Artificial Intelligence in Finance and Quantitative Analysis

Data-Driven Finance

1111AIFQA06
MBA, IM, NTPU (M6132) (Fall 2022)
Tue 2, 3, 4 (9:10-12:00) (B8F40)

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

Min-Yuh Day, Ph.D,
Associate Professor

Institute of Information Management, National Taipei University

https://web.ntpu.edu.tw/~myday

2022-10-25

Syllabus

Week	Date	Subject/Topics
1	2022/09/13	Introduction to Artificial Intelligence in Finance and Quantitative Analysis
2	2022/09/20	AI in FinTech: Metaverse, Web3, DeFi, NFT, Financial Services Innovation and Applications
3	2022/09/27	Investing Psychology and Behavioral Finance
4	2022/10/04	Event Studies in Finance
5	2022/10/11	Case Study on AI in Finance and Quantitative Analysis I
6	2022/10/18	Finance Theory

Syllabus

Week	Date	Subject/Topics
7	2022/10/25	Data-Driven Finance
8	2022/11/01	Midterm Project Report
9	2022/11/08	Financial Econometrics
10	2022/11/15	AI-First Finance
11	2022/11/22	Industry Practices of AI in Finance and Quantitative Analysis
12	2022/11/29	Case Study on AI in Finance and Quantitative Analysis II

Syllabus

Week	Date	Subject/Topics
13	2022/12/06	Deep Learning in Finance; Reinforcement Learning in Finance
14	2022/12/13	Algorithmic Trading; Risk Management; Trading Bot and Event-Based Backtesting
15	2022/12/20	Final Project Report I
16	2022/12/27	Final Project Report II
17	2023/01/03	Self-learning
18	2023/01/10	Self-learning

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.**

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

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

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

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.

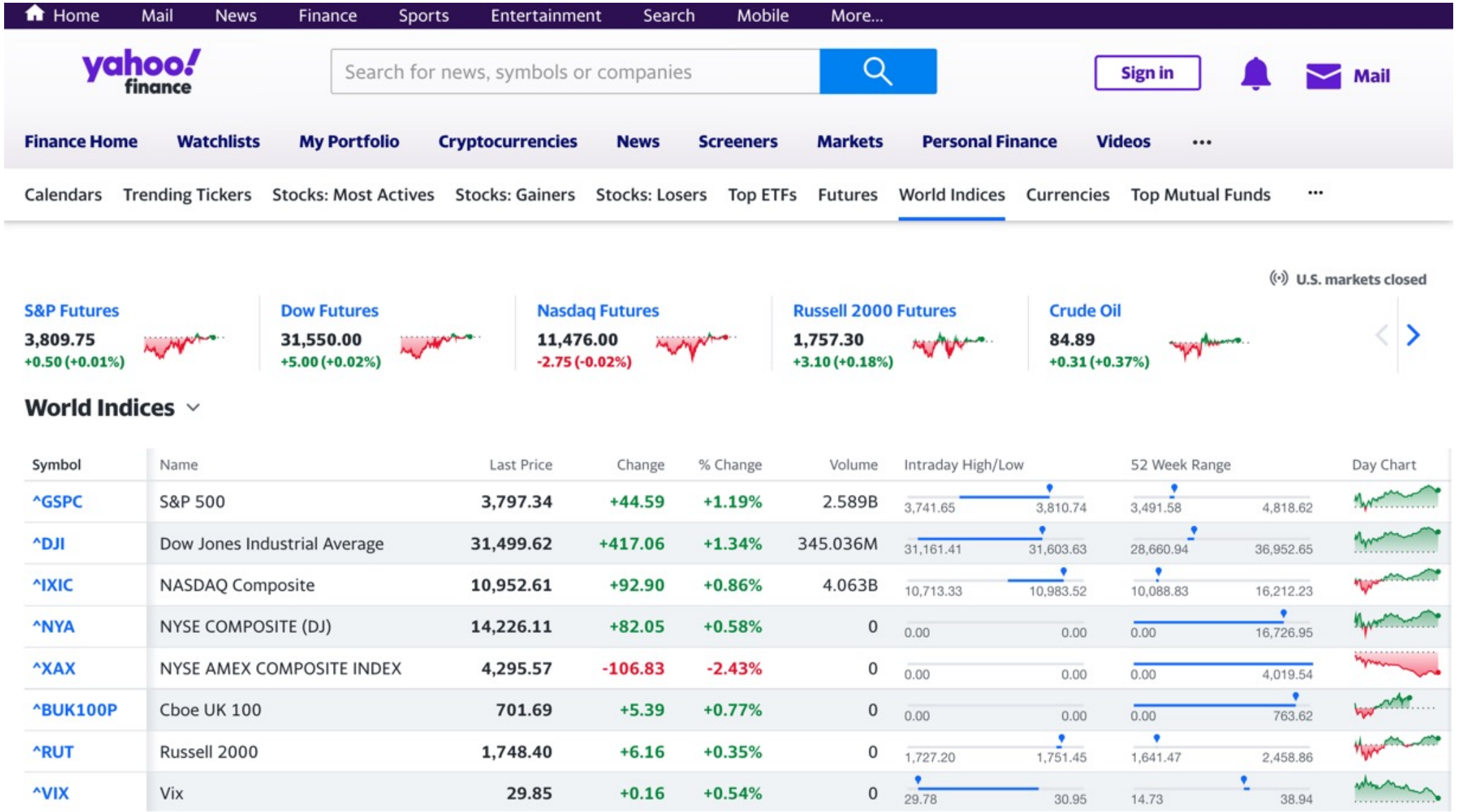
Relevant types of financial data

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/



Symbol	Name	Last Price	Change	% Change	Volume	Intraday High/Low	52 Week Range	Day Chart
^GSPC	S&P 500	3,797.34	+44.59	+1.19%	2.589B	3,741.65 3,810.74	3,491.58 4,818.62	
^DJI	Dow Jones Industrial Average	31,499.62	+417.06	+1.34%	345.036M	31,161.41 31,603.63	28,660.94 36,952.65	
^IXIC	NASDAQ Composite	10,952.61	+92.90	+0.86%	4.063B	10,713.33 10,983.52	10,088.83 16,212.23	
^NYA	NYSE COMPOSITE (DJ)	14,226.11	+82.05	+0.58%	0	0.00 0.00	0.00 16,726.95	
^XAX	NYSE AMEX COMPOSITE INDEX	4,295.57	-106.83	-2.43%	0	0.00 0.00	0.00 4,019.54	
^BUK100P	Cboe UK 100	701.69	+5.39	+0.77%	0	0.00 0.00	0.00 763.62	
^RUT	Russell 2000	1,748.40	+6.16	+0.35%	0	1,727.20 1,751.45	1,641.47 2,458.86	
^VIX	Vix	29.85	+0.16	+0.54%	0	29.78 30.95	14.73 38.94	

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
```

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^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')
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```

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())
```

Normative Theories Revisited

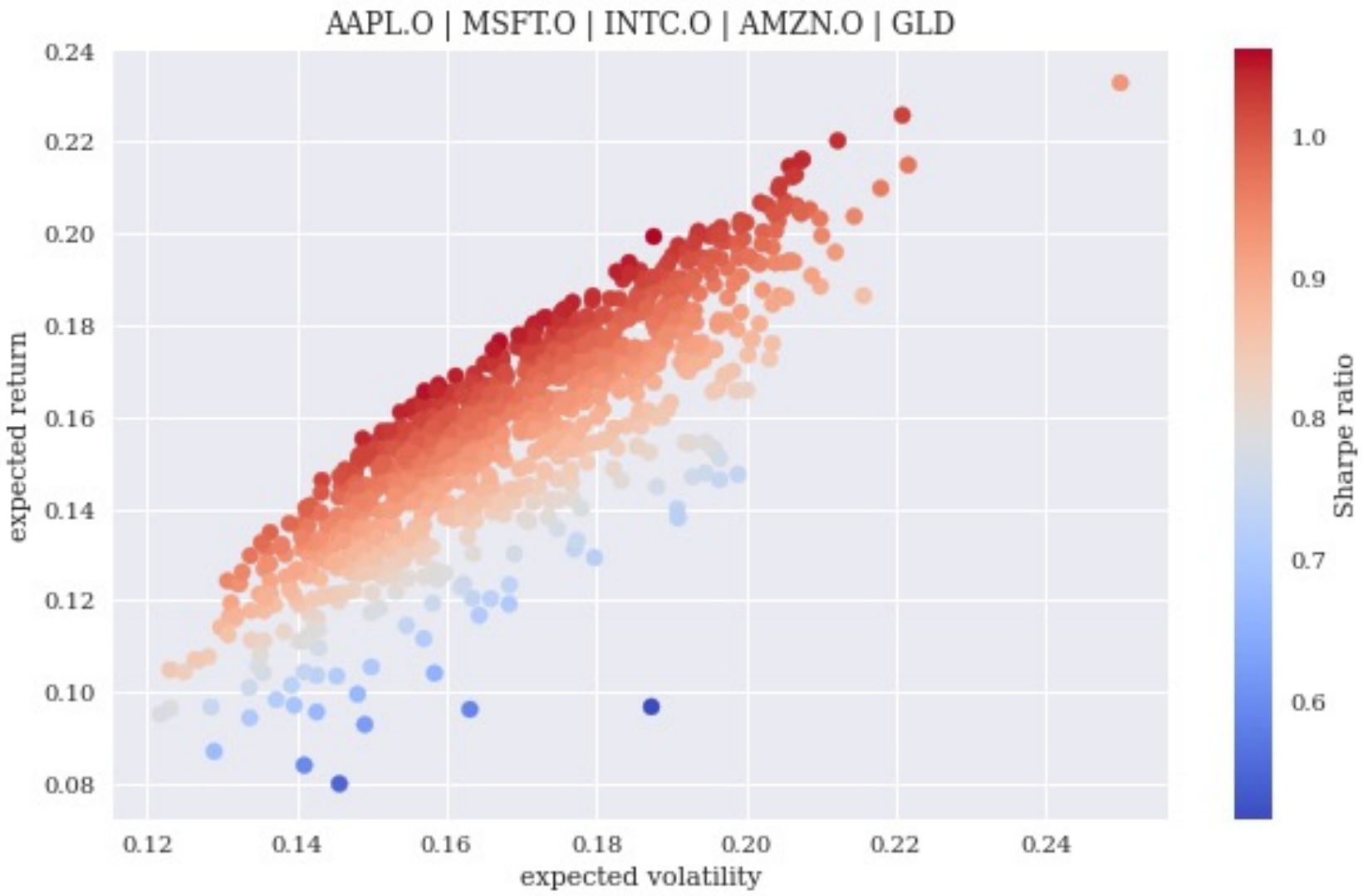
- **Revisits the normative theories and analyzes them based on real financial time series data**
- **Expected Utility and Reality**
- **Mean-Variance Portfolio Theory (MVPT)**
- **Capital Asset Pricing Model (CAPM)**
- **Arbitrage Pricing Theory (APT)**

