

ORF 474: High Frequency Trading
Spring 2020
Robert Almgren

Lecture 2a

Feb 10, 2020

High-Frequency Trading Is Changing for the Better

Pure speed is no longer the only thing that matters.

By Aaron Brown

February 10, 2020, 11:00 AM UTC

The key is to realize HFT is two things: latency arbitrage and liquidity provision. Latency arbitrage means getting an advantage by being faster. When an order comes to market at a good price, the fastest trader to take it wins. When prices move, the slowest trader to stop taking orders loses.

Of course, those two things are still true, but the arbitrage has gone away. The market for latency has become efficient. There are still advantages to faster software, faster hardware or co-location (putting your server next to the exchange computer to minimize transmission time), but the prices of those things have come in line with their values.

HFT-like techniques are now embedded into the market structure for liquid developed market stocks and the more active exchange-traded futures and options. It's no longer a separate business, nor a source of huge profits.

So pure HFT is moving into other markets. Less liquid stocks and exchange-traded derivatives. Emerging markets. Bonds and over-the-counter derivatives. Structured products. The rewards for supplying liquidity in these markets are much larger than those available for liquid stocks, but the challenges are larger. It's harder to get information about orders and transactions, and electronic execution may not be available. You have to be willing to hold positions longer as it may be weeks or months before another buyer or seller for a specific security comes to market. That in turn means you need to hedge, something traditional HFT shops either didn't do, or did only in simple ways.

Need intelligent trading not just fast trading

<https://www.bloomberg.com/opinion/articles/2020-02-10/high-frequency-trading-is-changing-for-the-better>

Money Stuff

Insider Trading on Securities Fraud

Also Deutsche Bank and Trump, Santander and Orcel, Google and YouTube, and robots.

By Matt Levine

February 4, 2020, 5:27 PM UTC

Faster robots

One theme that we talk about a lot around here is:

1. Financial markets mostly get more efficient over time, due to perpetual competition and improving technology and more data and so forth.
2. What it means, for markets to get more efficient, is that it is harder to reliably make money in the markets.
3. Many of the people who used to reliably make money in the markets are rich and famous and would like to continue to make money in the markets; they are sad about the increased efficiency, and they tend to have platforms to go on TV to complain about it.
4. But you shouldn't feel especially sorry for them.

<https://www.bloomberg.com/opinion/articles/2020-02-04/insider-trading-on-securities-fraud>



The London Fish Exchange (LFEX Ltd) is a single centralised venue for global participants trading in aquaculture, fisheries and related products.

Starting with farmed Atlantic Salmon with other fish species and crustaceans soon to follow, LFEX enables farmers, producers, exporters, traders, processors and buyers to connect, market, transact, communicate and distribute their products, in an independent, secure, transparent, trusted and controlled environment.

To date there is no global aquaculture exchange or seafood market, no trusted electronic price discovery mechanisms and no focal point for the industry. LFEX is at the forefront of a paradigm shift in fisheries and aquaculture trading.

A Changing World

The changing dynamics of fish supply, with farmed fish production now a \$150bln growth industry producing nearly 50% of all seafood for human consumption, LFEX recognises the challenges for marketing, distribution and transactions at scale on a global basis, for both sellers and buyers of aquaculture and for traditional fisheries species.

By linking the physical and digital (electronic) worlds LFEX offers users accessibility, distribution, efficiency, management and control, driving economic value to participants in this high growth industry.

Our vision is to become the industry standard for sourcing prices and transactions in this global market.

"Today I have seen the future of the industry" Major European Buyer

A Strong Foundation

Our core team have been at the forefront of the evolution of electronic (digitisation of) trading in financial markets, having managed the rollout of the first real-time electronic equities platform in Europe in 1996 and the world's first real-time internet based FX platform in 1998.

<https://www.lfexchange.com/>

Highly Flexible, Sophisticated, Real-Time Platform

The system features at its core a secured communications mechanism between the connected parties or user groups on the system, facilitating granularity of service to an individual user level. It is a highly flexible, sophisticated, real-time interactive platform that can be configured for a vast range of features and functionality, supporting the infrastructure and demands of different markets and market participants.

