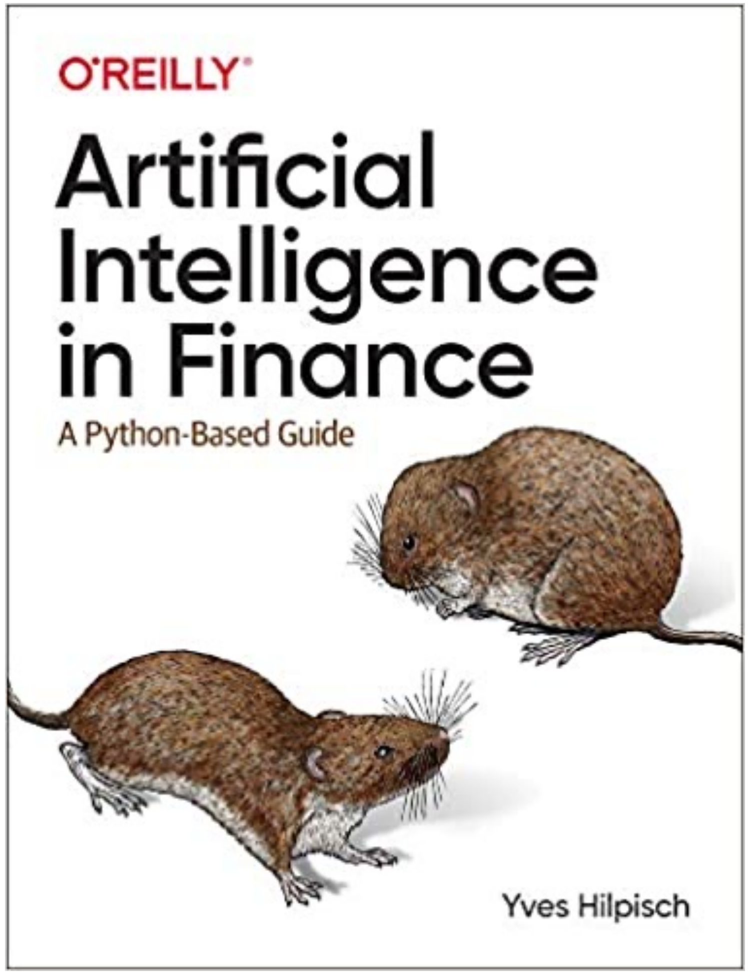
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

The Quant Finance PyData Stack



Source: http://nbviewer.jupyter.org/format/slides/github/quantopian/pyfolio/blob/master/pyfolio/examples/overview_slides.ipynb#/5

Yves Hilpisch (2020),
Artificial Intelligence in Finance:
A Python-Based Guide,
O'Reilly



Source: https://www.amazon.com/Artificial-Intelligence-Finance-Python-Based-Guide/dp/1492055433

Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly

yhilpisch / aiif Public

https://github.com/yhilpisch/aiif

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yves Code updates for TF 2.3. e334251 on Dec 8, 2020 | 4 commits

code	Code updates for TF 2.3.	11 months ago
.gitignore	Code updates for TF 2.3.	11 months ago
LICENSE.txt	Code updates.	11 months ago
README.md	Code updates.	11 months ago

README.md

Artificial Intelligence in Finance

About this Repository

This repository provides Python code and Jupyter Notebooks accompanying the **Artificial Intelligence in Finance** book published by O'Reilly.

