Fintech and Financial Engineering
–
Introductory Lecture

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General information on the lecture

- Lecturer: Dr. Lukas Gonon
  - Senior Lecturer (associate professor) at Imperial College London
  - Research and teaching on mathematical finance and machine learning
    - Deep learning for hedging / asset pricing / time series
    - Applications and mathematical foundations
- Course setup:
  - Weekly lecture
  - Slides / Python Notebooks
  - Questions: feel free to write in chat / interrupt during the lecture.
  - Office hours before the midterm and the final exams

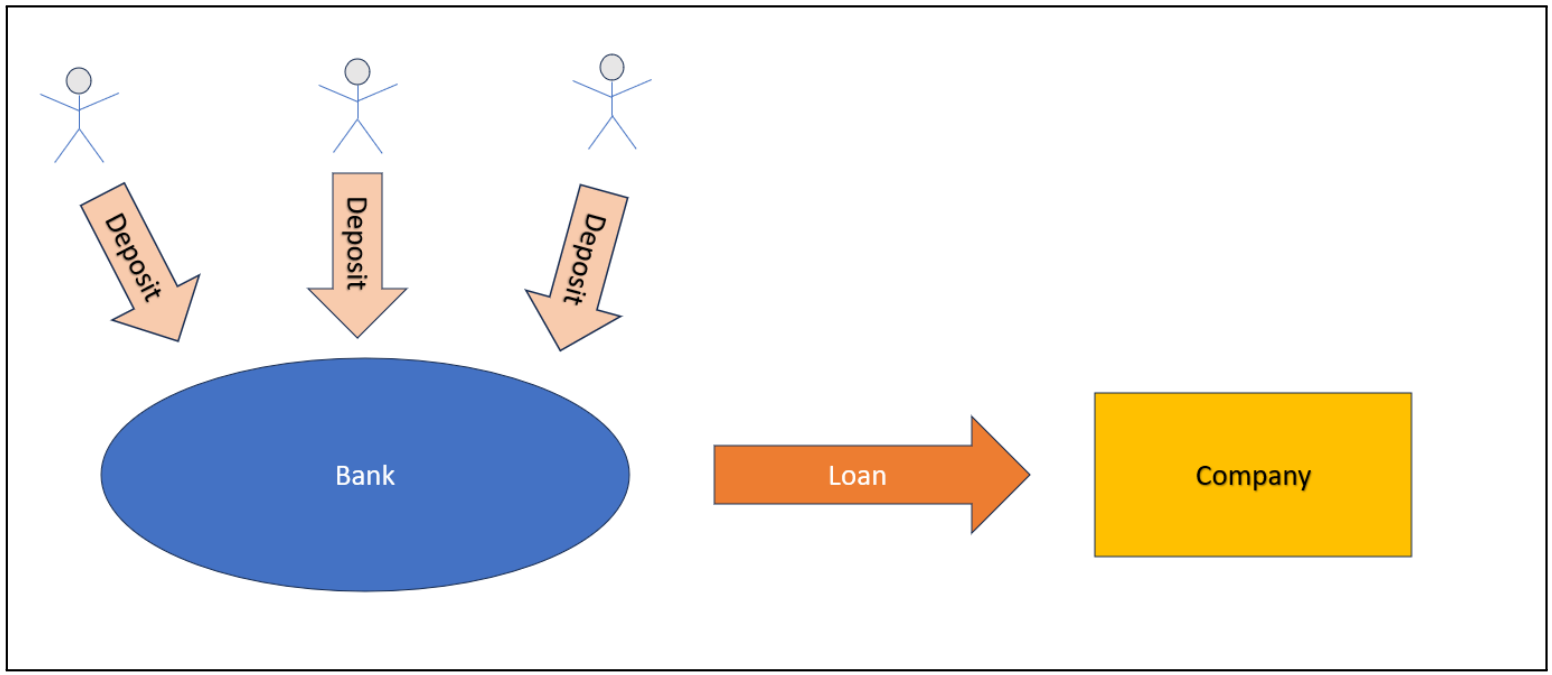
Content

1. What is a bank? What is FinTech? The challenges of FinTech
2. Introduction to Python
3. Python for (Financial) data analysis
4. The mathematics of portfolio optimisation
5. Financial derivatives: from classical to cryptocurrencies
6. The mathematical concept of option pricing
7. Building a model for a financial asset: part I (discrete time)
8. Building a model for a financial asset: part II (continuous time)
9. Introduction to deep learning
10. Deep learning in finance

1. What is a bank?

Banking: an overview

- Traditional role: loans and deposits



- Today: many other services, in particular in investment banking

- Main investment banking activities:
  - Raising debt and equity for corporations or governments
    - bonds / shares / convertible bonds
    - public offerings: best efforts / firm commitment
  - Mergers and acquisitions advice for companies
  - Securities trading
    - brokerage services
    - trading for hedging and services
    - market making
- Regulation:
  - capital requirements
  - conflicts of interest

Different types of risk

Types of risk (not always clearly separated) in the context of finance and insurance:

- market risk: risk of a change in the value of a financial position due to the change in value of the underlyings (for instance the stock and bond prices, exchange rates, commodity prices,...)
- credit risk: risk of not receiving promised payments due to the default of the borrower
- operational risk: risk of losses resulting from inadequate or failed internal processes, systems and people or from external events.

Other types of risk: model risk, liquidity risk, ...