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

Normalized financial time series data

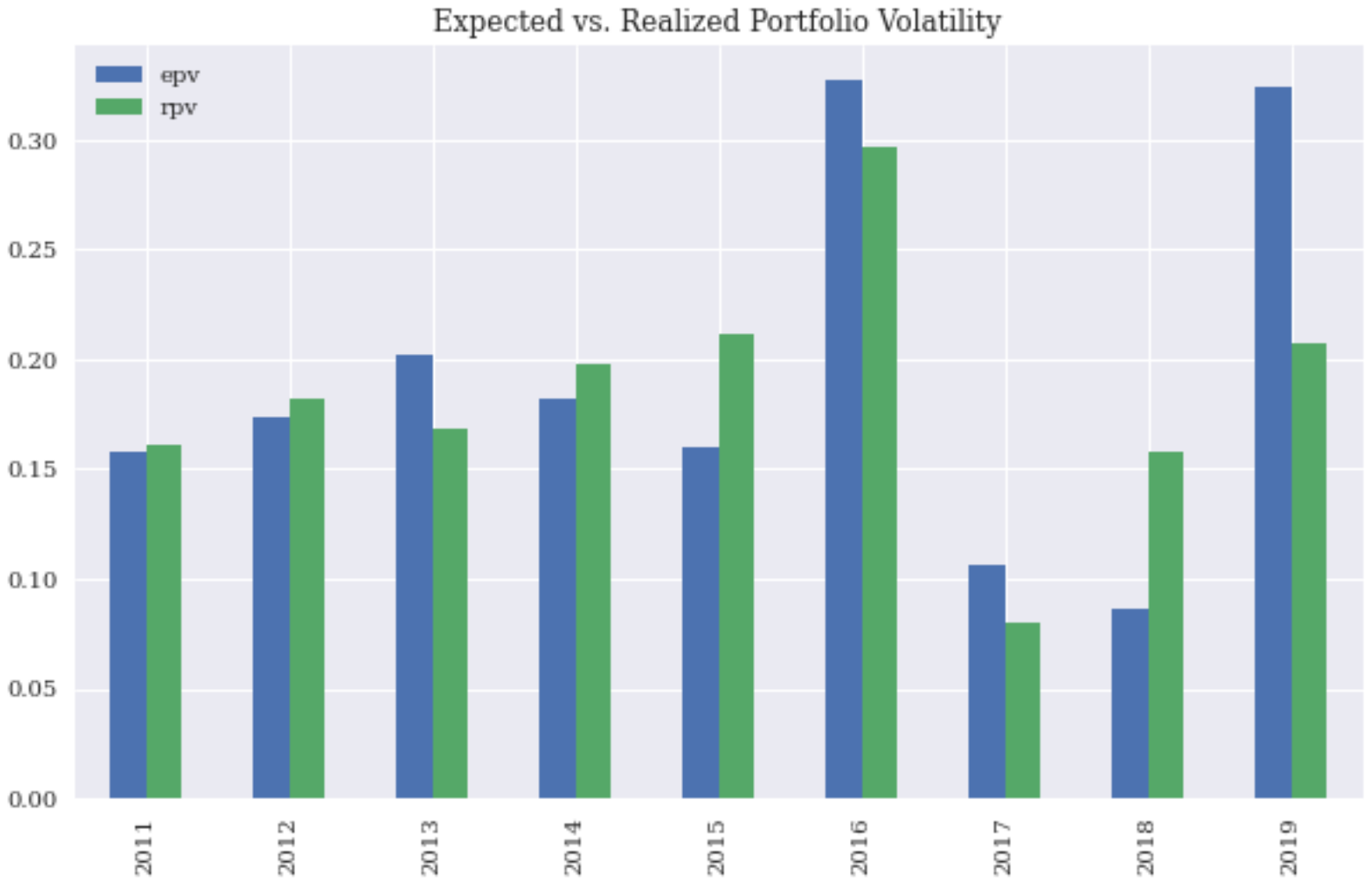
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

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.

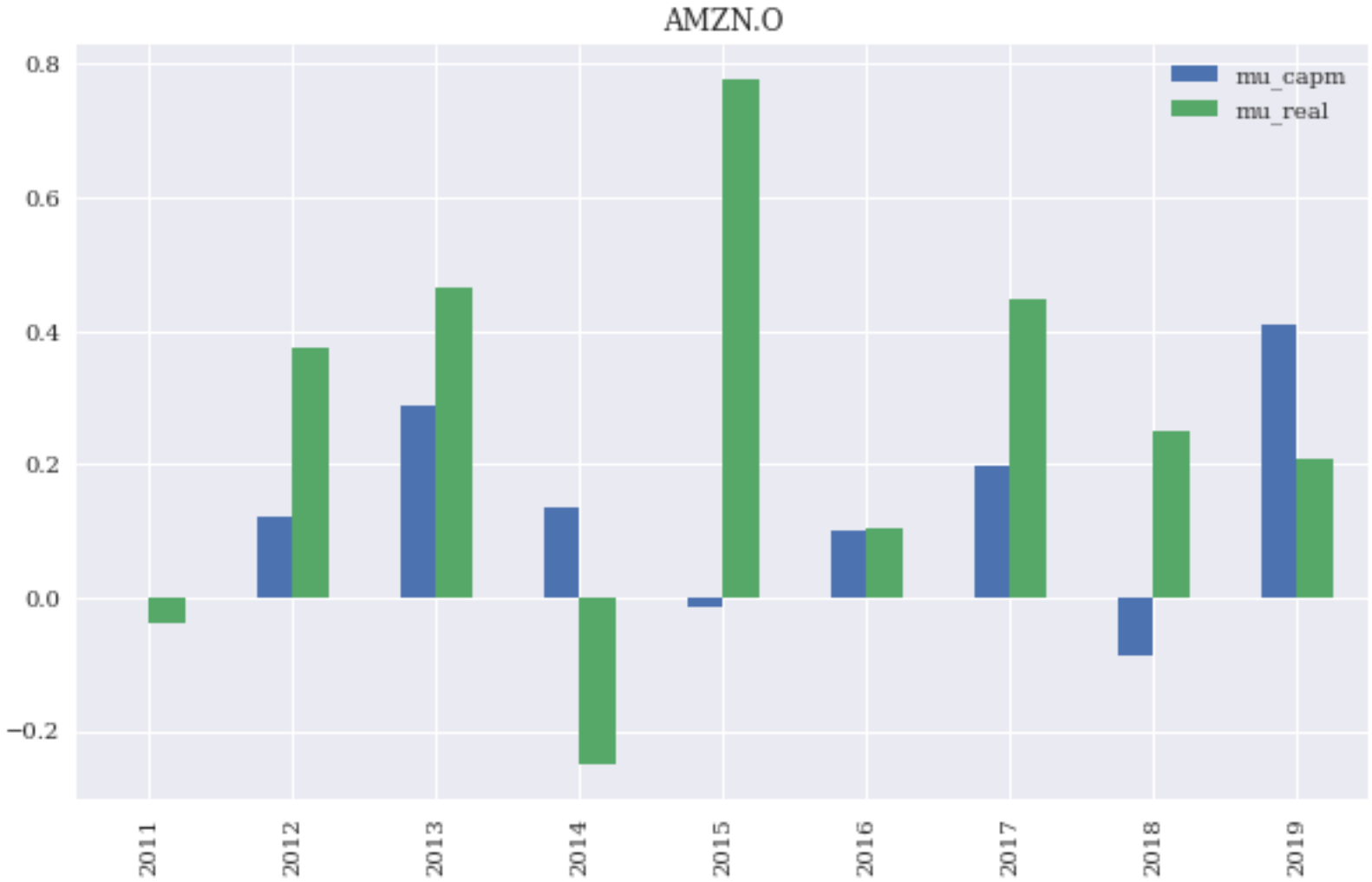
Expected versus realized portfolio returns

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

Expected versus realized portfolio Sharpe ratios

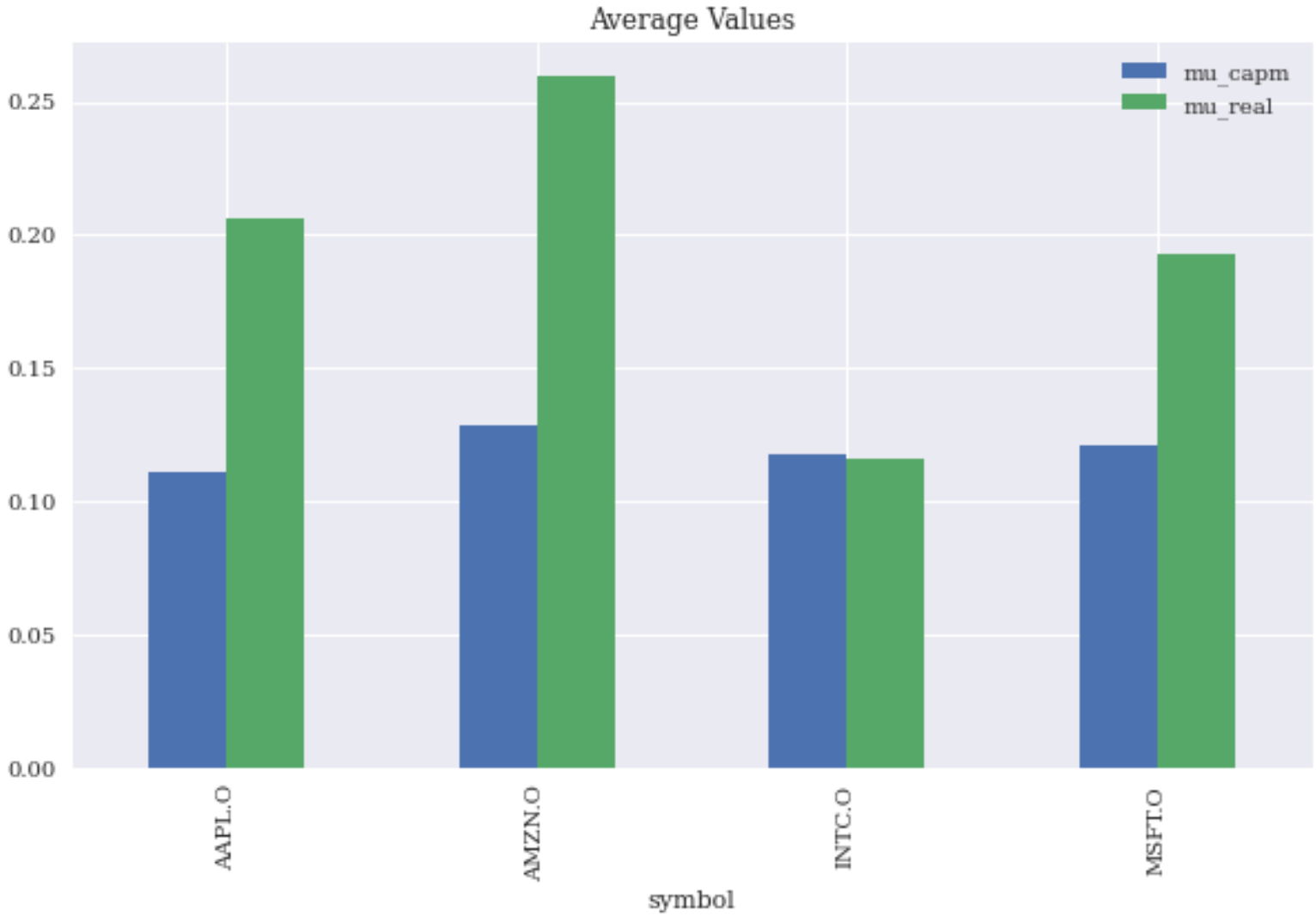
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

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)