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About

Jupyter Notebooks and code for the book Artificial Intelligence in Finance (O'Reilly) by Yves Hilpisch.

home.tpq.io/books/aiif

Readme

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Releases

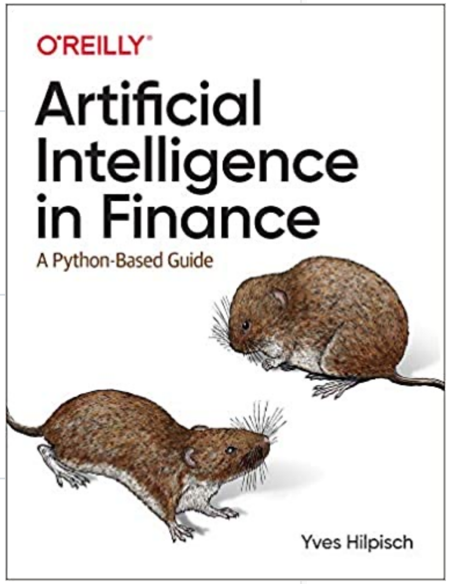
No releases published

Packages

No packages published

Languages

Jupyter Notebook 97.4% Python 2.6%



Source: https://github.com/yhilpisch/aiif

Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly

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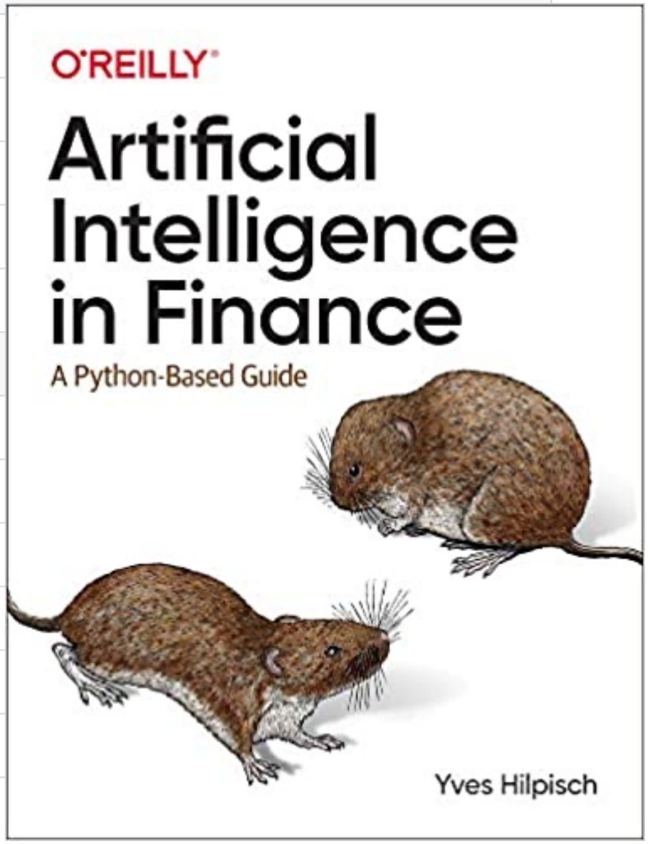
main | aiif / code /

https://github.com/yhilpisch/aiif/tree/main/code

Go to file

yves Code updates for TF 2.3. — e334251 on Dec 8, 2020 — History

..	
oanda	Code updates for TF 2.3.
01_artificial_intelligence.ipynb	Code updates for TF 2.3.
02_superintelligence.ipynb	Code updates for TF 2.3.
03_normative_finance.ipynb	Code updates for TF 2.3.
04_data_driven_finance_a.ipynb	Initial commit.
04_data_driven_finance_b.ipynb	Initial commit.
05_machine_learning.ipynb	Code updates for TF 2.3.
06_ai_first_finance.ipynb	Code updates for TF 2.3.
07_dense_networks.ipynb	Code updates for TF 2.3.
08_recurrent_networks.ipynb	Code updates for TF 2.3.
09_reinforcement_learning_a.ipynb	Code updates.
09_reinforcement_learning_b.ipynb	Code updates for TF 2.3.