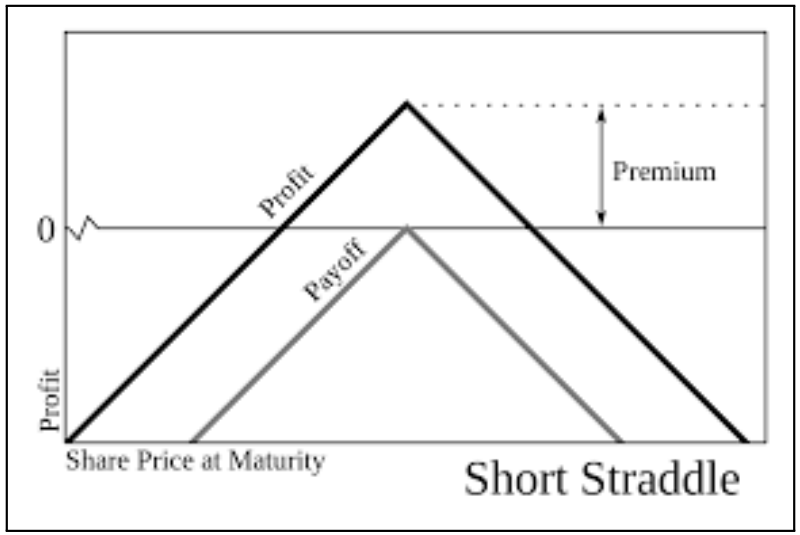

Trading by group
BUY
%
2,259.21
8.44%
6,513.46
24.33%
14,447.83
53.98%
3,545.70
13.25%
Key Indices
PREVIOUS
CHANGE
977.22
+8.69
1,488.55
+15.03
682.18
+7.17
1,176.81
+17.02
1,129.98
+5.45
1,413.47
+7.31
1,186.17
+5.82
1,179.07
+14.78
298.90
-4.77
+2.96
+2.16
+0.29
76.88
192.07
-0.24
138.25
+1.62
86.49
+0.15
+2.29
+4.75
Energy & Utility
Fashion
Finance
Food & Beverage
Health Care
Home & Office Prod
Ind Material & Mach
Info & Comm Tech
Insurance
Media & Publish
Mining
Packaging
Profession Services
Property Dev
Property Fund
Tour & Leisure
Transport & Logi
Foreign Board

Example: Operational risk (and market risk)

- Bankruptcy of Barings Bank caused by trader Nick Leeson:
  - Speculative trading with options on Nikkei Index
  - Final straw: in order to compensate for his losses he took a huge position in *Short Straddles*
    $\rightarrow$ enormous losses (700 Mio £) caused by price movements of the Nikkei Index due to the Kobe earthquake 1995.
- Additional "rogue trader" losses e.g. at Société Générale (4.9 Billion € losses from speculative trading by Jérome Kerviel) in 2007, very similar at UBS in 2011.

The supervision of risk limits did not work here / these were not respected and circumvented on purpose.

Short straddle $\leftrightarrow$ selling both a put and a call option with same maturity and strike. Payoff / profit:



More on market risk in banking

Risk management at different levels:

- Front office: Risks depend on future development of different market variables (Exchange rates, stock prices, interest rates). Each trader is normally responsible for trades exposed to only a few of these variables and has to ensure that at the end of the day certain risk limits are respected (otherwise a special permission has to be obtained) ($\rightarrow$ *hedging, greeks*)
- Middle Office: at the end of the day the total risk for the bank is calculated from the movements of all market variables. The risk (and the risk capital that is calculated based on it) has to lie within a range specified by the regulators.