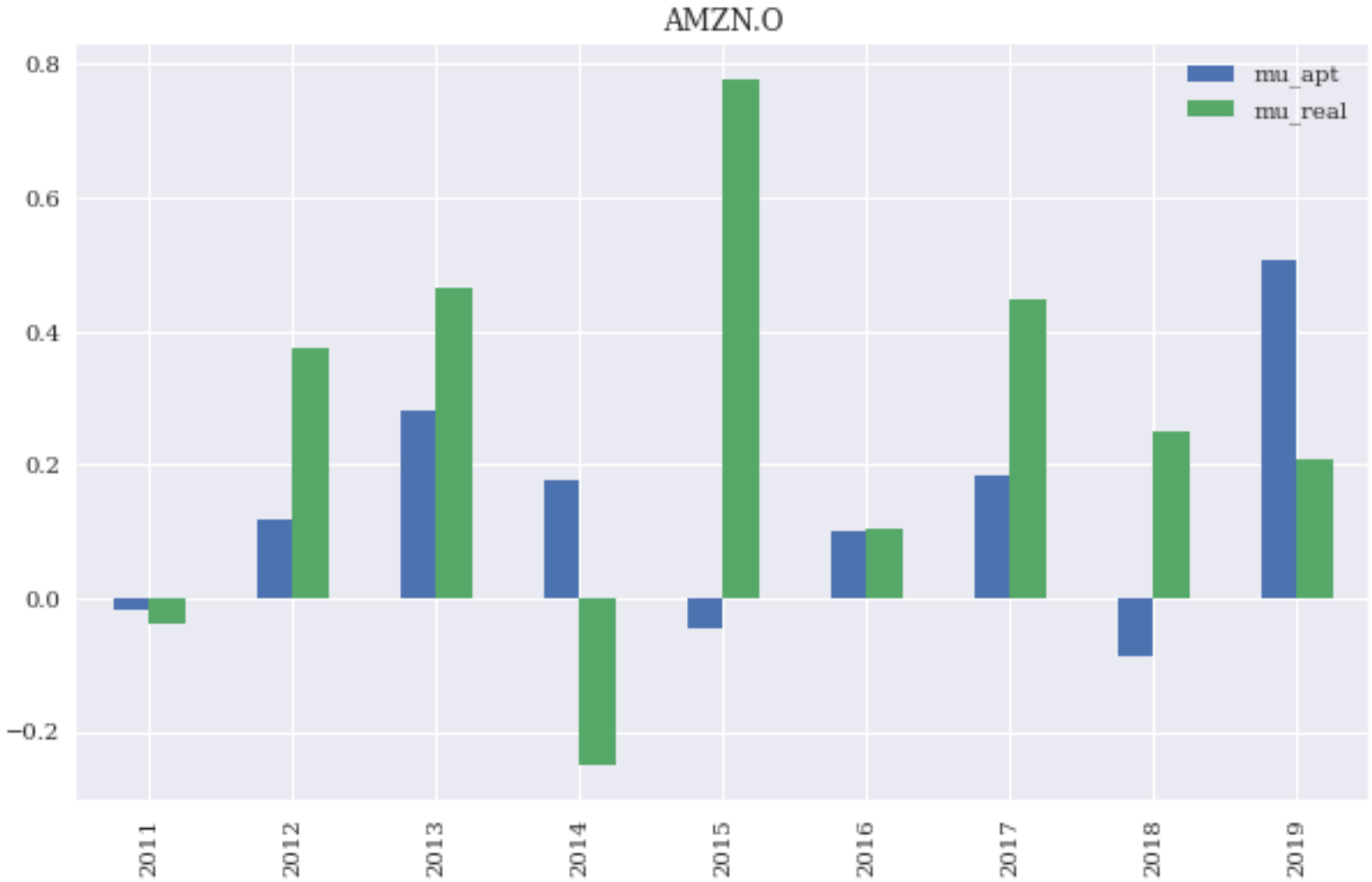
Relevant types of financial data

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



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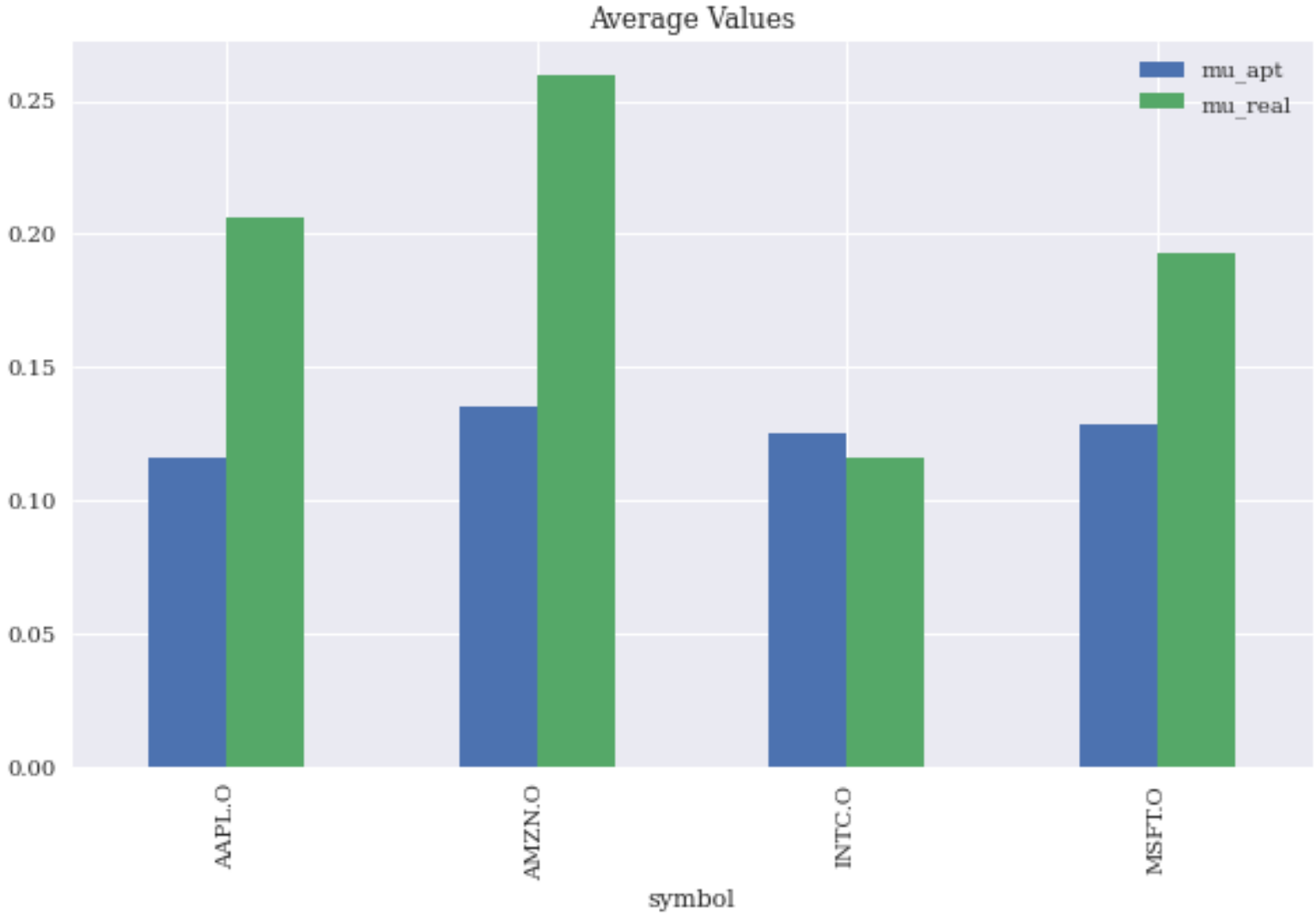
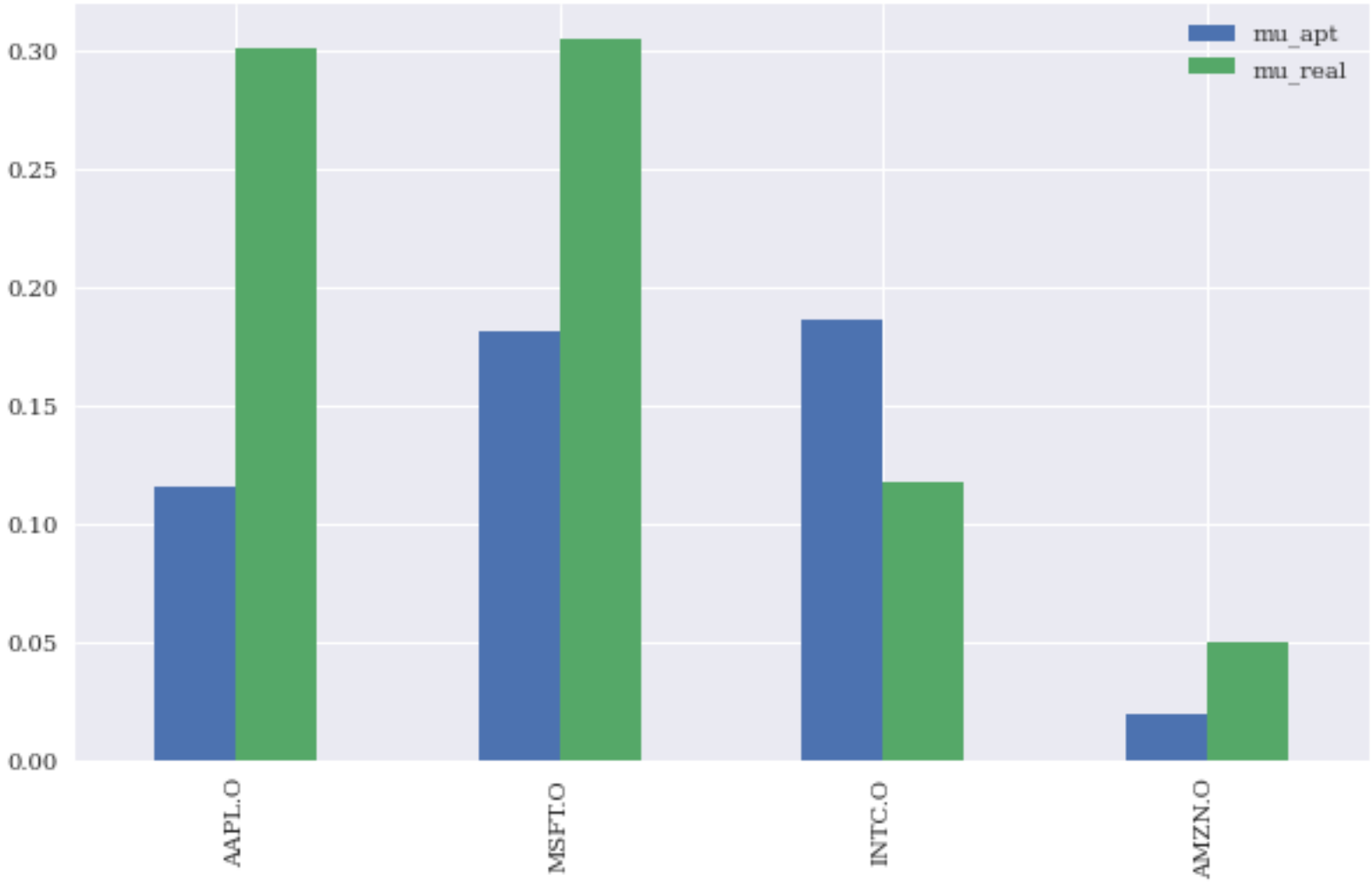


Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

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)

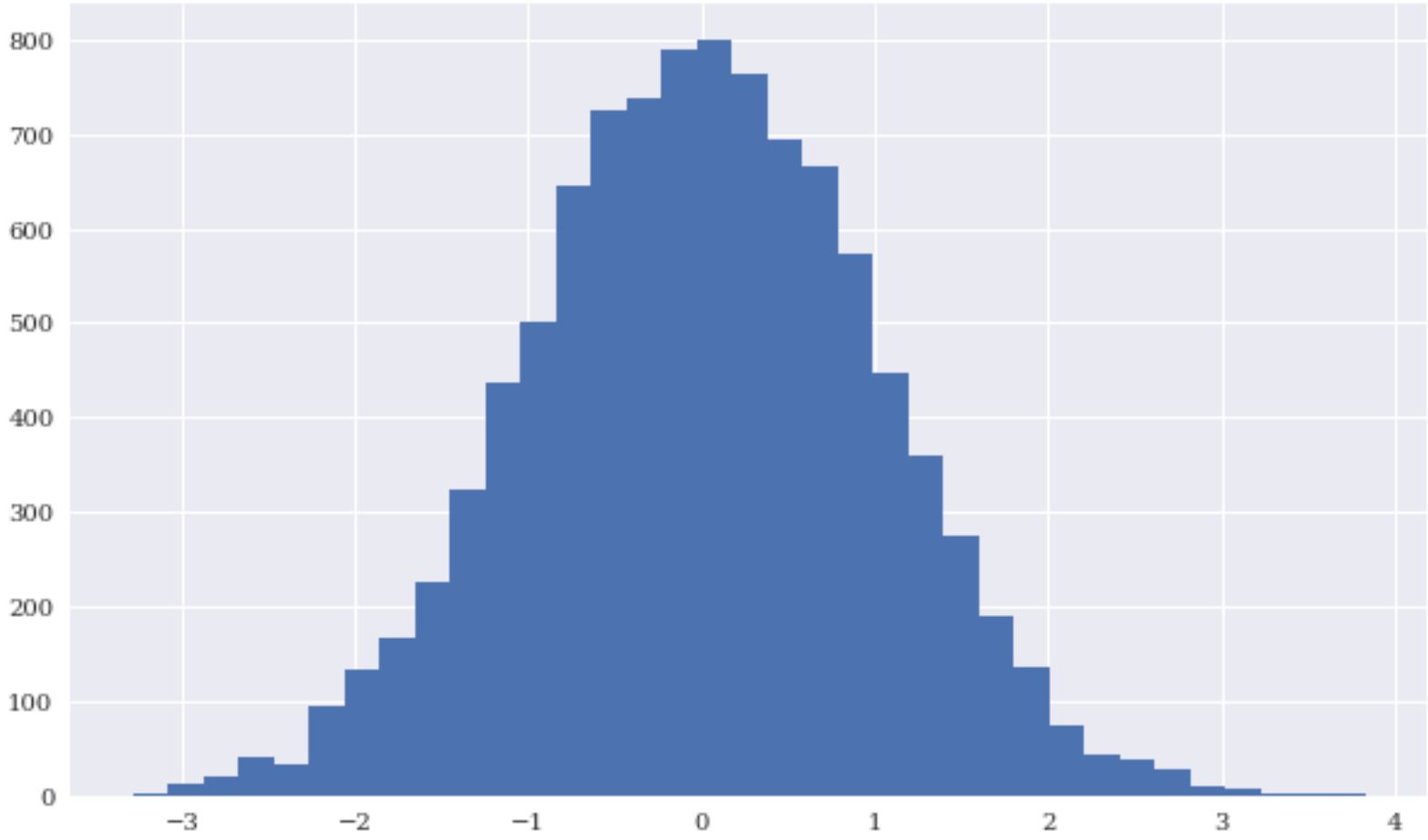
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Debunking Central Assumptions in Finance