Source: https://github.com/yhilpisch/aiif/tree/main/code

Python in Google Colab (Python101)

https://colab.research.google.com/drive/1FEG6DnGvwfUbeo4zJ1zTunjMqf2RkCrT

python101.ipynb

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AI in Finance

- Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.
- Github: https://github.com/yhilpisch/aiif/

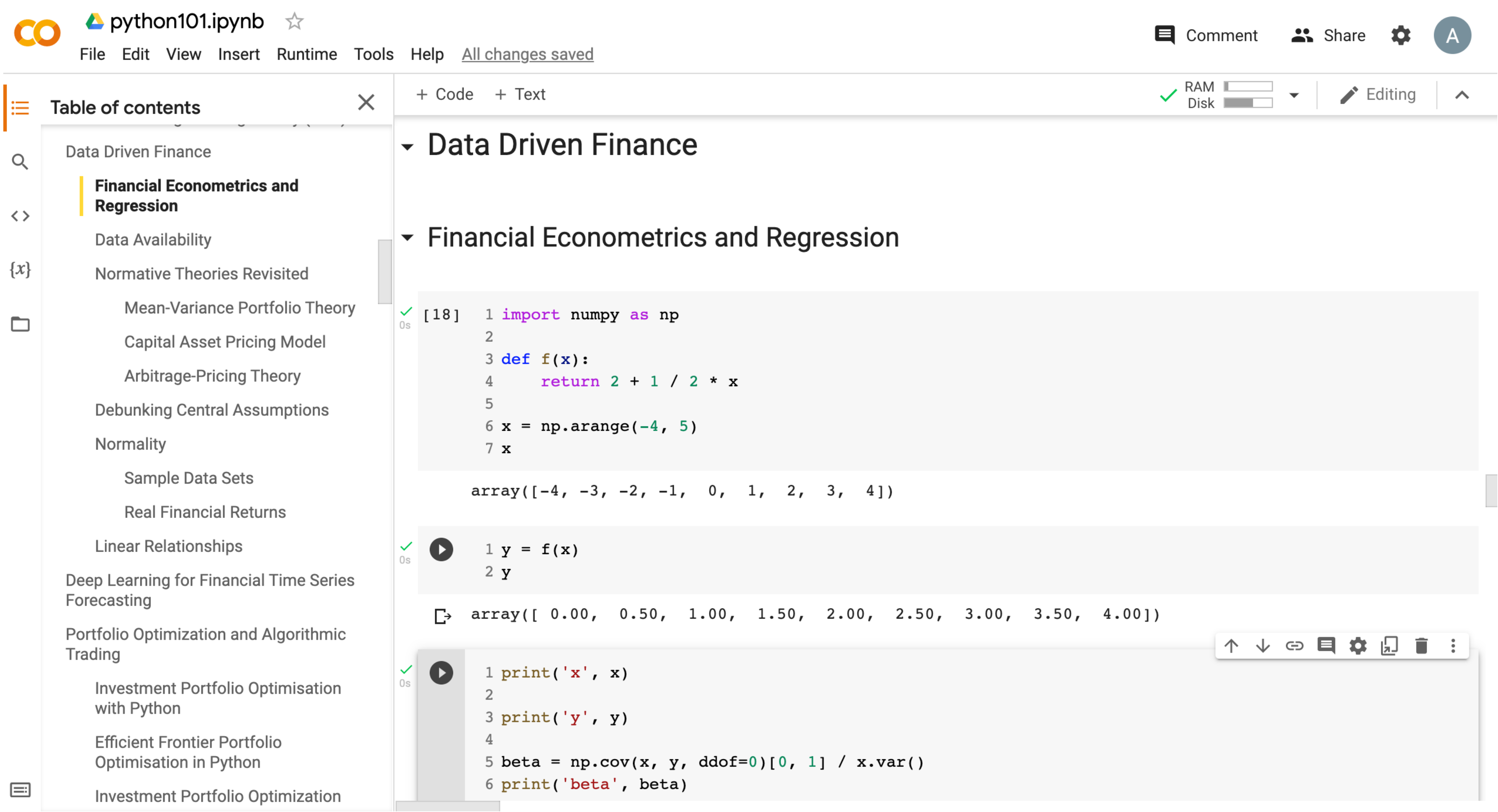
Normative Finance and Financial Theories

