SYSTEMATIC TRADING MTH9897
Lecture 1: Fixed Income
Quantitative Investment Framework

BaruchCOLLEGE | Master of Financial Engineering
WEISSMAN SCHOOL OF ARTS AND SCIENCES

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Brief History of Bond Market

> *"Hence the extraordinary growth of a class, or rather, of a stratum of rentiers, i.e., people who live by* **'clipping coupons'***, who take no part in any enterprise whatever, whose profession is idleness."*
>
> Vladimir Lenin, "Imperialism, the Highest Stage of Capitalism", 1920

- In the early 1600s, the Dutch East India Trading Co. became the first private company to offer corporate bonds to the public

- The first-ever Sovereign bond was issued in **1693** by the newly formed Bank of England.

- 1970's Rise of Mortgage-backed securities

- 1990's Futures, junk bonds, CMO's, Municipals

- 1994 Credit Default Swaps (Bankers' Trust, JPM)

- 2010's Fixed Income ETF's

- 2015 electronic credit trading

Outline

- Intro
  - FI vs Equities
  - Buy Side vs Sell side

- Fixed Income Primer

- Corporate Bonds

- Fixed Income ETFs and portfolio trading

- Municipal Bonds

- Trading System for buy-side vs sell-side

- Systematic factor Investing in credit

General Resources (favorite books)

- [The Complete Guide to Capital Markets for Quantitative Professionals](#) by Alex Kuznetsov

- [Arbitrage Theory in Continuous Time](#) by Thomas Bjork

- [Theory of Financial Risk and Derivative Pricing: From Statistical Physics to Risk Management](#) by JP Bouchaud

- [The Mythical Man-Month: Essays on Software Engineering](#), by Frederick Brooks Jr

Fixed Income Vs Equities Trivia

Measure	Fixed Income (Corp)	Equities
Market Size,$	**11.5T**	**47T**
Issuance,$	2.3T	400B
Daily Trading Volume,$	**46B**	**481B**
Electronic Volume,$	3B (*)	350B
Number of trades	70k	59m
ElectronicTrades	12.5k	50m
Instruments	100K	10K
Average trade size,$	650K	8K
Electronic trade size,$	240K	7K

*Sources: FINRA, SIFMA
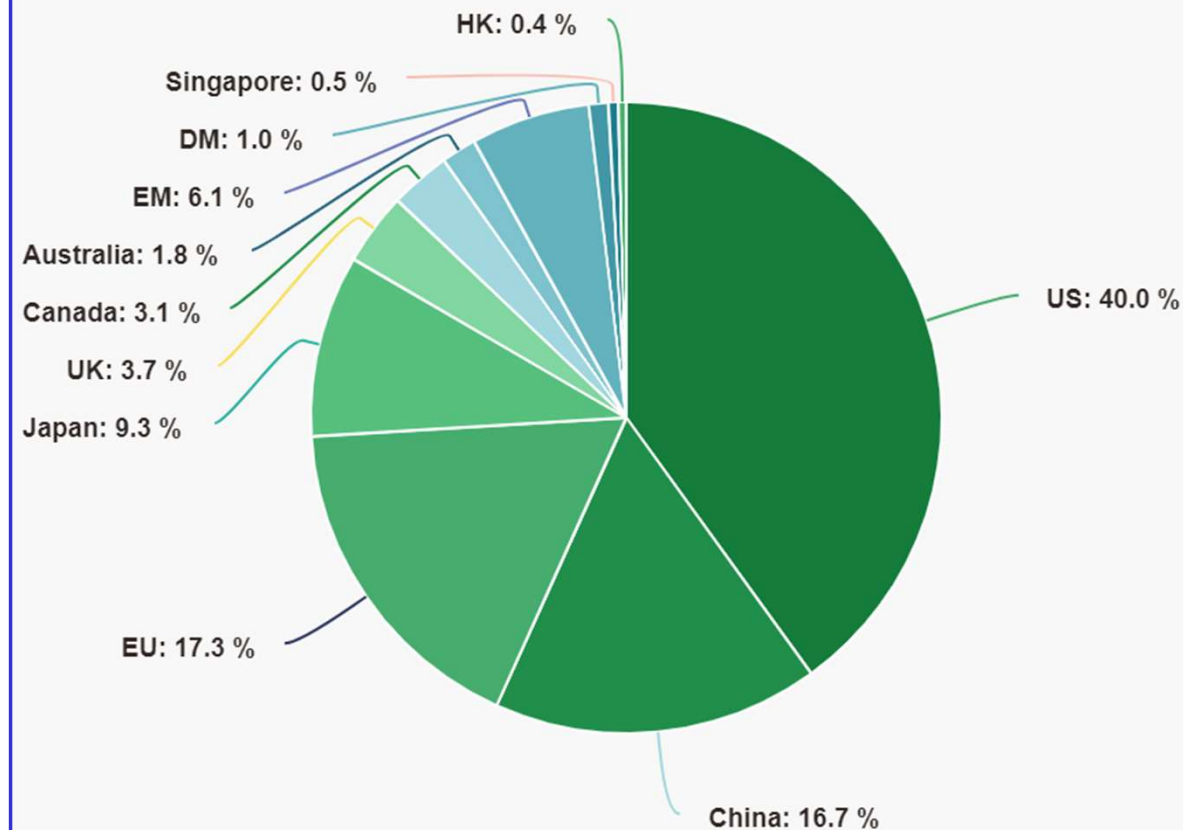
Why Organizations Trade

SELL-SIDE	BUY-SIDE

- Provides service (makes markets) to buy-side in competition
- Service provider to buy-side
- Market centers' customer
- **Revenue ~ BidAskSpread x Vol**
 	
- Spread ~0.1bp for OTR bonds
- Spread ~10-50bp for corporate bonds and munis
	- Provides service to end clients (real money) in competition
	- Is a sell-side customer
	- Market centers' customer
	- **Revenue ~ fee * AUM**
	
	fees
	10-60 bp (mm, fi, equity)
	
	AUM(t) = f(sales(t-1y),
	          performance(t-4y),
	          marketCond(t))

Brokerage pie: $350B (US only)	AssetMgmt pie $500B on $126T

https://www.sifma.org/resources/research/fact-book/

Global Fixed Income Market

Global Fixed Income Outstanding

Source: Bank for International Settlements, SIFMA estimates

- HK: 0.4 %
- Singapore: 0.5 %
- DM: 1.0 %
- EM: 6.1 %
- Australia: 1.8 %
- Canada: 3.1 %
- UK: 3.7 %
- Japan: 9.3 %
- US: 40.0 %
- EU: 17.3 %
- China: 16.7 %

$130 Trillion market
Comparable to equities
Linked instruments
Huge liquidity spectrum
Bonds are not the only way to borrow

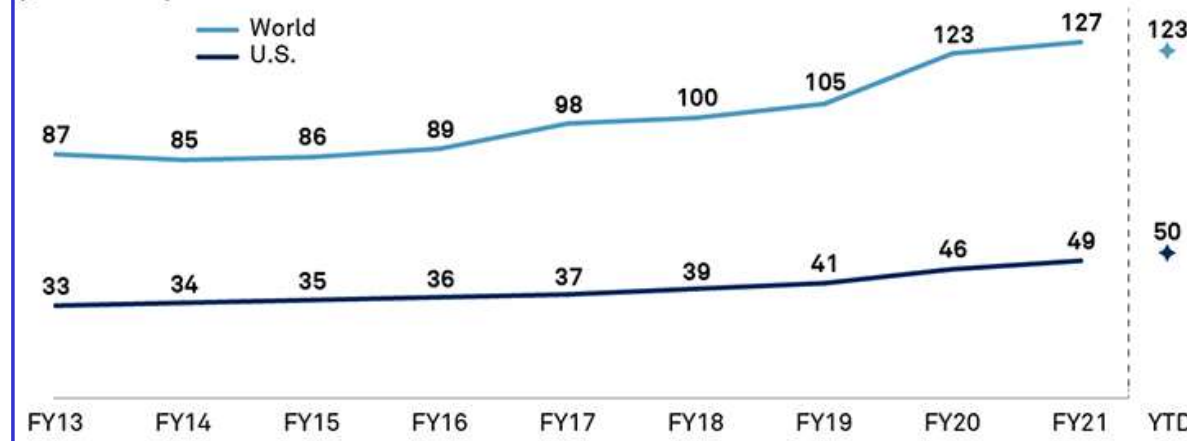**Debt Financing of Non-Financial Corporations**

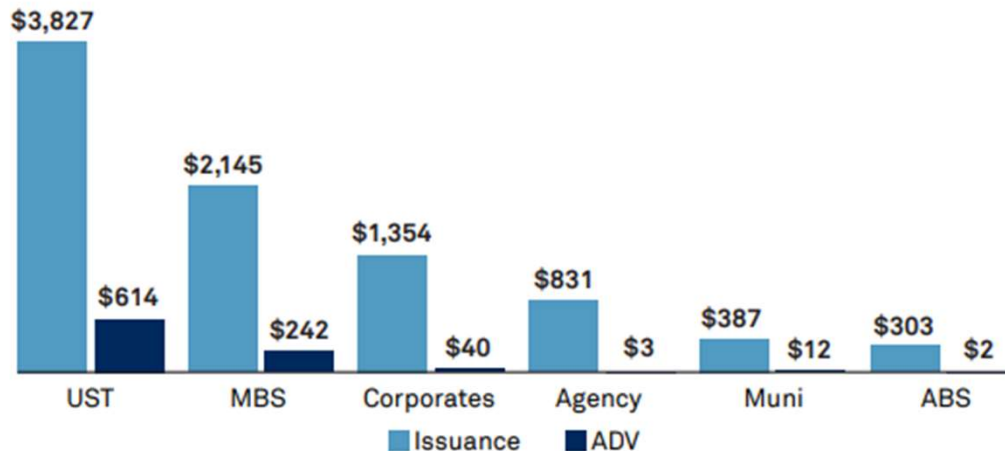|	U.S.	Euro area	U.K.	Japan	China
Loans	22%	76%	73%	78%	70%
DCM	78%	24%	27%	22%	30%
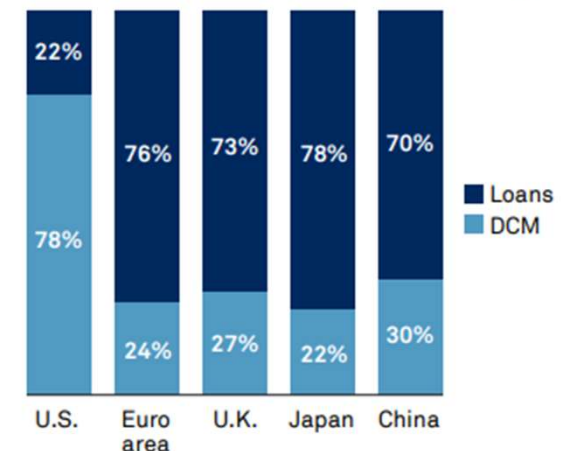
Note: As of 2021, China 2019; DCM = debt capital markets = corporate bonds only.
Source: U.S. Federal Reserve, ECB, Bank of Japan, National Bureau of Statistics of China

Fixed Income Market Size

U.S. Share of Global Fixed-Income Markets ($ Trillion)

World / U.S.

World: 87, 85, 86, 89, 98, 100, 105, 123, 127, 123

U.S.: 33, 34, 35, 36, 37, 39, 41, 46, 49, 50

FY13, FY14, FY15, FY16, FY17, FY18, FY19, FY20, FY21, YTD

Bond Market Breakdown

Fixed income debt in trillions of dollars

- Asset Backed $1,378.6B 3.6%
- Municipal $3,661.4B 9.8%
- Money Markets $2,683.0B 7.0%
- Federal Agencies $1,979.2B 5.2%
- Corporate Debt $7,664.5B 20.1%
- Mortgage Related $8,749.5B 22.9%
- Treasury $12.071B 31.6%

Source: SIFMA

Market Size by Asset Class (Outstanding/Issuance) ($ Billion)

- UST: Issuance $3,827, ADV $614
- MBS: Issuance $2,145, ADV $242
- Corporates: Issuance $1,354, ADV $40
- Agency: Issuance $831, ADV $3
- Muni: Issuance $387, ADV $12
- ABS: Issuance $303, ADV $2

Issuance / ADV

Source: SIFMA

Note how much ADV to issuance ratio varies: some instruments get parked faster, e.g. to pension funds and insurance accounts
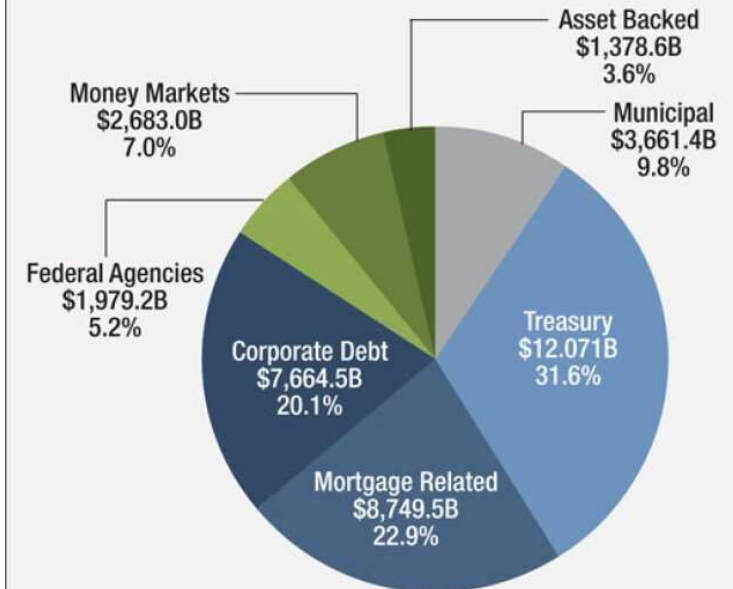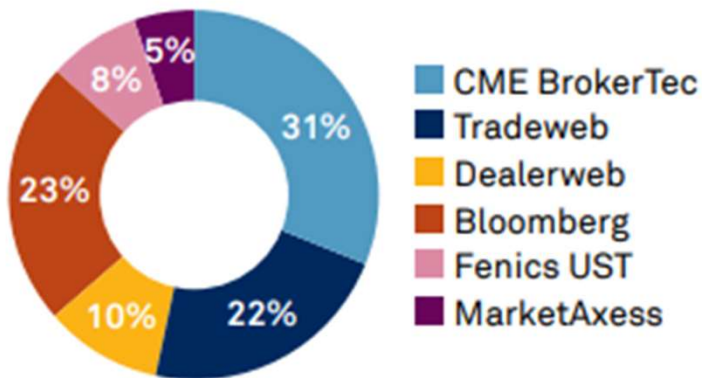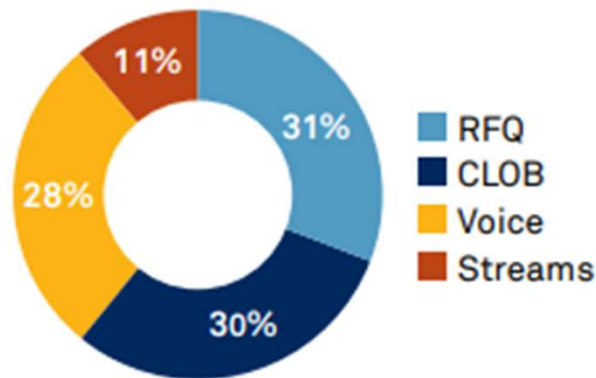
https://www.sifma.org/wp-content/uploads/2023/05/Understanding-Fixed-Income-Markets-2023-23-2007-FINAL.pdf

Rates vs Credit

U.S. Treasuries Electronic Trading

By Platform (notional share)

- CME BrokerTec — 31%
- Tradeweb — 22%
- Dealerweb — 10%
- Bloomberg — 23%
- Fenics UST — 8%
- MarketAxess — 5%

By Channel

- RFQ — 31%
- CLOB — 30%
- Voice — 28%
- Streams — 11%

Corporate Bonds Electronic Trading

By Platform (notional share)

- MarketAxess — 50%
- Tradeweb — 29%
- Trumid — 12%
- ICE — 4%
- Bloomberg — 3%
- MTS — 1%

By Channel

- Disclosed RFQ — 42%
- Anonymous RFQ — 16%
- Session-based — 13%
- CLOB — 10%
- Portfolio trading — 10%
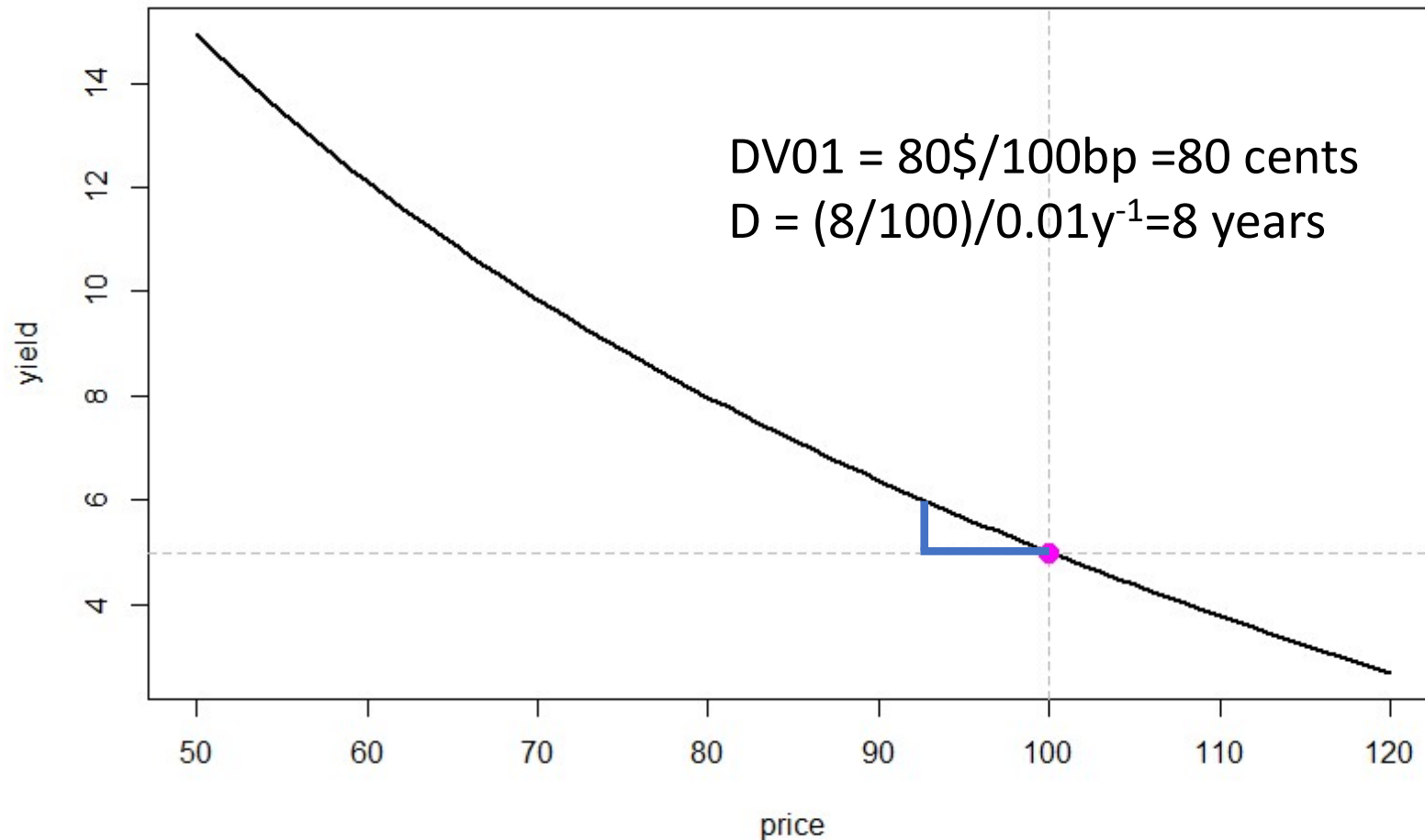- Stream/Click-to-engage — 9%
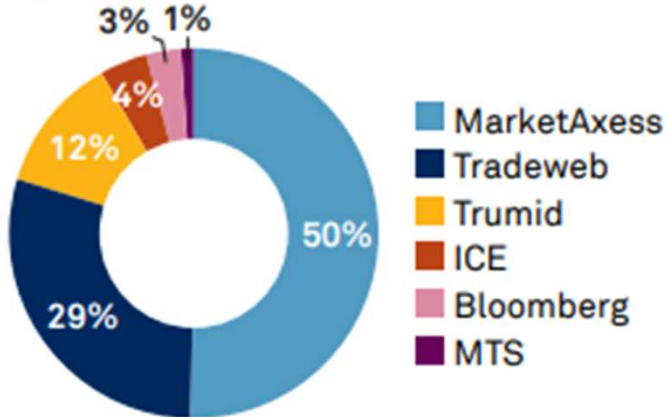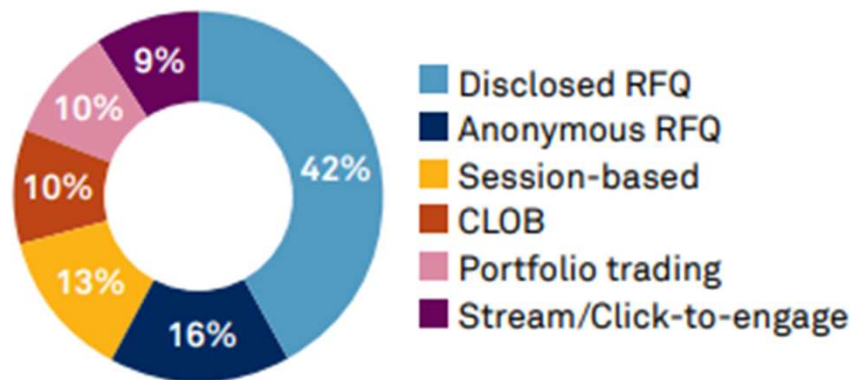
Source: Coalition Greenwich