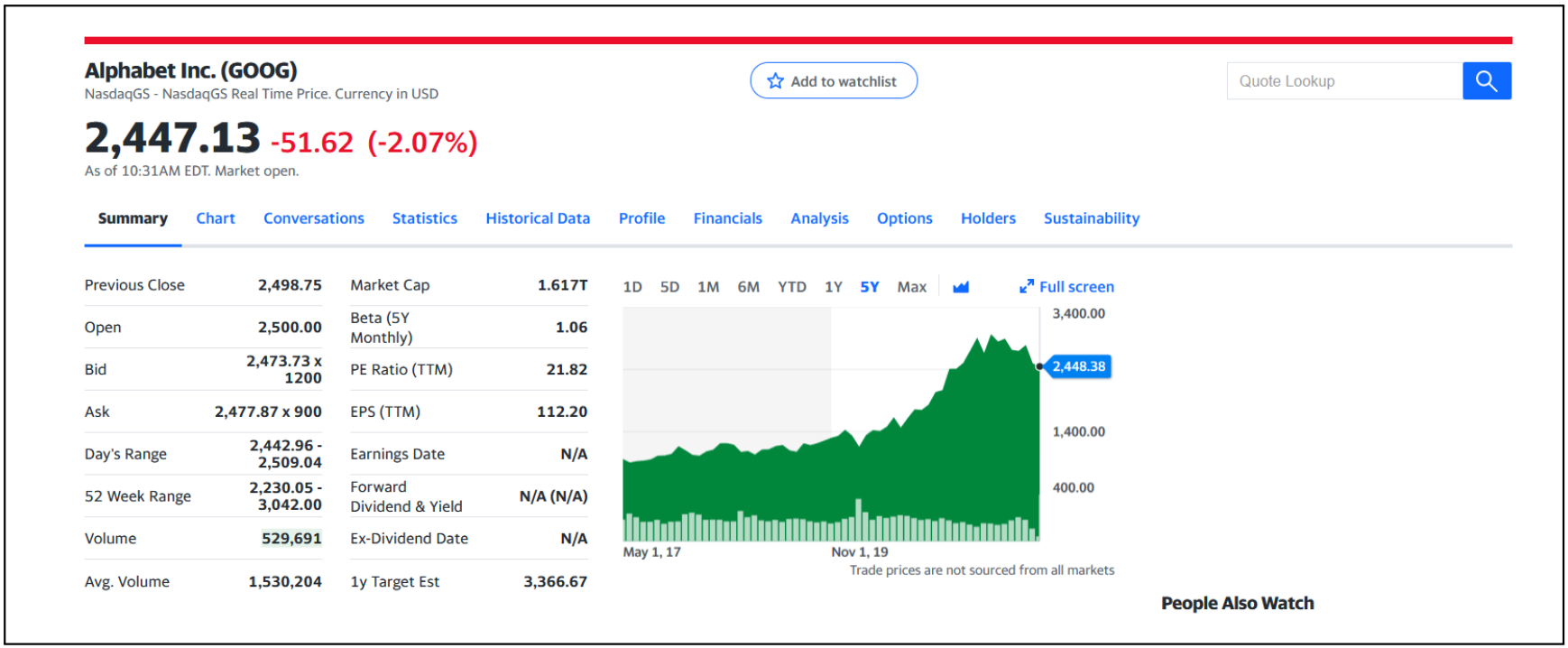
Front office

- Derivatives valuation and hedging ($\rightarrow$ later in the course)
  - Underlyings: equities, indices, commodities, ...
  - Standardized and listed (Eurex, ...) or traded "over the counter" (OTC)
  - Forwards / Futures, Swaps, Options, ...
- Risk management
  - Once derivatives have been bought/sold, how to manage the overall risks?

Example 1

Underlying could be google stock:

`https://finance.yahoo.com/quote/GOOG?p=GOOG&.tsrc=fin-srch`



Example 1

Options for different strikes and maturities

`https://finance.yahoo.com/quote/GOOG/options?p=GOOG`

February 23, 2024 | In The Money | Show: **List** | Straddle | Option Lookup

Calls for February 23, 2024

Contract Name	Last Trade Date	Strike	Last Price	Bid	Ask	Change	% Change	Volume	Open Interest	Implied Volatility
GOOG240223C00075000	2024-02-13 9:34AM EST	75.00	71.02	66.60	67.05	0.00	-	1	16	223.44%
GOOG240223C00080000	2024-02-06 12:41PM EST	80.00	65.29	61.55	62.10	0.00	-	1	6	202.34%
GOOG240223C00085000	2024-02-15 9:32AM EST	85.00	59.19	56.60	57.05	0.00	-	1	2	182.81%
GOOG240223C00095000	2024-02-09 1:39PM EST	95.00	55.70	46.55	47.10	0.00	-	-	1	146.09%
GOOG240223C00100000	2024-02-16 2:59PM EST	100.00	41.84	41.65	42.05	-5.16	-10.98%	20	165	135.16%
GOOG240223C00105000	2024-02-09 1:40PM EST	105.00	45.69	36.55	37.10	0.00	-	1	7	113.28%
GOOG240223C00110000	2024-02-16 12:32PM EST	110.00	32.54	31.60	32.10	-3.36	-9.36%	10	1	101.95%
GOOG240223C00115000	2024-02-16 3:54PM EST	115.00	26.89	26.65	27.15	-1.47	-5.18%	23	1	92.38%
GOOG240223C00120000	2024-02-16 2:12PM EST	120.00	22.47	21.60	22.15	-1.38	-5.79%	17	26	73.83%
GOOG240223C00125000	2024-02-15 11:10AM EST	125.00	18.00	16.60	17.15	0.00	-	31	42	58.20%
GOOG240223C00126000	2024-02-13 12:52PM EST	126.00	20.87	15.60	16.15	0.00	-	1	5	55.08%