Uncertainty and Risk

```python
import numpy as np

#The prices of the stock and bond today.
S0 = 10
B0 = 10
print('S0', S0)
print('S0', S0)

#The uncertain payoff of the stock and bond tomorrow.
S1 = np.array((20, 5))
B1 = np.array((11, 11))
print('S1', S1)
print('B1', B1)

#The market price vector
M0 = np.array((S0, B0))
```

https://tinyurl.com/aintpupython101

Python in Google Colab (Python101)



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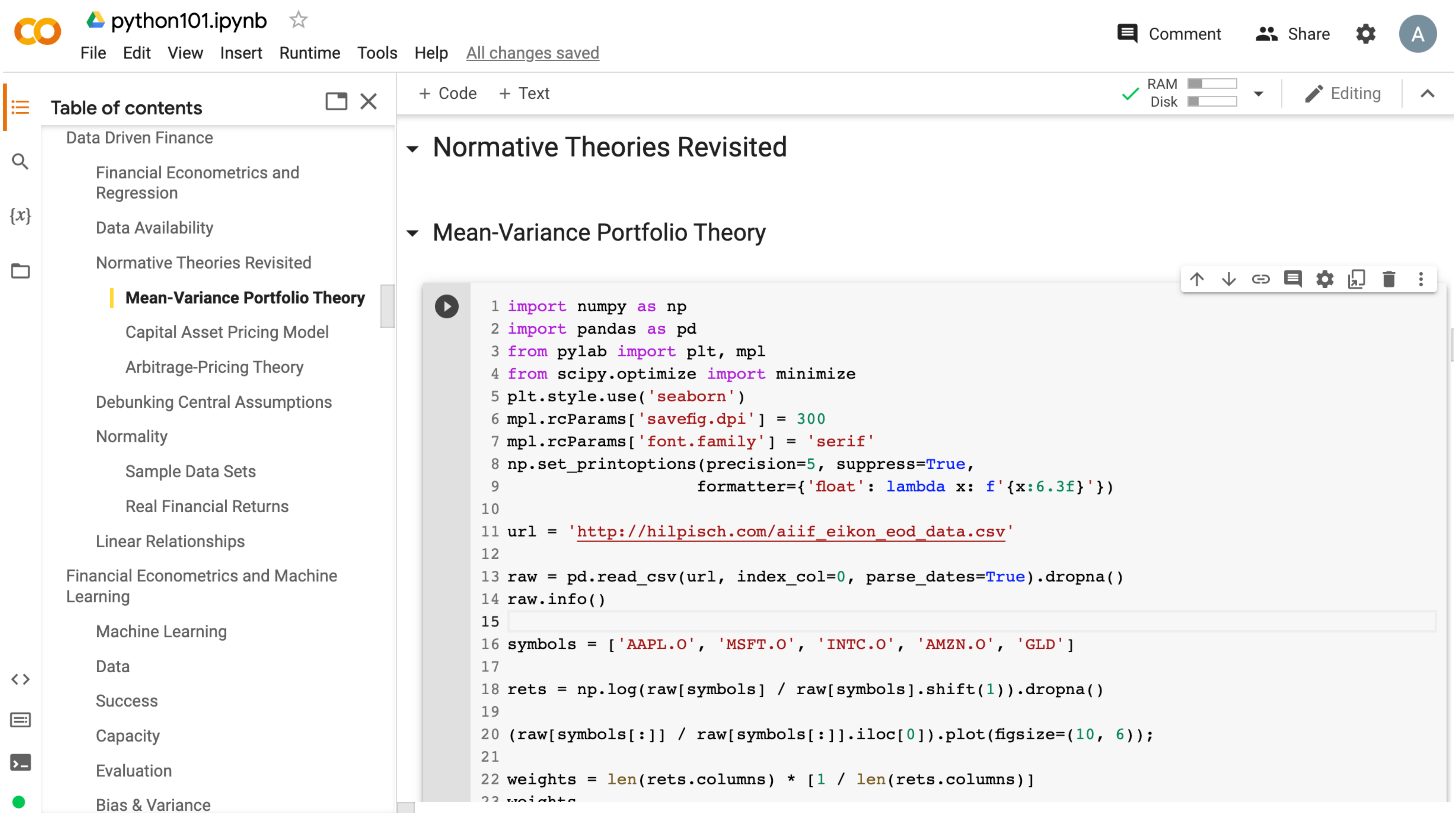
Python in Google Colab (Python101)



