智慧金融量化分析
(Artificial Intelligence in Finance and Quantitative Analysis)

国立臺北大學
National Taipei University

財務金融理論
(Finance Theory)

1101AIFQA05
MBA, IM, NTPU (M6132) (Fall 2021)
Tue 2, 3, 4 (9:10-12:00) (8F40)

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2021-11-02

課程大綱 (Syllabus)

週次 (Week)	日期 (Date)	內容 (Subject/Topics)
1	2021/09/28	智慧金融量化分析概論 (Introduction to Artificial Intelligence in Finance and Quantitative Analysis)
2	2021/10/05	AI 金融科技: 金融服務創新應用 (AI in FinTech: Financial Services Innovation and Application)
3	2021/10/12	投資心理學與行為財務學 (Investing Psychology and Behavioral Finance)
4	2021/10/19	財務金融事件研究法 (Event Studies in Finance)
5	2021/10/26	智慧金融量化分析個案研究 I (Case Study on AI in Finance and Quantitative Analysis I)
6	2021/11/02	財務金融理論 (Finance Theory)

課程大綱 (Syllabus)

週次 (Week) 日期 (Date) 內容 (Subject/Topics)

7 2021/11/09 數據驅動財務金融 (Data-Driven Finance)

8 2021/11/16 期中報告 (Midterm Project Report)

9 2021/11/23 金融計量經濟學 (Financial Econometrics)

10 2021/11/30 人工智慧優先金融 (AI-First Finance)

11 2021/12/07 智慧金融量化分析產業實務
(Industry Practices of AI in Finance and Quantitative Analysis)

12 2021/12/14 智慧金融量化分析個案研究 II
(Case Study on AI in Finance and Quantitative Analysis II)

課程大綱 (Syllabus)

週次 (Week)	日期 (Date)	內容 (Subject/Topics)
13	2021/12/21	財務金融深度學習(Deep Learning in Finance); 財務金融強化學習 (Reinforcement Learning in Finance)
14	2021/12/28	演算法交易 (Algorithmic Trading); 風險管理 (Risk Management); 交易機器人與基於事件的回測 (Trading Bot and Event-Based Backtesting)
15	2022/01/04	期末報告 I (Final Project Report I)
16	2022/01/11	期末報告 II (Final Project Report II)
17	2022/01/18	學生自主學習 (Self-learning)
18	2022/01/25	學生自主學習 (Self-learning)

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

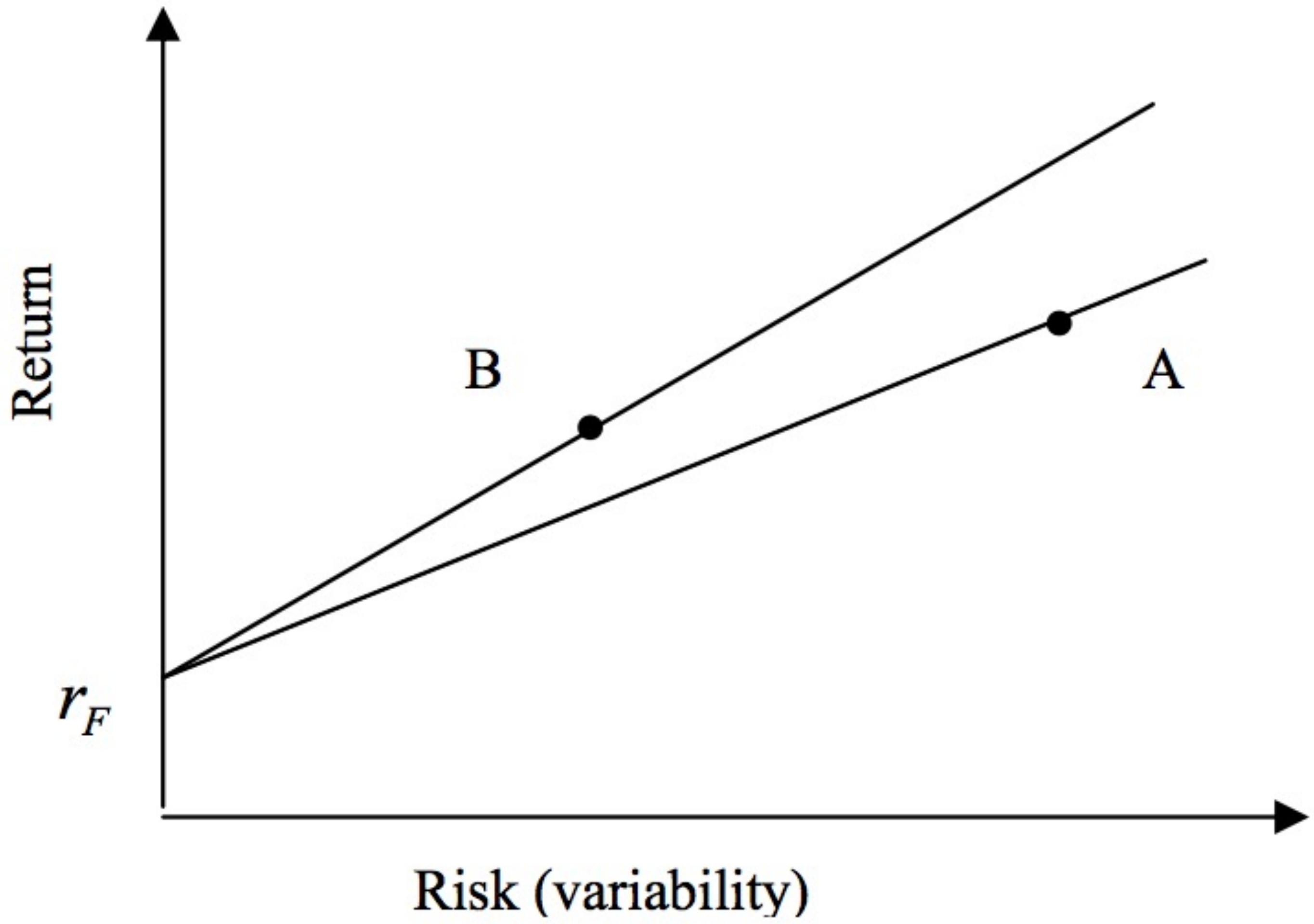
- **The CAPM is based on many unrealistic assumptions.**
  - **The assumption that investors care only about the mean and variance of one-period portfolio returns is extreme.**
    (Eugene Fama and Kenneth French, 2004)

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

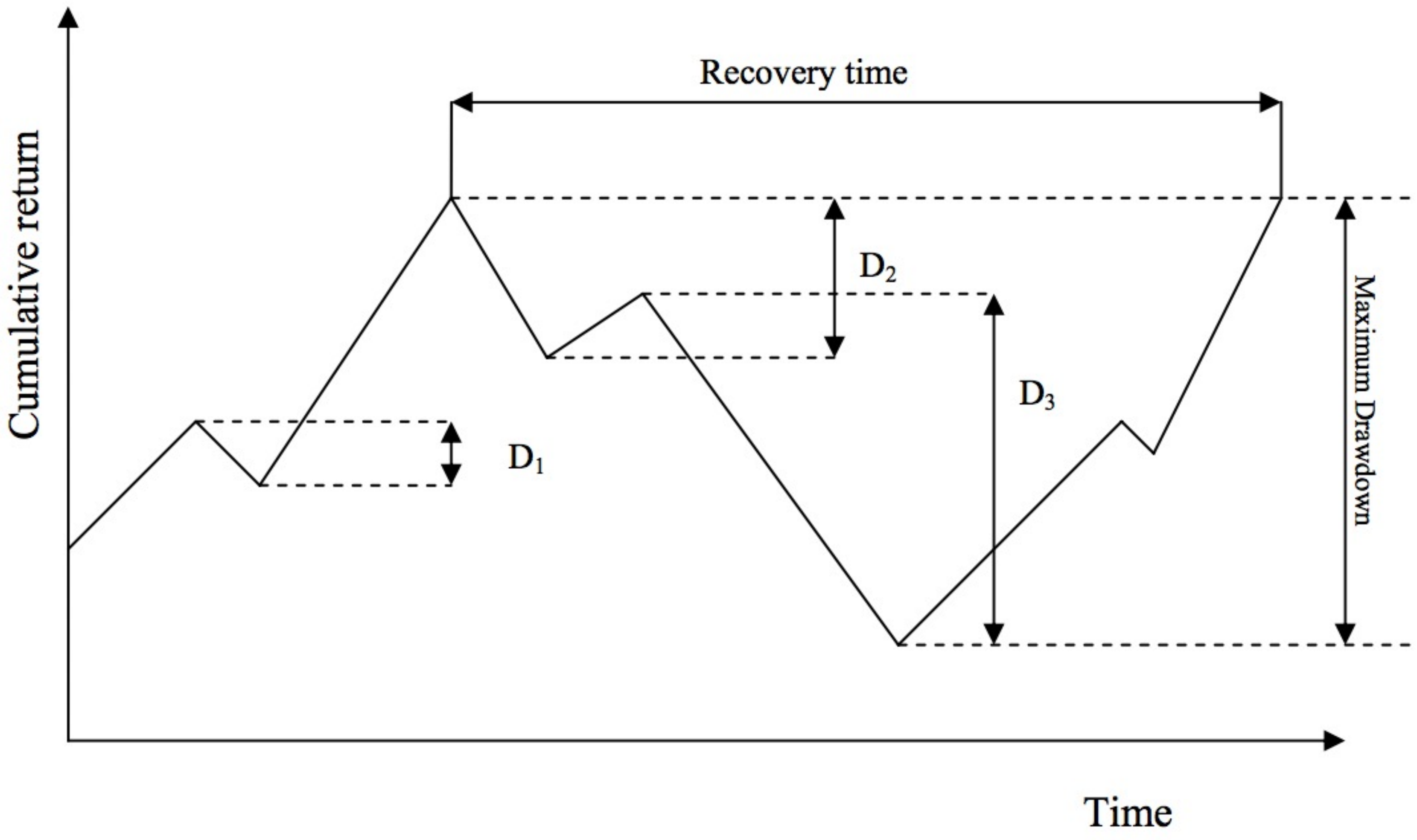
r_T = Minimum Target Return

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).