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

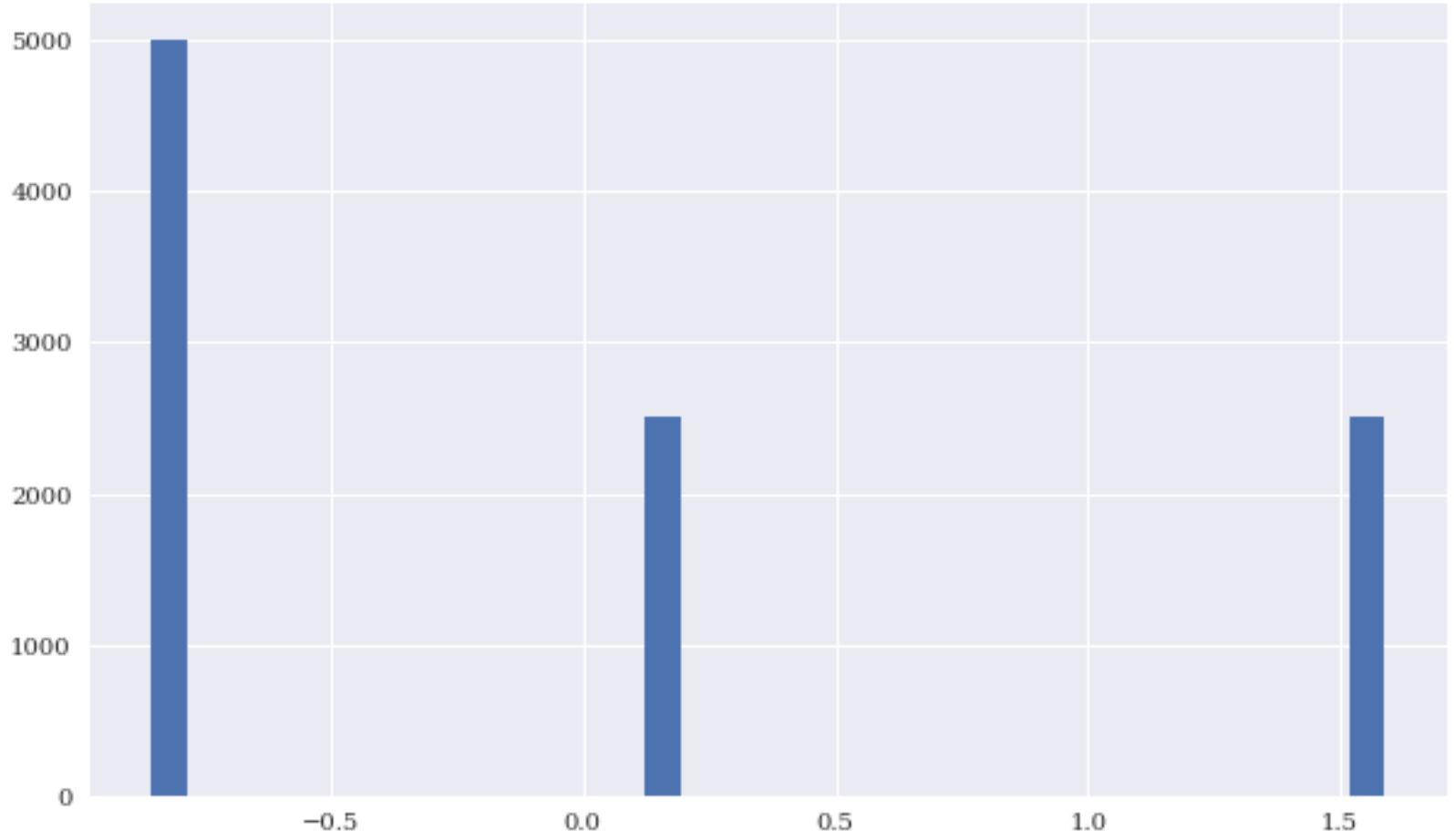
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Standard normally distributed random numbers



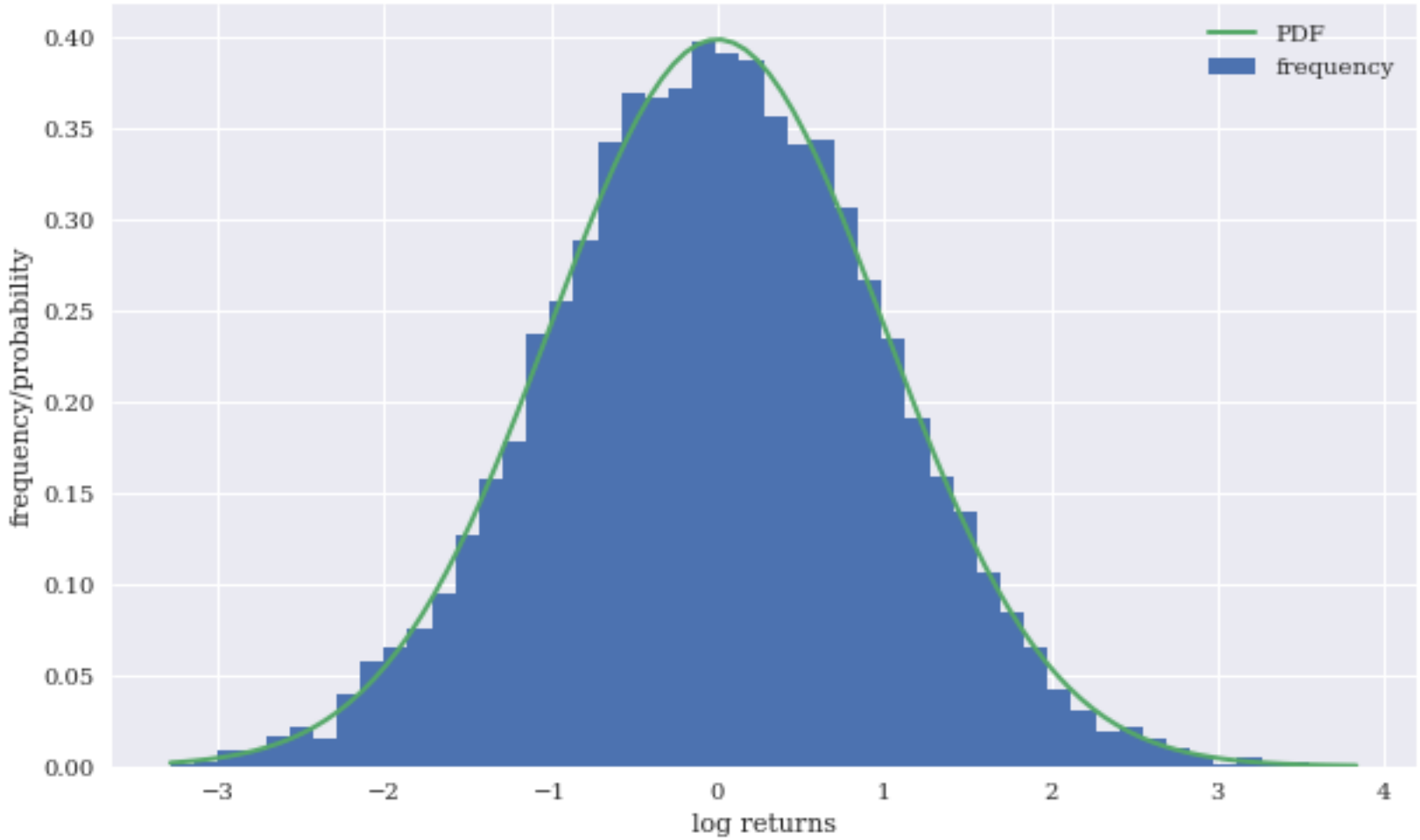
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

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



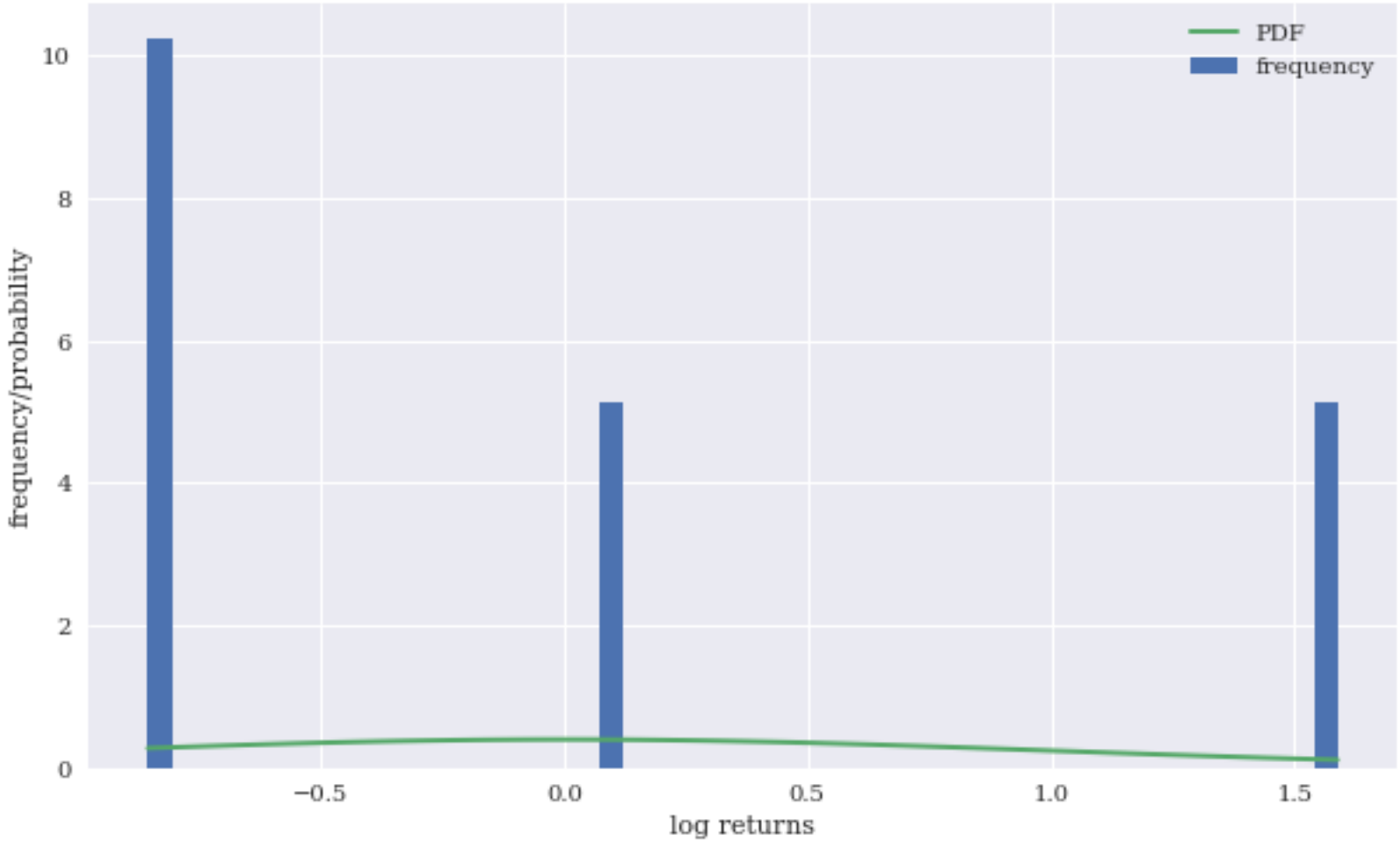
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