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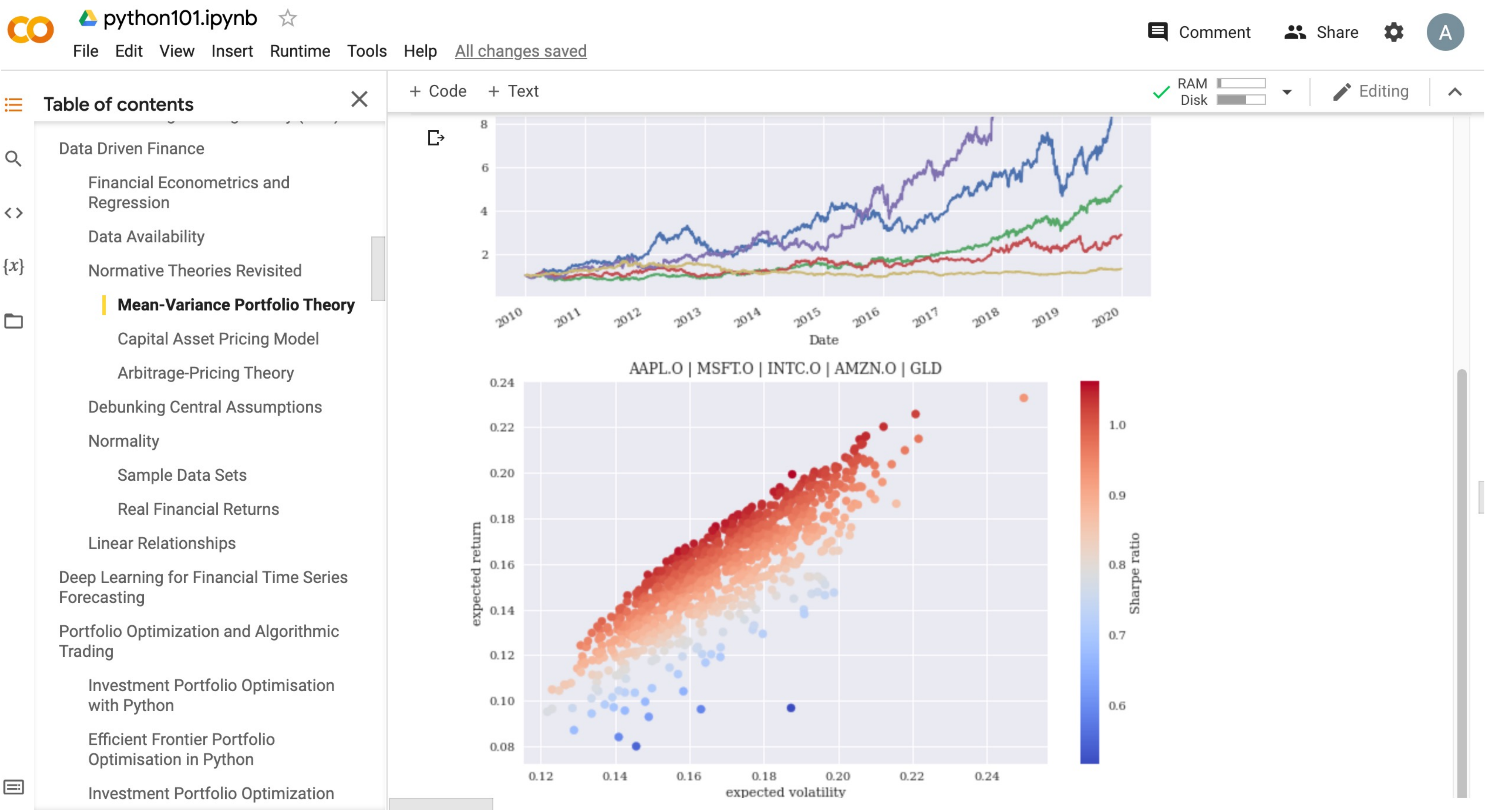