Bond primer

- "Atomic" instrument is a zero-coupon bond a.k.a. bill
  - You pay price P get face value F back at time T
  - Yield y is rate of return: $P = F * \exp(-yT) \equiv Fd$.
    - For a given bond, yield defines price, and vice versa
    - yield and price move in opposite directions
  - Who decides what y is today? Is it known for every time T?
  - Typically, zero-coupon bonds are issued up to 1 year.

- Bonds (T=30 years) and Notes (in-between) pay coupons, typically twice a year, so n=2T
  - $P = \sum_{k=1}^{n} \frac{C_k}{(1+y/2)^k} + \frac{F}{(1+y/2)^n} \equiv \sum_{k=1}^{n} C_k d_k + F d_n$
  - C_k – coupon (may be different), F is face value, y is yield, d discount factor
  - Nothing to do with bond pricing. These are just two ways to describe bond value.
  - A bond can be quoted on price (percentage), yield, or discount.
  - Note that $y \rightarrow P$ is easier than $P \rightarrow y$

- DV01 = -dP/dy*1bp = -0.0001 * dP/dy
  - Dollar Value of a basis points
  - Measures bond - or bond portfolio – value's sensitivity to change in yields

- Duration
  - $dP/P = d(log\ P) = -D\ dy$
    - has dimension of years
    - Describes sensitivity to interest rates
  - Applies to an instrument of a portfolio, fund, or ETF
  - $D = 10000*DV01/P$
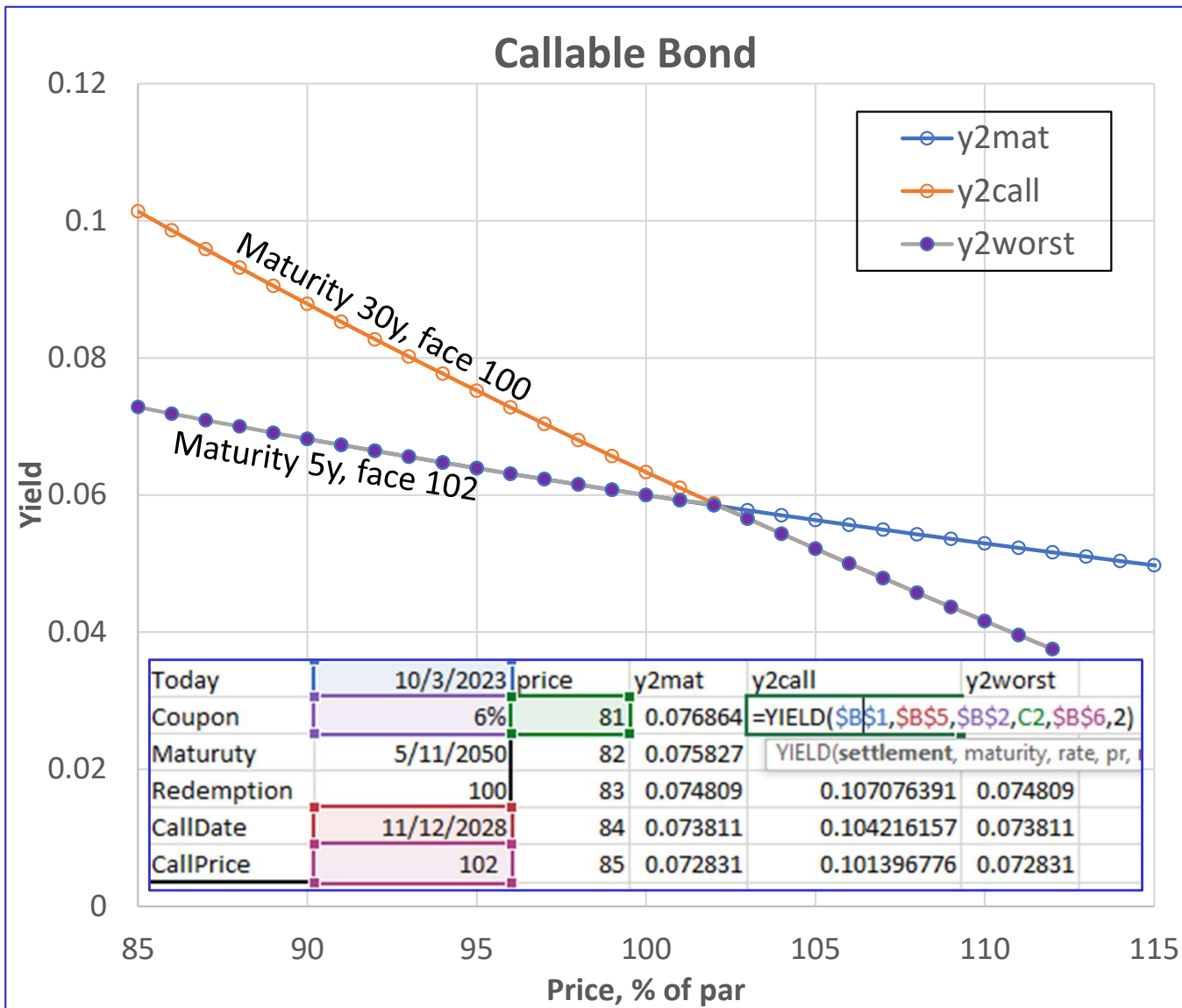 - For zero coupon bond D = T; coupon bonds D < T as seen from DCF equation

10 year bullet bond 5% coupon trading at par

DV01 = 80\$/100bp =80 cents
$D = (8/100)/0.01y^{-1} = 8$ years

- "Duration-neutral portfolio"
- "Hedge spread duration"

Callable bonds

Callable Bond

- y2mat
- y2call
- y2worst

Maturity 30y, face 100

Maturity 5y, face 102

Today	10/3/2023	price	y2mat	y2call	y2worst
Coupon	6%	81	0.076864	=YIELD(B1,B5,B2,C2,B6,2)	
Maturuty	5/11/2050	82	0.075827	YIELD(settlement, maturity, rate, pr,	
Redemption	100	83	0.074809	0.107076391	0.074809
CallDate	11/12/2028	84	0.073811	0.104216157	0.073811
CallPrice	102	85	0.072831	0.101396776	0.072831

Yield (y-axis)
Price, % of par (x-axis)

- Issuers exercise option when they can refinance cheaper, that is paying lower yield
- Investors need to be compensated for the loss of income, callable bonds are cheaper.
- Calls can be discrete, more than one, and with different prices
- Kink in the price-yield curve is not quote right ➔ OAS
- Options-Adjusted Spread (or yield) is not observable, but provides a framework for pricing optionality in bonds.
- Call date can be M-30, just an accounting trick allowing to call a bond at maturity.
- Make-Whole is a "mild" option that allows an issuer to call a bond but at a premium to compensate bond-holders.

Practical details
They call it "fixed income" for a reason

Rarely compute cash flows from scratch: QuantLib, YieldBook, Bloomberg, etc
https://quantlib-python-docs.readthedocs.io/en/latest/dates.html

- Calendar Types, Holidays, treatment of the end of months etc
    - Actual/Actual - Treasuries
    - 30/360 -- US corporate bonds and many US agency issues
- Settlement
    - T+1 Treasury
    - T+2 Corp,Muni
- Accruals
    - Coupon freq
        - Schedule
    - Clean price
        - For quoting
    - Dirty price
        - Settlement
    - Daily PNL
        - Coupon/360

Clean price vs Dirty price
Buy 5 months after coupon @ 100 clean ➜ 102.5 dirty
Get 2 coupons 6/2
Sell 2 months after coupon @100 clean ➜ 101.0 dirty
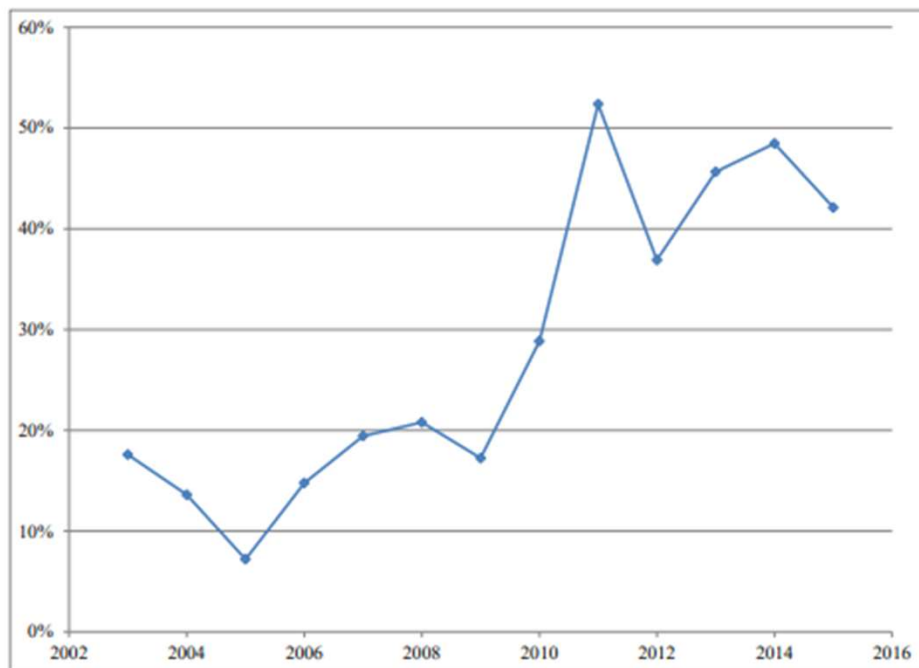What if you buy 1 day before coupon date?
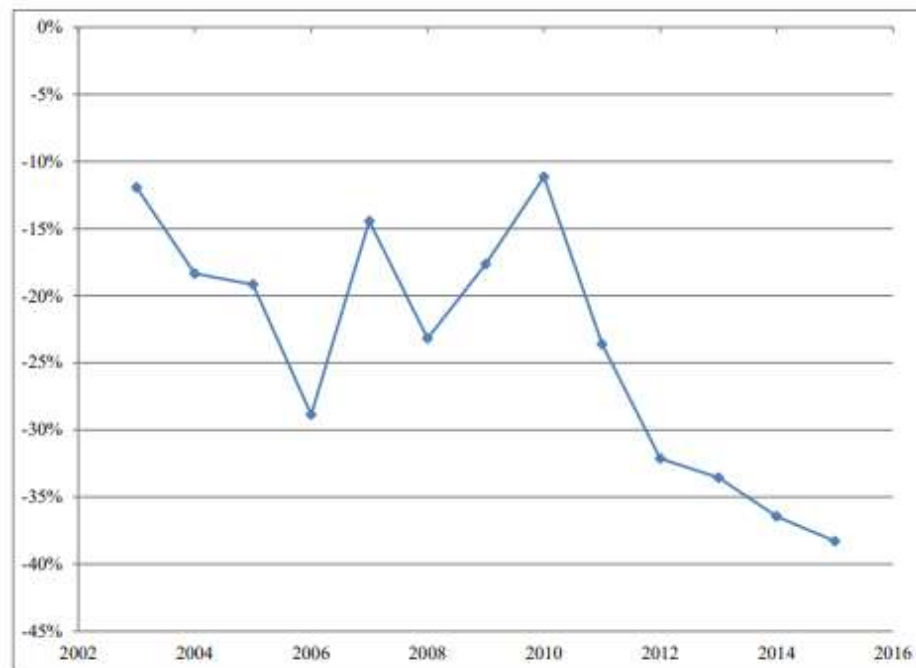

accruals for 6% bond
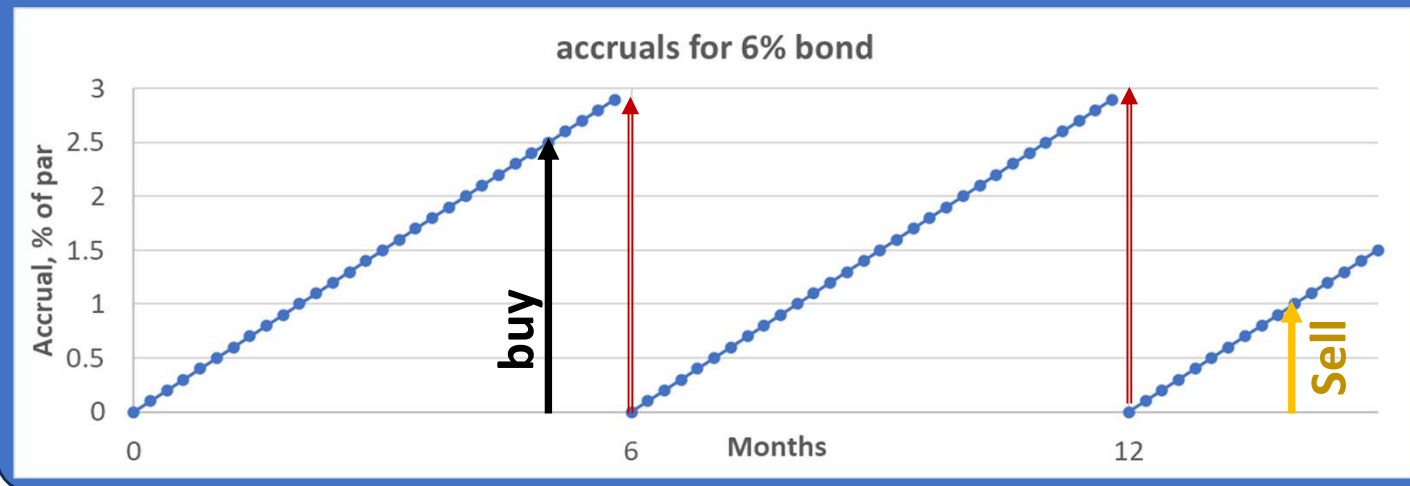
Bond Lifecycle

1. Issued
2. Actively traded
3. Parked
4. Taken out for rebalance
5. Parked
6. Mature
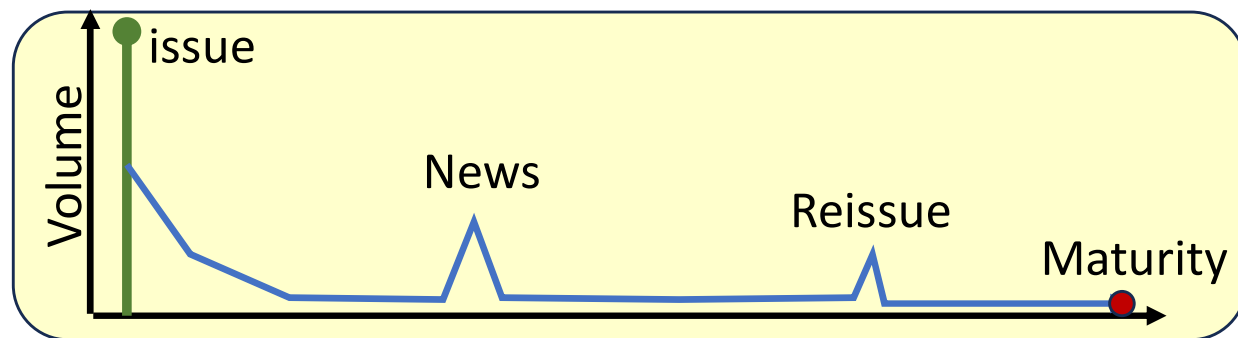
Percentage of Most Actively Traded Bonds Issued in the Last 90 Days