Example 2

OTC derivatives can be arbitrarily complex

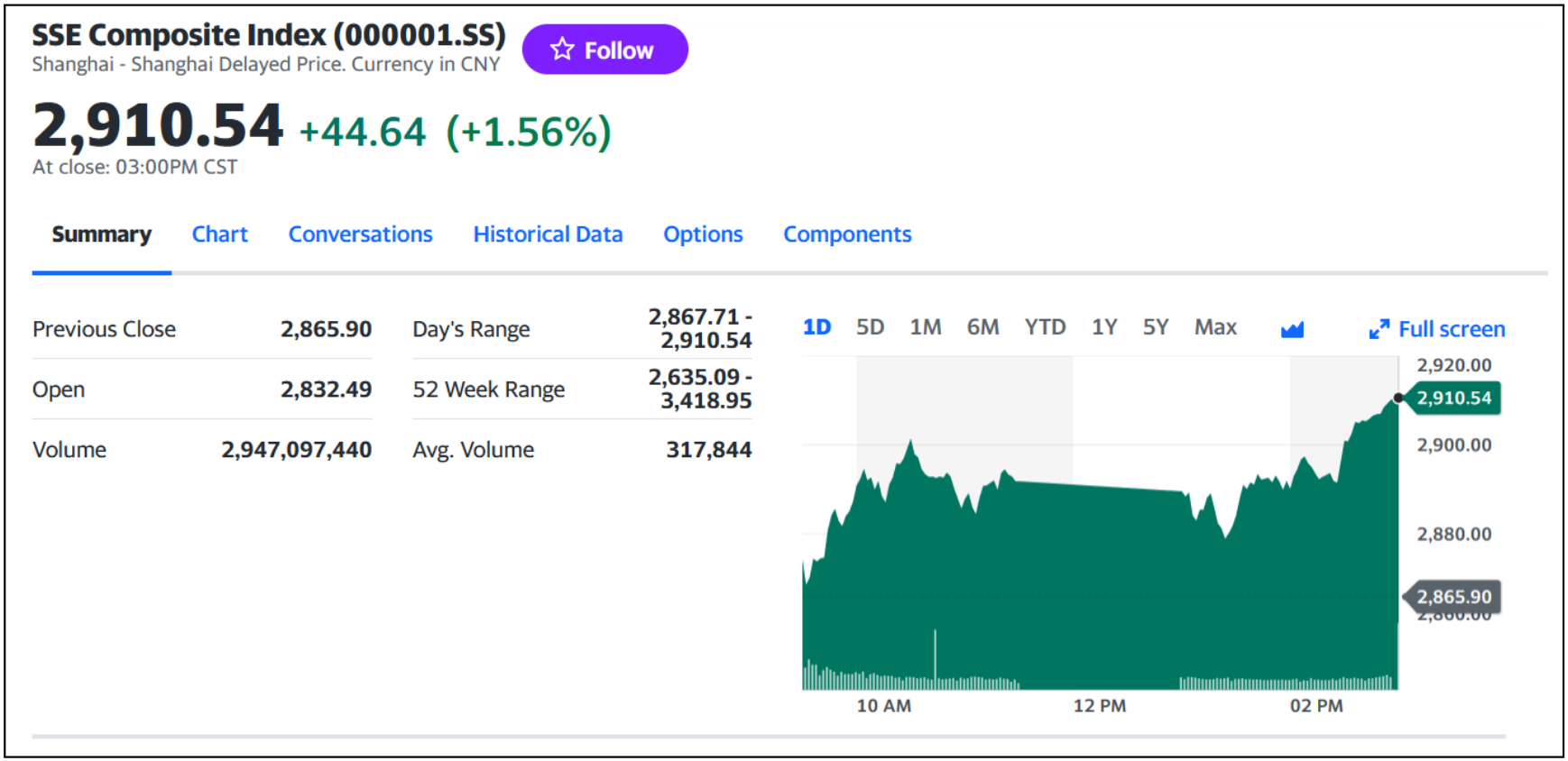
Five-year Minimum Coupon Cliquet on ABC Index

Option Buyer	XXXX
Option Seller	YYYY
Notional Amount	EUR 25MM
Start Date	dd/mm/yyyy
Maturity Date	Start Date + Five years
Option Seller Pays at Maturity	$\text{Notional} * \max\left(\sum_{i=1}^{5} \max\left(0, \min\left(\text{Cap}, \frac{S_i - S_{i-1}}{S_{i-1}}\right)\right), \text{Floor}\right)$
Index	ABC Index
Cap	8%
Floor	16%
Option Premium	???
Index Levels	S_i = Closing Level of Index on Start Date + i years

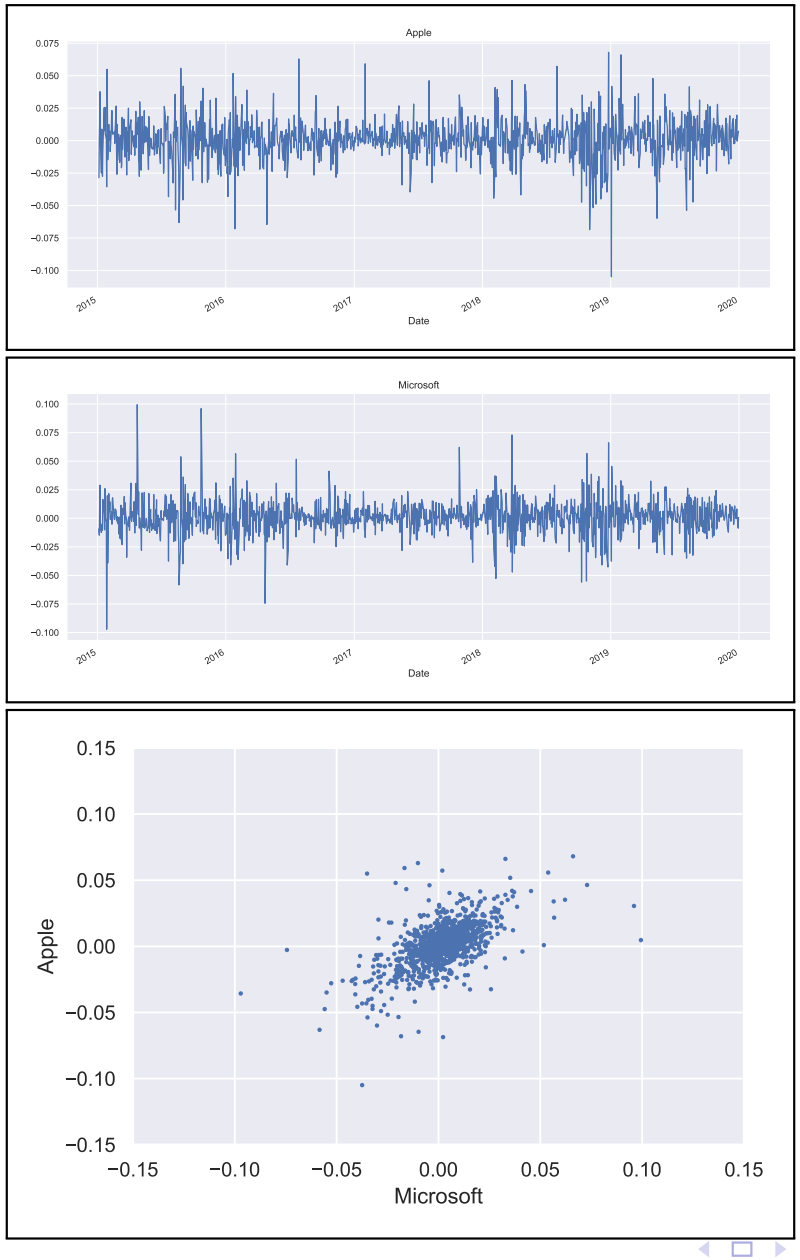
This indicative term sheet is neither an offer to buy or sell securities or an OTC derivative product which includes options, swaps, forwards and structured notes having similar features to OTC derivative transactions, nor a solicitation to buy or sell securities or an OTC derivative product. The proposal contained in the foregoing is not a complete description of the terms of a particular transaction and is subject to change without limitation.