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

Expected Utility Theory (EUT)

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

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 M^2.**
- **One possible set of axioms leading to EUT**
  - **Completeness**
  - **Transitivity**
  - **Continuity**
  - **Independence**
  - **Dominance**

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.**

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

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.**

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.

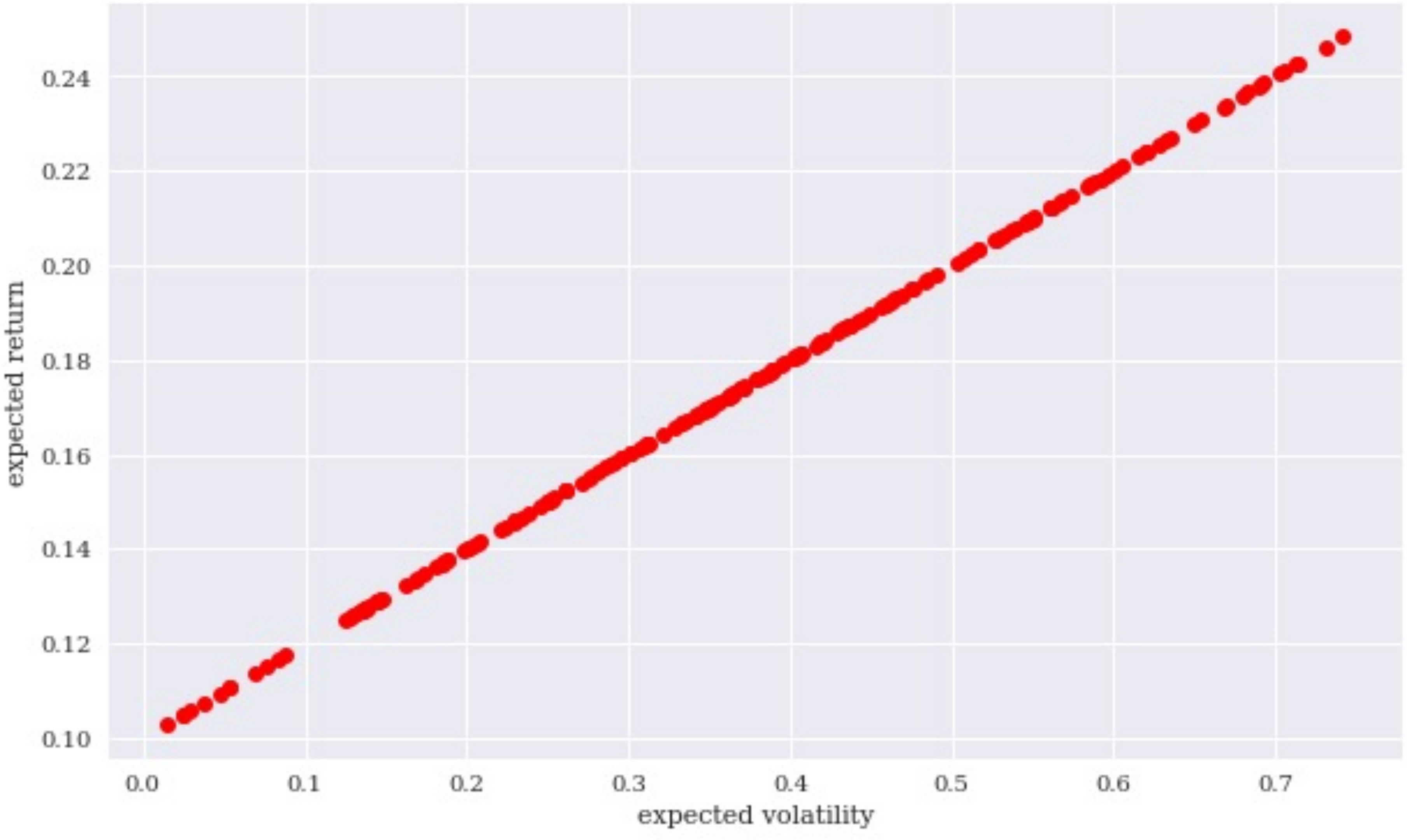
Sharpe ratio

- **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

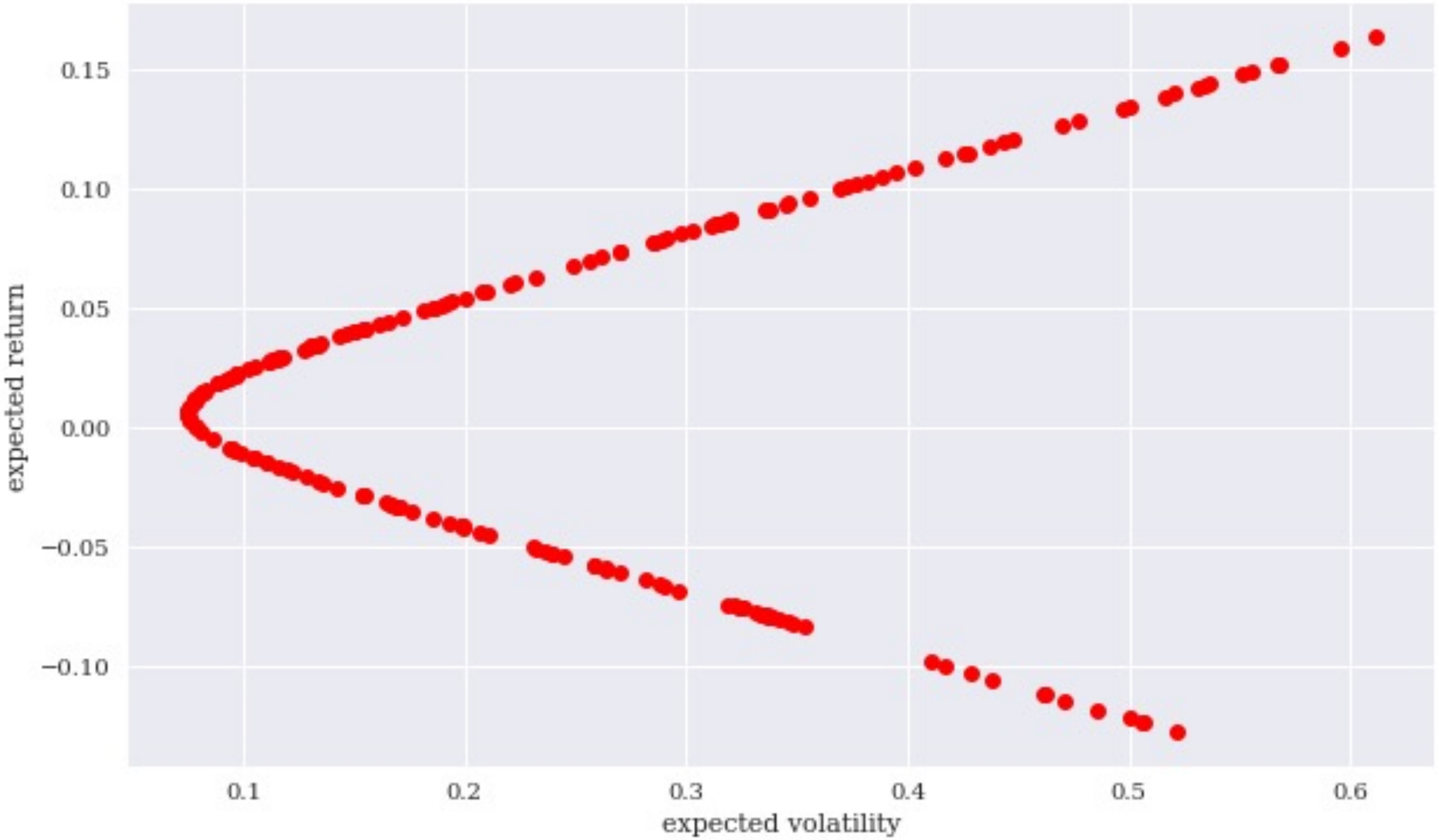
Simulated expected portfolio volatility and return (one risky asset)