Histogram and PDF for standard normally distributed numbers



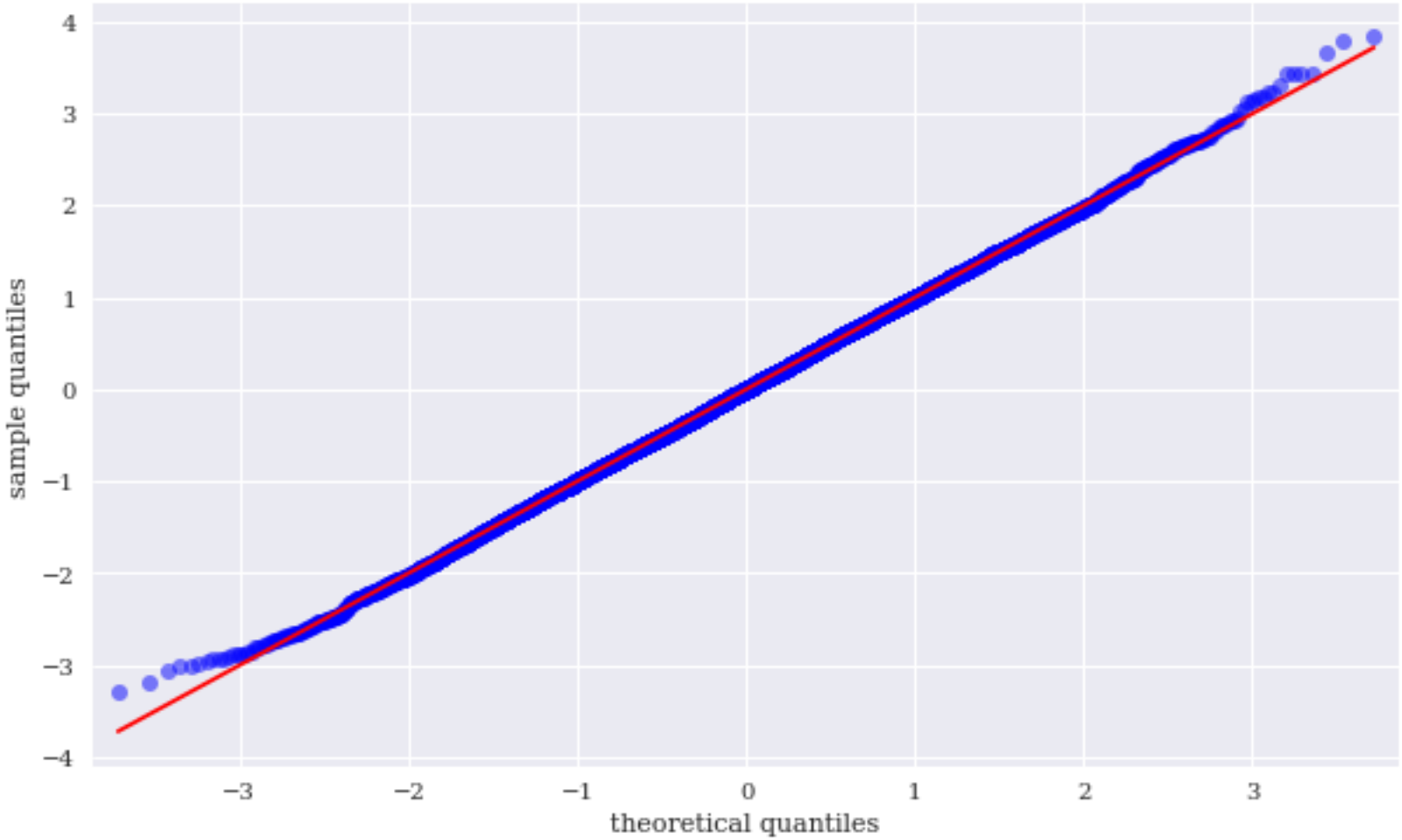
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

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



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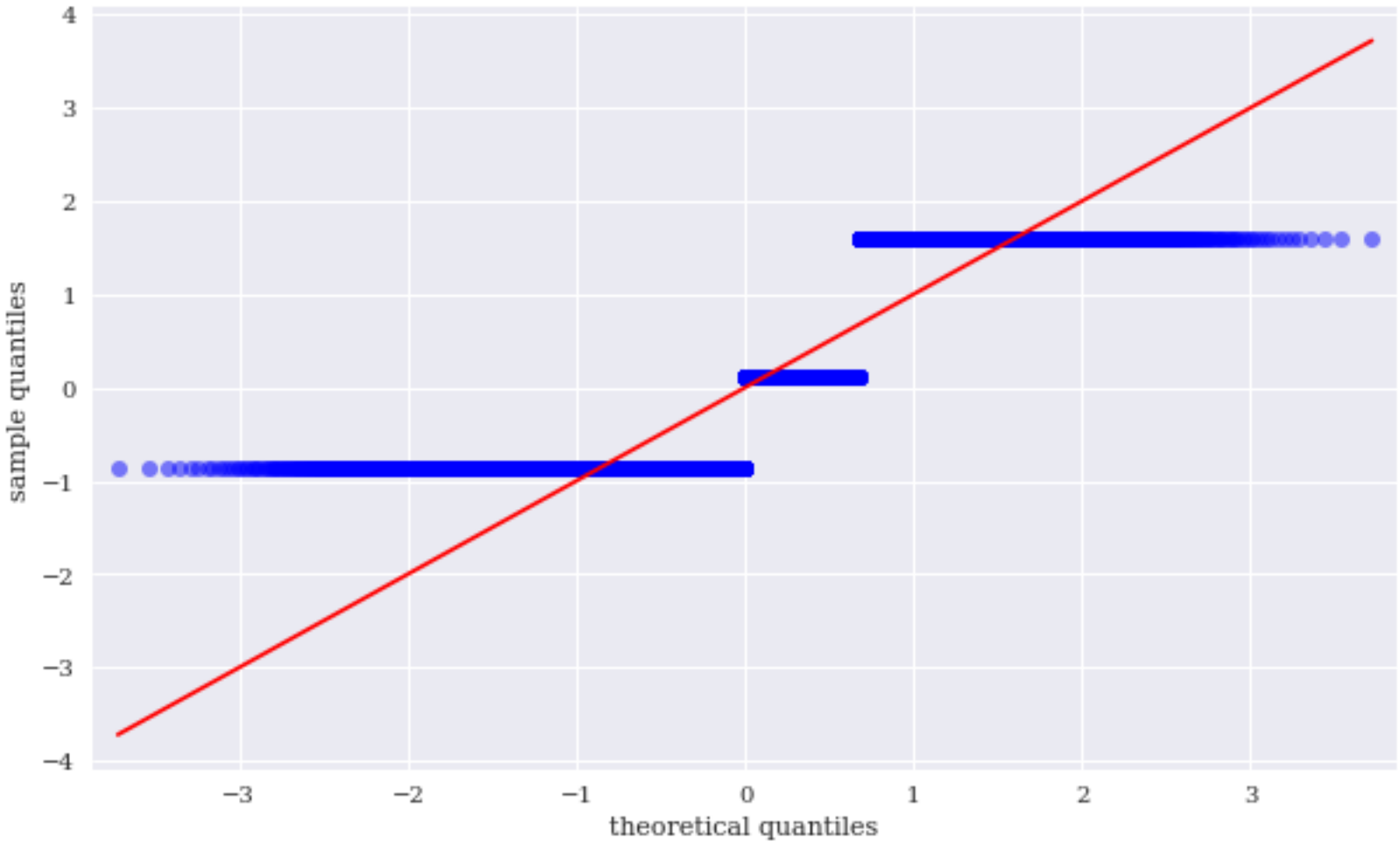
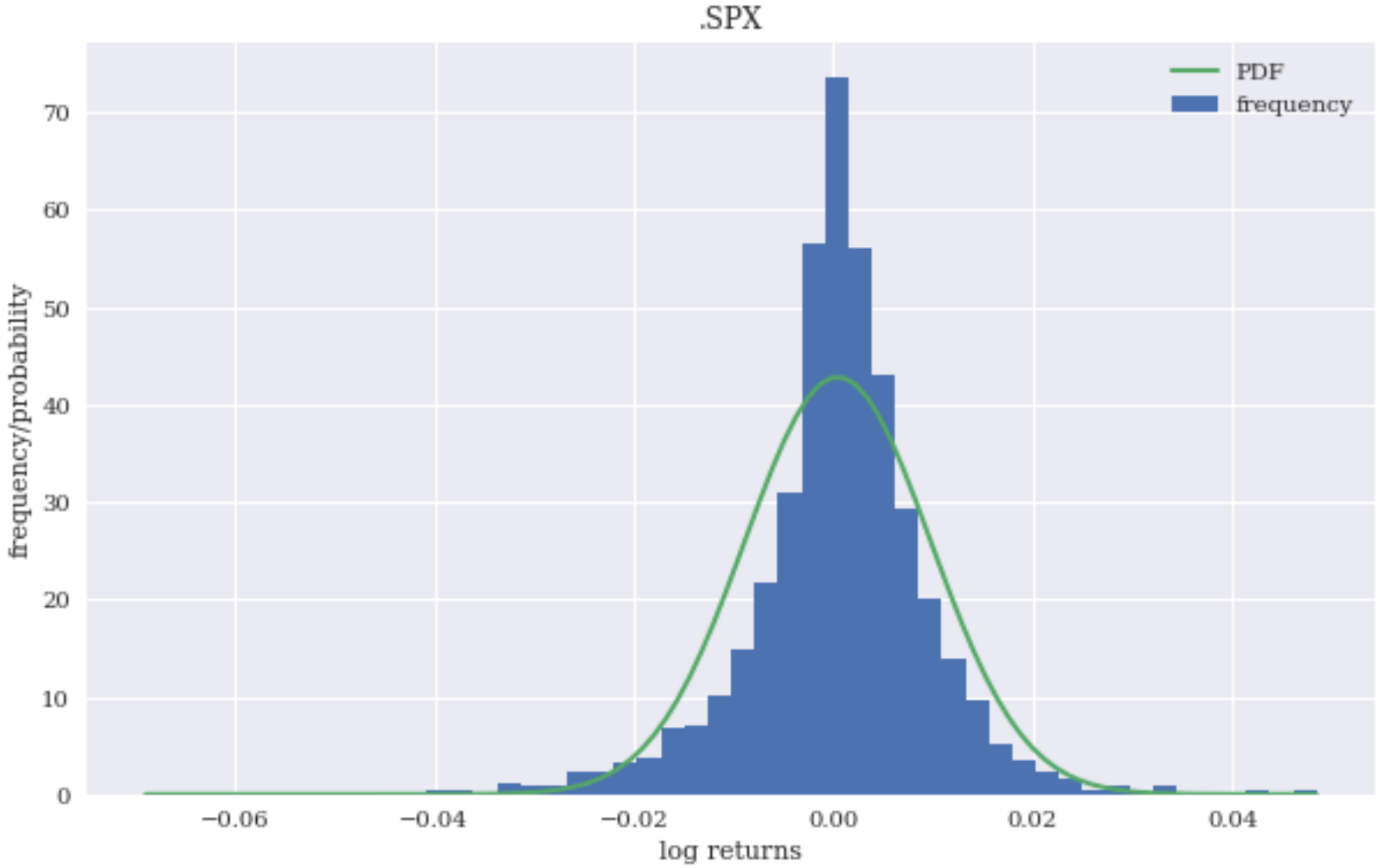
Q-Q plot for discrete numbers