Example 2

ABC Index could for instance be SSE Composite Index (Shanghai Stock Exchange Composite Index)



Daily (log) returns:



Overview of regulation

Growth and liberalization of markets starting 1970

1970 (-1973) Abolition of the Bretton-Woods system of fixed exchange rates

1973 Chicago Option Exchange opens (at the same time: Black-Scholes-Merton formula)

Beginnings of today's regulation

1974 G10 found Basel Committe of Banking Supervision

1988 Basel I: Minimum capital requirements ($\rightarrow$ limitations on lending, maximal credit volume depends on capital available to the bank)

Disasters of the 1990s

1995 Bankruptcy of Barings Bank

1998 Bailout of Long-Term Capital Management

$\rightarrow$ Discussion of need for more/better regulation, in particular for derivatives (focus of Basel I: credit risk).

Refined regulation in banking

1993 G-30 report and *Weatherstone 4.15 report* to take into account market risk (in particular for derivatives).

1996 Adjustments to Basel I (market risk).

2001 (-2004) Birth of Basel II, goal: a finer system to evaluate credit risk, operational risk as a new type of risk

2010 Basel III: Developments to Basel II (still valid in principle).

Regulation in insurance

1997 (-2002) Solvency I

2001 Solvency II: risk-based solvency capital, which respects all types of risk (market, credit, operational risk as well as additional insurance risk).

Regulation

Goal: ensure that a bank or insurance has a sufficient amount of capital so that unforeseen losses do not lead to default. In banking:

- Basel Committe on Banking Supervision: no formal supervision/ not legally binding, but develops recommendations and guidelines (expecting that national authorities implement them adapted to their system).
- Basel III: current state (not fully implemented yet) at `https://www.bis.org/basel_framework`.

Example

Risk-weighted assets

20.3

The Basel framework describes how to calculate RWA for credit risk, market risk and operational risk. The requirements for calculating RWA allow banks to use different approaches, some of which banks may only use with supervisory approval. The nominated approaches of a bank comprise all the approaches that the bank is using to calculate regulatory capital requirements, other than those approaches used solely for the purpose of the capital floor calculation outlined below. The nominated approaches of a bank may include those that it has supervisory approval to use and those for which supervisory approval is not required.

20.4

The RWA that banks must use to determine compliance with the requirements set out in RBC20.1 (and the buffers in RBC30 and RBC40) is the higher of:

(1) the sum of the following elements:

  (a) RWA for credit risk;

  (b) RWA for market risk; and

  (c) RWA for operational risk; and

(2) for banks using the internal ratings-based (IRB) approach for credit risk or the Advanced Measurement Approaches (AMA) for operational risk, the sum of the elements listed in RBC20.4(1) adjusted as required by RBC20.11 to RBC20.16, which describes the capital floor.

Hedge funds and mutual funds

- Mutual funds: more regulated
  - Index funds
  - ETFs. Examples: `https://finance.yahoo.com/etfs/`
- Hedge funds use different types of strategies. Examples:
  - Long/Short Equity
  - Short
  - ...

What is FinTech? The challenges of FinTech

Fintech: overview

- Technologies:
  - Artificial intelligence
  - Blockchain
  - Cloud computing
  - Big data
- Services:
  - Payments and Transfers
  - Lending and Financing
  - Personal Finance and Wealth Management
  - Insurtech
  - Regtech
  - Open Banking and APIs
  - ...