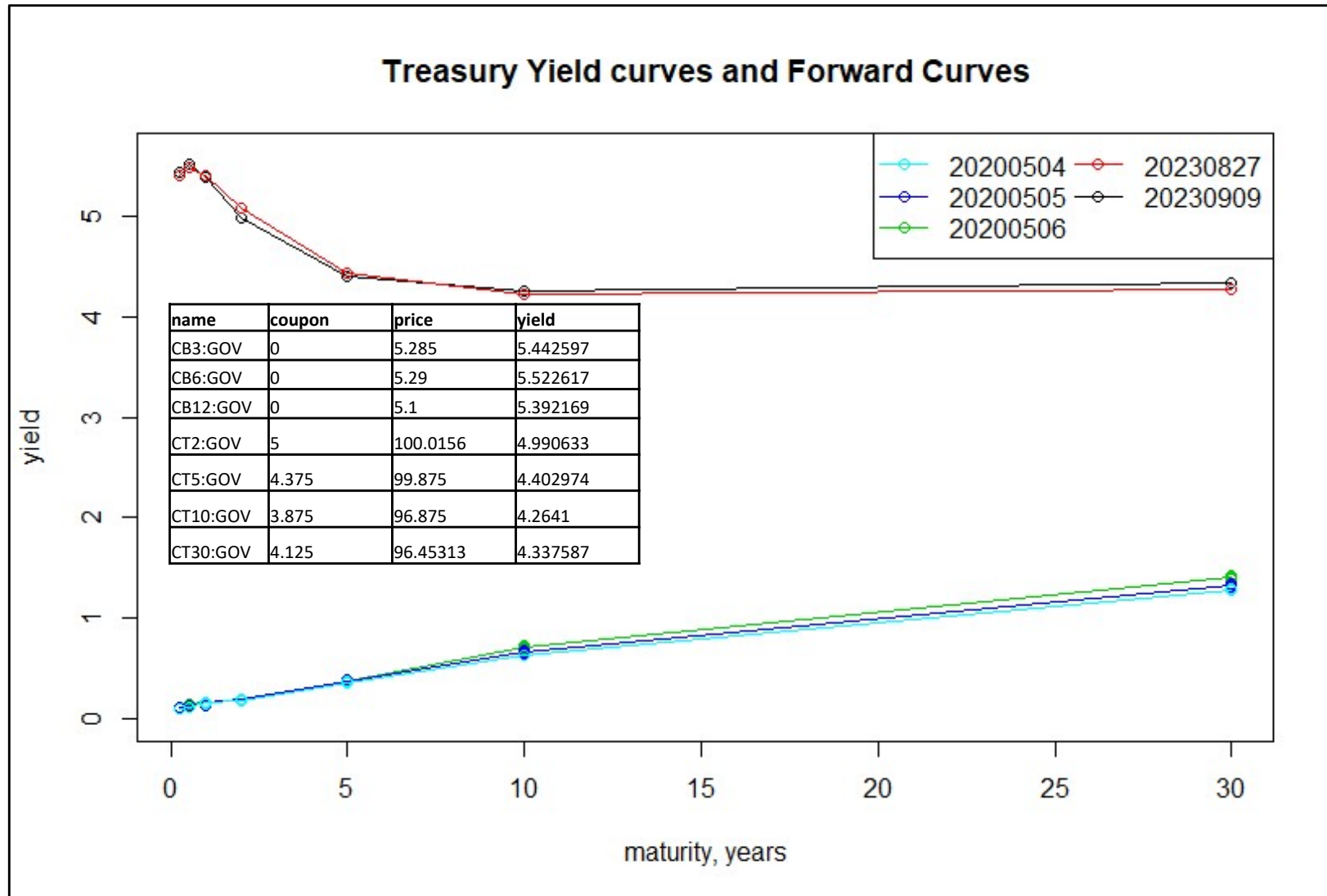Trading Volume Reduction After 90 Days in the Secondary Market

"Analysis of Corporate Bond Liquidity" from Finra
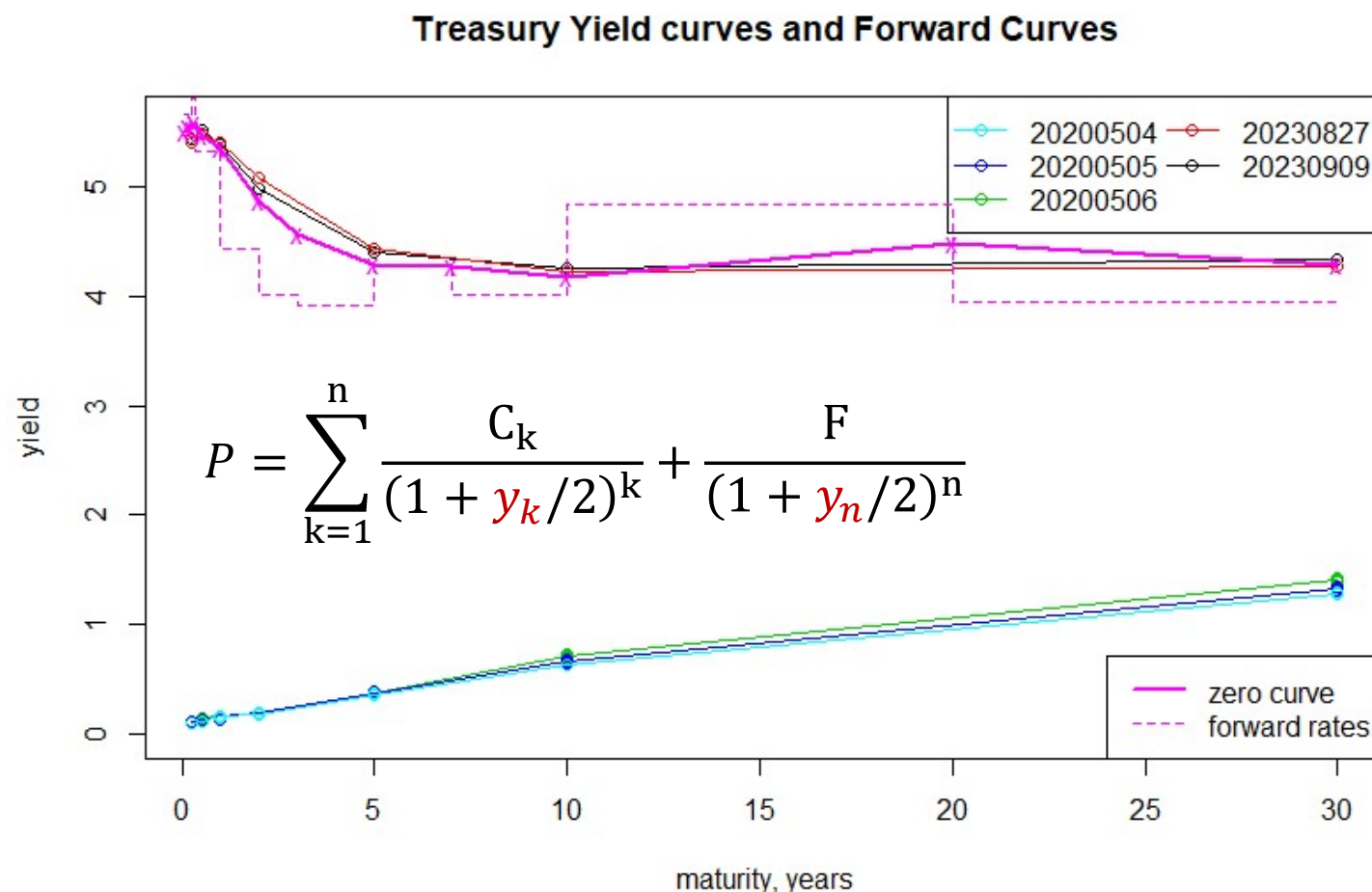
Treasury Yield Curves

Treasury Yield curves and Forward Curves

Legend: 20200504, 20230827, 20200505, 20230909, 20200506

| name	coupon	price	yield
CB3:GOV	0	5.285	5.442597
CB6:GOV	0	5.29	5.522617
CB12:GOV	0	5.1	5.392169
CT2:GOV	5	100.0156	4.990633
CT5:GOV	4.375	99.875	4.402974
CT10:GOV	3.875	96.875	4.2641
CT30:GOV	4.125	96.45313	4.337587

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zero yields
https://home.treasury.gov/resource-center/data-chart-center/interest-rates/TextView?type=daily_treasury_yield_curve&field_tdr_date_value_month=202408

Treasury Yield curves and Forward Curves

Legend:
- 20200504
- 20200505
- 20200506
- 20230827
- 20230909
- zero curve
- forward rates

$$P = \sum_{k=1}^{n} \frac{C_k}{(1 + y_k/2)^k} + \frac{F}{(1 + y_n/2)^n}$$

yield / maturity, years

Moving around a curve: carry

Carry: expected profit and loss (P&L) assuming yield of the bond remaining fixed.
- For a bod trading at par carry is coupon the coupon,
- for a bond trading > 100 the bond price will decrease
- for a bond trading < 100 it will increase as a result of the pull-to-par-effect.
- No curve implied in carry calculation

Pull to par: 5% coupon bond
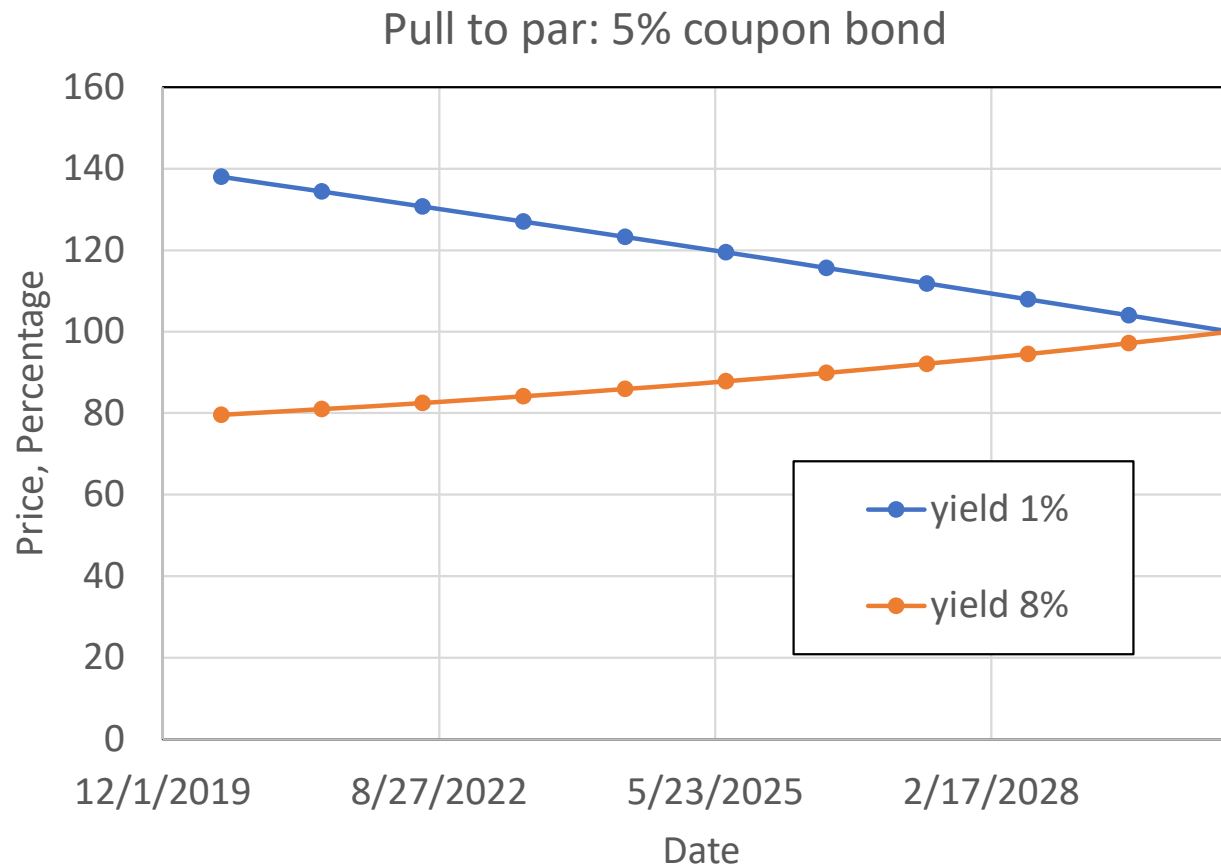
Moving around a curve: Roll

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Rolldown PL reflects yield change from maturity reduction, with fixed yield curve
- For regular upward-sloping curve the yield reduces, and the rolldown is positive
- For inverted curve is will be negative. Carry and rolldown are often taken together, and represent the total PL arising from ageing of the bond while the curve remains fixed.
- $P(0) = \int_0^T D(t)c(t)dt + FD(T)$ price now, D stands for discount factor (not duration)

- $P(\Delta T) = \int_0^{T-\Delta T} D(t)c(t)dt + FD(T - \Delta T) \approx P(T) - cD(T)\Delta T - F\frac{dD}{dT}\Delta T$

- $\Delta P = -cD(T)\Delta T - F\frac{dD}{dT}\Delta T$

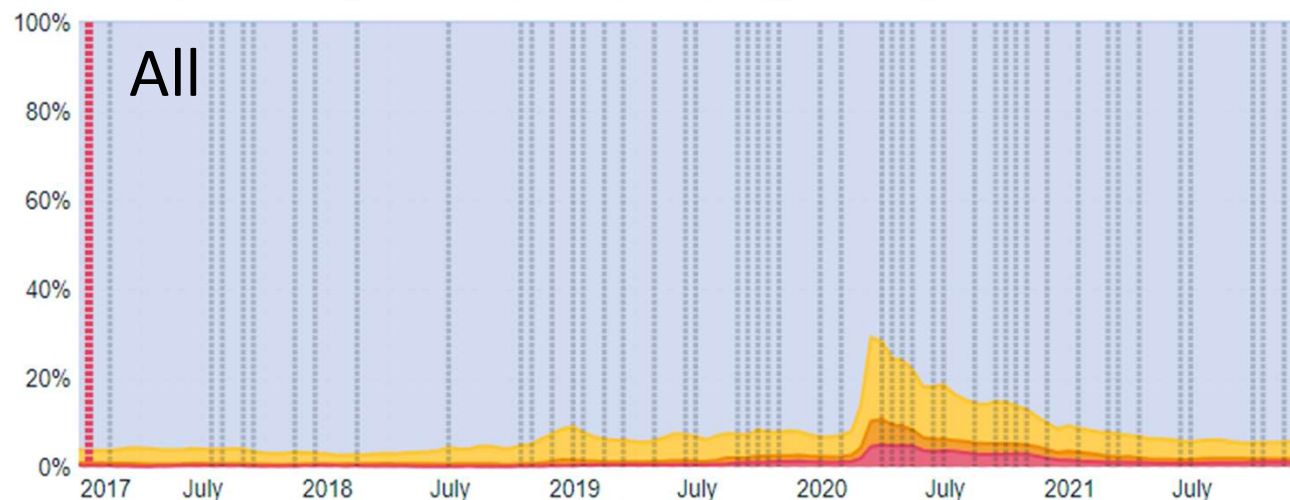Credit relative value (RV) expresses the bond value relative to its peers.
- Often referred to as 'rich/cheap to the curve'— implying a curve.

Rolldown and RV require the construction of an issuer's curve.

What if something goes wrong

Code	S&P	Moody's	Fitch
1	AAA	Aaa	AAA
2	AA+	Aa1	AA+
3	AA	Aa2	AA
4	AA-	Aa3	AA-
5	A+	A1	A+
6	A	A2	A
7	A-	A3	A-
8	BBB+	Baa1	BBB+
9	BBB	Baa2	BBB
10	BBB-	Baa3	BBB-
11	BB+	Ba1	BB+
12	BB	Ba2	BB
13	BB-	Ba3	BB-
14	B+	B1	B+
15	B	B2	B
16	B-	B3	B-
17	CCC+	Caa1	CCC+
18	CCC	Caa2	CCC
19	CCC-	Caa3	CCC-
20	CC	Ca1	CC
21	C	Ca2	C
22		C	DDD
23			DD
24	D		D
25	NR	NR	NR

https://www.msci.com/research-and-insights/insights-gallery/probabilities-of-default-in-the-corporate-bond-market

Toy unscientific default model
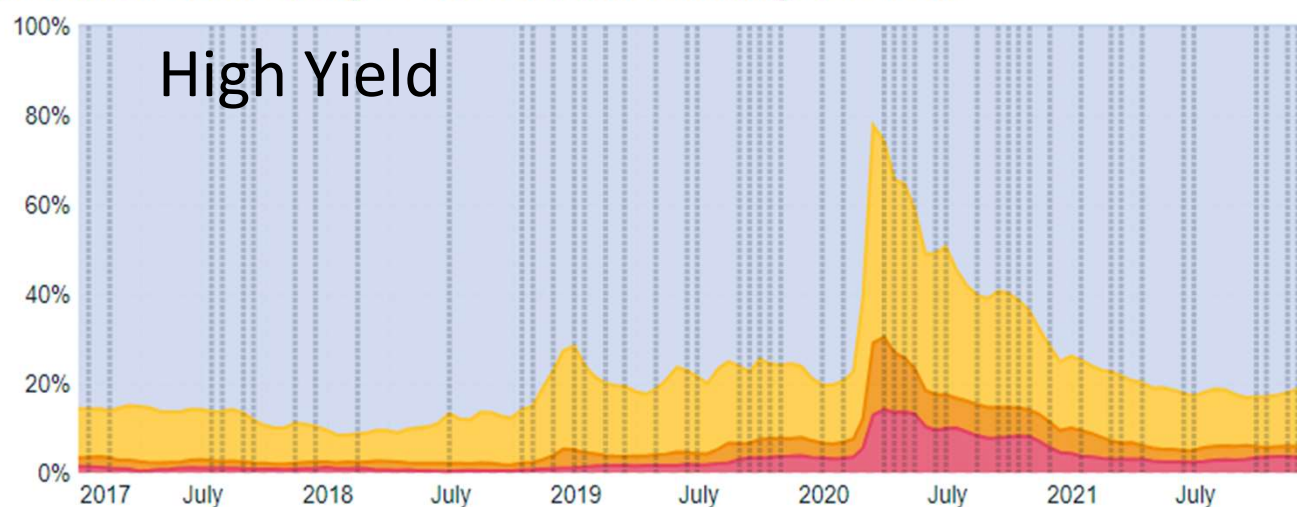
- Default-free DCF pricing