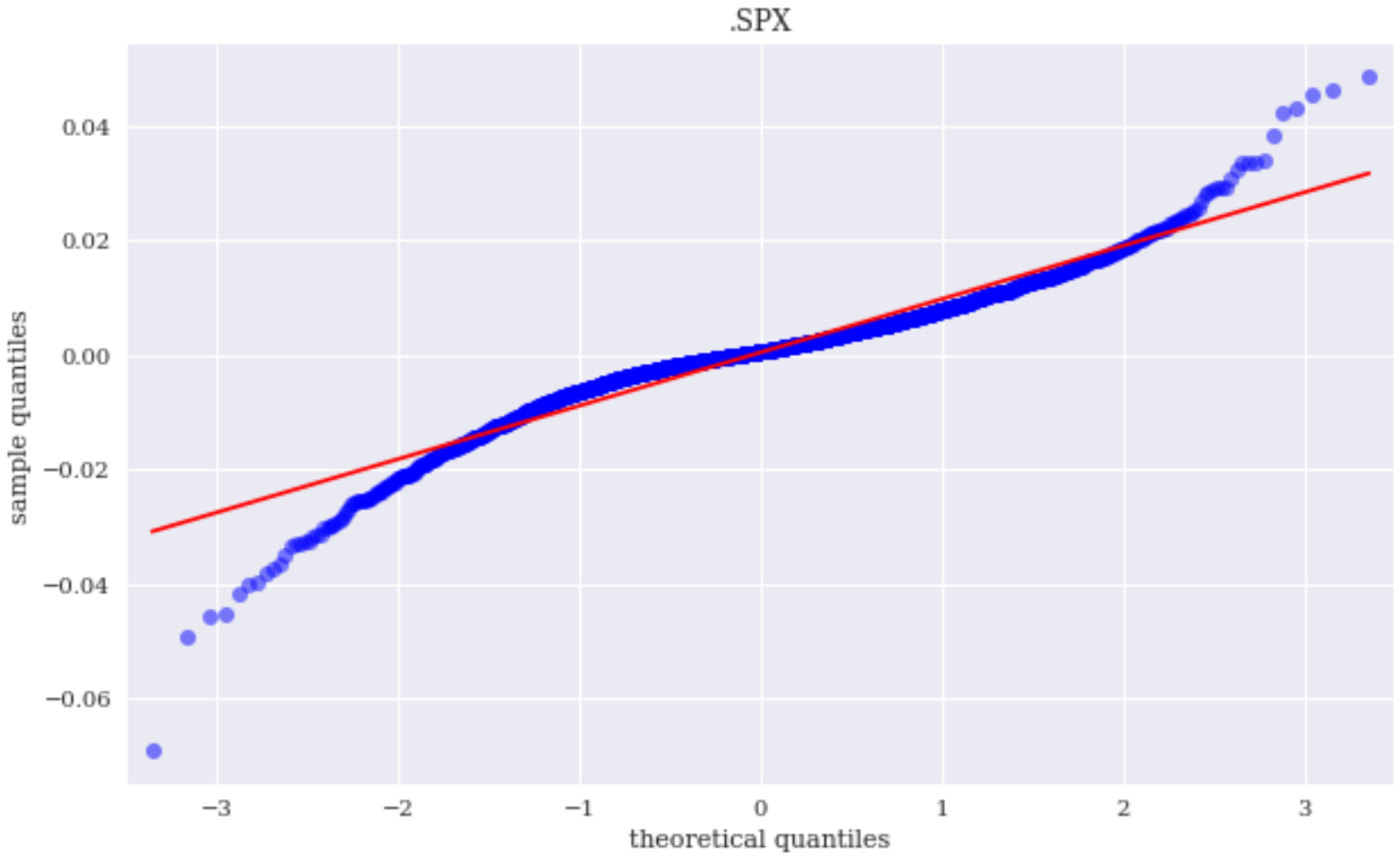
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

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



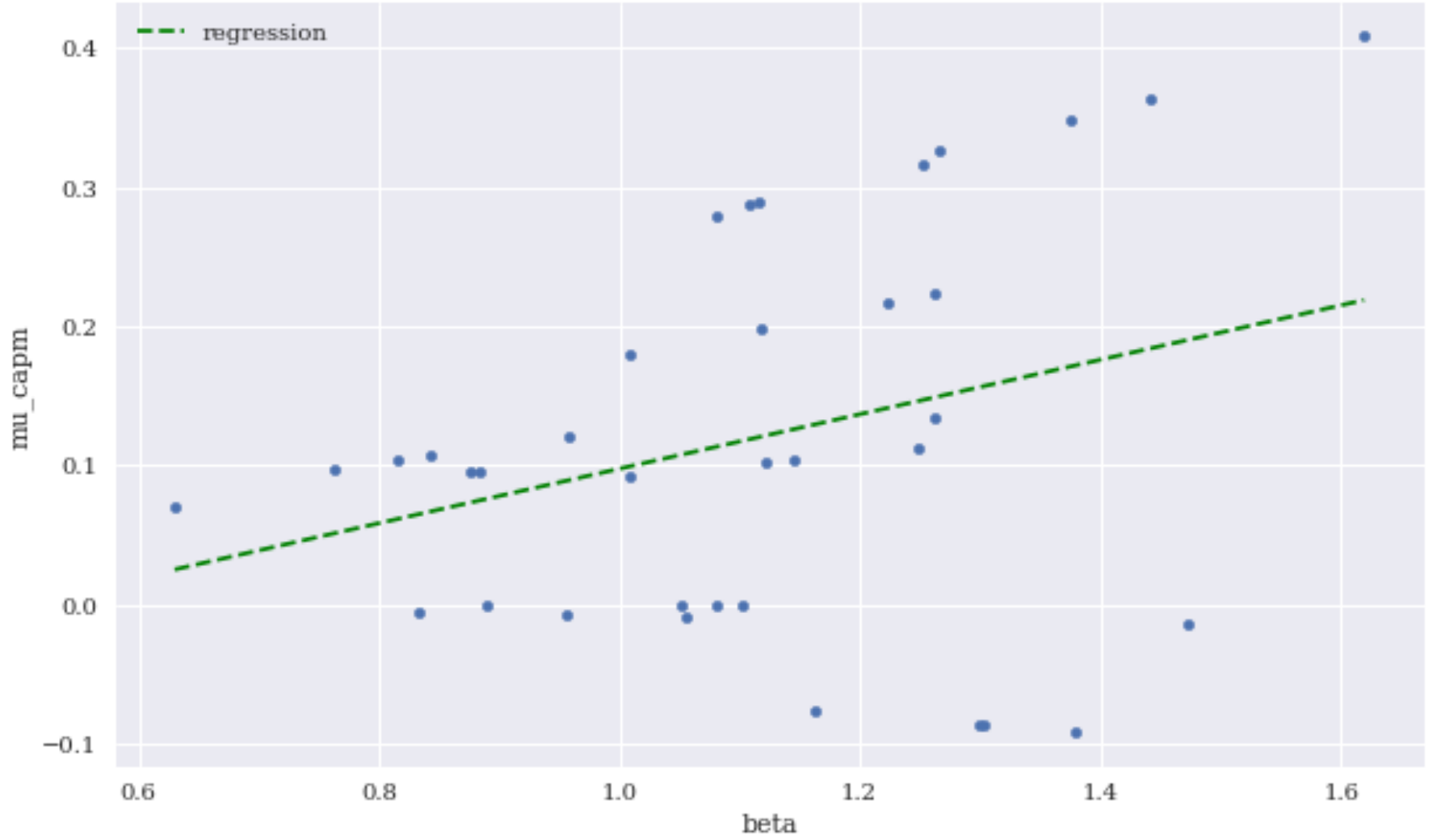
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

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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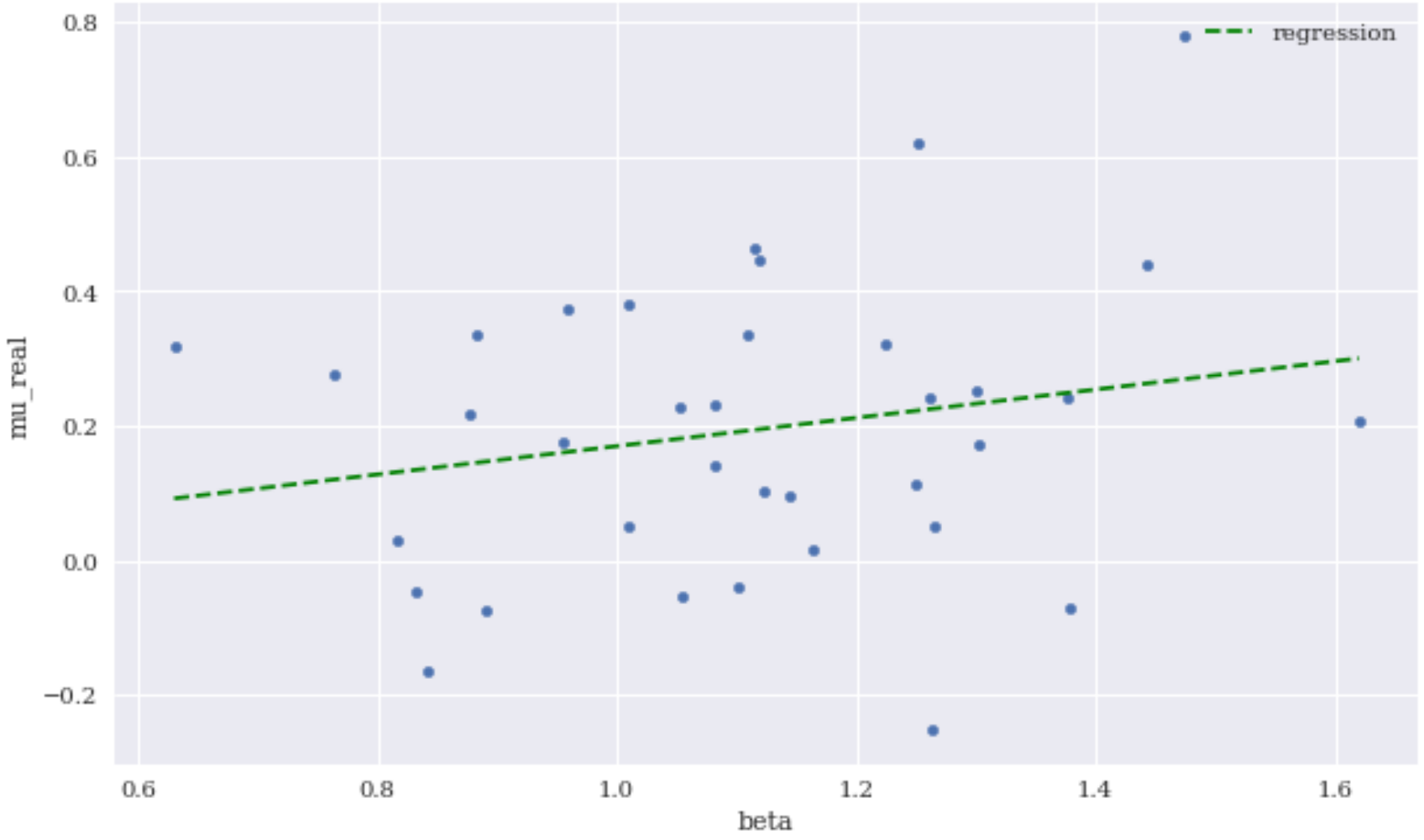


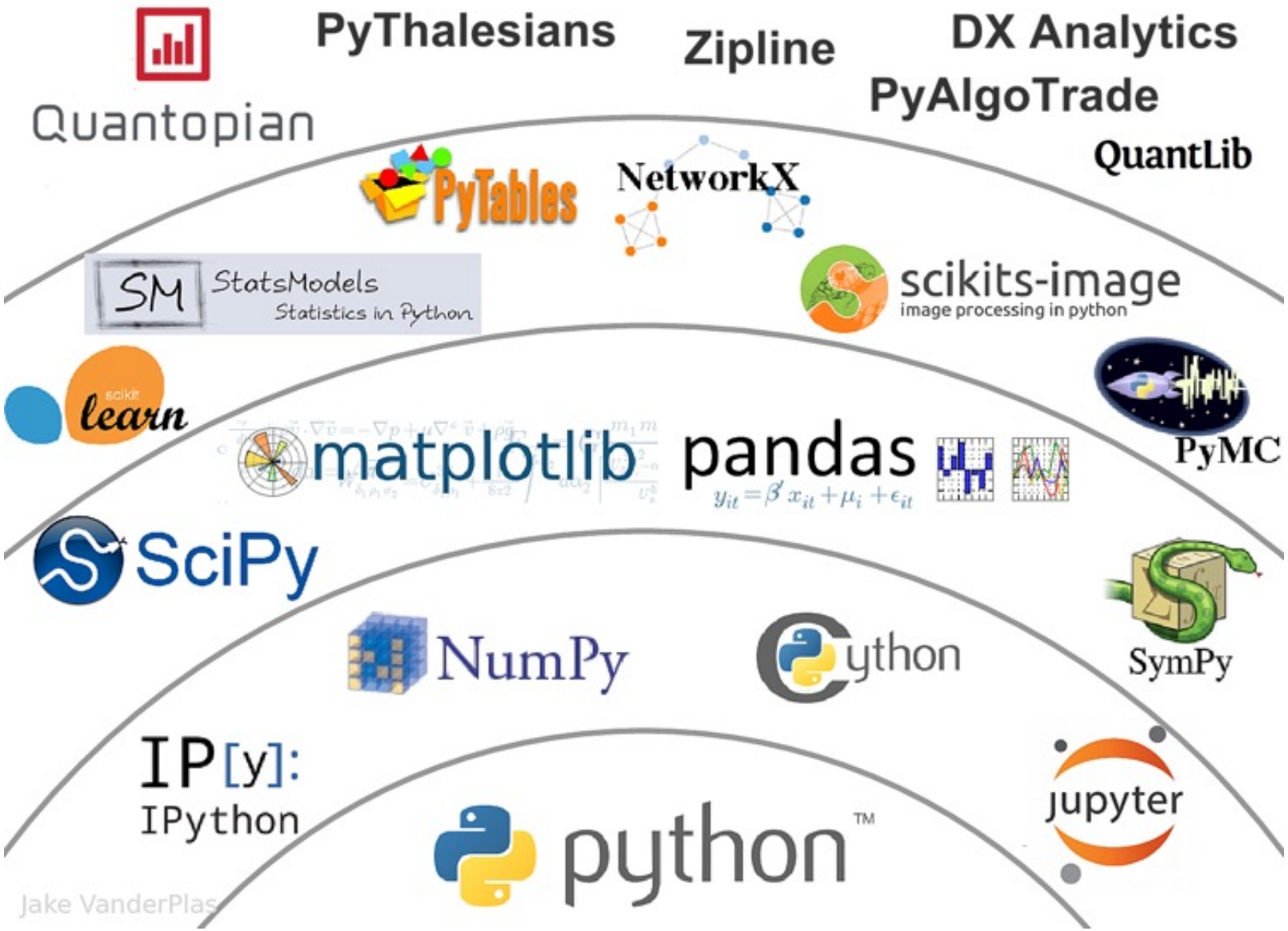
Source: Yves Hilpisch (2020), Artificial Intelligence in Finance: A Python-Based Guide, O'Reilly Media.