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

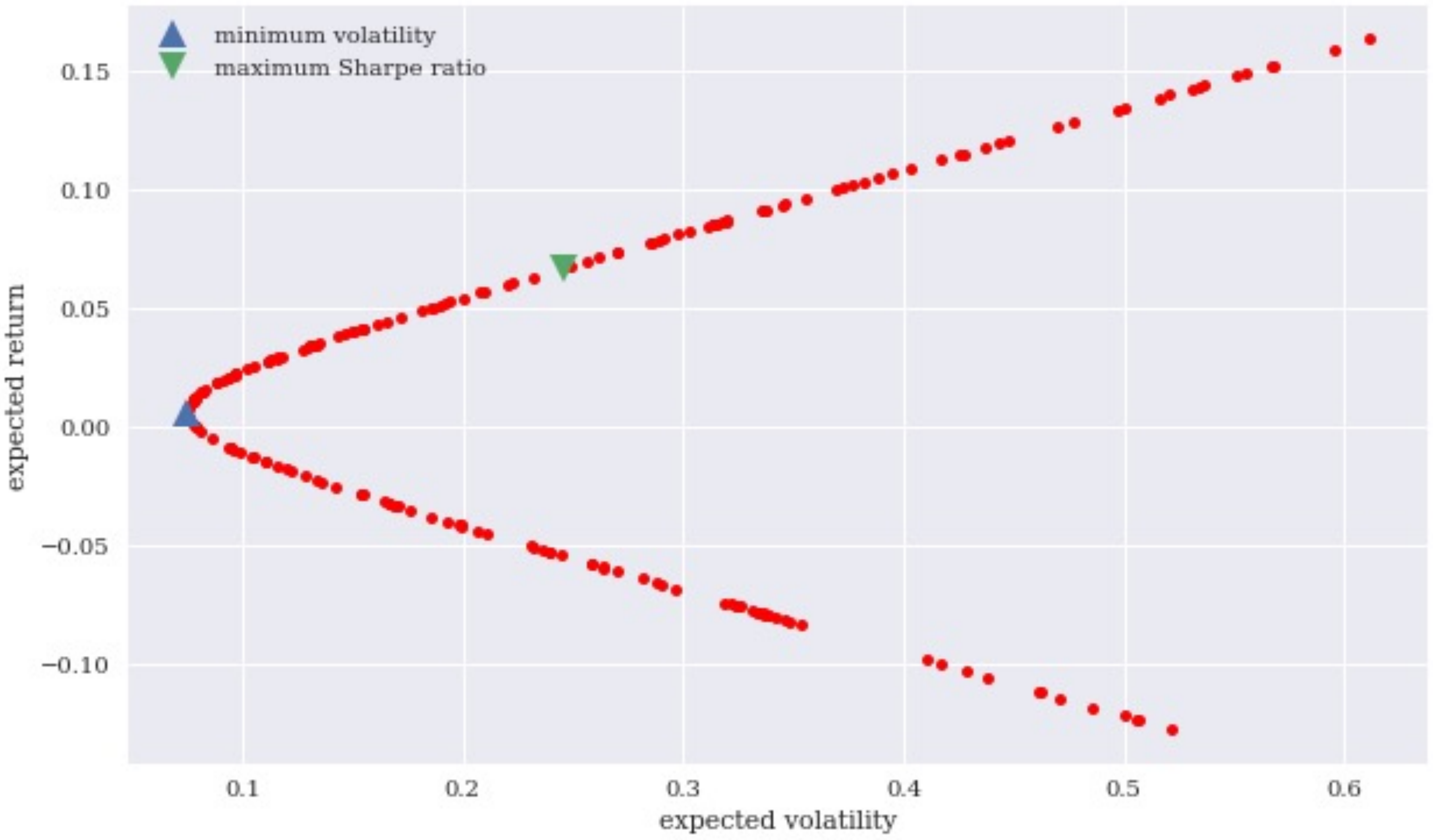
Investment Opportunity Set

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



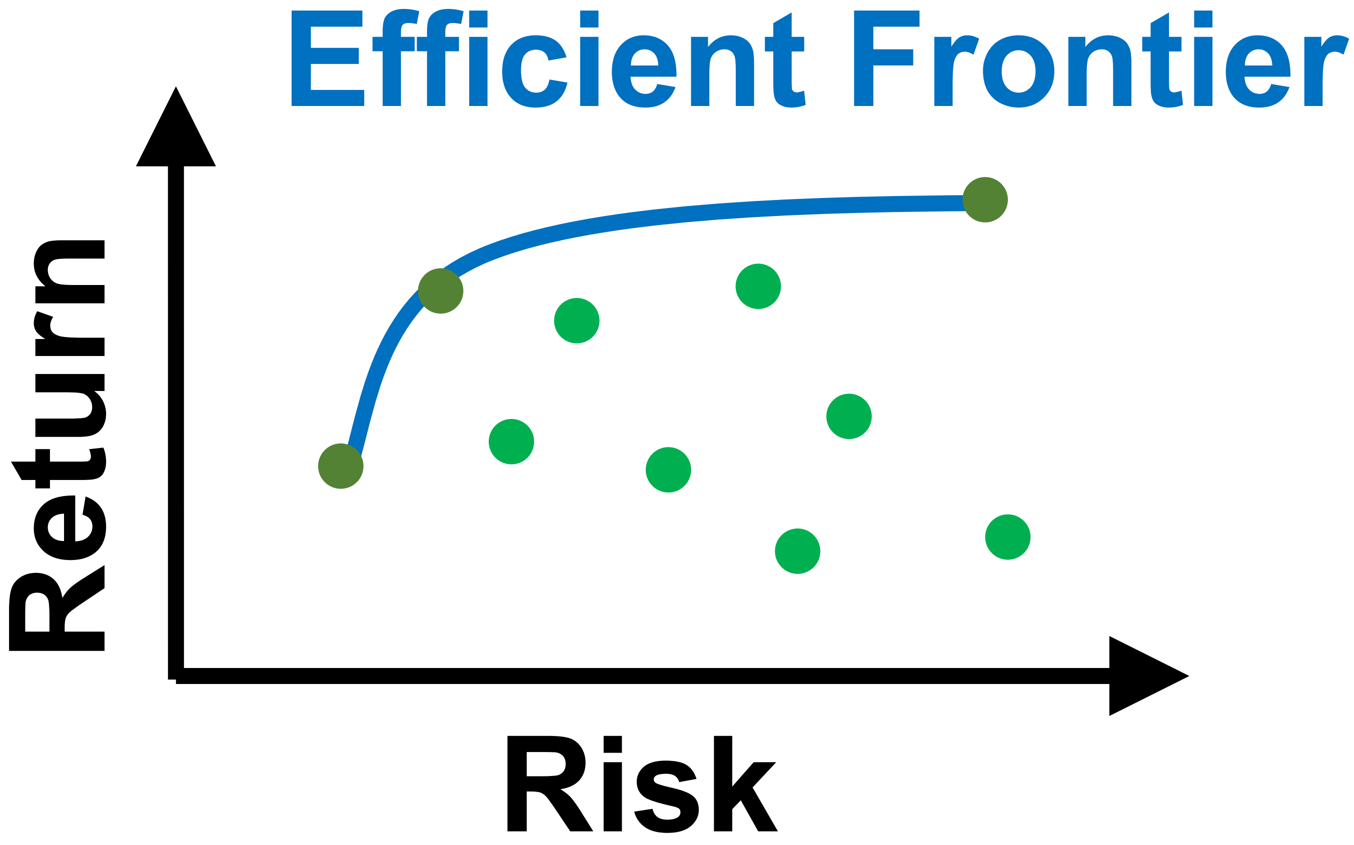
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

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

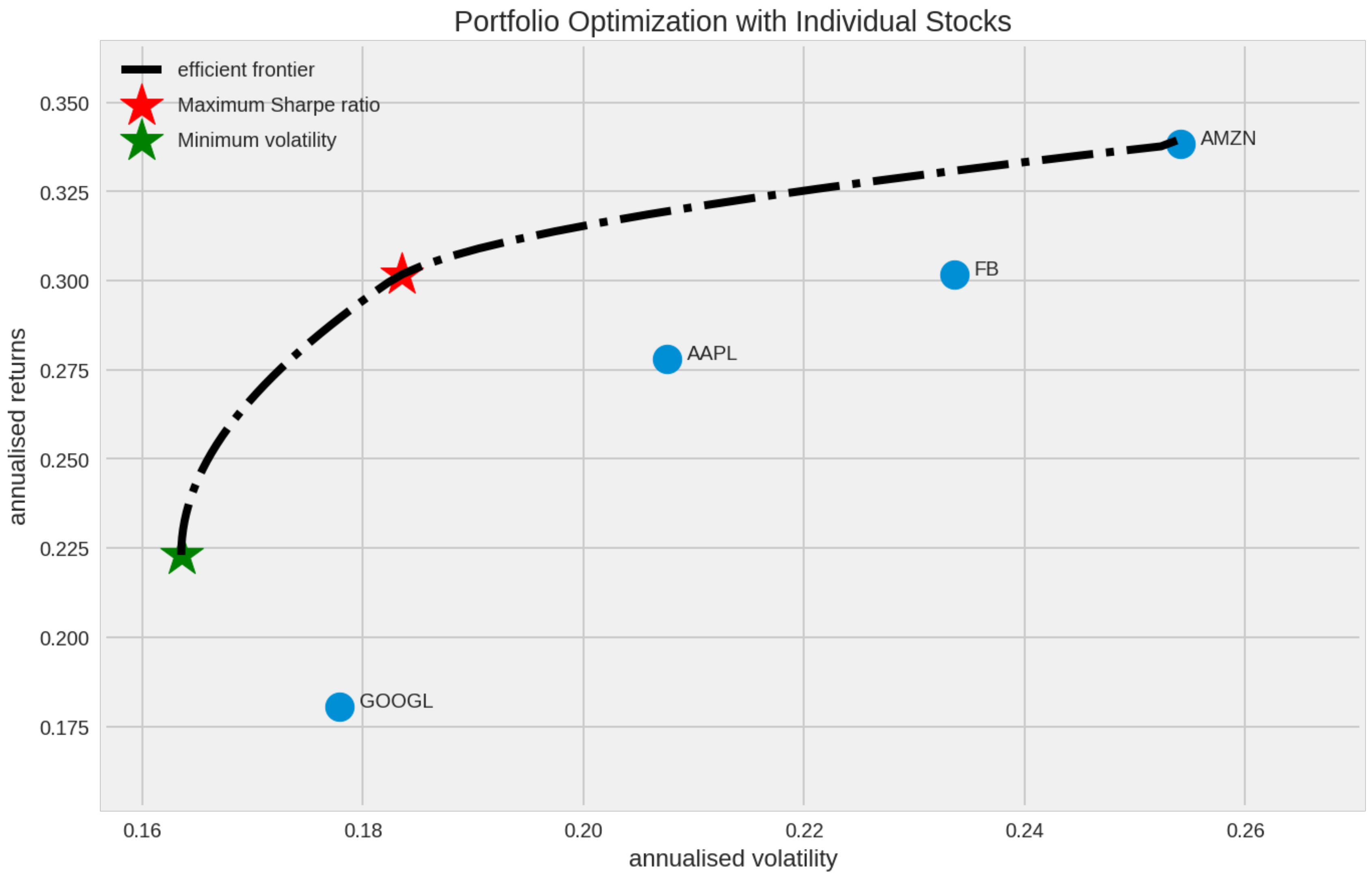
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