Image generated using DALL·E 3

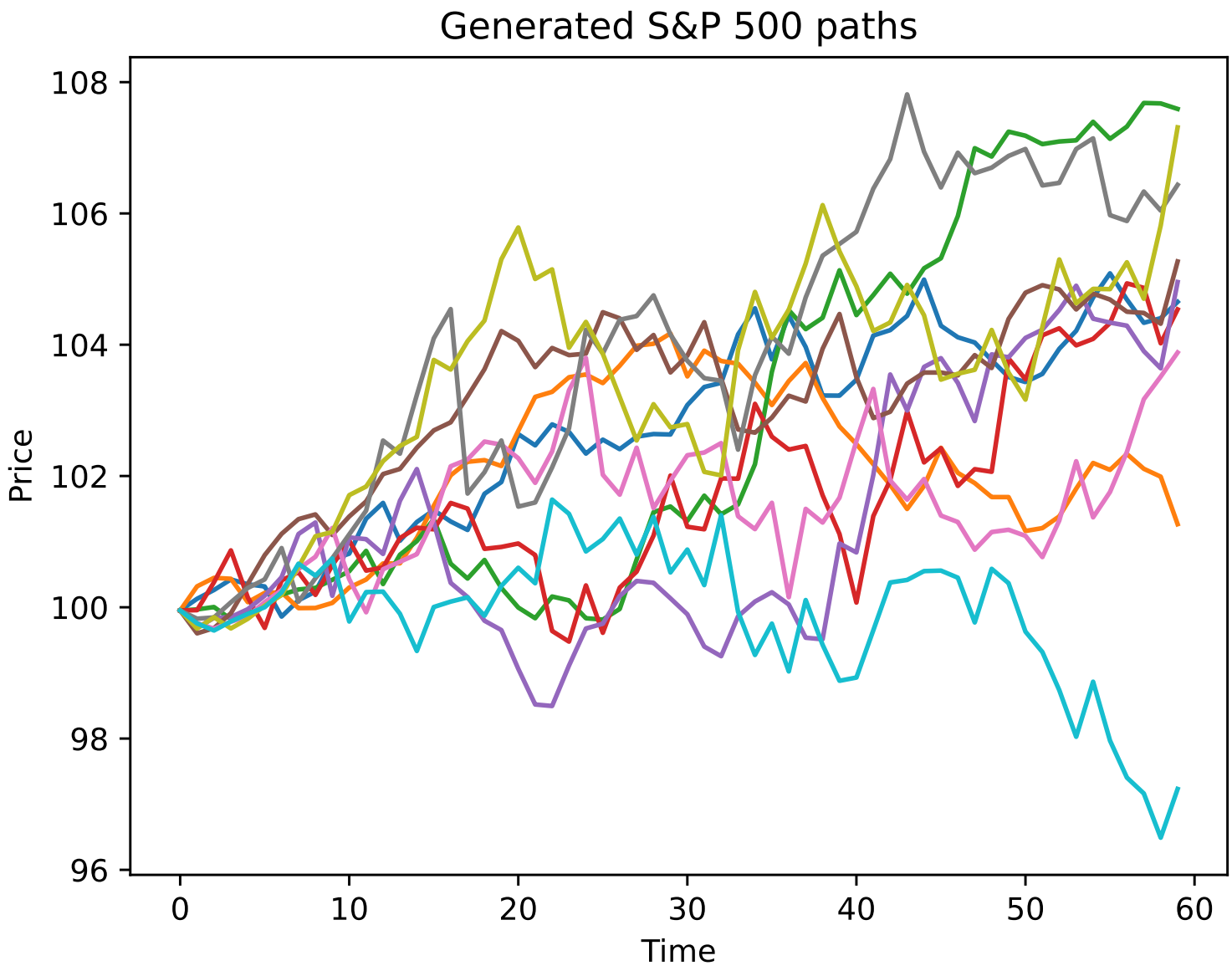
AI in finance

- Portfolio management
- Customer services & Robo-Advising
- Credit scoring
- Fraud detection
- Anti-money laundering
- Risk management
- Trading