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



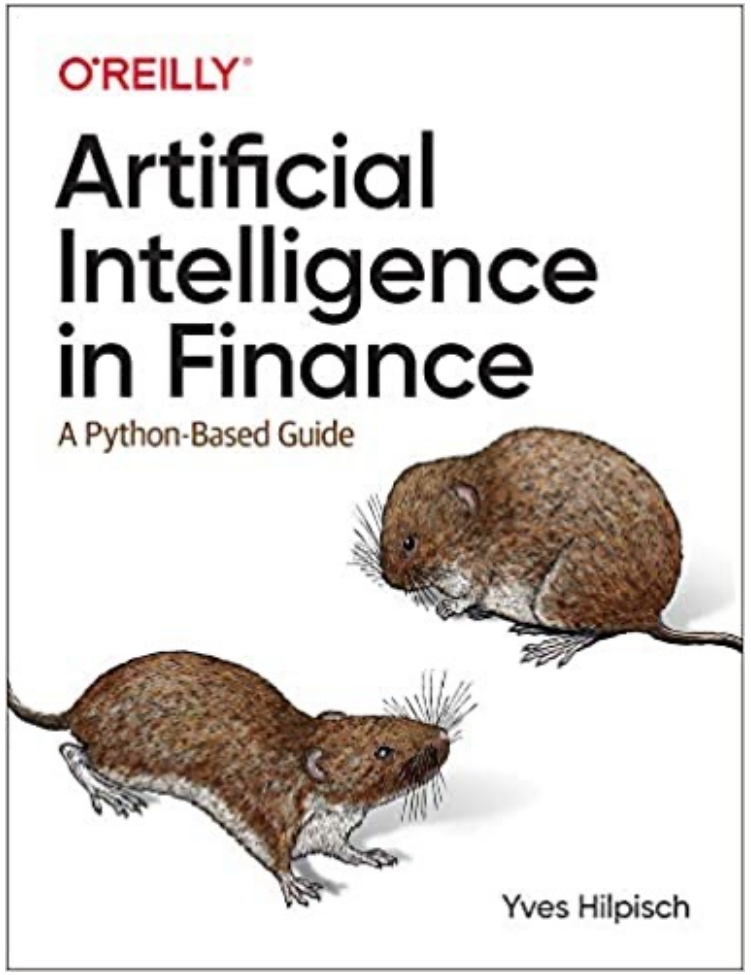
Source: http://nbviewer.jupyter.org/format/slides/github/quantopian/pyfolio/blob/master/pyfolio/examples/overview_slides.ipynb#/5

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

https://github.com/yhilpisch/aiif

yhilpisch / aiif Public

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Code | Issues | Pull requests | Actions | Projects | Wiki | Security | Insights

main | 1 branch | 0 tags | Go to file | Code

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.

O'REILLY

About

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

home.tpq.io/books/aiif

Readme

View license

Releases

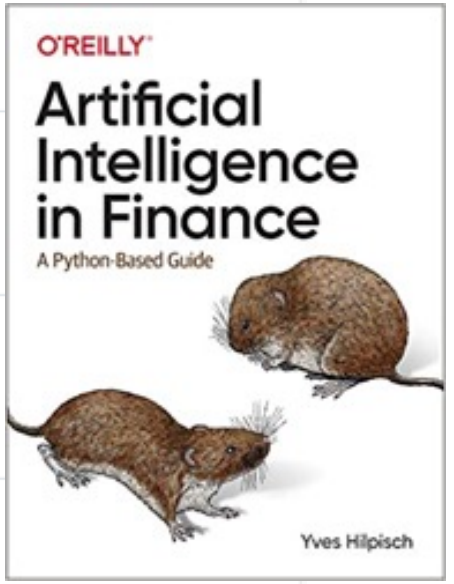
No releases published

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

yhilpisch / aiif Public

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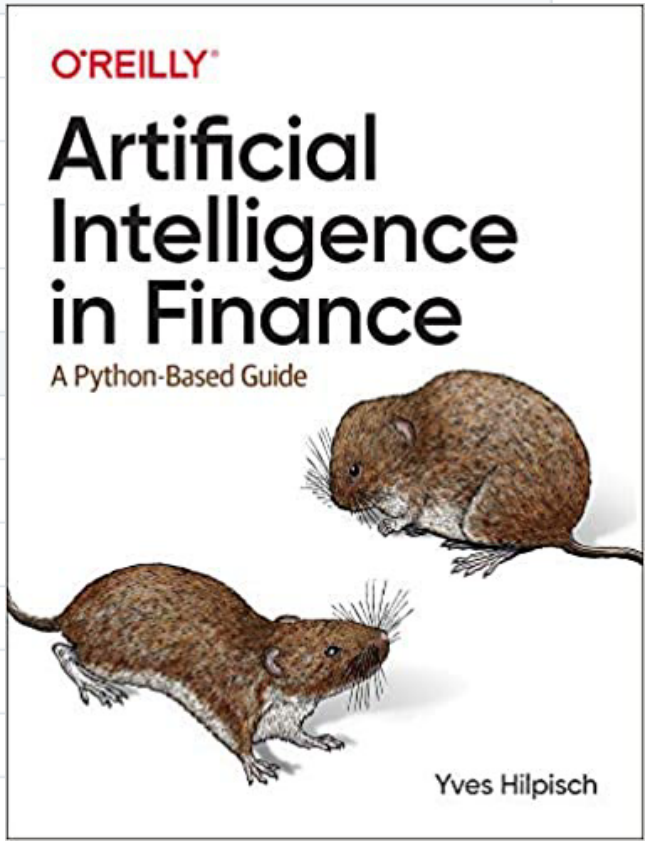
https://github.com/yhilpisch/aiif/tree/main/code

main | aiif / 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

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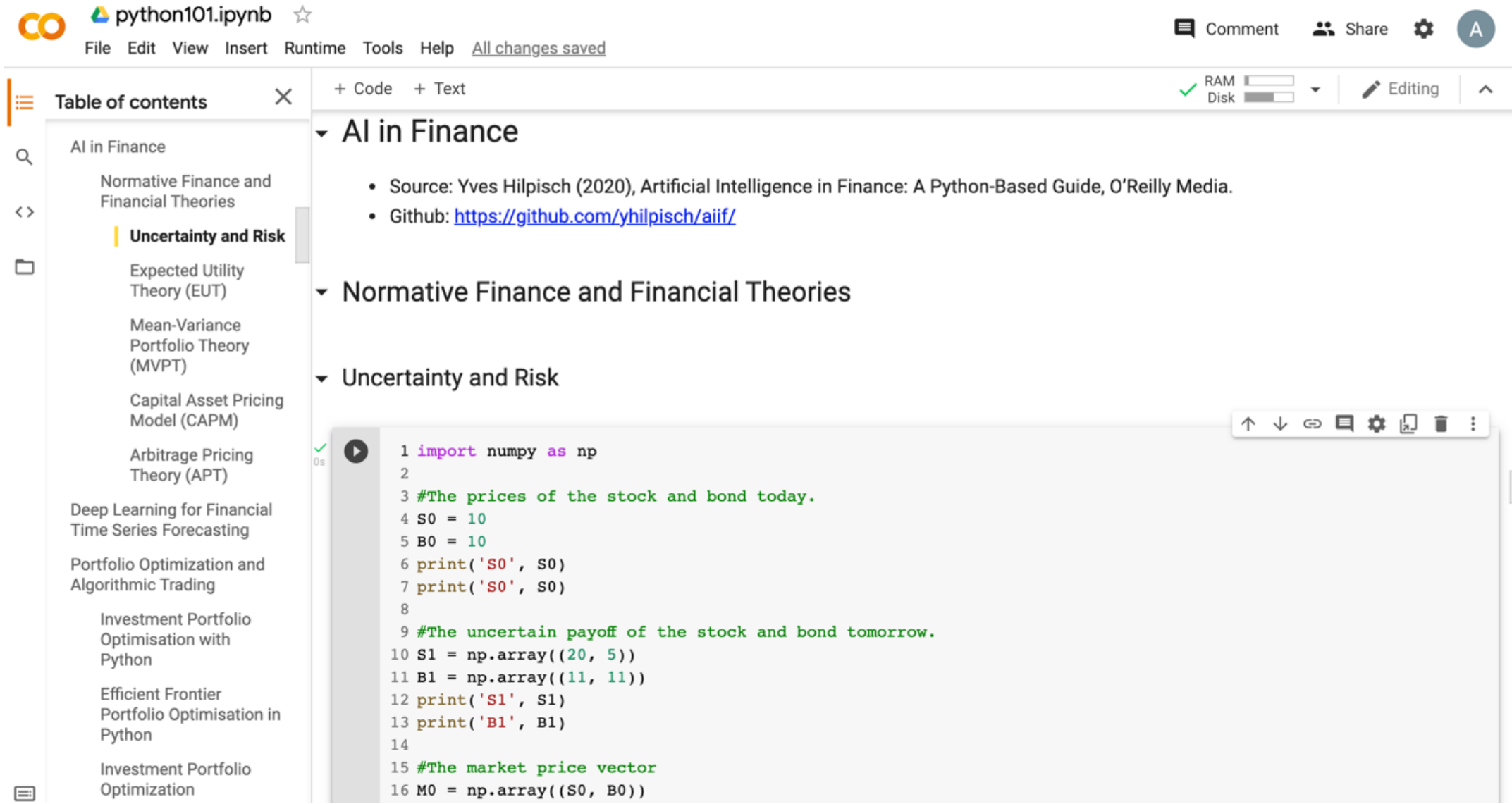