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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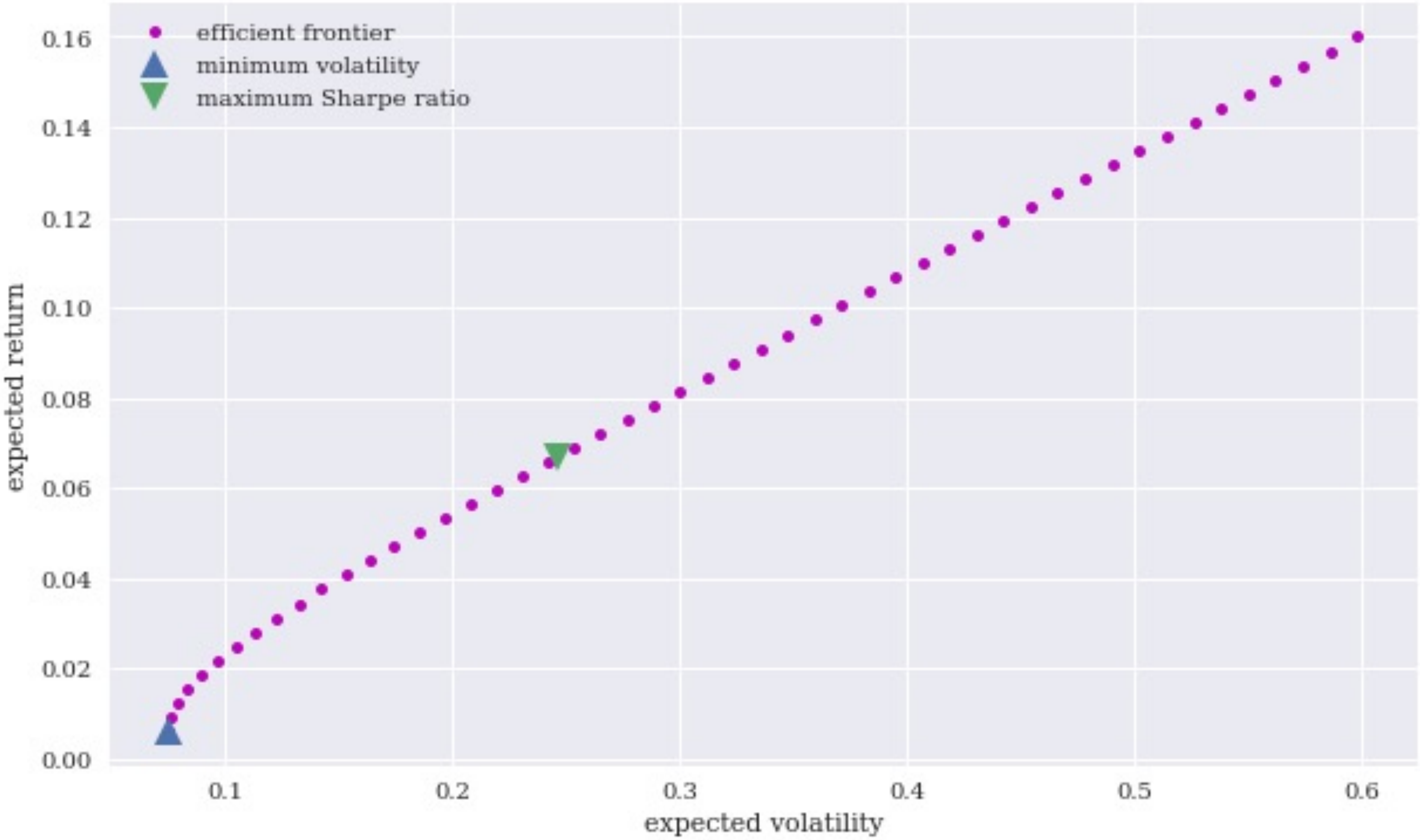
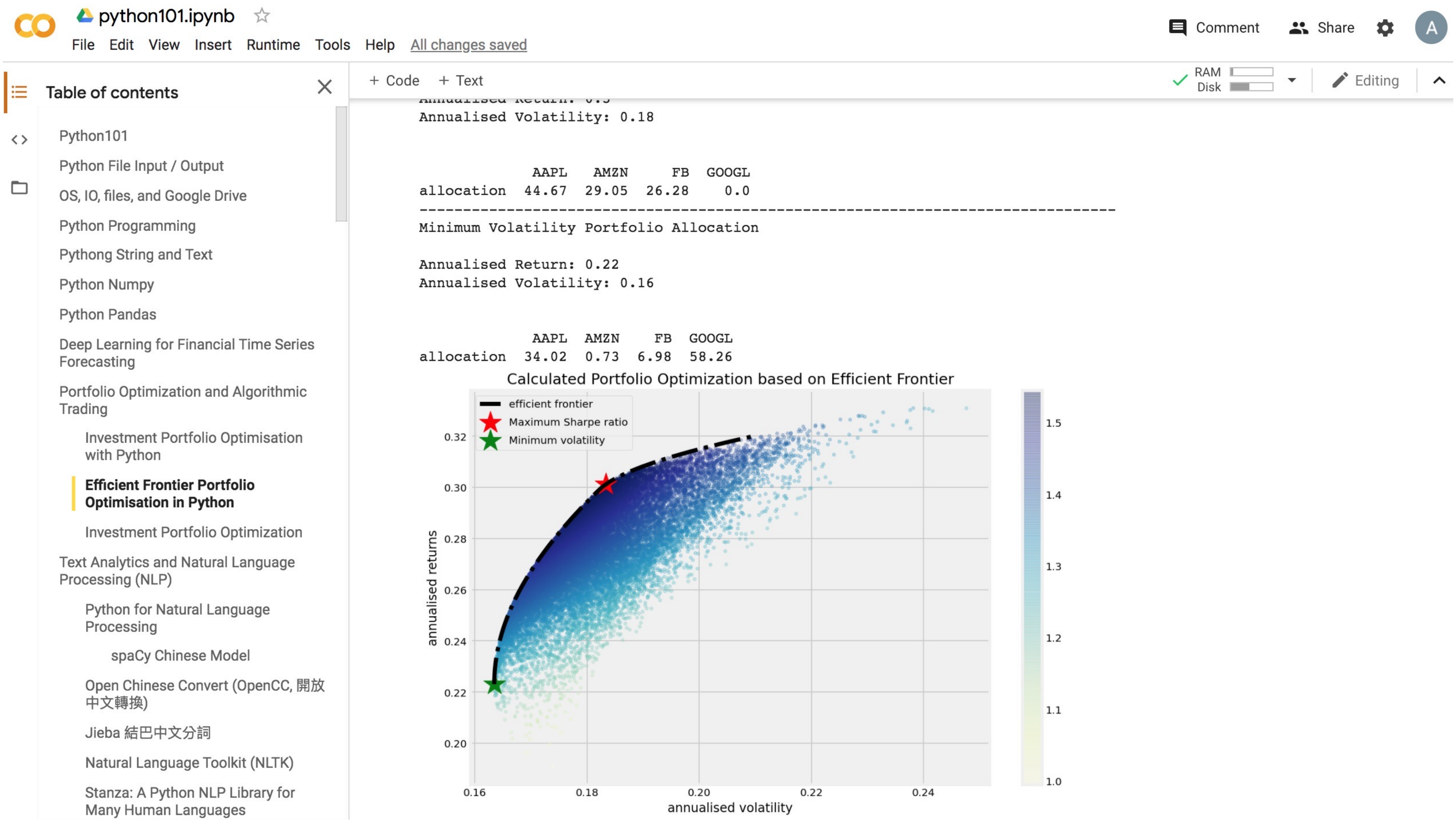
Efficient Frontier



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



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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)

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.