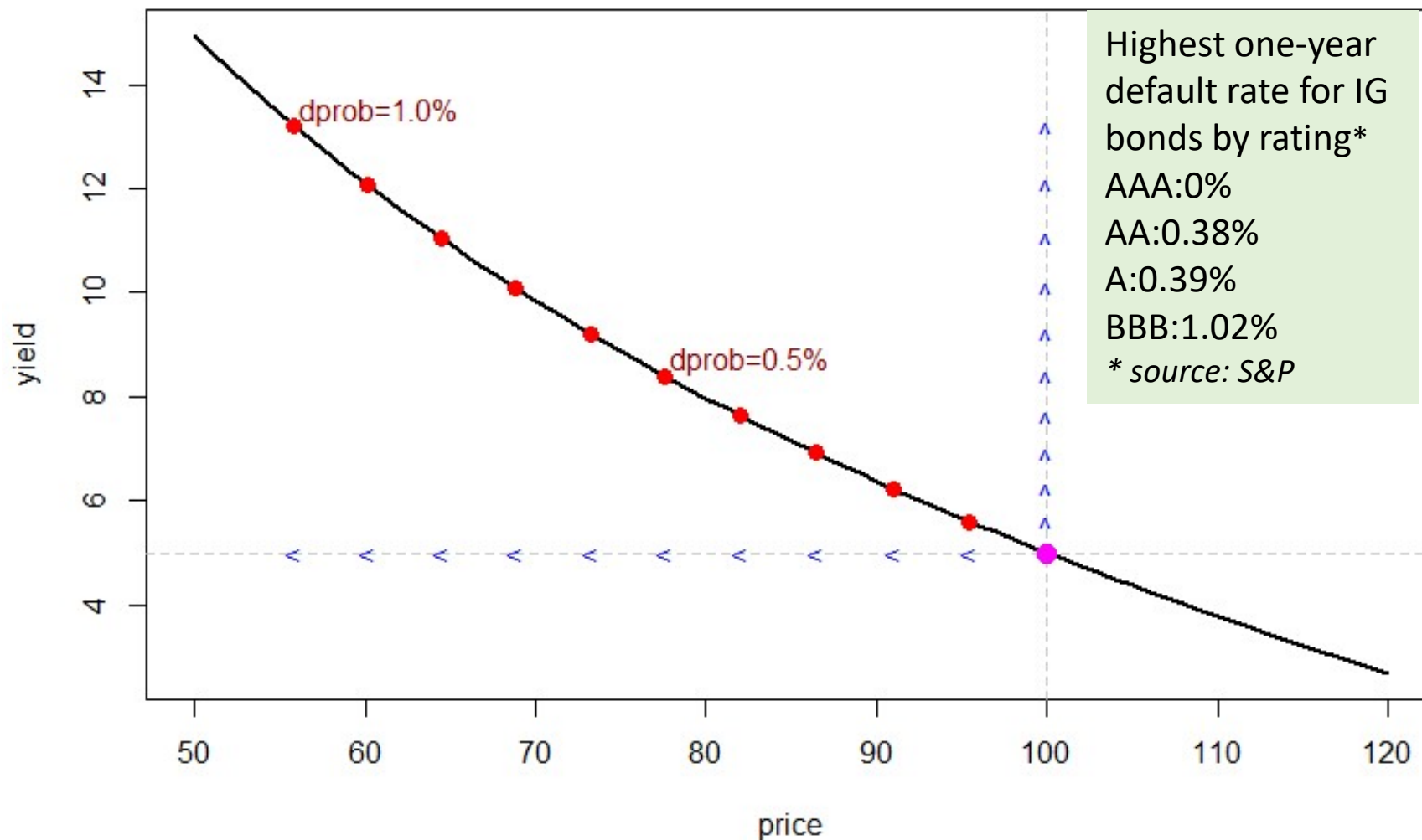$$P(k = 1, n) = \sum_{k=1}^{n} \frac{C_k}{(1 + y_k/2)^k} + \frac{F}{(1 + y_n/2)^n}$$

- Assume default rate d per period.
  - The in the periods will be losing future cash flows.
  - Probability of default in period k but not sooner $d(1 - d)^k$
  - Assume zero recovery rate. Normally 40-50% recovery

$$P_D = P(n) - \sum_{k=1}^{n} d(1 - d)^k P(k, n)$$

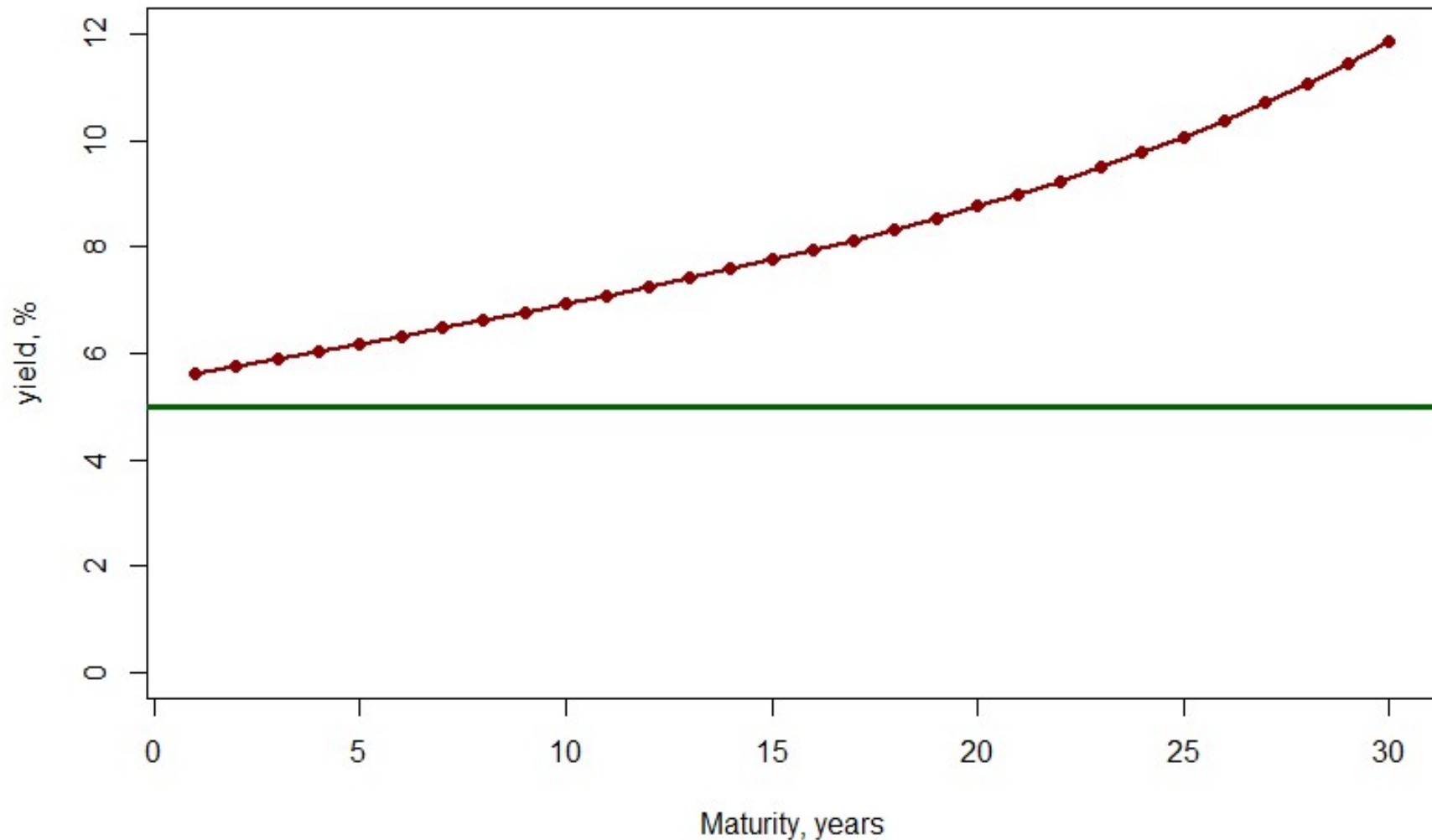For simplicity assume flat yield curve with $Y_{zero}(t)=5\%$

bullet bond 5% coupon trading at par

Highest one-year default rate for IG bonds by rating*
AAA:0%
AA:0.38%
A:0.39%
BBB:1.02%
source: S&P

Higher yield needed to compensate for expected default loss

Yield vs maturity for default prob=0.3% per year

[A Practical Guide to the Valuation of Coupon-Bearing Fixed Income Securities](#), RA. Jarrow and DR. van Deventer (Kamakura)

Credit spreads

- Spread to treasury: $Y_{bond} - Y_{bm}$
  - Y_{bm} nearest on-the-run (recently issued), aka OTR, treasury
  - No curves involved – simple
  - Widely used for quoting
  - Maturity mismatch
  - Jumps when new treasuries are issued and benchmark changes

<18	[18, 48)	[48, 72)	[72, 96)	[96,180)	>=180
CT2	CT3	CT5	CT7	CT10	CT30B

- G-spread: spread to a hypothetical treasury
  - Yield - DCF(zero t-curve, cashflow)
  - Use of the zero curve
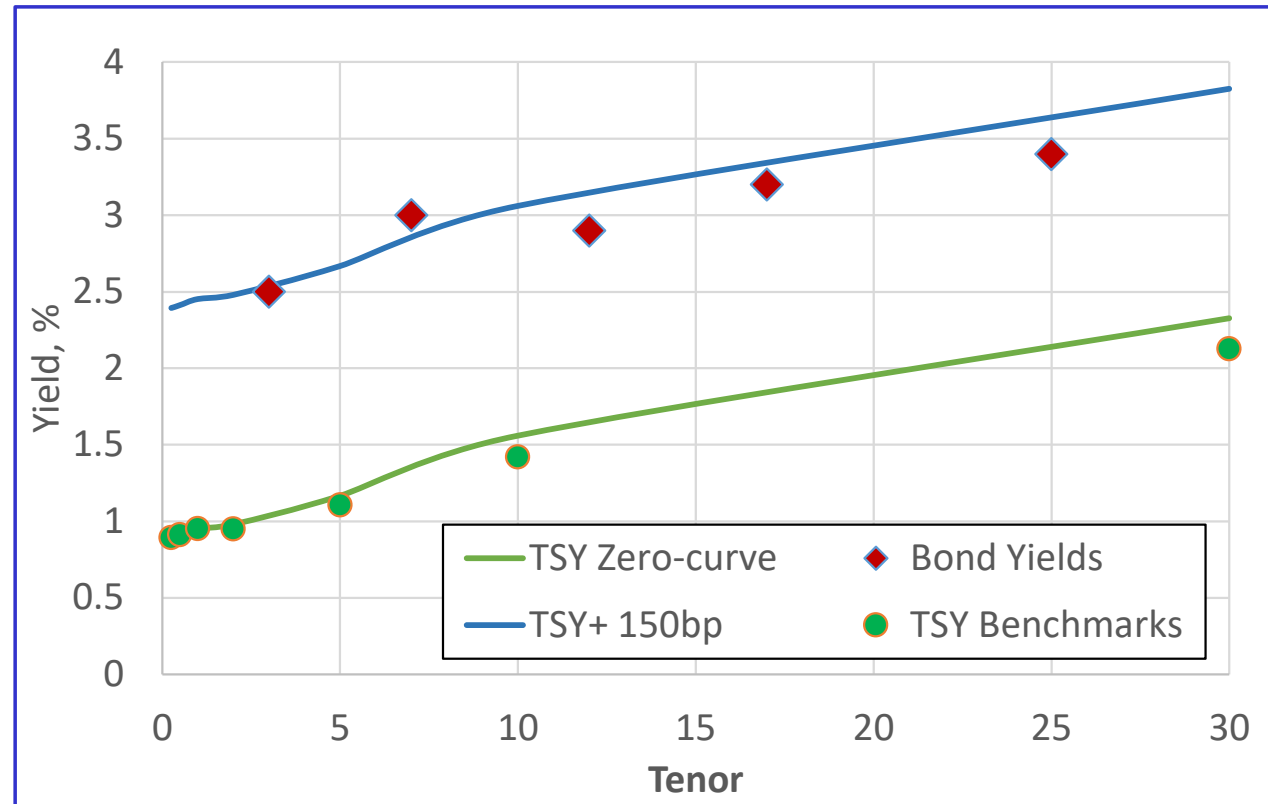 - Independent of individual TSY behavior.
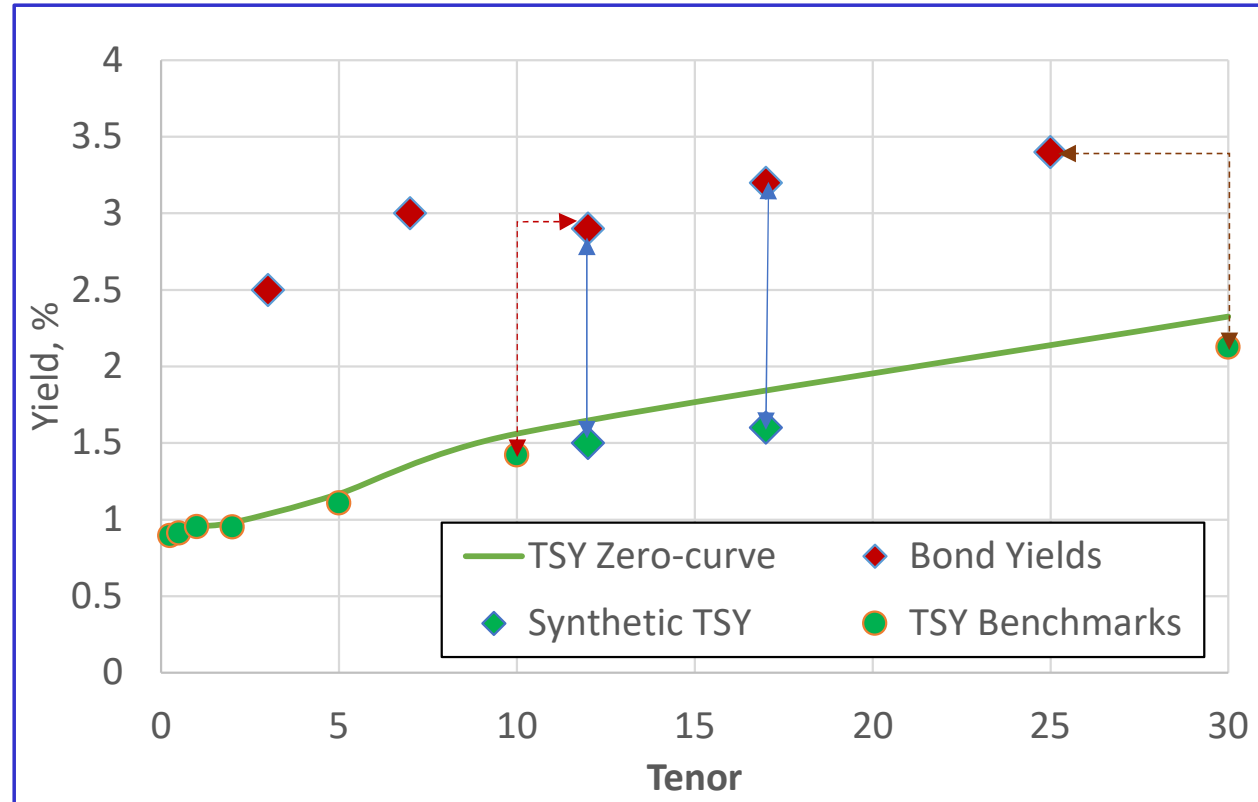
Credit spreads

- Z-spread or zero-curve spread
  - By how much I need to shift zero-coupon treasury curve y_k to get current bond price/yield
  - Useful for comparing bonds and simple models of bond spreads (with a constant)
  - $P = \sum_{k=1}^{n} \dfrac{C_k}{(1+(z+y_k)/2)^k} + \dfrac{F}{(1+(z+y_n)/2)^n}$
  - Solve for z, given P, and y_k
  - Z-spread is bond-specific

[The credit spread curve I: Fundamental concepts, fitting, par-adjusted spread, and expected return](#) by R.J. Martin (2022)

Security Master

- Bloomberg back-office
- ThomsonReuters aka Refinitiv (LSEG)
- Venues (subsets of instruments and fields)
- Exchange-Traded Funds

FIGI	Name	Ticker ↑	Exchange Code	Security Type
Filter	Filter	Filter	Filter	Filter
BBG001B59334	ANHEUSER-BUSCH INBEV WOR	ABIBB 3.65 01/15/16 MPLE	NOT LISTED	PRIV PLACEMENT
BBG00BW1Q8V7	ANHEUSER-BUSCH INBEV FIN	ABIBB 3.65 02/01/26	TRACE	GLOBAL
BBG00NWNWYZ5	ANHEUSER-BUSCH CO/INBEV	ABIBB 3.65 02/01/26 *	NEW YORK	GLOBAL
BBG00MJFVPK5	ANHEUSER-BUSCH CO/INBEV	ABIBB 3.65 02/01/26 144A	TRACE	PRIV PLACEMENT
BBG00MJFVV59	ANHEUSER-BUSCH CO/INBEV	ABIBB 3.65 02/01/26 REGS	TRACE	EURO-DOLLAR

https://www.openfigi.com/search#!?page=1&simpleSearchString=anheuser&marketSector=Corp&facets=

Bond Symbology

- CUSIP (US+Canada) Equities, Credit, Treasurues
  - Entity(numeric 6) + instrument(charnum 2) + checksum(1) : 035242*AP*1
  - Tends to run out, messed up by M&A
  - Can be all numbers, messes up parsers
  - "9128" US Treasury
- ISIN (international)
  - Country(2) + InternalID (9) + checksum(1): US035242AP13
  - Incorporates CUSIP for US and CA
  - https://www.boerse-frankfurt.de/bonds/search
- CINS
  - Cusip-like format for non-US instruments
- SEDOL
- FIGI
  - BBG00BW1Q8V7 free in openFIGI API
  - https://www.openfigi.com/search#!?page=1&simpleSearchString=US035242AP13

Do secmaster fields matter?

- Issuer – Ford vs Ford Fin Svs
- Callable/puttable/make-whole bond?
    - Call schedule [(date1,price1}, (date2,price2),…]
    - Call at Maturity-30d
    - Call notice period
    - Called (yes/no)
- RegS / 144A – issues for institutional investors
- Coupon
    - Step-up, first coupon payment, long/short first|last, floating rate
- Sinkable
- Insured, asset-backed
- Issue date, issueSize, amountOutstanding, float
- Bond rating; place in capital structure (Senior/Junior)
- minSize, minIncrement ➔ Can be overloaded by venue or traders

What affects bonds prices?

- 5-6-7-8 Factor models
  - https://faculty.georgetown.edu/qw50/RiskFactor.pdf
  - downside risk, credit risk, and liquidity risk positively predict the cross-sectional variation in future bond returns.

- Trade Price Clustering
  - https://www.emerald.com/insight/content/doi/10.1108/CFRI-02-2022-0013/full/pdf?title=trade-price-clustering-in-the-corporate-bond-market

How do we know default prob?
...and do we need to know it?