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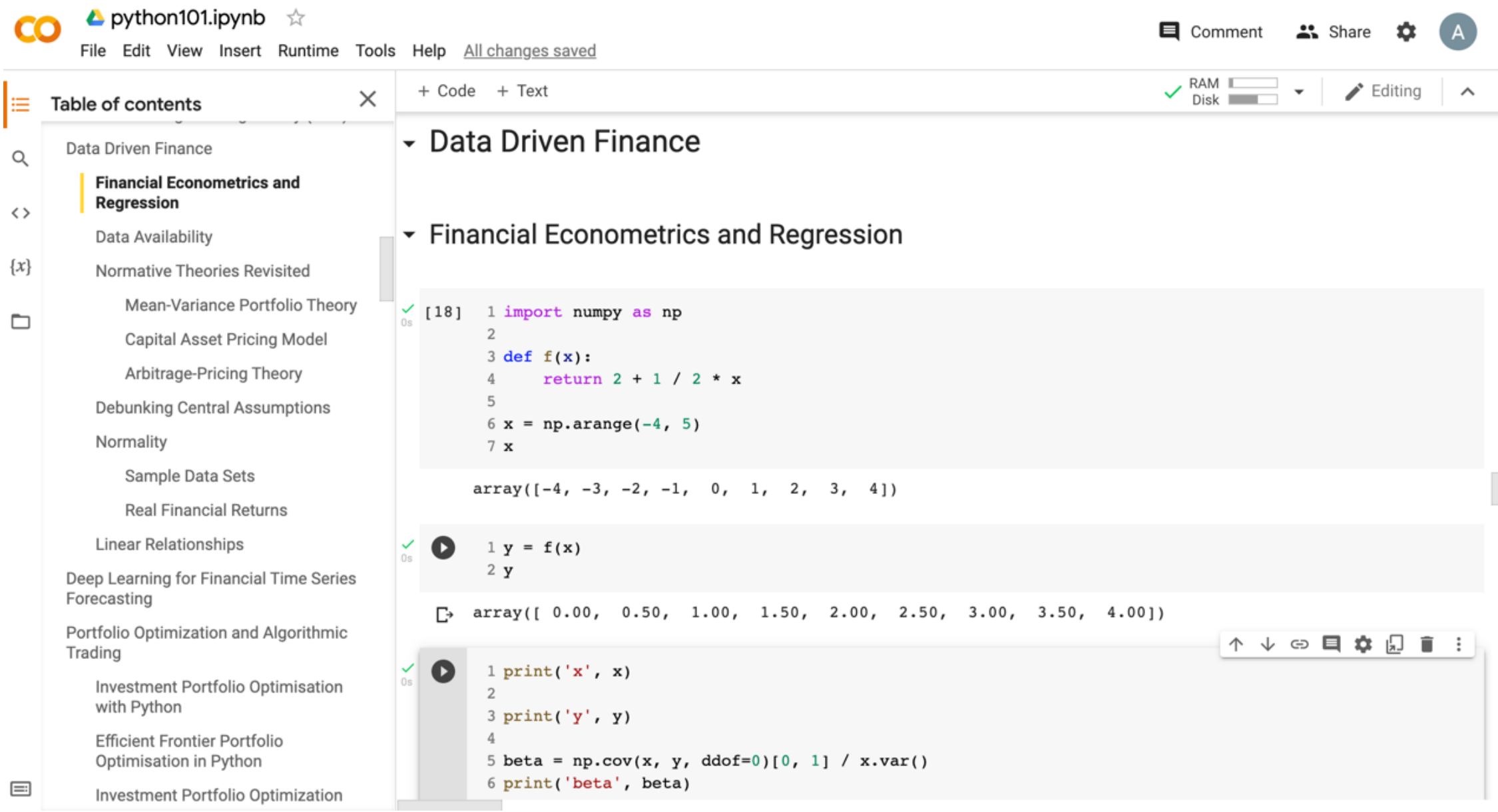

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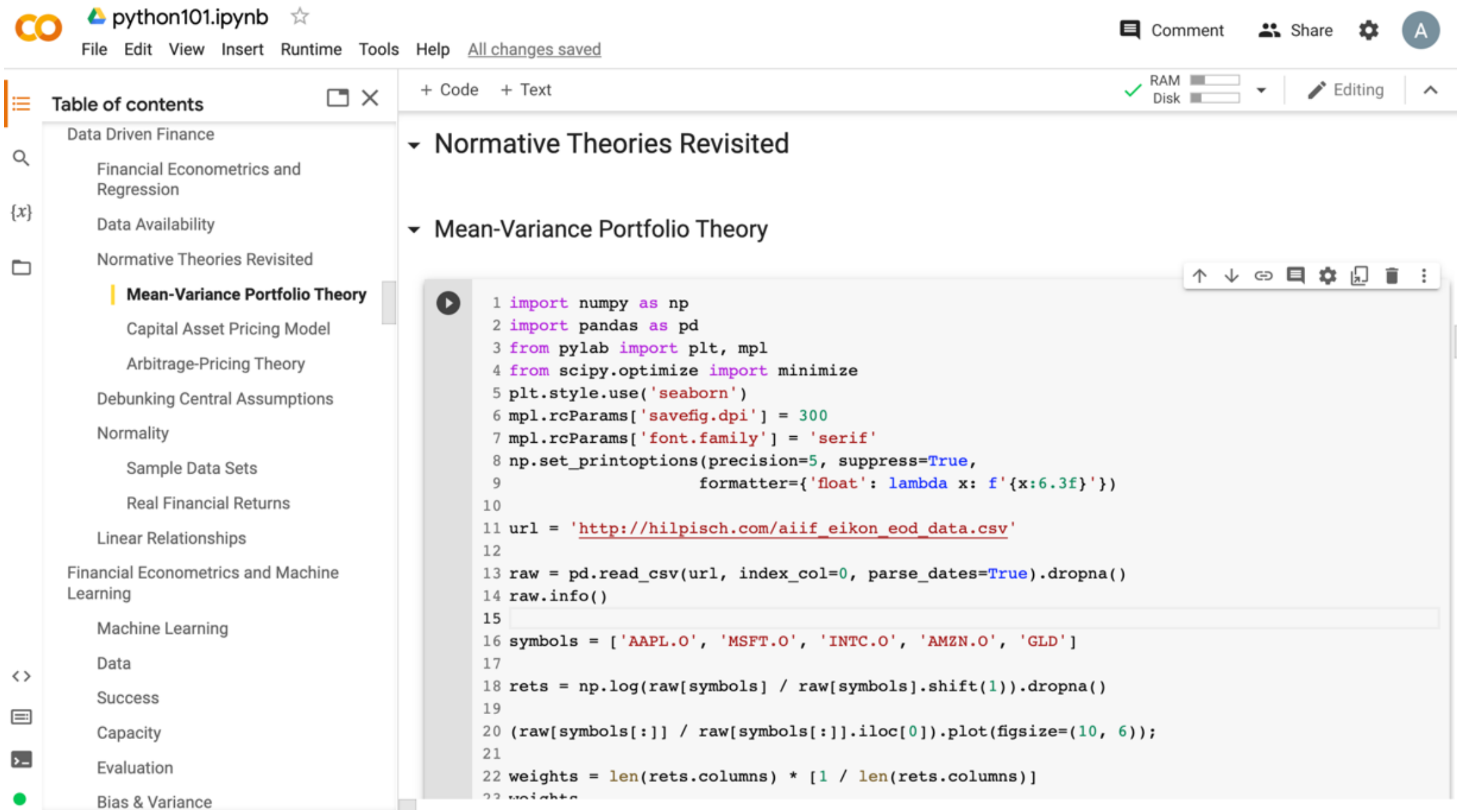

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+ Code + Text RAM Disk Editing

```
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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+ Code + Text

RAM Disk Editing

```
92 rets_sym.cumsum().apply(np.exp).plot(figsize=(10, 6));
93
94 rets_sym['same'] = (np.sign(rets_sym[sym + '_apt']) ==
95                     np.sign(rets_sym[sym + '_real']))
96
97 rets_sym['same'].value_counts()
98
99 rets_sym['same'].value_counts()[True] / len(rets_sym)
```

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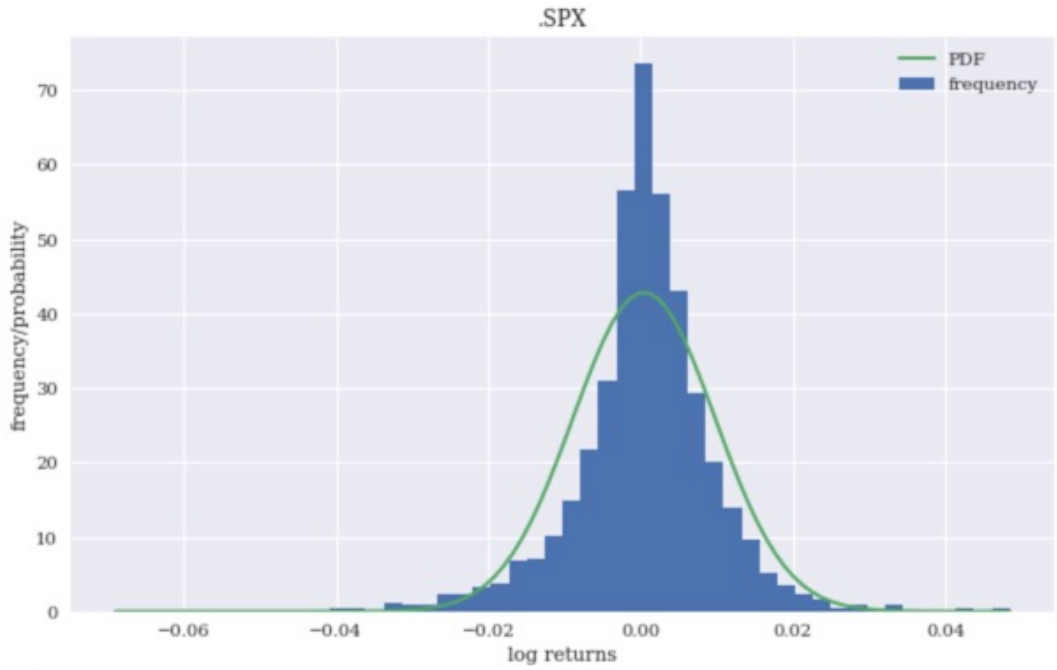
+ Code + Text

RAM Disk Editing

```
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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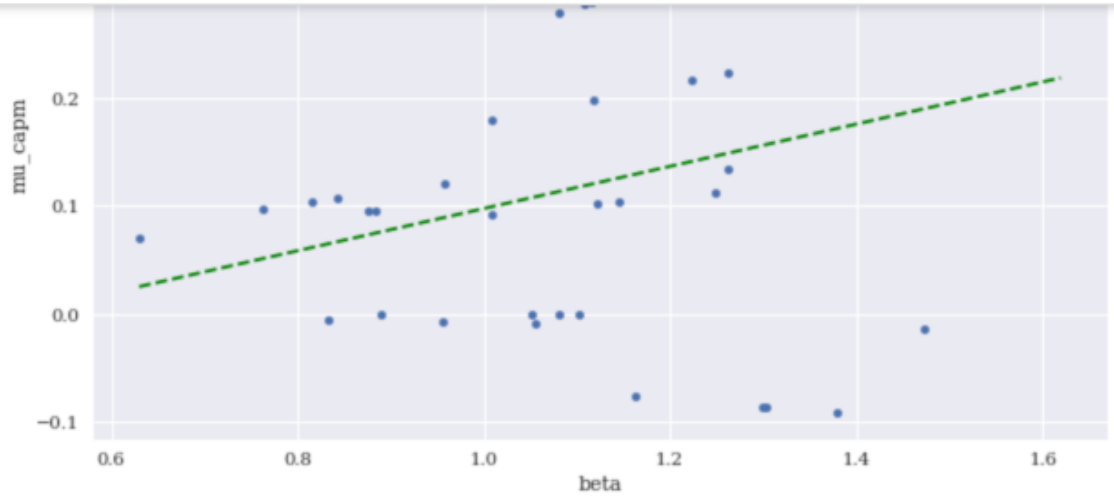
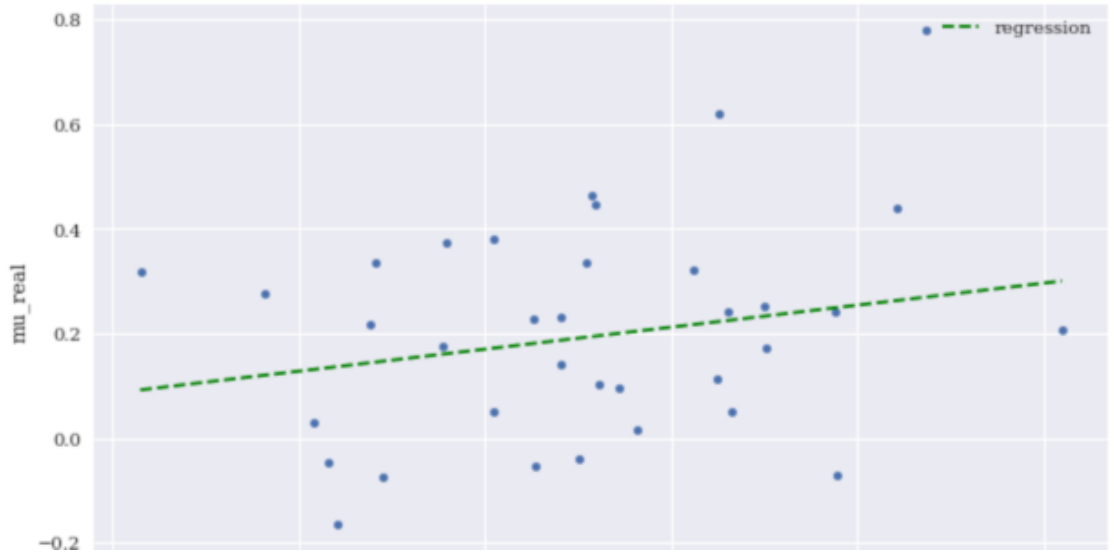
RAM Disk

Editing





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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.

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