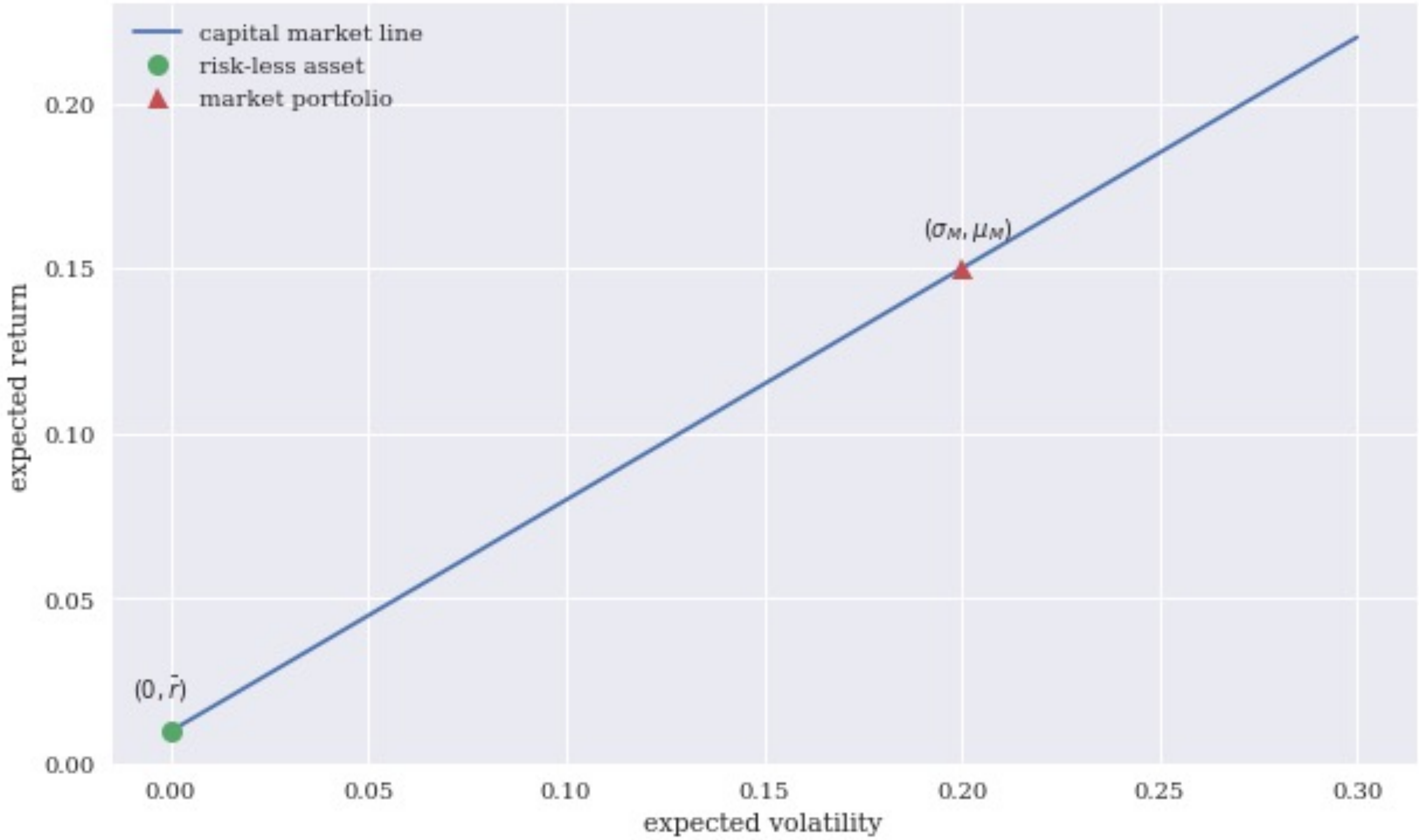
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

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).

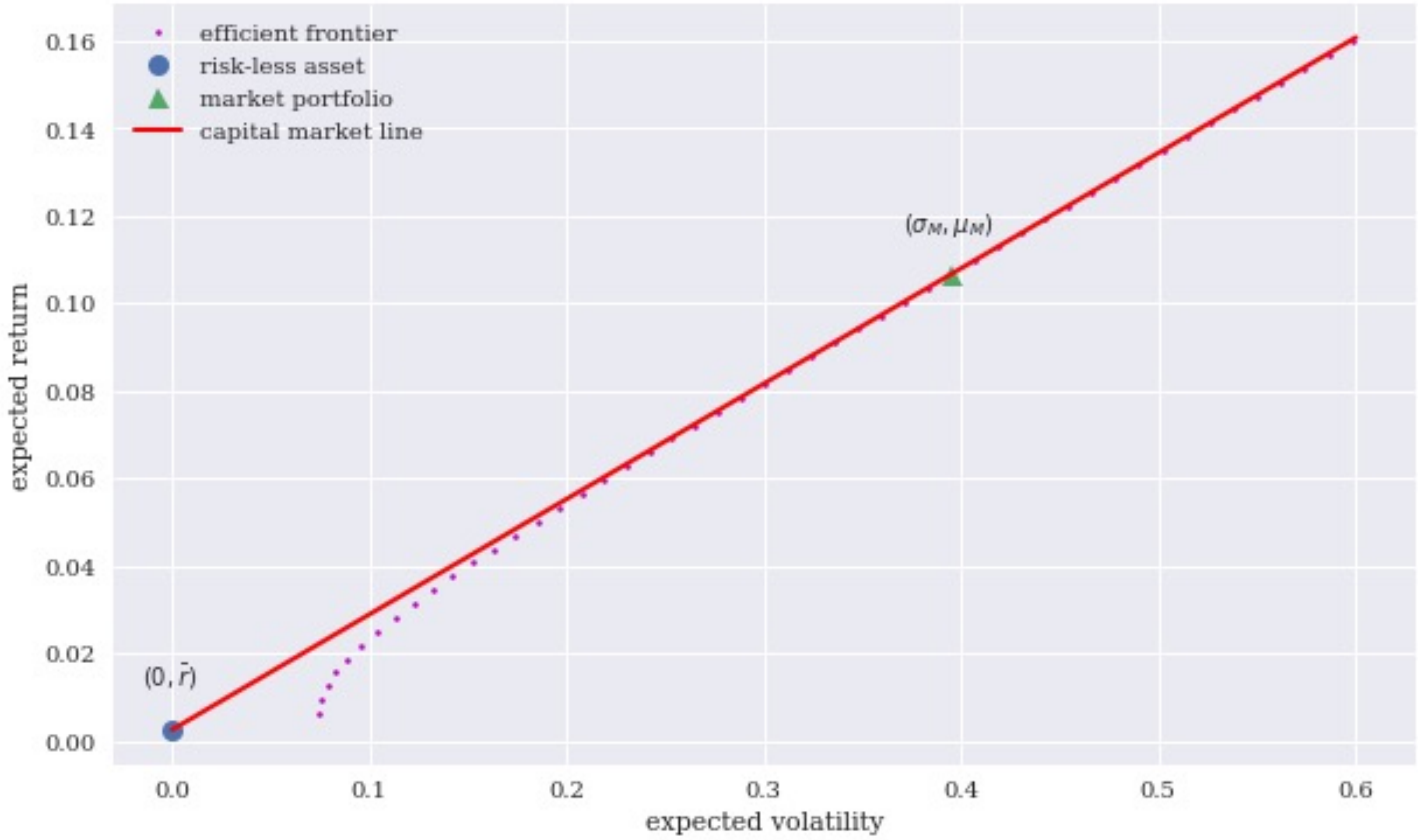
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Capital Market Line (CML)



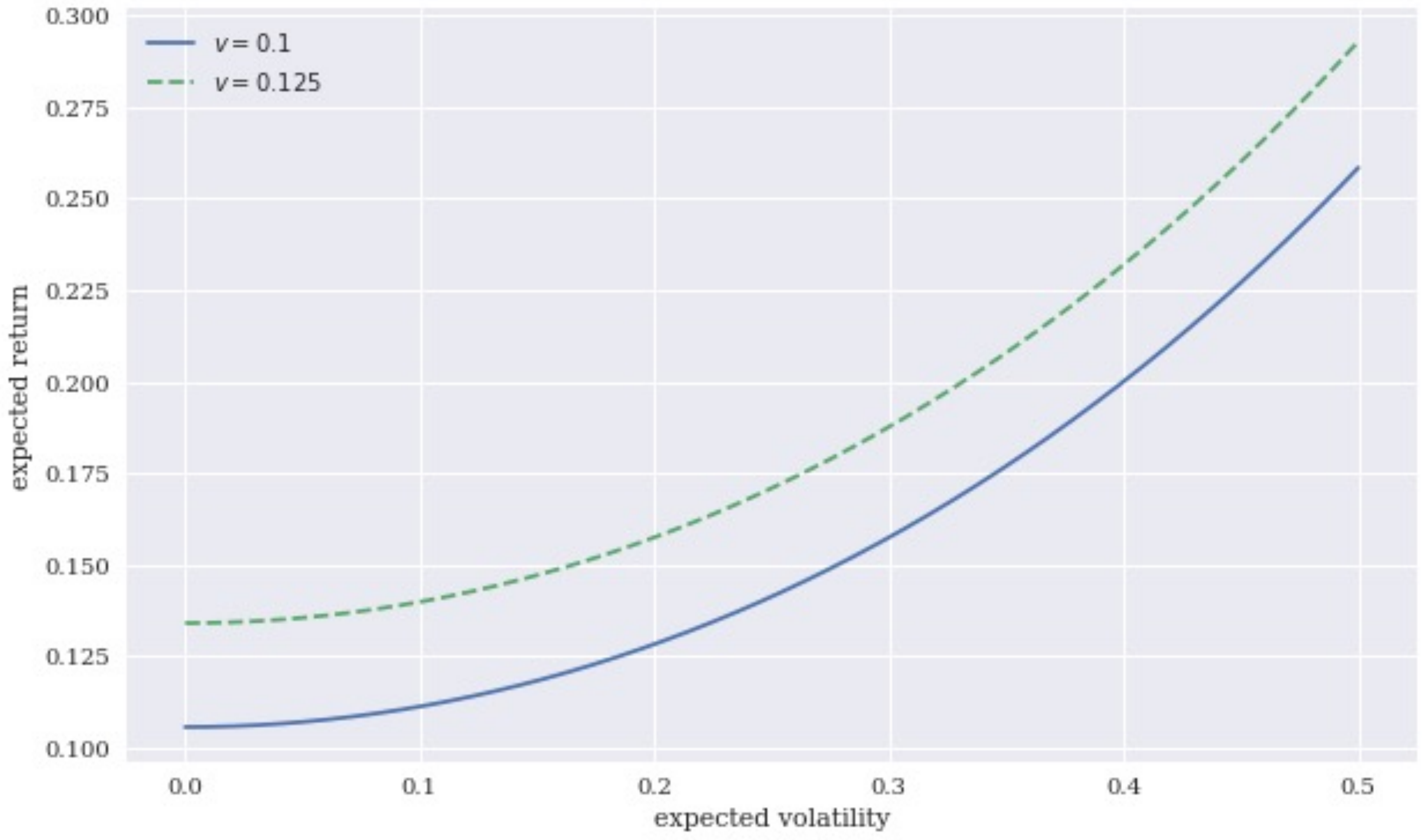
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Capital Market Line with Two Risky Assets