- Ratings (Moody's, S&P, Fitch)
  - Derived from capital structure
    https://www.moodys.com/sites/products/defaultresearch/2006200000425249.pdf

- Market Pricing
  - How much cheaper is a bond than a risk-free bond in the market?
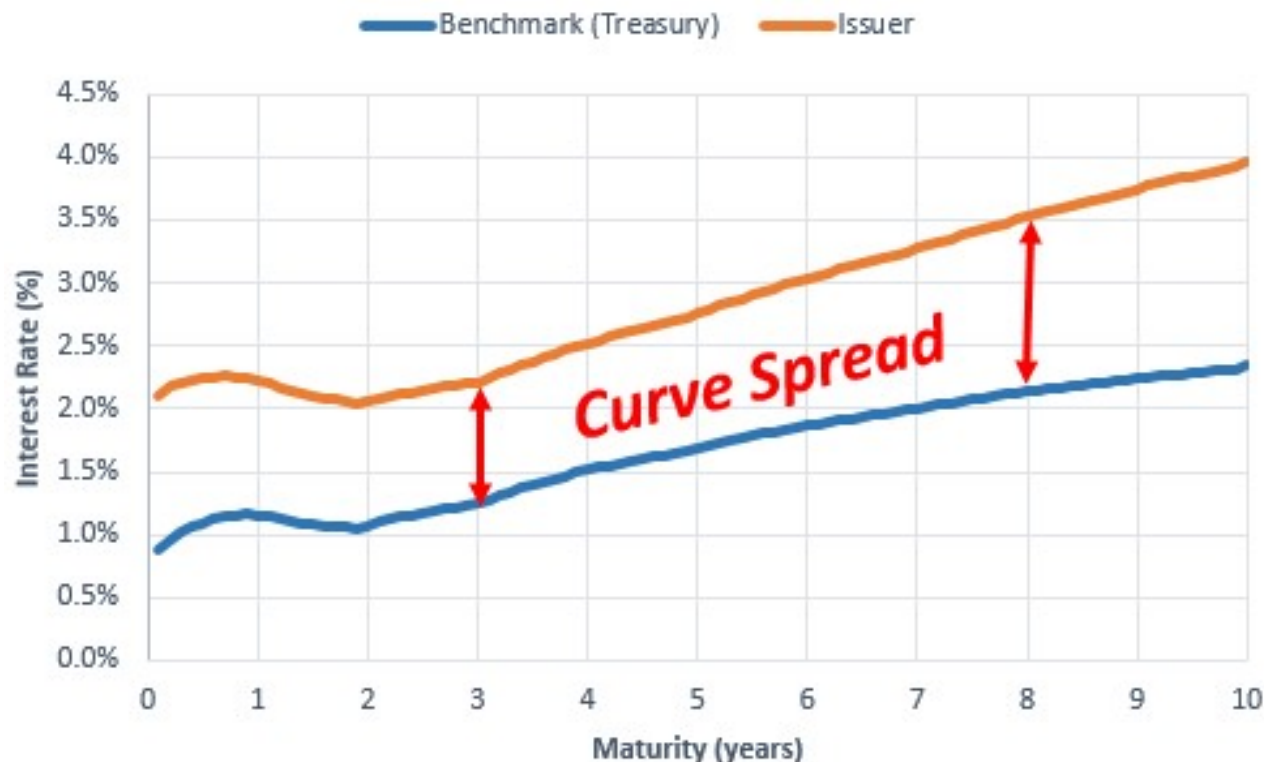
# Systematic trading? Let's try to build a corporate bond trading system.

- Green-field vs legacy?
- List of instruments
- Market Data – can be voluminous
- Model
  - Signals. What time scale?
  - Risk model / inventory management
  - Quoting/trading
- Strictly speaking Systematic != Automated
- Connectivity to the venues or clients
- Reporting (sell-side)
- Allocation, constraints (buy-side)

Market Data

- Distributed over FIX (Financial Information eXchange)
  - tag=value text based
  - 10k msg/second
  - https://fixparser.targetcompid.com/ for quick debugs
- Order, IOI,
  - datetime, symbol, side, action, price, pType, msgId, [refMsgId]
  - Action = [New(Add),   Change(Modify), Delete(Cancel)]
  - pType = [Percentage, Yield(yieldType), Spread (benchmark)]
- Quote
  - datetime, symbol, bid, bidSize, ask, askSize, pType, quoteId
  - priceType = [Percentage, Yield(yieldType), Spread (benchmark)]
- Permissioning – not everyone sees everyone quotes

Market Data: quote and orders

09:03:13 symbol=00206RBH4 side=S price=100.300 size=75 action=ADD   id=12
09:13:21 symbol=00206RBH4 side=S price=100.255 size=75 action=MODIFY id=13 ref=12
09:25:21 symbol=00206RBH4 side=S price=100.155 size=75 action=MODIFY id=14 ref=12
09:31:44 symbol=00206RBH4 side=S price=100.250 size=75 action=CANCEL id=15 ref=12
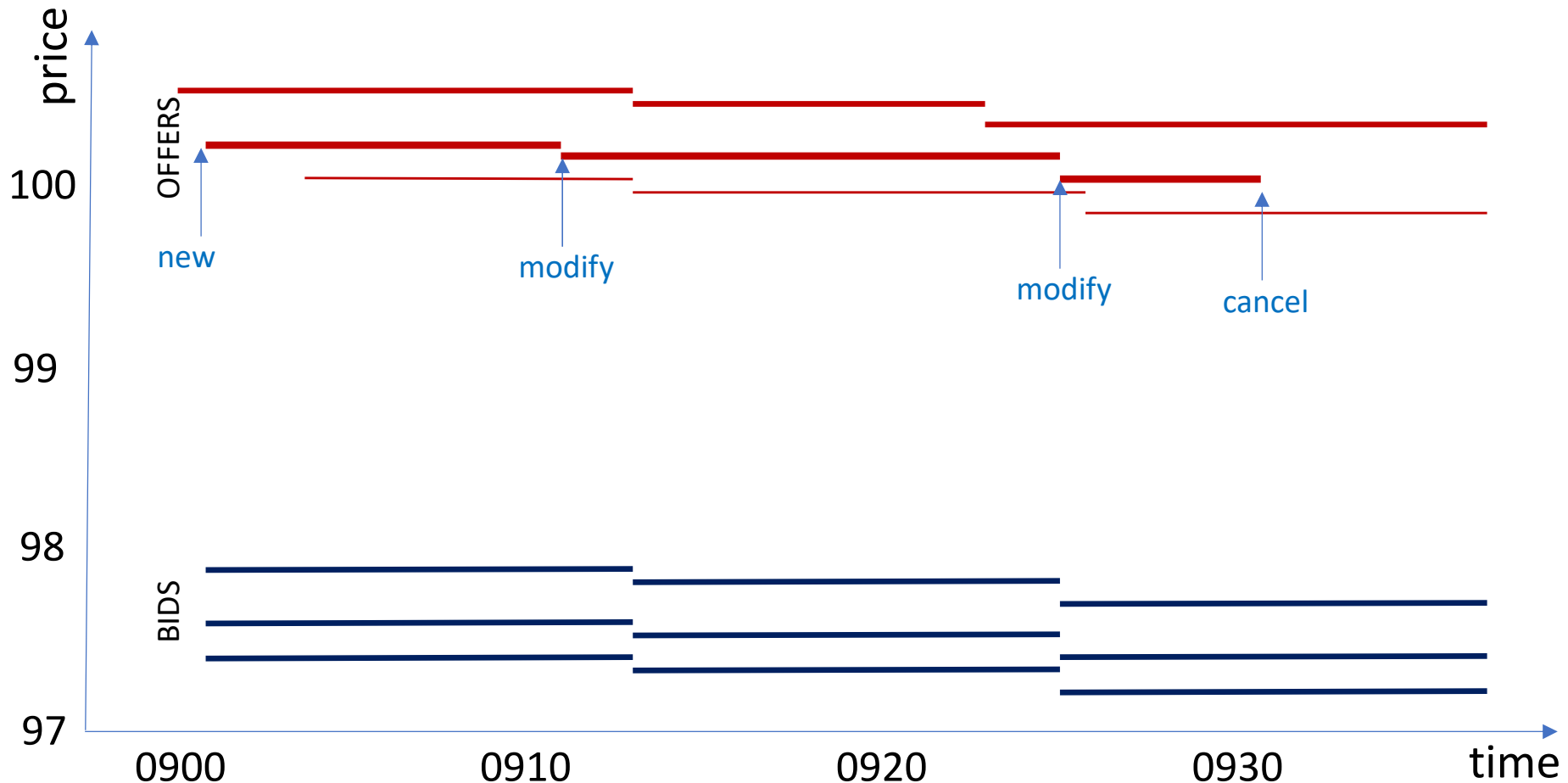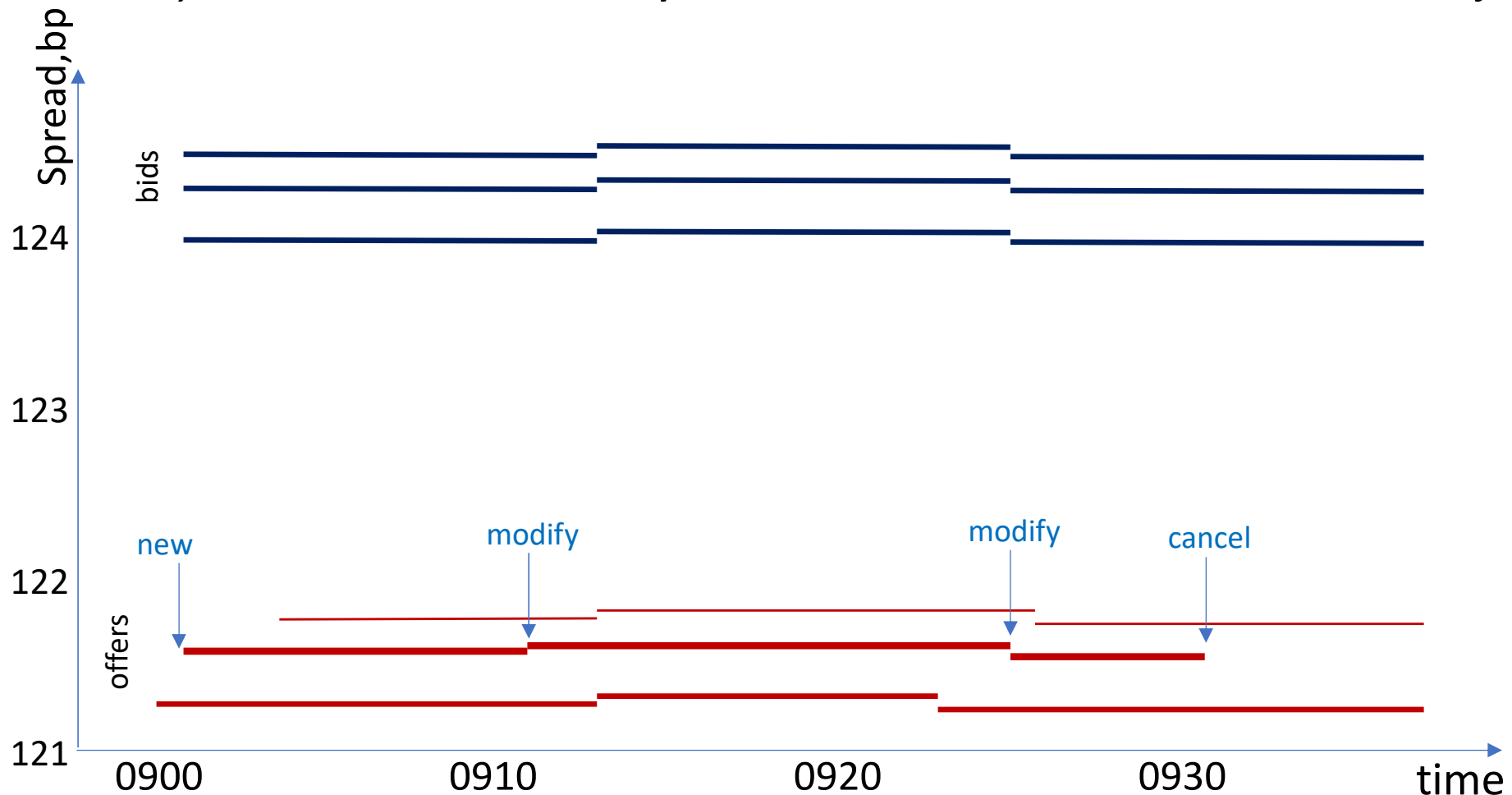
Market Data: order book

09:03:13 symbol=00206RBH4 side=S **yield=5.627** size=75 action=ADD   id=12
09:13:21 symbol=00206RBH4 side=S **yield=5.627** size=75 action=MODIFY id=13 ref=12
09:25:21 symbol=00206RBH4 side=S **yield=5.631** size=75 action=MODIFY id=14 ref=12
09:31:44 symbol=00206RBH4 side=S **yield=5.631** size=75 action=CANCEL id=15 ref=12
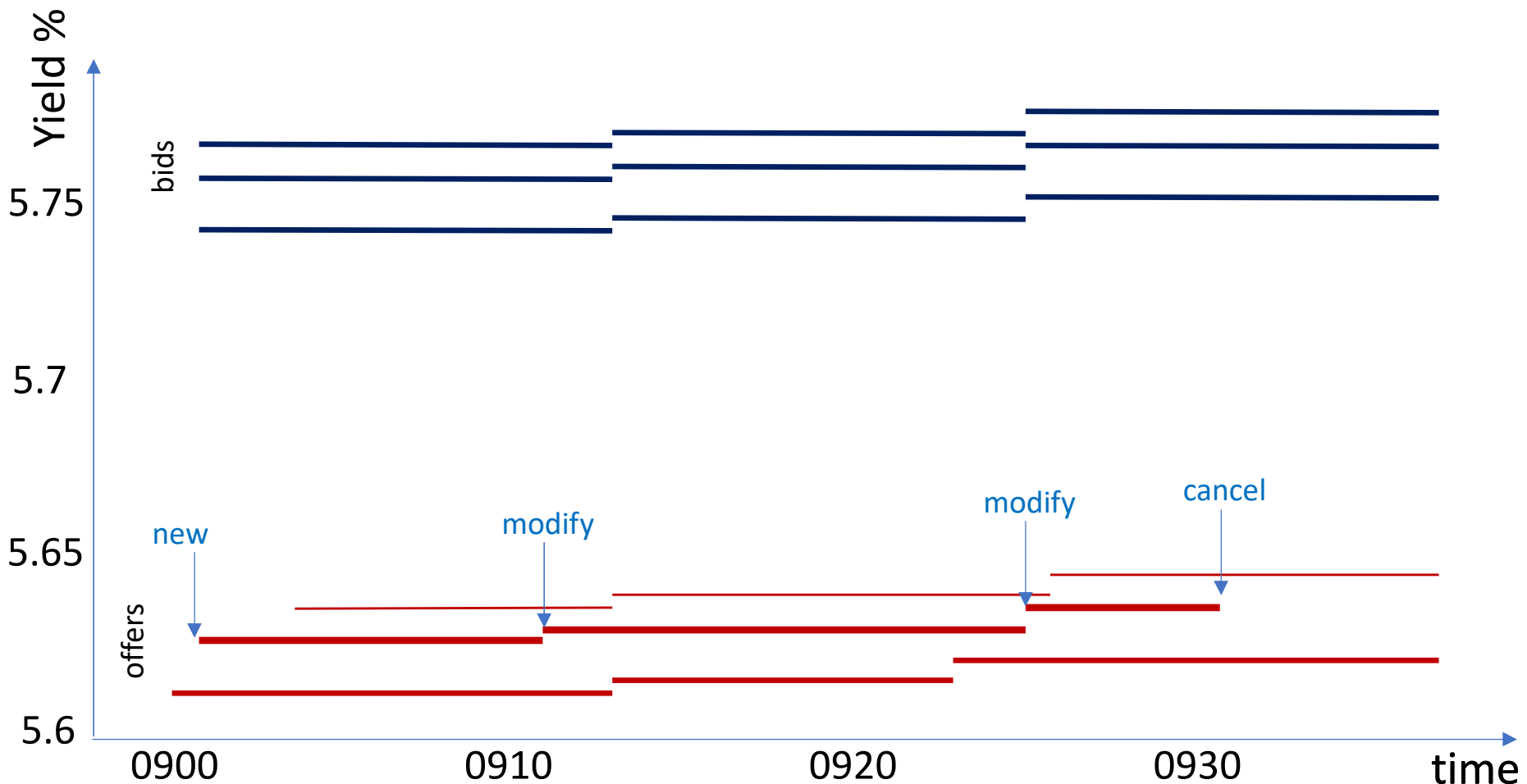
Market Data: order book

*09:03:13 symbol=00206RBH4 side=S **spread=121.5** size=75 action=ADD   id=12*
*09:13:21 symbol=00206RBH4 side=S **spread =121.6** size=75 action=MODIFY id=13 ref=12*
*09:25:21 symbol=00206RBH4 side=S **spread =121.5** size=75 action=MODIFY id=14 ref=12*
*09:31:44 symbol=00206RBH4 side=S **spread =121.5** size=75 action=CANCEL id=15 ref=12*

TRACE
Trade Reporting and Compliance Engine

https://www.finra.org/filing-reporting/trace
http://www.finra.org/sites/default/files/BTDS-specs-v4.4.pdf

- Introduced 2003
- Documented evidence of improved transparency (e.g. lower bid-offer spread)*
- Expanded to structured productes and 2012, treasuries 2023
- Portfolio Trading indicator for corporate bonds added May 2024

Each dealer or market venue trade has to be report its trades to FINRA
RPS – Reporting Party Side [**B**uy|**S**ell]
RPT – Reporting Party Type [**D**ealer]
CPT – Counterparty Type [**C**lient|**A**ffiliate|**D**ealer|A**T**S]
ATS – Automated Trading System [YES|*blank*]

Clean-up
- For each cusip order transactions by size, then execution time.
- For matching size and ts, "D"+"S"="S"; D+D+S=S; S+B=D etc.
- Mark "compressed" entries.