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```
AMZN.O
=======================================================
2011 | beta: 1.102 | mu_capm: -0.001 | mu_real: -0.039
2012 | beta: 0.958 | mu_capm:  0.122 | mu_real:  0.374
2013 | beta: 1.116 | mu_capm:  0.289 | mu_real:  0.464
2014 | beta: 1.262 | mu_capm:  0.135 | mu_real: -0.251
2015 | beta: 1.473 | mu_capm: -0.013 | mu_real:  0.778
2016 | beta: 1.122 | mu_capm:  0.102 | mu_real:  0.104
2017 | beta: 1.118 | mu_capm:  0.199 | mu_real:  0.446
2018 | beta: 1.300 | mu_capm: -0.086 | mu_real:  0.251
2019 | beta: 1.619 | mu_capm:  0.408 | mu_real:  0.207
```

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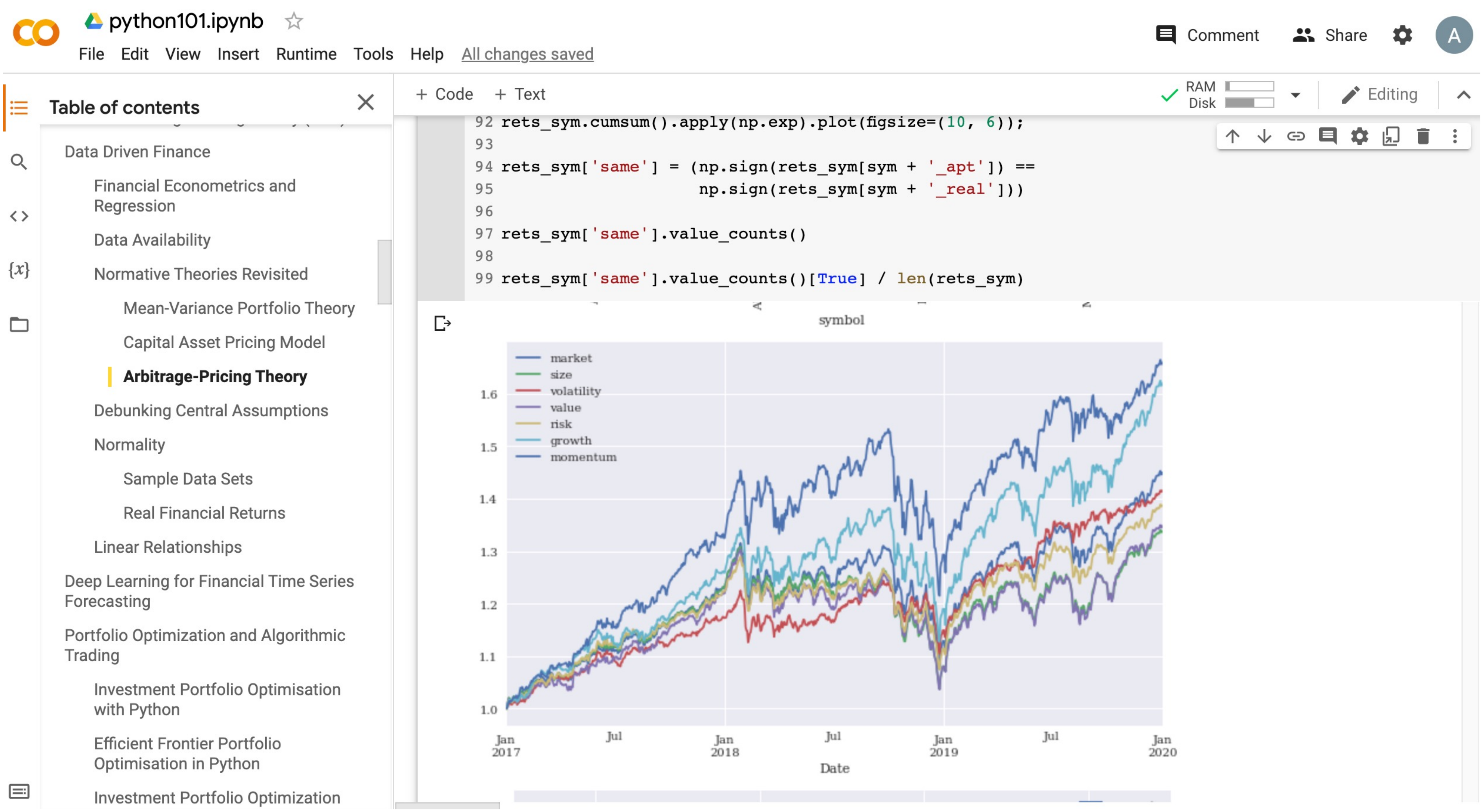
Python in Google Colab (Python101)



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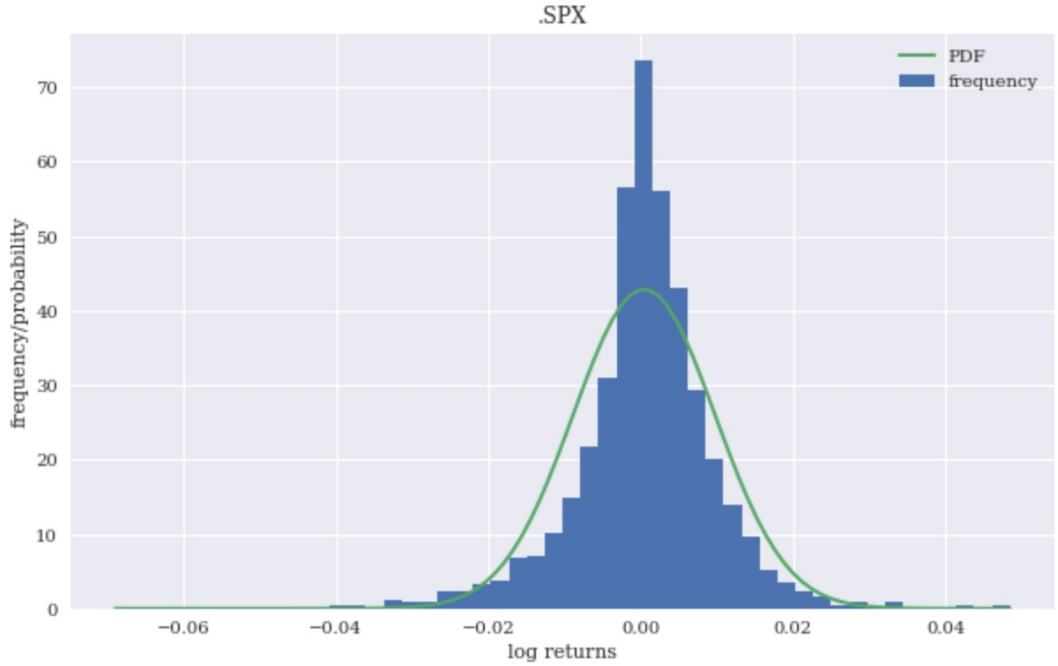
```
GLD
============================================
RETURN SAMPLE STATISTICS
--------------------------------------------
Skew of Sample Log Returns -0.581025
Skew Normal Test p-value    0.000000
--------------------------------------------
Kurt of Sample Log Returns  5.899701
Kurt Normal Test p-value    0.000000
--------------------------------------------
Normal Test p-value         0.000000