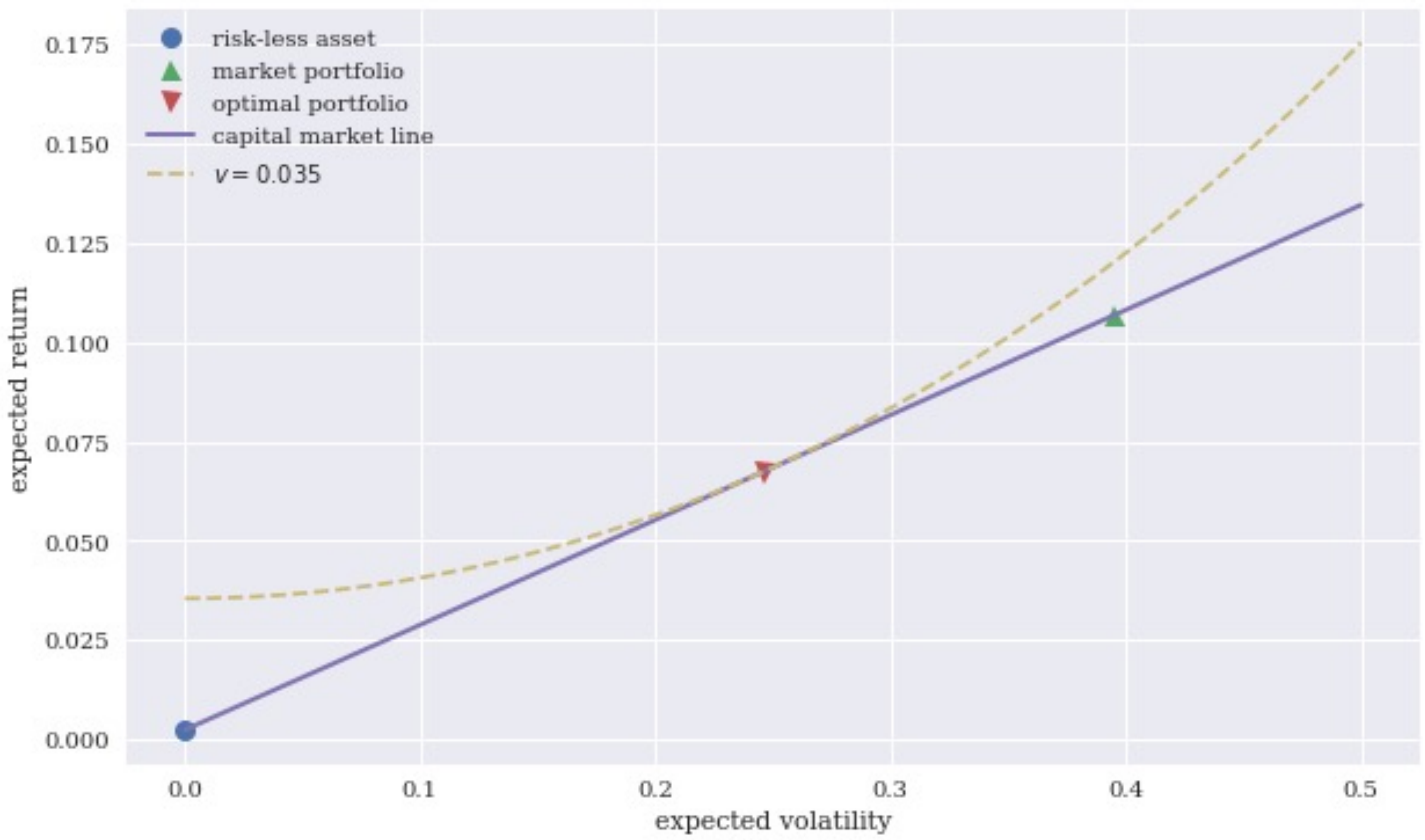
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

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)

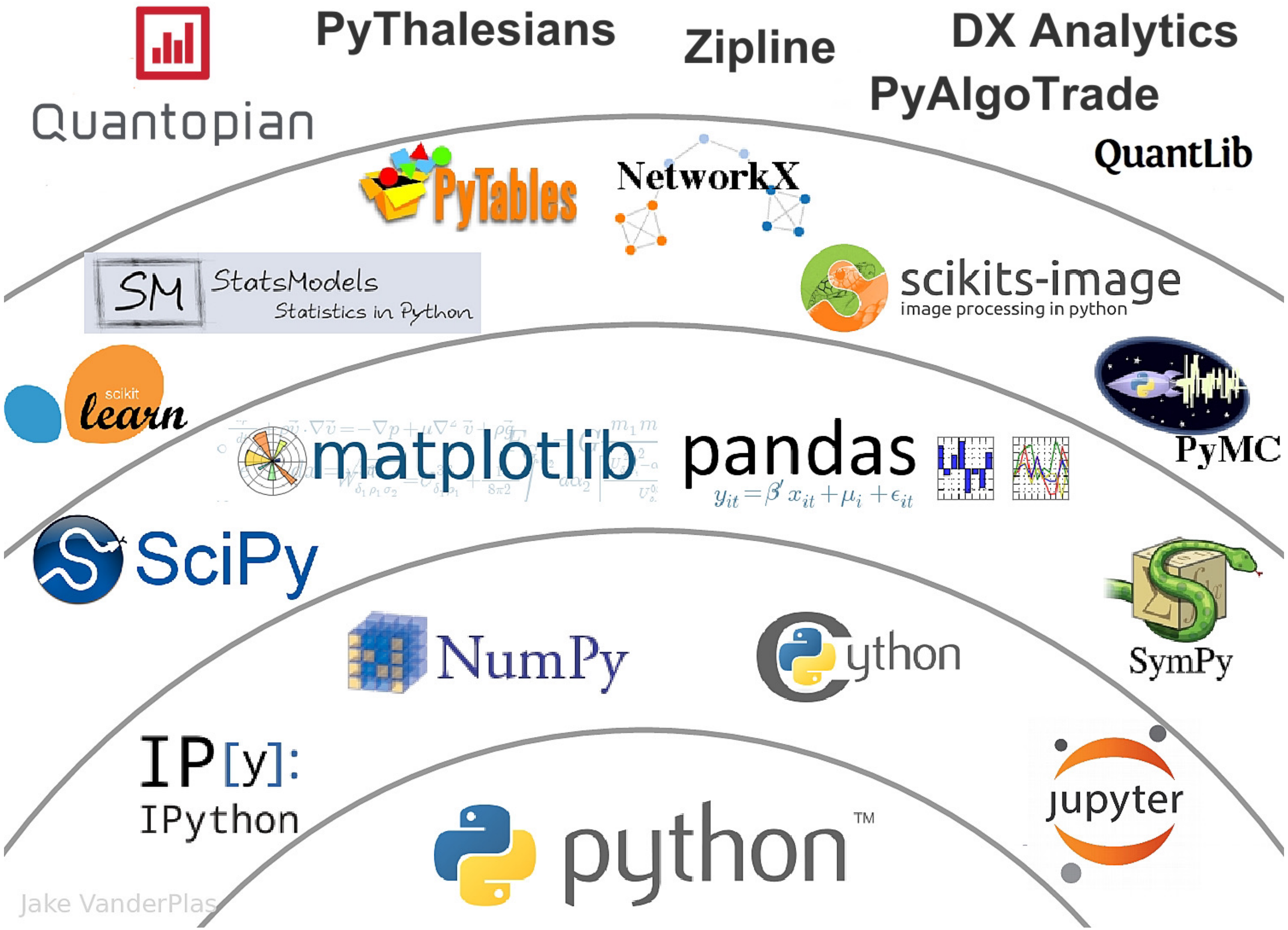
- The APT is a generalization of the CAPM to multiple risk factors.
- APT does not assume that the market portfolio is the only relevant risk factor
  - There are rather multiple types of risk that together are assumed to drive the performance (expected returns) of a stock.
  - Such risk factors might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