Derived data for modeling and universe filtering (examples)
- Compute daily volume on cleaned data
- Compute daily ADV and ADV-250 (retail trades) files.
- Trade imbalance (buy minus sell)

Capital Commitment and Illiquidity in Corporate Bonds Hendrik Bessembinder et al, 2016

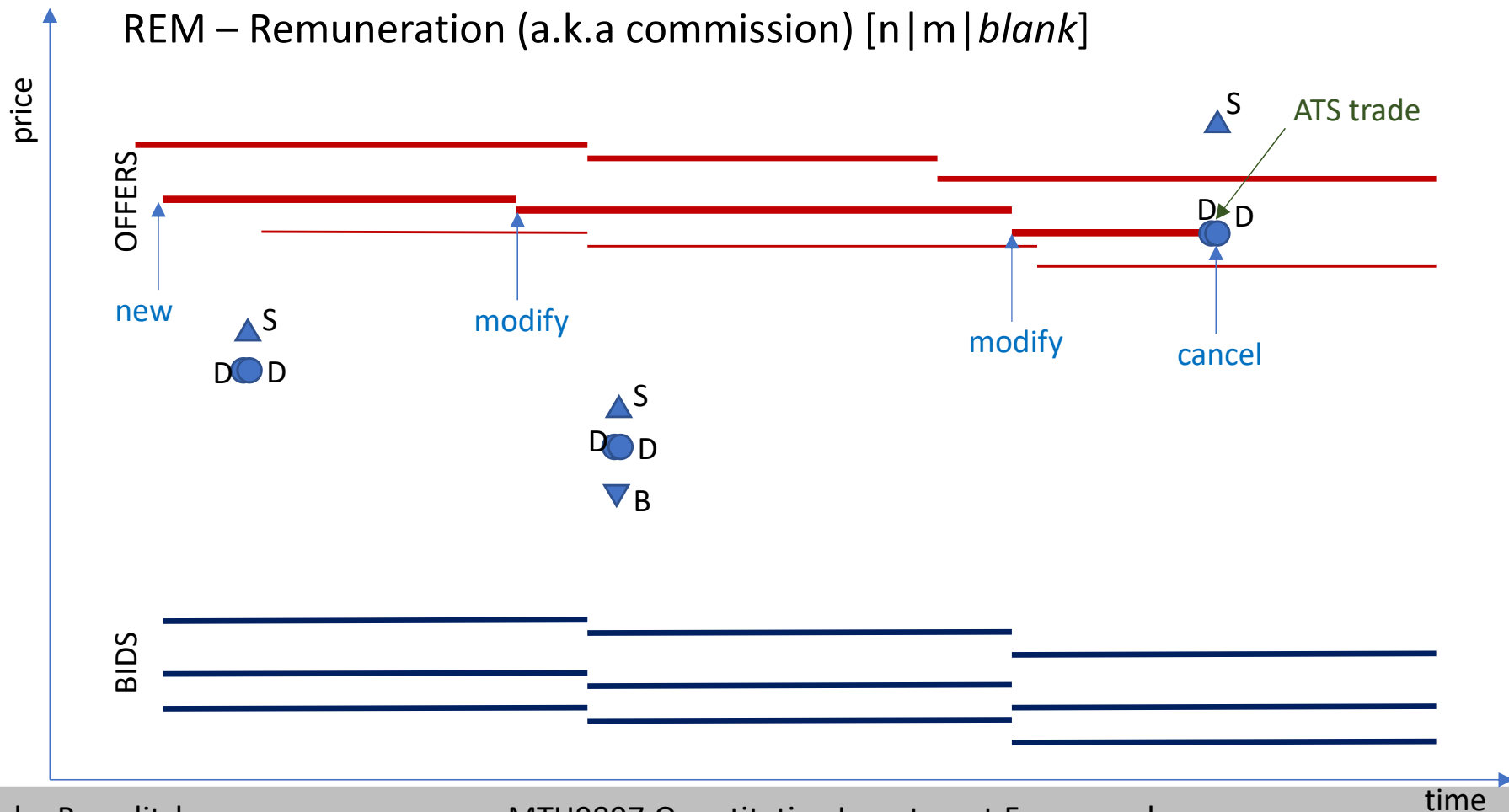RPS – Reporting Party Side [**B**uy|**S**ell]
RPT – Reporting Party Type [**D**ealer]
CPT – Counterparty Type [**C**lient|**A**ffiliate|**D**ealer|A**T**S]
　　　for practical purposes C==A and D==T
ATS – Automated Trading System [YES|*blank*]
REM – Remuneration (a.k.a commission) [n|m|*blank*]

TRACE matching example

RPS – Reporting Party Side [**B**uy|**S**ell]

RPT – Reporting Party Type [**D**ealer]

CPT – Counterparty Type [**C**lient|**A**ffiliate|**D**ealer|A**T**S]

ATS – Automated Trading System [YES|*blank*]

Date	Time	Size(M)	Price	Yield	RPS	RPT	CPT	Sprd	Trd Date	Trd Time	Rem	ATS	IGNORE	SIDE
11-Aug	16:14:21	3	99.95	N.A.	S	D	D	NA	11-Aug	16:14:12			NO	B
11-Aug	16:14:21	3	99.95	N.A.	B	D	C	NA	11-Aug	16:14:12	n		YES	
11-Aug	15:45:16	35	100.279	N.A.	S	D	C	NA	11-Aug	15:45:12	m			
11-Aug	14:29:41	5	100.205	N.A.	S	D	D	NA	11-Aug	14:29:41			NO	B
11-Aug	14:29:41	5	100.17	N.A.	B	D	C	NA	11-Aug	14:29:40	m		YES	
11-Aug	13:35:29	76	100.161	N.A.	B	D	C	NA	11-Aug	13:35:25	m			
11-Aug	11:24:02	55	100.117	N.A.	B	D	C	NA	11-Aug	11:23:42	n		YES	
11-Aug	11:24:02	55	100.117	N.A.	S	D	D	NA	11-Aug	11:23:42			NO	B
10-Aug	17:12:06	200	100.3	N.A.	S	D	C	NA	10-Aug	17:12:05	m			
10-Aug	**14:29:05**	**500**	**100.228**	**N.A.**	**S**	**D**	**D**	**NA**	**10-Aug**	**14:27:00**			**???**	**???**
10-Aug	14:22:09	13	100.26	N.A.	S	D	D	NA	10-Aug	14:21:31				
10-Aug	**14:21:47**	**500**	**100.208**	**N.A.**	**S**	**D**	**D**	**NA**	**10-Aug**	**14:21:45**			**???**	**???**
10-Aug	13:50:42	2	100.127	N.A.	B	D	C	NA	10-Aug	13:46:16	m			
10-Aug	10:31:34	5	100.309	N.A.	S	D	D	NA	10-Aug	10:31:01		Y	NO	S
10-Aug	10:31:05	15	100.309	N.A.	S	D	D	NA	10-Aug	10:30:43		Y	NO	S
10-Aug	10:31:01	5	100.309	N.A.	S	D	C	NA	10-Aug	10:31:00	n		YES	
10-Aug	10:30:42	15	100.309	N.A.	S	D	C	NA	10-Aug	10:30:40	n		YES	
10-Aug	10:14:14	530	100.322	N.A.	S	D	C	NA	10-Aug	10:13:12	m			
9-Aug	12:01:32	4	100.188	N.A.	S	D	C	NA	9-Aug	12:01:28	m			
9-Aug	11:56:20	10	100.02	N.A.	B	D	C	NA	9-Aug	11:56:19	n		YES	
9-Aug	11:56:20	10	100.02	N.A.	S	D	D	NA	9-Aug	11:56:19		Y	NO	B
9-Aug	11:52:55	120	100.188	N.A.	S	D	A	NA	9-Aug	11:52:55	n		NO	B
9-Aug	11:52:55	120	100.162	N.A.	B	D	C	NA	9-Aug	11:52:54	m		YES	
9-Aug	11:45:14	50	100.043	N.A.	S	D	D	NA	9-Aug	11:45:07		Y	NO	B
9-Aug	11:45:14	50	99.963	N.A.	B	D	C	NA	9-Aug	11:45:07	m		YES	

BBG005Q4TXF1
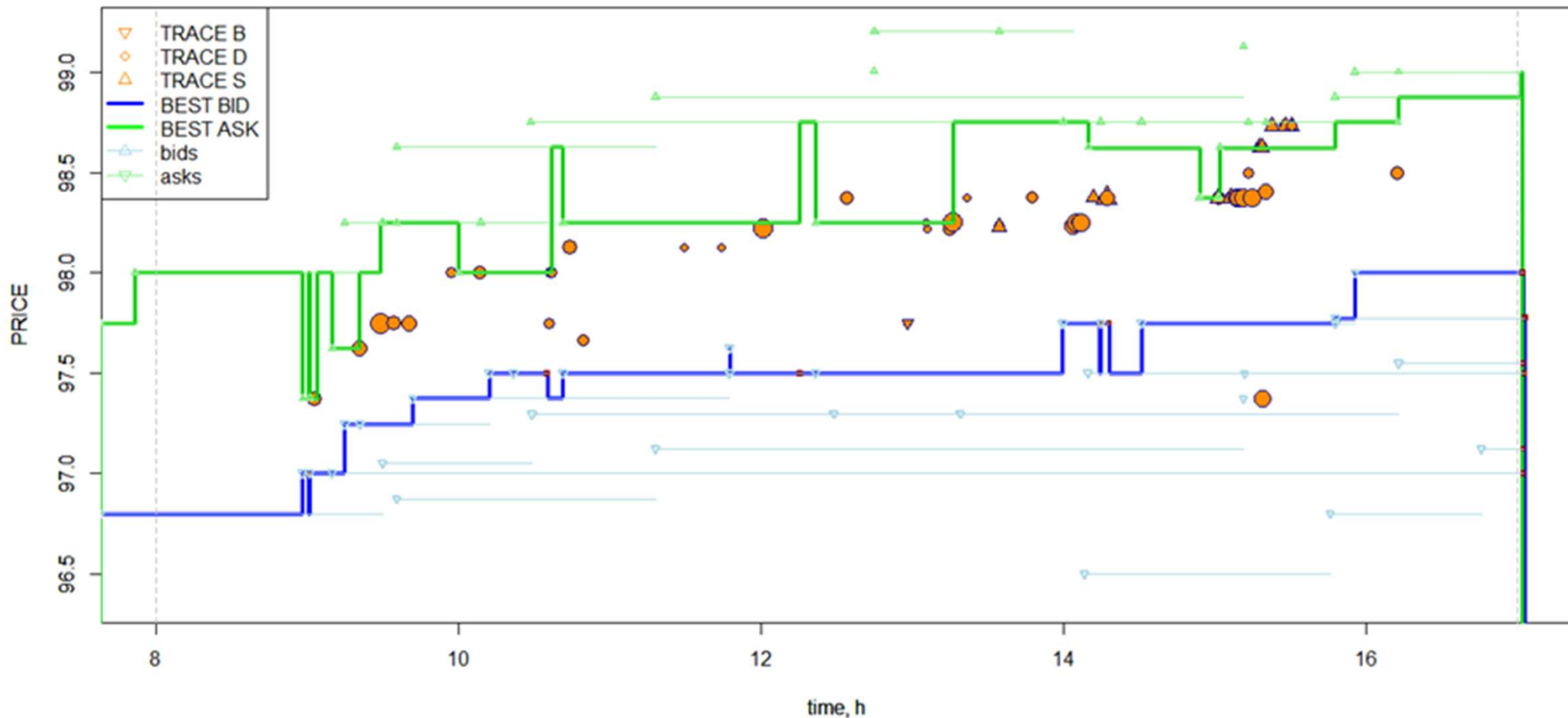
ABIBB 3.65 02/26 (035242AP1)
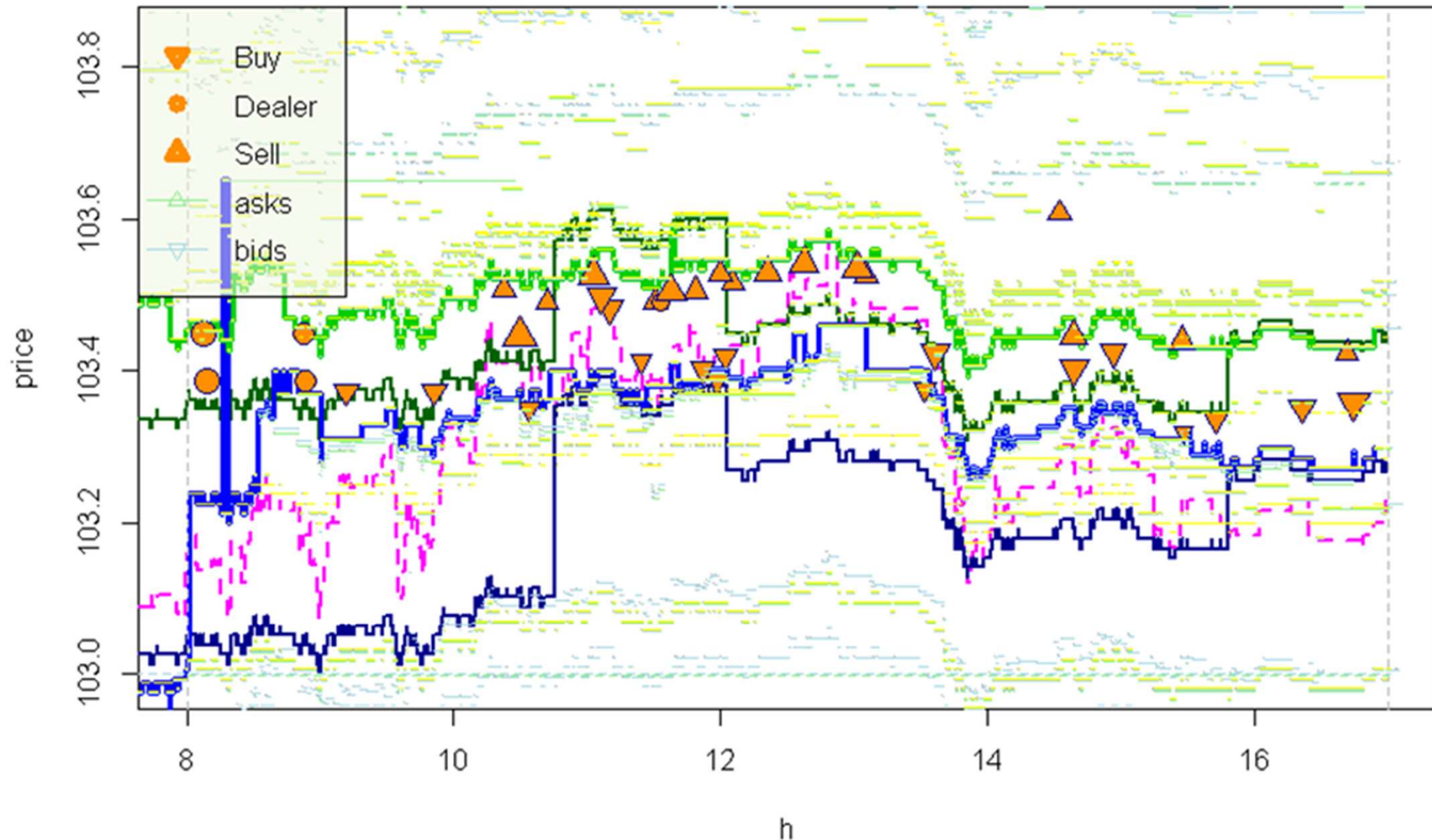
Notes on market data

- Bond with 10 trades in a day is "liquid"

- Most bonds don't trade on a given day

- Quotes can be subject/indicative or firm

- Firm (e.g. Bloomberg 'magenta' quotes) 90% firm

- Prices can be stale

- Spread quotes can be coming with different non-default benchmarks

<18	[18, 48)	[48, 72)	[72, 96)	[96,180)	>=180
CT2	CT3	CT5	CT7	CT10	CT30B

SYSTEMATIC TRADING MTH9897
Lecture 2: Fixed Income
Quantitative Investment Framework

BaruchCOLLEGE | Master of Financial Engineering

WEISSMAN SCHOOL OF ARTS AND SCIENCES

Misha Boroditsky, PhD

Core Quant Strats

Goldman Sachs Asset and Wealth Management

mboroditsky@hotmail.com

Teaching Assistants:

Aneesh Subramanya aneeshsubramanya@gmail.com

Tony Zhang haobo.zhang.baruchmfe@gmail.com

Trading & Technology Landscape

Baruch COLLEGE

Trading mode (in order of complexity)

ATS Liquidity Taking (IBP, TMC, TWD, MTS, ALLQ)
 Hit bid/lift offer ➔
 ⬅ Get trade or DNT
RFQ Taking (MKTX, IBP, TMC, TWD, ALLQ, BOLT)
 Send RFQ ➔
 ⬅ Get Quote
 Accept or DNT (*auto-accept) ➔
 ⬅ Get trade
Auction (TruMid, LiquidNet, GFI)
 Send Interest ➔
 ⬅ Get matching interest
 ⬅ Get trade
RFQ Providing anonymous (MKTX OT, IBP, TMC)
 ⬅ Get RFQ
 Send Quote ➔
 ⬅ Client accepts or DNT (* auto-accept)
 Get trade ⬅
Streaming Quotes Anonymous (MTS, IBP, TMC)
 Send Quote ➔
 Send Quote ➔
 Send Quote ➔
 ⬅ Get trade

Technology

Connectivity (FIX)
 Logon/Logoff/Reconnect
 Normalization to message schema {Order, RFQ, Quote, Trade}.
 Kafka producer/Consumer

Trading engine -- real time event processor

Real time risk management
 e.g. outstanding orders
 trading controls

Load examples
 TRACE (bond trades) < 100K / day
 MSRB (muni trades) < 50K / day
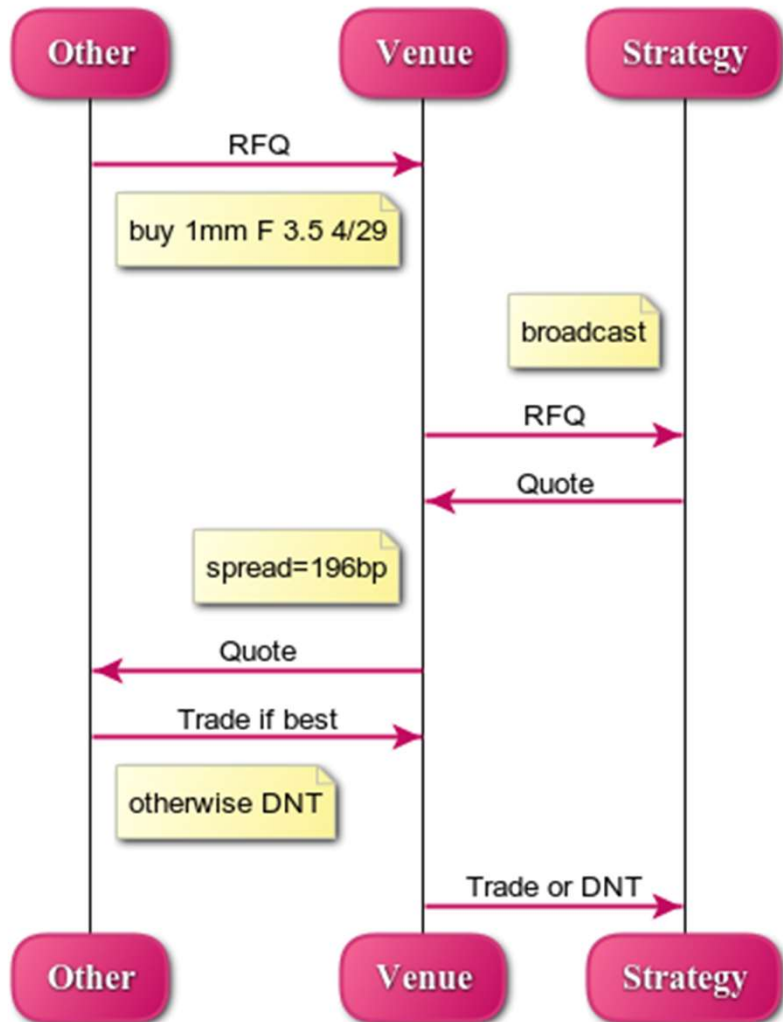 FI RFQ ~ 100K / day
 Runs/Axes ~ 200K / day
 Evaluated CP+ ~ 1000/second
 MarketData ~ 4000/second/venue
 Processed market data ~ 300/sec

Request For Quote

Request For Quote (RFQ)