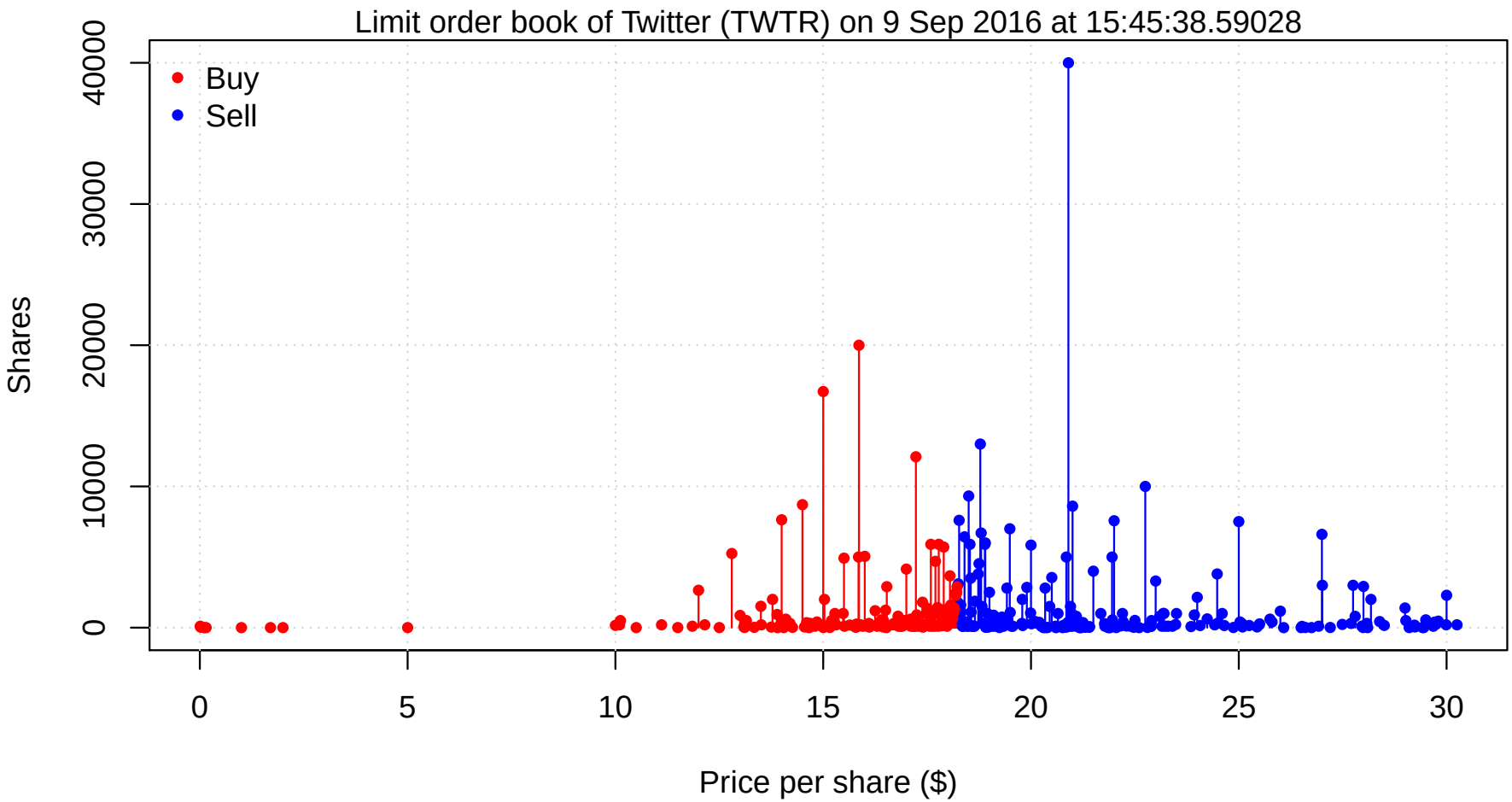
Deep learning in quantitative finance

- Key examples:
  - Derivative pricing
  - Model calibration
  - Hedging
  - Portfolio optimization
  - Market scenario generation
  - ...

Artificial financial time series

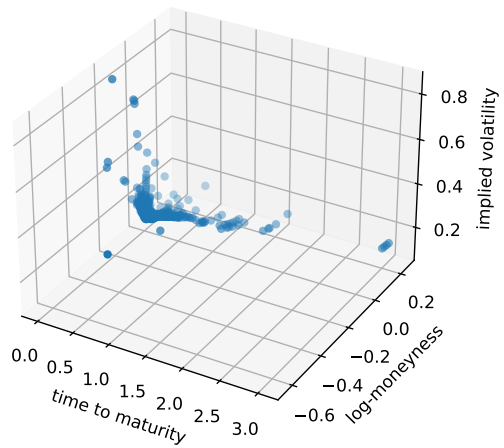


Predicting price moves

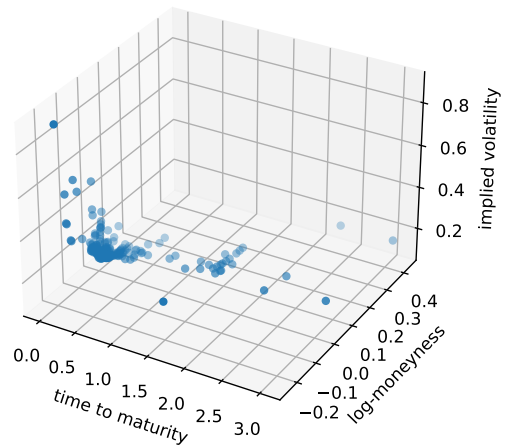


Option pricing

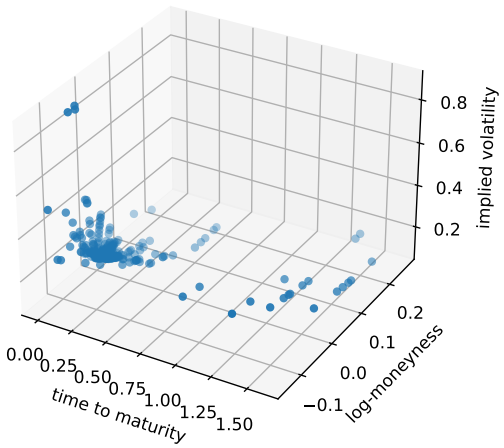
SPX implied volatilities 2021-11-08 09:50:00



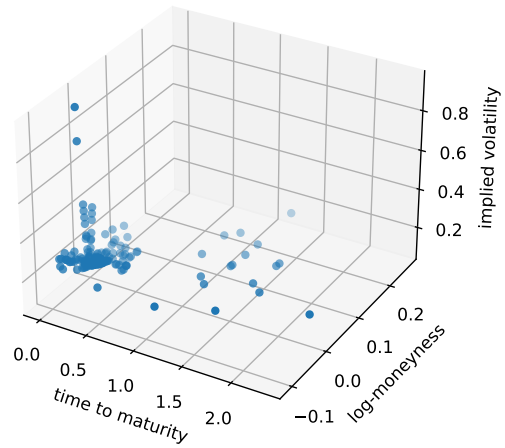
SPX implied volatilities 2021-11-08 11:10:00



SPX implied volatilities 2021-11-08 11:30:00



SPX implied volatilities 2021-11-08 14:50:00



Deep Hedging (2018/2019)