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**

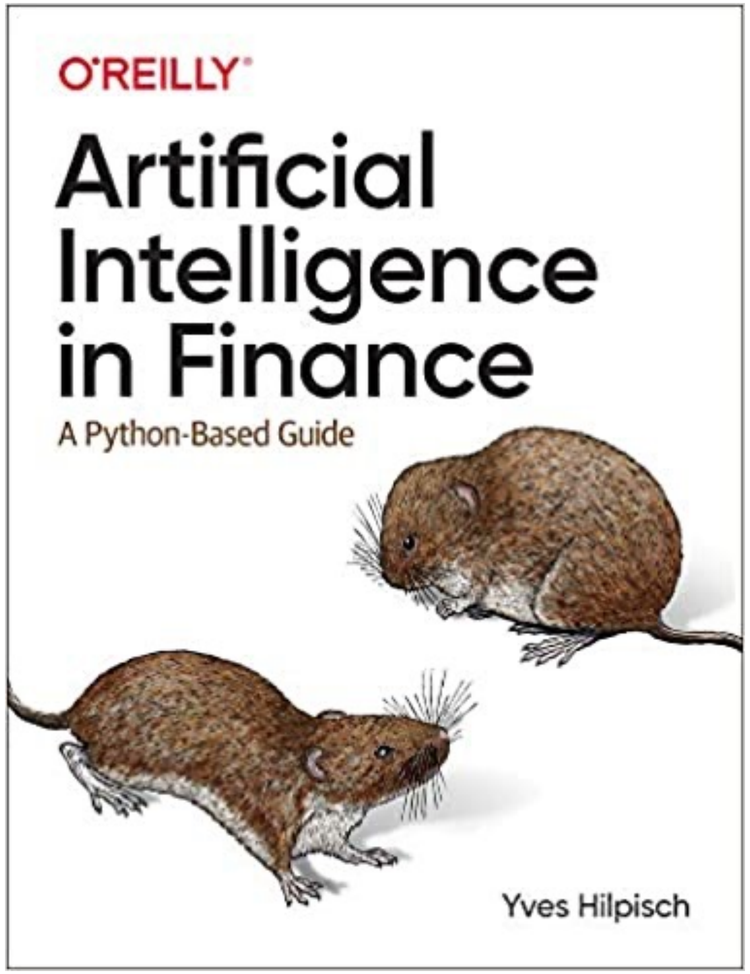
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

The Quant Finance PyData Stack



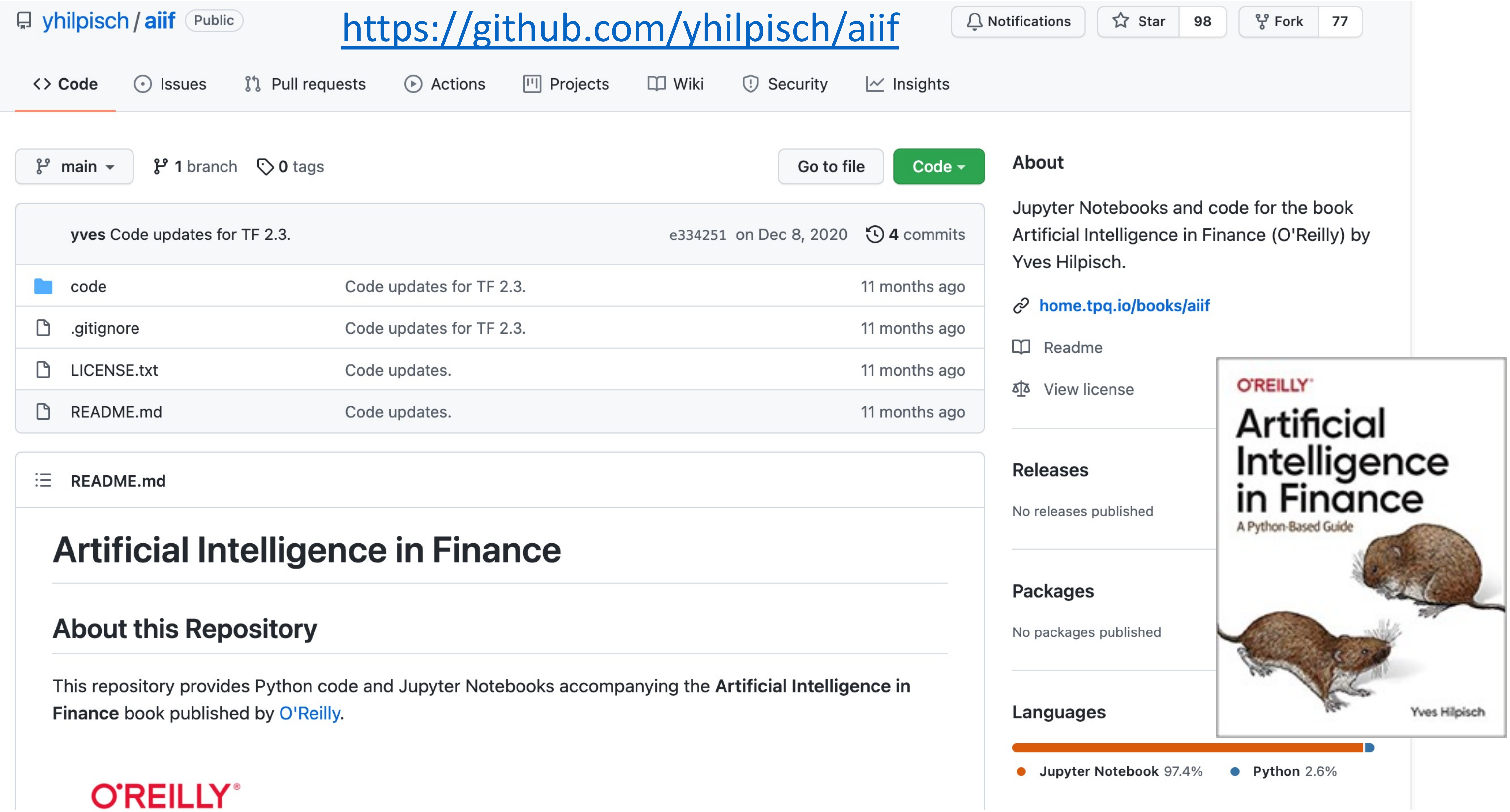
Source: http://nbviewer.jupyter.org/format/slides/github/quantopian/pyfolio/blob/master/pyfolio/examples/overview_slides.ipynb#/5

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



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

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

yhilpisch / aiif Public

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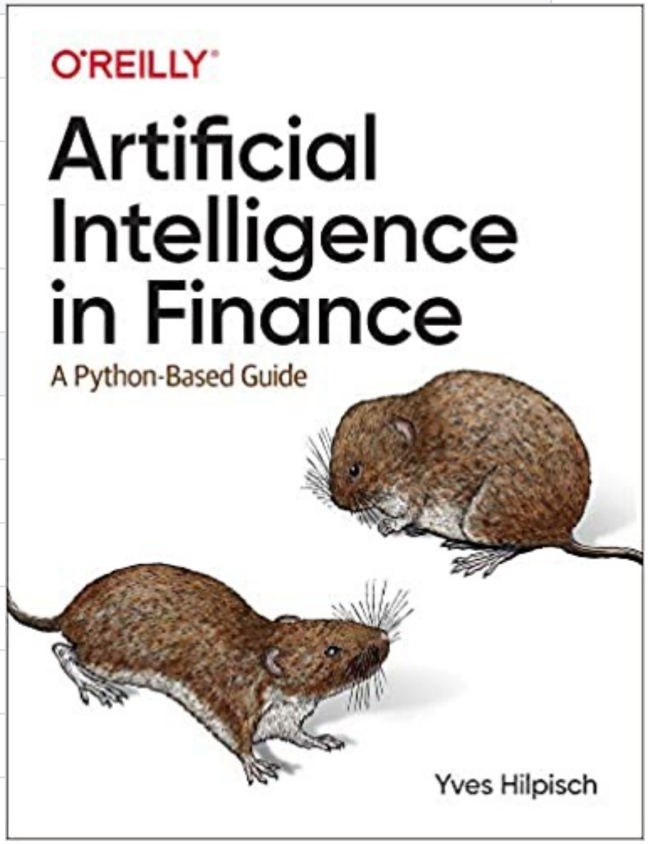
main | aiif / code /