--------------------------------------------
```



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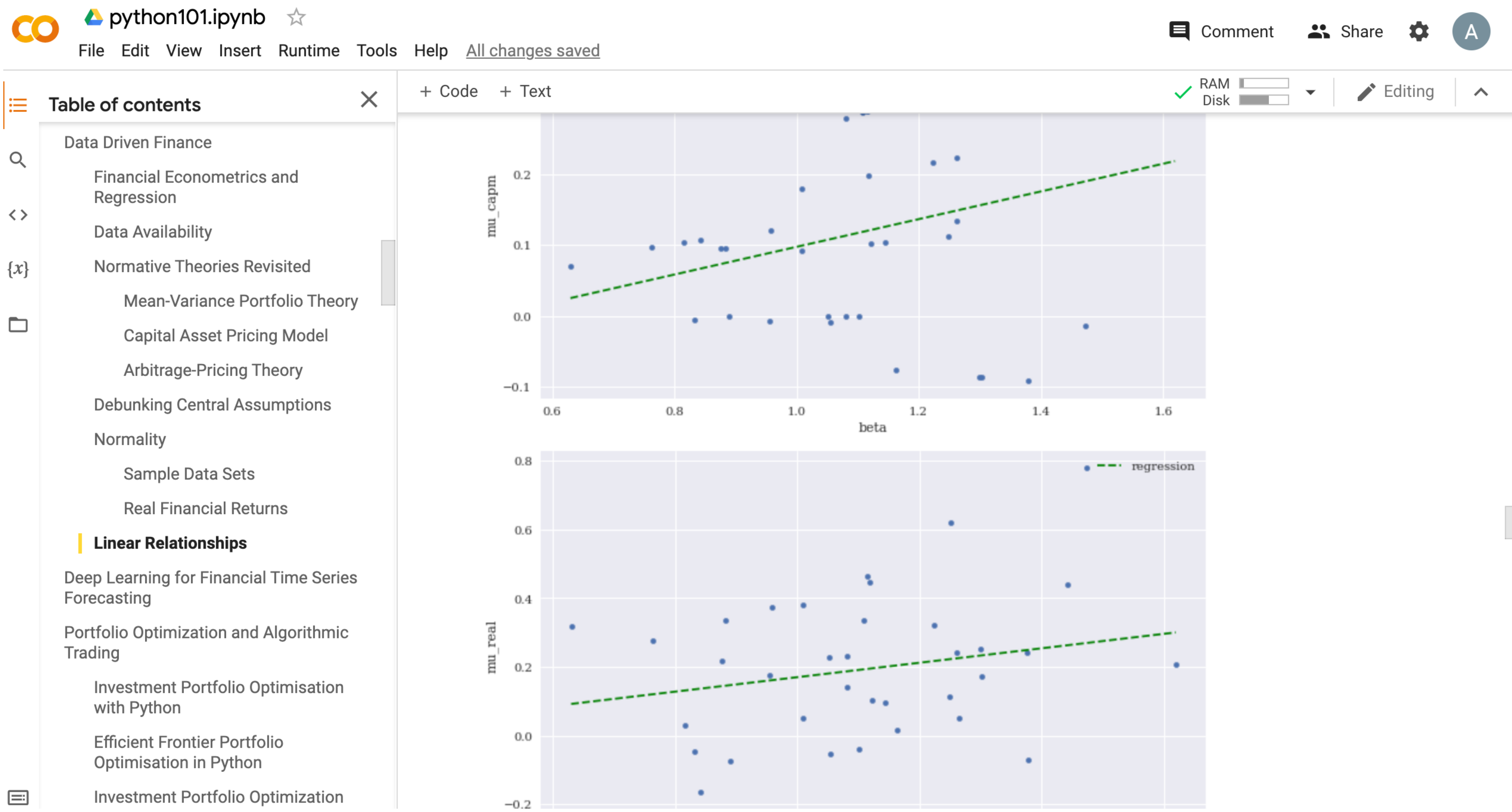

https://tinyurl.com/aintpupython101

Summary

- Data-Driven Finance
- Scientific Method
- Financial Econometrics and Regression
- Data Availability
- Normative Theories Revisited
- Debunking Central Assumptions in Finance

Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

References

- Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O’Reilly Media, https://github.com/yhilpisch/aiif .
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