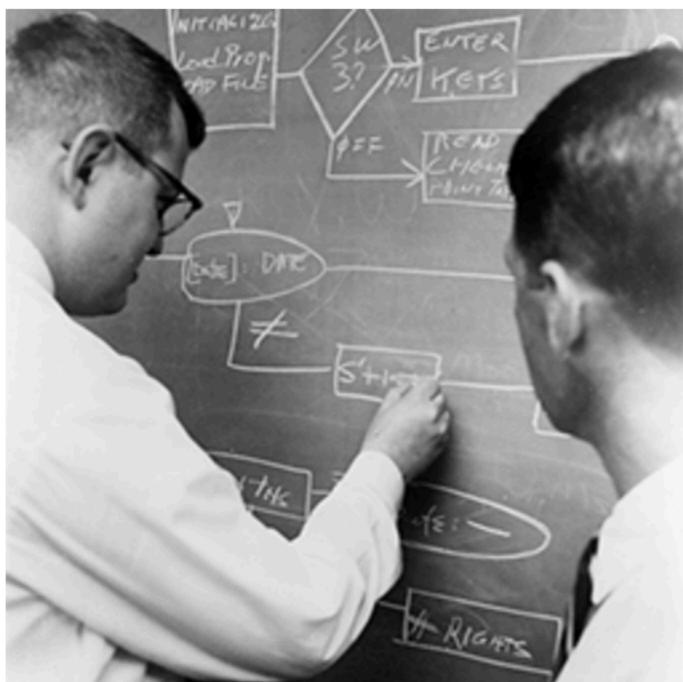
This week: empirical facts from market data

- Cross-sectional stock information: CRSP data
 - spectrum of market capitalization
 - correlation with other parameters
- Trade data and volume curves
 - bid-ask spread from trades?
 - volume curve estimation
 - event effects
- Quote data
 - matching trades and quotes
 - National Best Bid and Offer (NBBO)

Cross-sectional data (CRSP)

- 7000 equities in US
- Widely varying characteristics
- How to pick good examples for research?
- Source for overall information: CRSP data set

Why CRSP?



In 1960, Chicago Booth embarked on the development of the world's first comprehensive database for historical security prices and returns information. The research-quality data created by this transformational project spawned a vast amount of scholarly research from several generations of academics. The initial database required 3 1/2 years of painstaking research and programming. When the initial findings of the study were announced in December 1963, the investment community took notice and results were published in the

Wall Street Journal, the Washington Post, The New York Times and the Chicago Tribune. See our 50th Anniversary section to read more about our history.

<http://www.crsp.com/>

▶ **SUBSCRIBER PROFILES**

▶ **FUNDING CRSP SUBSCRIPTIONS**

Representative Academic Subscribers

▪ [London Business School](#)

1926 – present

“ Any time you hear an investment professional mention the year 1926, he's telling you he's gotten his data from CRSP. ”

**90
YEARS**

In 1960, Chicago Booth embarked on development of the world's first comprehensive database for historical security prices and returns information. The research-quality data created by this transformational project established a vast amount of scholarly research for several generations of academics. [Visit the special 90 Years of Data page to view a historical timeline, read a few factoids, and utilize our related graphic resources.](#)

CRSP at WRDS

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The Center for Research in Security Prices (CRSP)

For more about this dataset, see the [Dataset List](#), [Manuals and Overviews](#) or [FAQs](#).

Annual Update

Databases in this section are updated once each year, in early February. Update schedules should not be confused with end-of-day, end-of-month, or end-of-quarter data such as stock prices.

» Stock / Security Files

» Stock / Events

» Stock / Portfolio Assignments

» Index / Stock File Indexes

» Index / Cap-Based Portfolios

» Index / S&P 500 Indexes

» Index / Treasury and Inflation

» Index / CRSP Select Series

» CRSP/

» Treasury

» Treasury

» Treasury

» Ziman REIT

» Tools

Stock / Security Files

For more about this dataset, see the [Dataset List](#), [Manuals and Overviews](#) or [FAQs](#).

Monthly Stock File

Daily Stock File

Stock Market Indexes

Stock Header Info

data fields in CRSP

Step 2: Apply your company codes.

TICKER PERMNO PERMCO CUSIP NCUSIP HSICCD SICCD

Select an option for entering company codes

Company Codes

Please enter Company codes separated by a space.

Example: IBM MSFT AAPL [[Code Lookup](#)]

[Browse...](#) No file selected

Upload a plain text file (.txt), having one code per line.

-----Select Saved Codelists-----

Choose from your saved codelists.

Search the entire database

This method allows you to search the entire database of records. Please be aware that this method can take a very long time to run because it is dependent upon the size of the database.

Step 3: Query Variables.

Selected

Clear All

(6)

Company Name

COMNAM

Ticker

TICKER

Share Class

SHRCLS

Price

PRC

Share Volume

VOL

Number of Shares Outstanding

SHROUT

Step 4: Select query output.

Select the desired [format](#) of the output file. For large data requests, select a compression type to expedite downloads. If you enter your email address, you will receive an email that contains a URL to the output file when the data request is finished processing.