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

```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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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

python101.ipynb

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RAM Disk Editing

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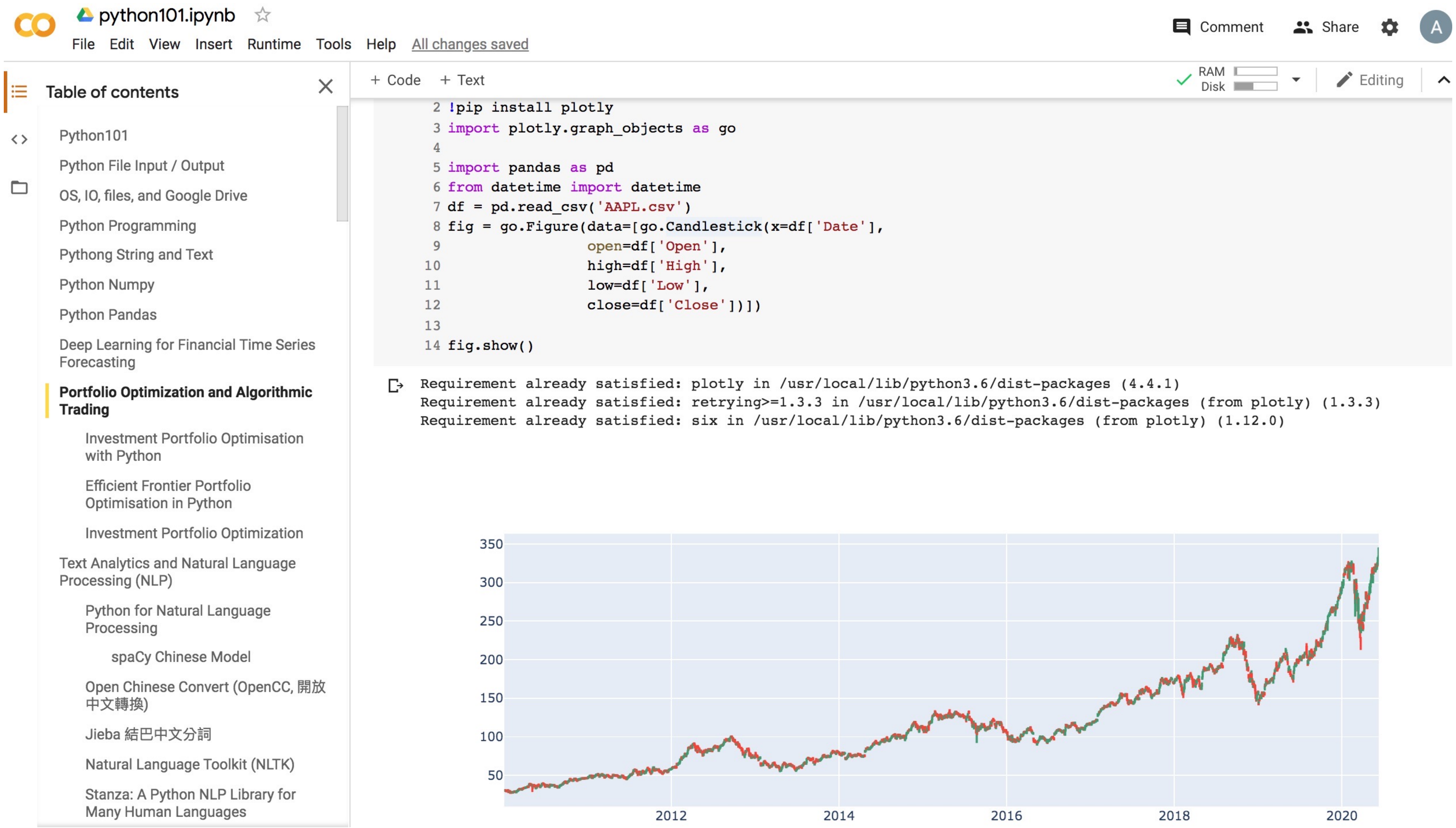
Portfolio Optimization and Algorithmic Trading

```
! pip install pandas_datareader
import pandas as pd
import pandas_datareader.data as web
import matplotlib.pyplot as plt
import seaborn as sns
import datetime as dt
%matplotlib inline

#Read Stock Data from Yahoo Finance
end = dt.datetime.now()
#start = dt.datetime(end.year-2, end.month, end.day)
start = dt.datetime(2010, 1, 1)
df = web.DataReader("AAPL", 'yahoo', start, end)
df.to_csv('AAPL.csv')
#df = pd.read_csv('AAPL.csv')
print(df.head())
print(df.tail())
print(df.describe())

df['Adj Close'].plot(legend=True, figsize=(12, 8), title='AAPL', label='Adj Close')
plt.figure(figsize=(12,9))
top = plt.subplot2grid((12,9), (0, 0), rowspan=10, colspan=9)
bottom = plt.subplot2grid((12,9), (10,0), rowspan=2, colspan=9)
top.plot(df.index, df['Adj Close'], color='blue') #df.index gives the dates
bottom.bar(df.index, df['Volume'])

# set the labels
top.axes.get_xaxis().set_visible(False)
top.set_title('AAPL')
top.set_ylabel('Adj Close')
bottom.set_ylabel('Volume')

plt.figure(figsize=(12,9))
```

https://tinyurl.com/aintpupython101

Python in Google Colab (Python101)

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



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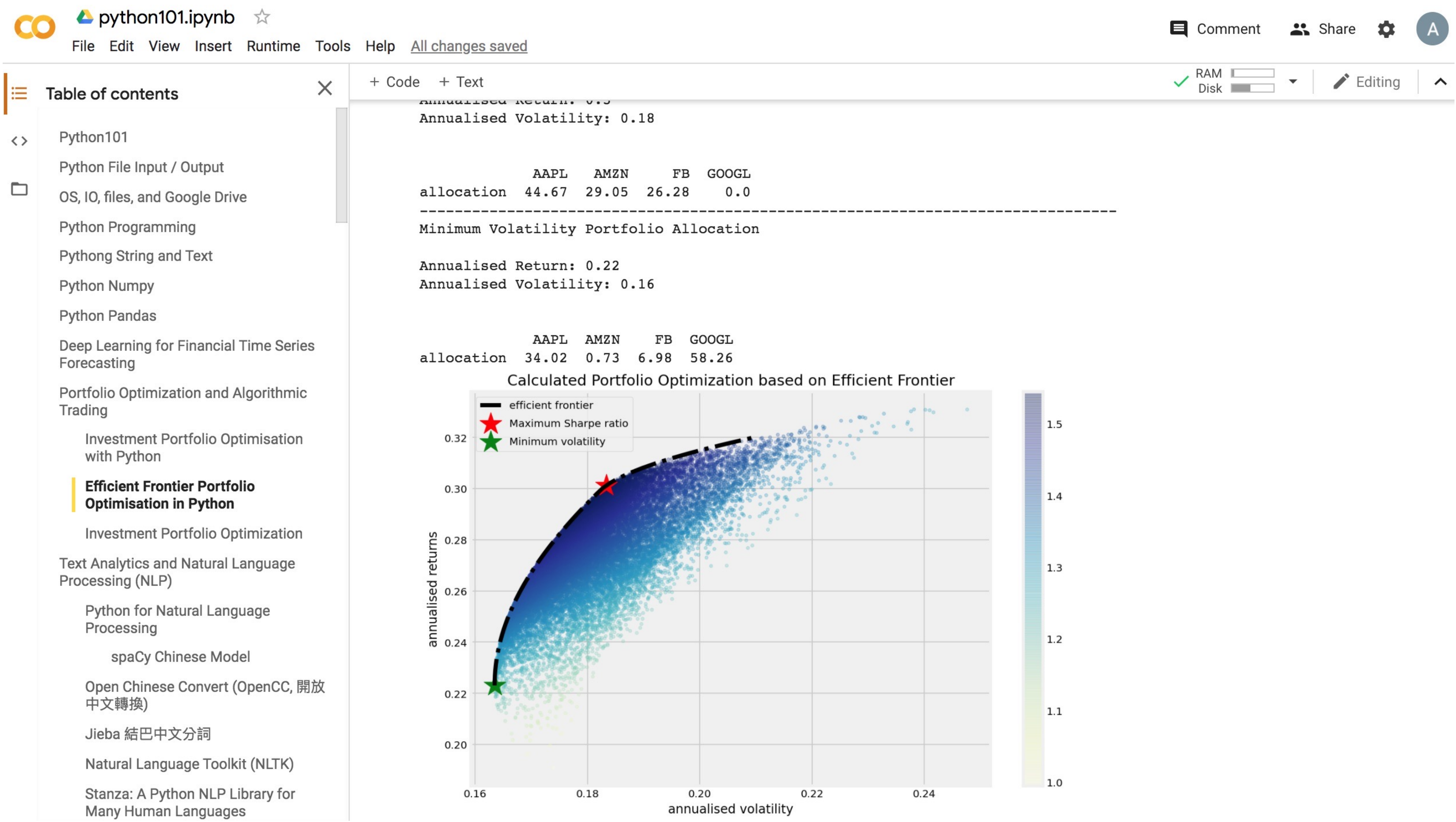

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Portfolio Optimization
Efficient Frontier Portfolio Optimization

python101.ipynb

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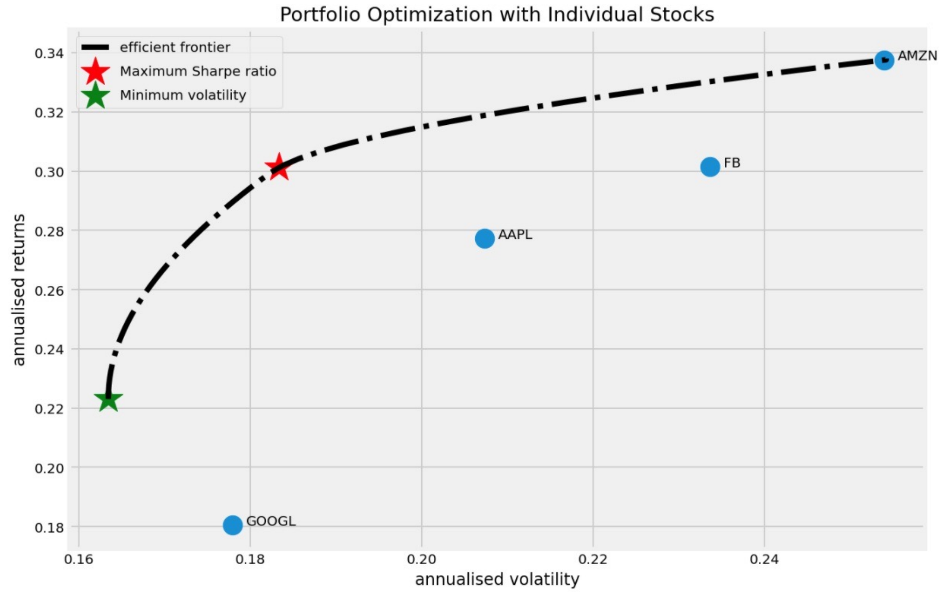
```
Annualised Return: 0.22
Annualised Volatility: 0.16


              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
--------------------------------------------------------------------------------
```



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Summary

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

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