Other → Venue: RFQ
buy 1mm F 3.5 4/29
broadcast
Venue → Strategy: RFQ
Strategy → Venue: Quote
spread=196bp
Venue → Other: Quote
Other → Venue: Trade if best
otherwise DNT
Venue → Strategy: Trade or DNT

www.websequencediagrams.com

RFQ Attributes
- Symbol & Symbology
  - AltSymbol
- Side
  - From whose perspective?
- Size
- PricingProtocol
  - Pecentage, Yield, Spread
  - Benchmark if Spread
- HoldingBin | ASAP
  - Due Time
  - Firm Until
- RFQ ID
  - To be referenced
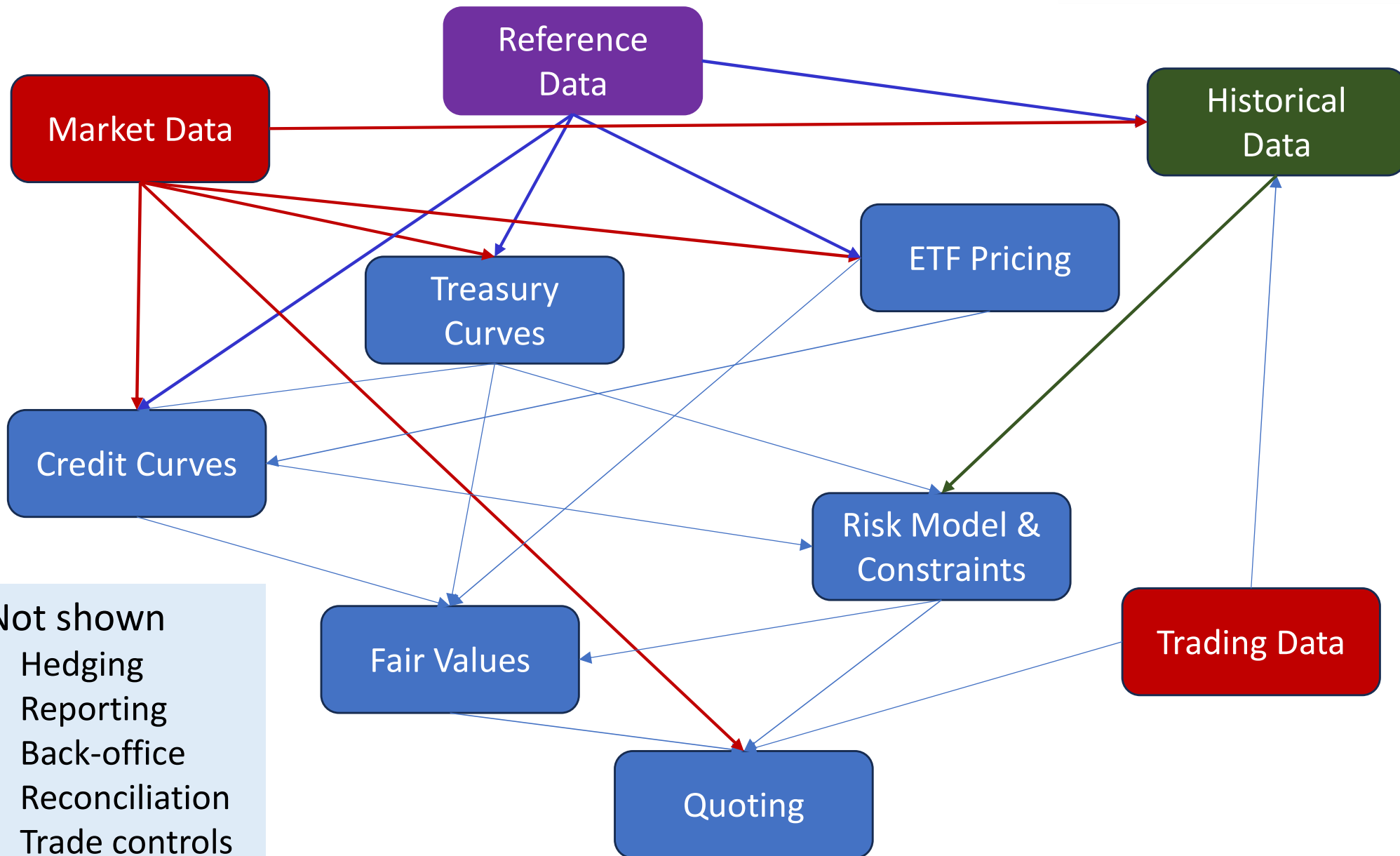- [Sender]
- [# in competition]
- [PartialFillAllowed]

Venues and Data Vendors

VENUES		OrderBook	RFQ	Auction	Sweet spot	Data
MarketAxess Disclosed,OT			YES		>1M & <20K	RFQ, EvalPrice
Bloomberg ALLQ		YES	YES		[1 - 400]	Scraped
Bloomberg BOLT			YES			RFQ
ICE TMC		YES	YES		[25-200]	MD, RFQ
ICE BondPoint		YES	YES		[10 -200]	MD, RFQ
TradeWeb Direct		YES	YES		50-400	MD, RFQ
TradeWeb Institutional			YES			MD, RFQ, EvalPrice
MTS		YES			50K - 1M	MD
NYSE (ICE)		YES				0 MD?
Trumid				YES	6M	Mids, EvalPrice
Liquidnet				YES	3M	
GFI				YES	500+	
Chappy			YES		Muni	
JPM	Single Dealer		YES			MD
MS	Single Dealer	Quotes	YES			MD
Jane St	Single Dealer	Quotes				
Headlands	Single Dealer	Quotes			Muni	
DATA		TYPE				
NEPTUNE		IOI				
TRACE		TRADE			Corp, Treasury, Mtge	
CP+		EVALUATED				
MSRB		TRADE			Muni	
SOLVE		IOI				
CC&S		MUNI IOI				
IDC		EVALUATED				

Request For Quote (RFQ)
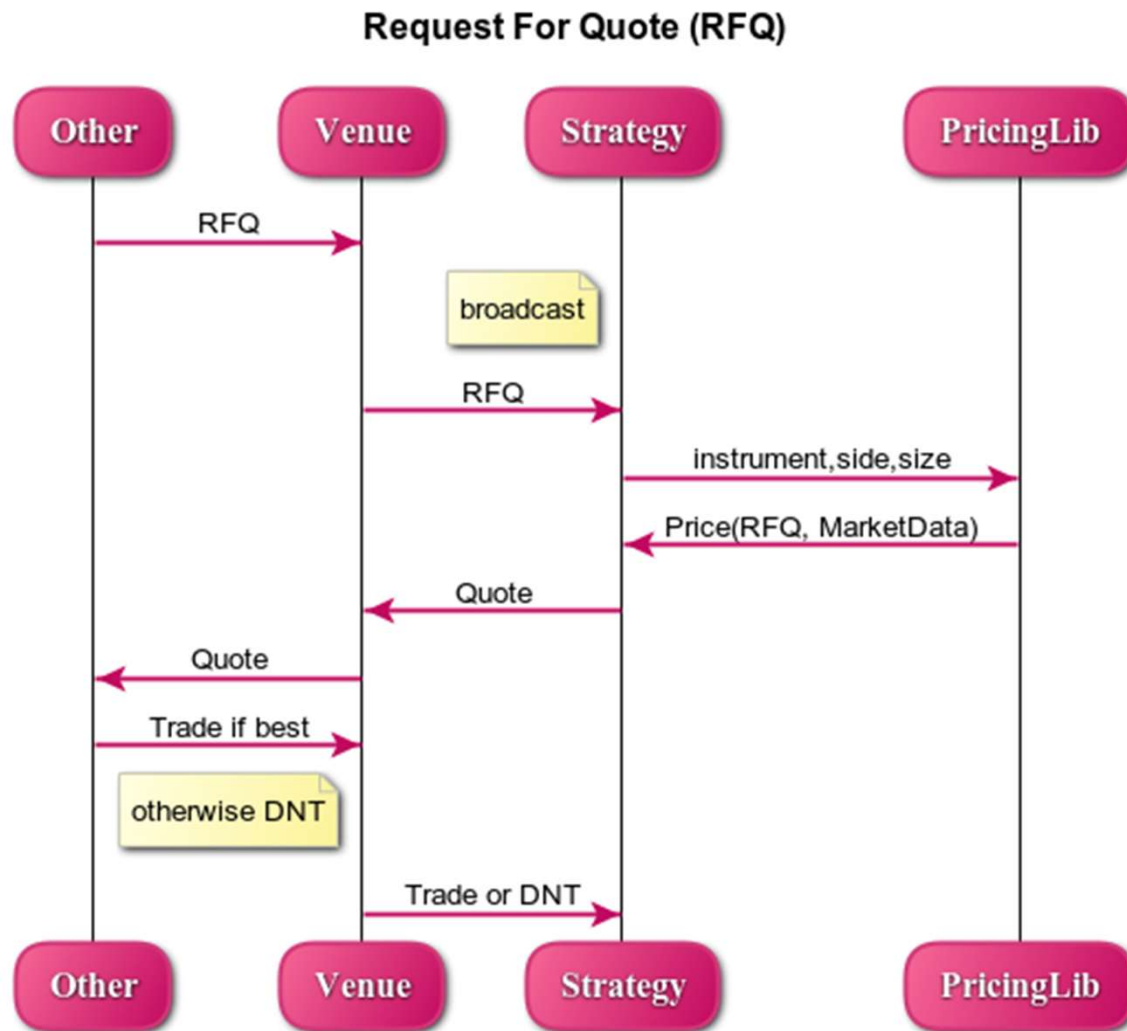
Incomplete* bond trading system

*Not shown
- Hedging
- Reporting
- Back-office
- Reconciliation
- Trade controls

Systematic Bond Trading

- ❖ Preparing Static Data
  - ➢ Acquisition (download, B-Pipe etc)
  - ➢ Filtering/Normalizing, preprocessing
  - ➢ Grouping
- ❖ Market Data Processing
  - ➢ Maintain current state of data (order book)
    - ➢ Data from corporate bond venues
    - ➢ Treasury pricing
    - ➢ Trades (TRACE/MSRB/Venues)
    - ➢ Requests for Quotes
    - ➢ New feeds
  - ➢ Fitting the Functional Form
- ❖ Curve Construction
  - ➢ Updating reference curve
  - ➢ Converting to z-Spread
  - ➢ Fitting the Functional Form
- ❖ Quantifying The Opportunity
  - ➢ Comparing bonds to the curve
  - ➢ Comparing to pricing implied by ETFs
- ❖ Monetizing The Opportunity
  - ➢ Use pricing in market/risk context
  - ➢ Short term tactical signals
  - ➢ Sending order/quotes/RFQ responses
- ❖ Hedging residual exposures
  - ➢ Treasuries
  - ➢ Treasury futures
  - ➢ Fixed Income ETFs (e.g. LQD for corporates, TLT, SHY rates)

- ❖ Classical Portfolio optimization
  - ➢ Implies ability to trade into desired portfolio
  - ➢ Getting different prices is a correcttion
  - ➢ Not getting into position is a correction
  - ➢ Has a baked in assumption about liquidity
- ❖ Credit trading
  - ➢ Multitude of correlated instruments
  - ➢ Trading cost could be comparable to returns on shorter horizion
  - ➢ Most instruments cannot be traded whenever you want
  - ➢ Opportunity-driven optimization is one approach

Filtering Bonds - example

Filter Level (usage)	Basic (store in history)	Tradable (publish prices)	High Quality (used in calibration)
Min Amount Issued	$50M	$50M	$250M
Min Amount Outstanding	$40M	$40M	$200M
Max Average Price Spread	Any	$3	$2
Other Conditions	• Not defaulted • Not matured	• Not called (if callable) • Avg daily volume of large trades ≥ 250K • Quotes with tight bid-ask spread are present > 40% of the day	• Matures at least 1Y away • Avg yield spread < 20 bps • 4+ high quality bonds per curve • Junior/Senior attribution

Grouping Bonds

To construct the curves, we need to arrange the bonds into logical units, related by common features:

- Grouping Characteristics
  - Issuer (e.g., AAPL, GS, MO)
  - Industry (e.g., Financials, Industrials)
  - Rating (e.g., A-, BB+)
  - Industry & Rating (e.g. Financials/BBB)

- Features
  - Distinguish between junior and senior bonds, if necessary
  - Spread from a relevant benchmark curve (called the reference curve)
  - Curve captures common risk of the entire group

Converting Prices to Spreads

- Initialization
  - Prepare the structures
    - ✓ Construct cash flows, calendars, etc.
    - ✓ Construct bond objects

- Real-Time Processing
  - Obtain market prices
  - Calibrate the reference curves
  - Calculate the spreads for each bond
    - ✓ Imply yields from clean prices
    - ✓ Calculate the corresponding values from the base curve
    - ✓ Compute the spreads
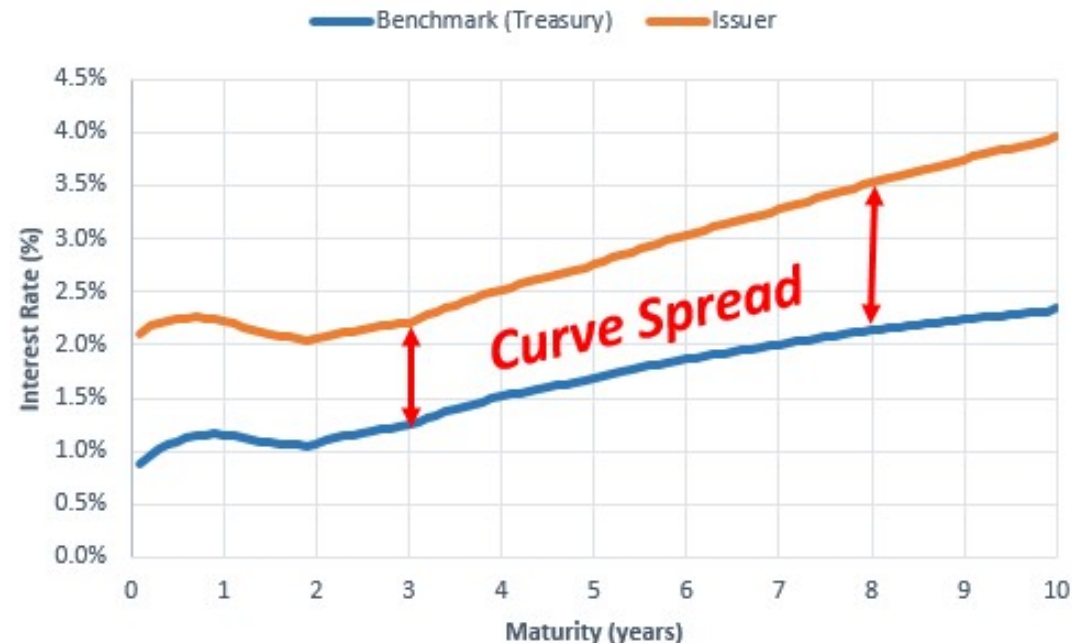
Buy-sell asymmetry

- Most bonds not shorted and are held to maturity
  - munis are a good example
  - Corporates are expensive to short
- Buyer buys **a** bond (any in a group)
  - Chooses be best price among many nearly fungible bonds
- Seller can be motivated (he needs to close on a house, a yacht)
- Seller sells **the** bond (what he owns)
  - Seller sends bid-wanted (RFQ)
  - Dealers compete to buy "at bid"
  - Dealer turns around post liquidity on exchange
- May vary quoting logic between bidding and offering

Constructing the Treasury Curve

- Arrange instruments (anchors) by maturity

- Bootstrap the zero-coupon rates for each anchor
  - Find the (unique) zero-coupon rate to match the theoretical price of the anchor to its market price
  - Interpolate using
    - constant forward or
    - linear log of discount

Treasury Curve Bootstrapping
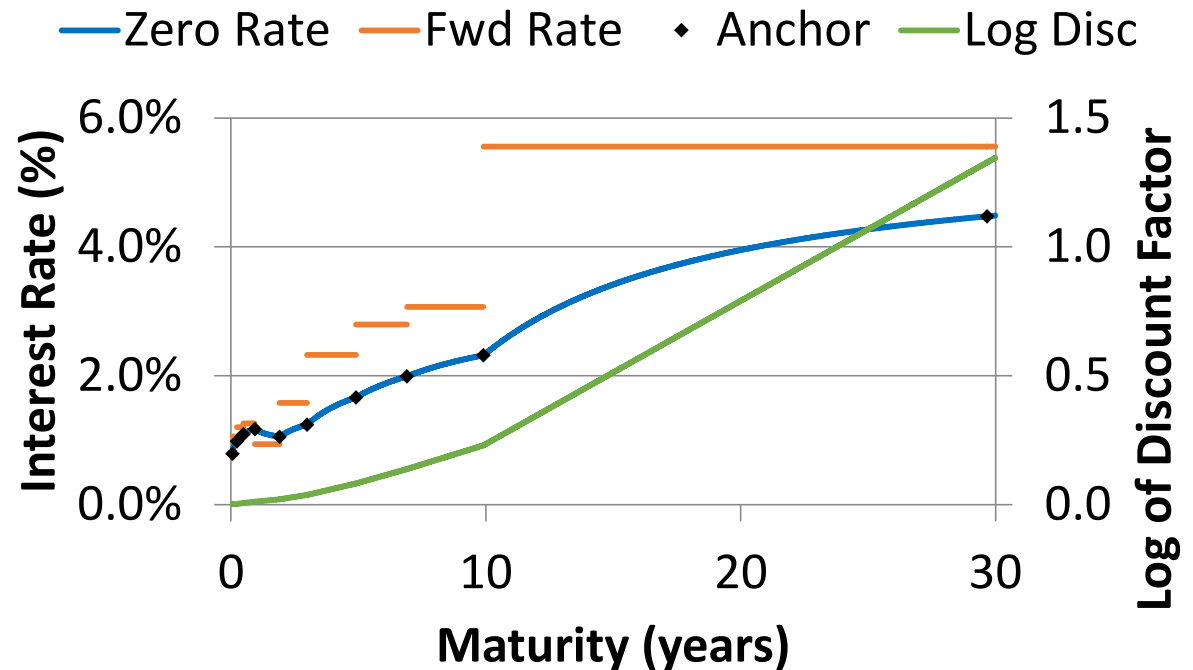
https://www.atlantafed.org/-/media/documents/research/publications/economic-review/2004/vol89no3_fisher.pdf
http://gouthamanbalaraman.com/blog/quantlib-term-structure-bootstrap-yield-curve.html

Constructing the Issuer Curve – Model

Nelson-Siegel 4-Parameter Model

- Assumes implied forward as Laguerre function with constant shift:

$$f_t = L + Se^{-tD} + CDte^{-tD} = L + e^{-tD}(S + CDt)$$

- Resulting zero curve is then

$$z_t = \frac{1}{t}\int_0^t f(s)ds = L + (S + C)\frac{e^{-tD} - 1}{tD} - Ce^{-tD}$$

Nelson, C., & Siegel, A. F. (1987). Parsimonious modeling of yield curves. The Journal of Business, 60(4), 473-89.
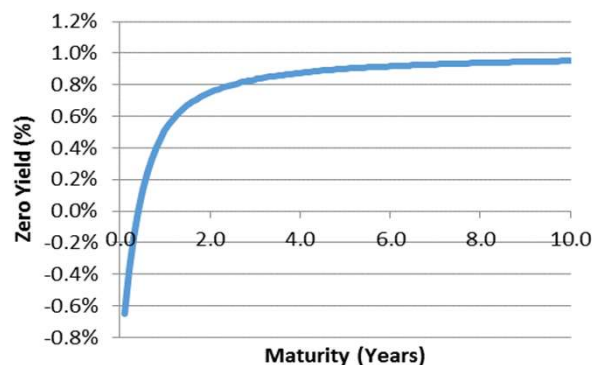
Constructing the Issuer Curve – Intuition