Joint work with H. Buehler, J. Teichmann, B. Wood

`https://www.tandfonline.com/doi/full/10.1080/14697688.2019.1571683`

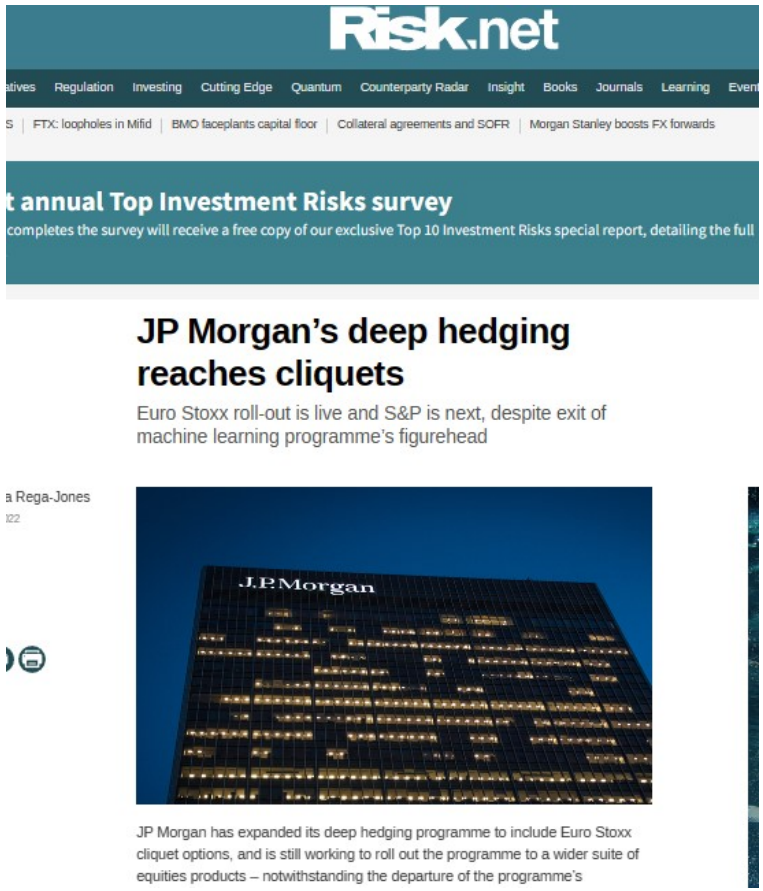


Figure: Risk.net article from May 2022

Asset price bubble detection (Here: Nvidia)

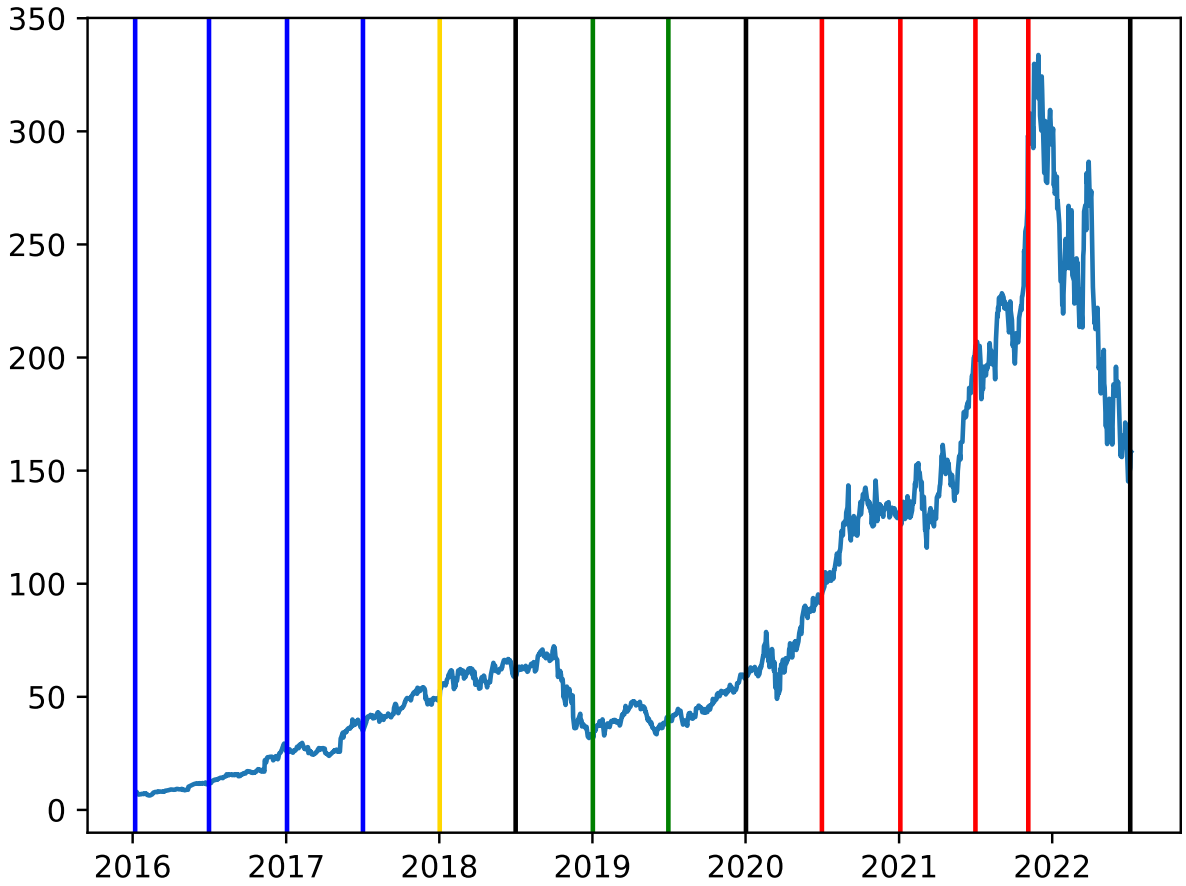


Figure: Bubble probability P_b at different dates. For the red lines we have $P_b > 95\%$, for the yellow line $P_b = 71.2\%$, for the black lines $40\% < P_b < 45\%$, for the green lines $19\% < P_b < 21\%$ and for the blue lines $P_b < 10\%$.

Blockchain

- High-level principle:
  - Distributed ledger technology
  - Decentralized & "irreversible"
  - Consensus mechanism
  - Cryptographic security
- Key uses:
  - Cryptocurrencies
  - Decentralized Finance
  - ...

Cryptocurrencies

Challenges

- Explainability / black-box nature of machine learning
- Data privacy
- Data security
- Regulation
- Stability risks
- Systemic Risks and Contagion

This course gives an introduction (from mathematical and coding perspective) to...

- financial data (as above) and how to work with it in python
- various types of derivatives
- stochastic models for pricing and hedging of derivatives
- classical portfolio optimization
- the use of deep learning for these tasks

$\rightarrow$ students can go in further depth on each of these topics in the future. Techniques not covered in this course: advanced numerical methods for pricing and hedging derivatives, complex models, ...