Geometric Interpretation of Parameters

- Level (z_∞), slope ($z_0 - z_\infty$), curvature and decay D
- L, $(S + C)$ and $-C$ are the top 3 principal component factors
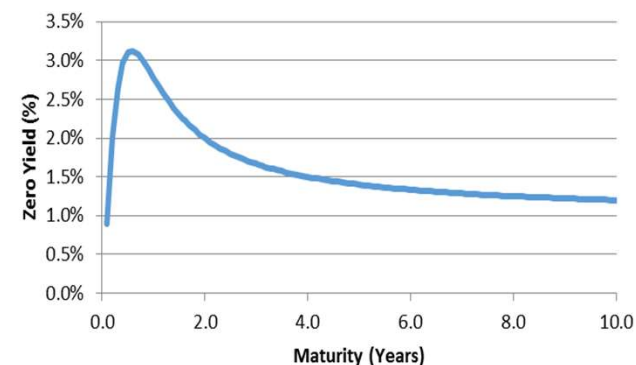- D determines the shape of the curve (location of hump/bend)
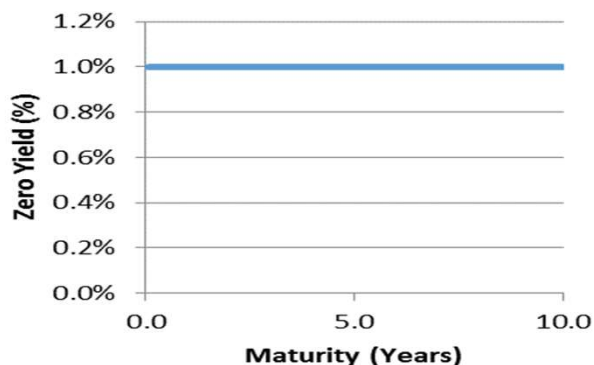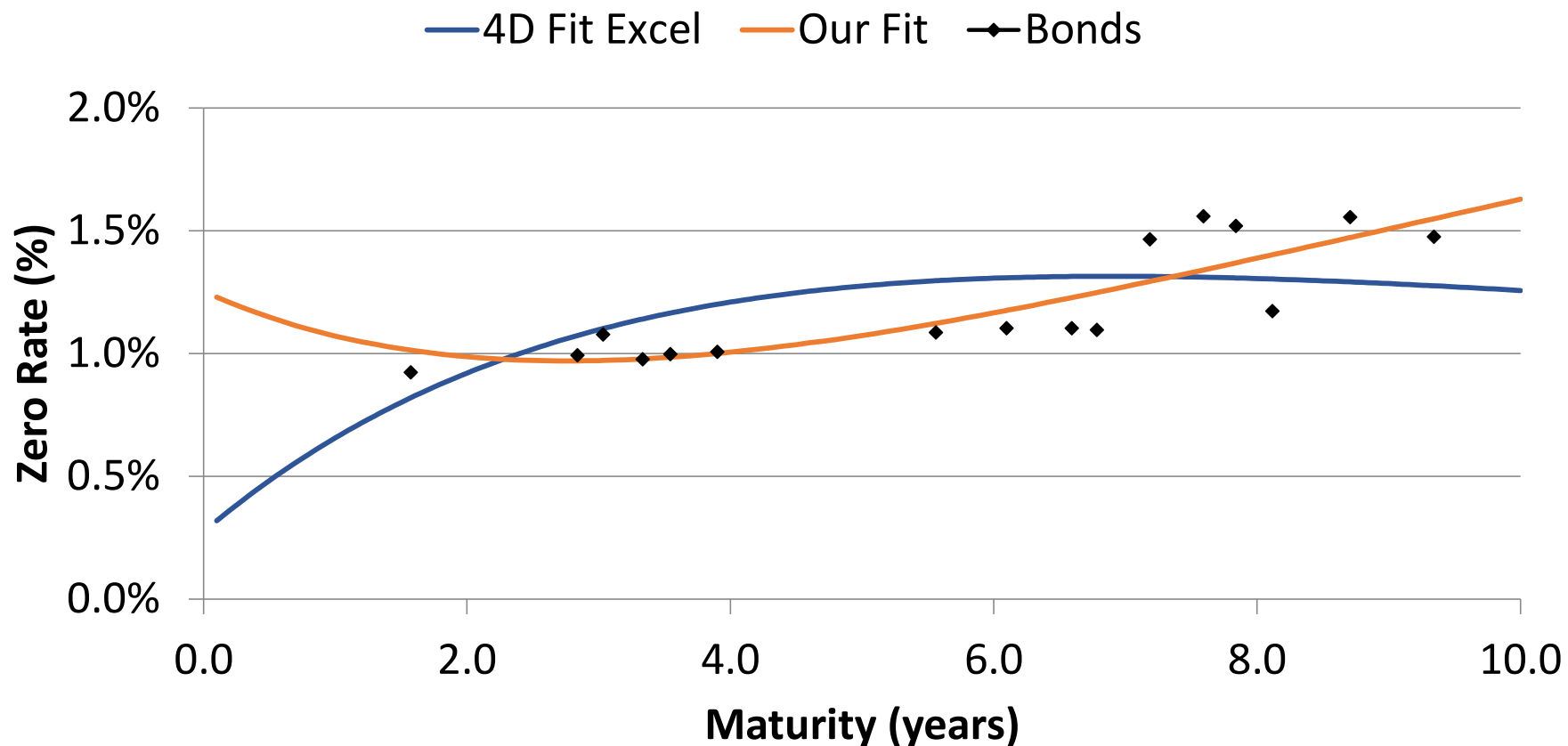
Constructing the Issuer Curve

Optimize model parameter choice

- Exact non-linear optimization in 4-D is computationally intensive

- Clever formulation allows fast progress
  - Work with z-Spread, not with prices directly
  - Finding just level, spread and curvature is a linear least squares problem
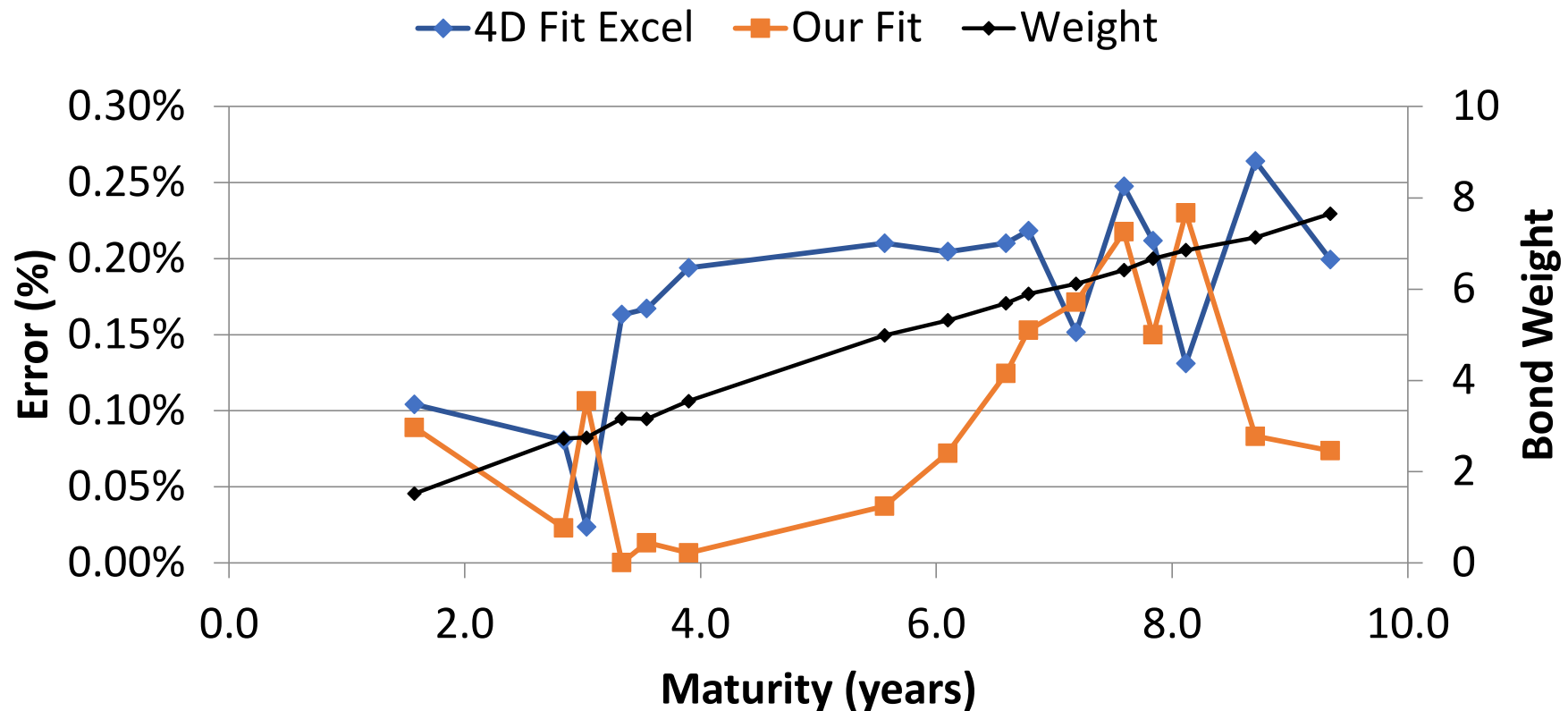 - Decay determined by 1D numerical minimization of the weighted square error

Fitting the Issuer Spread Curve
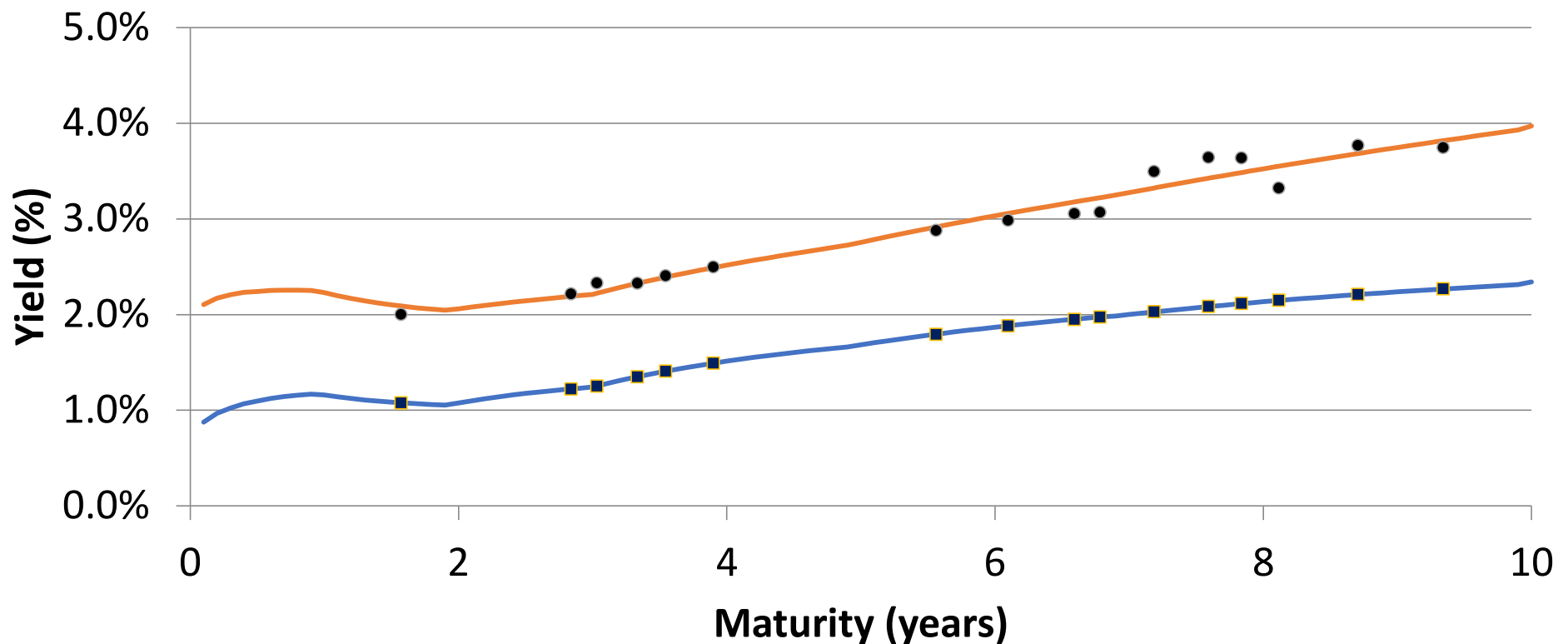

BAC 2017-06-01 08:13:38: Raw 4D Fit vs. new scheme

BAC 2017-06-01 08:13:38: Fitting Error

Constructing the Issuer Curve – Final Fit

2017-06-01 08:13:38 – BAC vs. Treasury

Rich and Cheap Bonds vs. The Curve
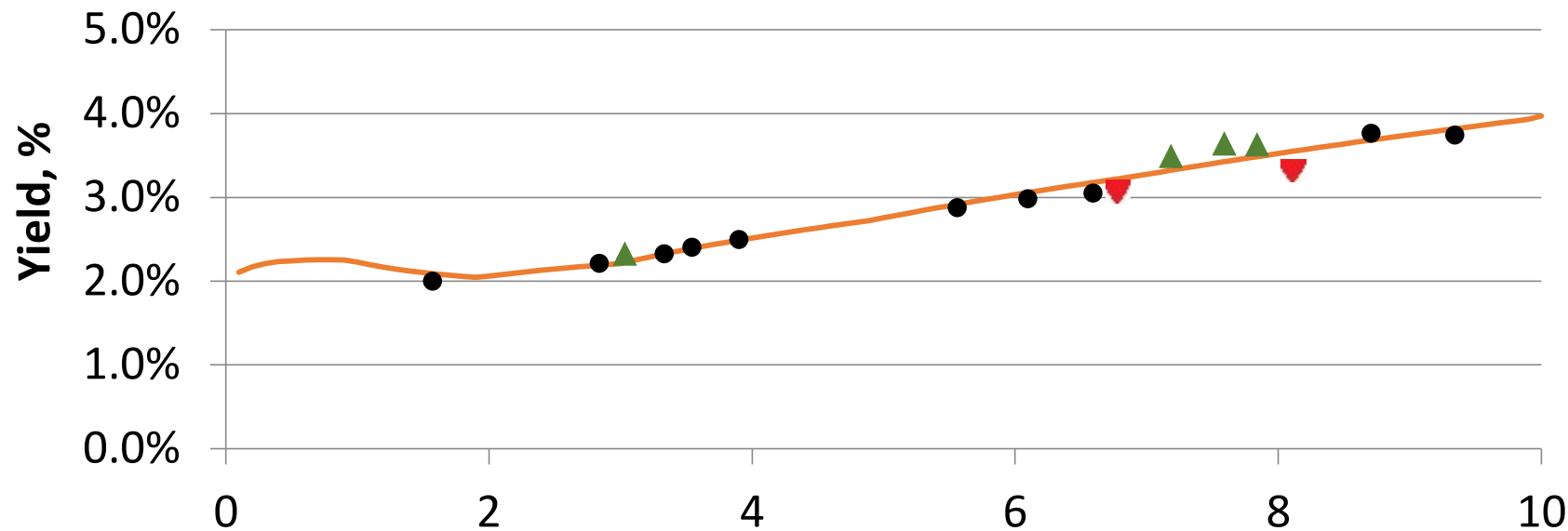
Notes on Curve fitting

- Some bond prices are more reliable than others
  - Volume of trades [issue size, age, index inclusion]
  - Volume of market data
  - Bid-offer spread
  - Need enough bonds to build a curve (>4 for Nelson-Siegel)
  - Simplicity of bonds priced off the yield curve
    - Bullet [no options, fixed coupon]
    - Callable/Puttable => yield to worst, convention
    - Senior/Junior
    - Issued by a subsidiary with a different rating ➔ mispriced
    - 144A / Reg S ➔ less liquid
    - Insured or asset-backed ➔ will always look rich
    - Step-up or step-down coupon ➔ different cash flow

Can you tell a good curve from bad curve?

- What is the purpose?
- Back-test "sanity check" for mean reversion
  - Buy cheap at mid
  - Short rich at mid
  - Control risk (e.g. DV01-neutral)
  - Compute PNL, analyze "losers"
- Back test for real
  - Replay [possibly preprocessed] market data
  - Compute your pricing model
  - Replicate your actions (place orders, RFQ responces)
  - Develop a "fill model" (simulated counterparties)
  - Compute PNL, analyze exposures, "losers"
  - Update your model

SAME STORY IN 1MM LINES

...[UNIVERSE INIT]...

2017-06-19 08:00:00,535|simMain|INFO|TradeConfigMgr:initFromYAML: trade configuration C:\src\dima\Config\trade.dev.yaml loaded

2017-06-19 08:00:00,908|simMain|INFO|BondMgr CreateFromDB: Read 2457 tradable bonds from security master at 20170619.080000

2017-06-19 08:00:00,908|simMain|INFO|BondMgr CreateFromDB: Read 10 on-the-run bonds from security master at 20170619.080000

2017-06-19 08:00:00,111|simMain|INFO|BondMgr CreateFromDB: 432 (17.5%) tradable bonds created, 2035 ignored

...[GROUP INIT]...

2017-06-19 08:00:00,125|simMain|INFO|SecMasterGroupMgrReference:initGroups: 1 reference bond group(s) initialized

2017-06-19 08:00:00,125|simMain|INFO|SecMasterGroupMgrComplex:initGroups: group Issuer using filter BAC

2017-06-19 08:00:00,127|simMain|WARNING|SecMasterCurveMgrComplex:BAC: ref Treasury cannot calibrate on 0 bonds

2017-06-19 08:00:00,127|simMain|INFO|SecMasterGroupMgrComplex:initGroups: Issuer bond grouping is pricing 25 bonds on 1 curves

...[BASE CURVE CALIBRATION]...

2017-06-19 08:14:05,845|simMain|INFO|BulletBond:BBG00GQQJ2X7: new market price 100.242000/100.250000 venue TMC ts 2017-06-19 08:14:05.350000

2017-06-19 08:14:05,846|simMain|INFO|Curve Treasury: creating on 10 quotes

2017-06-19 08:14:05,848|simMain|INFO|BulletBond:BBG00GQQJ2X7: Treasury model price 100.25 --> 100.246000

...[ISSUER CURVE CALIBRATION]...

2017-06-19 08:13:38,438|simMain|INFO|Curve BAC: calibrating on 16 quotes

2017-06-19 08:13:38,471|simMain|INFO|Curve BAC: update level 0.042572 slope -0.030039, curve -0.050581, decay 0.233477

...[SIMULATED TRADE]...

2017-06-19 08:41:33.238|simMain|INFO|RiskMgr:onFITradeEvent: processing SimEventFITrade(name = 06051GEH8, ts = 2017-06-19 08:13:38.084000, price = 109.203626, size = 200, side = BUY, venue = TMC)

...[EOD SUMMARY]...

2017-06-19 17:00:00,161|simMain|INFO|('BulletBond:getPositionPnl:BBG001P9WYR1 initial position PNL: 0',)

2017-06-19 17:00:00,161|simMain|INFO|("BulletBond:getTradesPnl:BBG001P9WYR1 today's trades are: deque([SimEventFITrade(name = 06051GEH8, ts = 2017-06-19 08:13:38.084000, price = 109.203626, size = 200, side = BUY, venue = TMC, orderId = None, clientId = None)])",)95.26342418',)

2017-06-19 17:00:00,161|simMain|INFO|('BulletBond:getPnl:BBG001P9WYR1 total PNL: 129.52634',)