Output Format

- fixed-width text (*.txt)
- comma-delimited text (*.csv)
- Excel spreadsheet (*.xlsx)
- tab-delimited text (*.txt)
- HTML table (*.htm)

Compression Type

- None
- zip (*.zip)
- gzip (*.gz)

Date Format

- YYMMDDn8. (e.g. 19840725)
- DATE9. (e.g. 25JUL1984)
- DDMMYY6. (e.g. 250784)
- MMDDYY10. (e.g. 07/25/1984)
- DDMMYY10. (e.g. 25/07/1984)

Recommend .csv.gz

Monthly CRSP

The CRSP US Stock Databases contain daily and monthly market and corporate action data for securities with primary listings on the NYSE, NYSE MKT, NASDAQ, and Arca exchanges and include CRSP broad market indexes. CRSP databases are characterized by their comprehensive corporate action information and highly accurate total return calculations.

```
europia: gunzip -c CRSP-monthly-201912.csv.gz | head -5
```

```
PERMNO,date,TICKER,COMNAM,SHRCLS,PRC,VOL,SHROUT
```

```
10026,20191231,JJSF,J & J SNACK FOODS CORP.,184.27000,19552,18899
```

```
10028,20191231,ELA,ENVELA CORP.,1.35000,5185,26924
```

```
10032,20191231,PLXS,PLEXUS CORP.,76.94000,33693,29247
```

```
10044,20191231,RMCF,ROCKY MOUNTAIN CHOC FAC INC NEW,,9.23000,2133,5995
```

PERMNO

CRSP permanent identifier

date
trade date

TICKER
trading symbol

COMNAM
Company name

SHRCLS
Share class

PRC
Close price
on date

VOL
Traded volume
total for month,
in 100s of shares

SHROUT
Shares
outstanding
(in 1000's)

Unlike the CUSIP, Ticker Symbol, and Company Name, the PERMNO neither changes during an issue's trading history, nor is it reassigned after an issue ceases trading. The user may track a security through its entire trading history in CRSP's files with one PERMNO, regardless of name or capital structure changes.

Market Cap

In CRSP the market capitalization as the product of price and shares outstanding is **computed** as follows:

```
1 | mktcap = abs(prc)*shroud
```

CRSP details (from WRDS popups)

TICKER

The combination of ticker, exchange, and date uniquely identifies a security. A ticker may be one to three characters for NYSE and AMEX securities or four or five characters for Nasdaq securities. Nasdaq trading tickers have four base characters and a fifth character suffix that provides information about an issue's type or temporary information about an issue's status. CRSP only includes the suffix when it provides permanent descriptive information.

SHRCLS

SHRCLS describes the class of share and is generally blank. Any letter that identifies the class of stock (e.g., "A" for class A common) is contained in this field, left justified, and padded with three blank spaces.

Delete non-blank, or append to symbol

COMNAM

CRSP allocates a 32 character name description field for all securities. Preference is given to the spellings and abbreviations provided in Standard & Poor's CUSIP Directory. In cases where all name sources provide descriptions in excess of 32 characters, CRSP furnishes its own abbreviations.

PRC

Prc is the closing price or the negative bid/ask average for a trading day. If the closing price is not available on any given trading day, the number in the price field has a negative sign to indicate that it is a bid/ask average and not an actual closing price. Please note that in this field the negative sign is a symbol and that the value of the bid/ask average is not negative.

If neither closing price nor bid/ask average is available on a date, prc is set to zero.

In a monthly database, prc is the price on the last trading date of the month. The price series begins the first month-end after the security begins trading and ends the last complete month of trading.

**Better: "vol" is for volatility
volume should always be "vlm"**

VOL

In monthly files, VOL is the sum of the trading volumes during that month. In daily files, VOL is the total number of shares of a stock sold on day I. It is expressed in units of one share, for daily data, and on hundred shares for monthly data. Our data source for NYSE/AMEX reports the number rounded to the nearest hundred. For example, 12,345 shares traded will be reported on the Nasdaq Stock Exchange as 12,345 and on the NYSE or AMEX exchanges as 12,300. Volume is set to -99 if the value is missing. A volume of zero usually indicates that there were no trades during the time period and is usually paired with bid/ask quotes in price fields.

CRSP: Trades on all exchanges connected to the consolidated pricing network are included in the volume.

Hard to match this with TAQ trade data

SHROUT

SHROUT is the number of publicly held shares, recorded in thousands.

R code for reading

```
C <- fread(infile, header=TRUE,  
           colClasses=c(date='character',  
                         PRC='numeric',VOL='numeric',SHROUT='numeric') )  
  
C$date <- as.Date(as.character(C$date),format='%Y%m%d')  
  
# Negative prices are bid-ask midpoint, zero prices are null  
C$PRC <- abs(C$PRC)  
C$PRC[ C$PRC == 0 ] <- as.numeric(NA)  
  
# Traded volumes are in hundreds for monthly data  
if (monthly) C$VOL <- 100 * C$VOL  
  
# Shares outstanding are in thousands  
C$SHROUT <- 1000 * C$SHROUT
```

```
> sum( C.day$vlm[ C.day$sym=='IBM' ] )  
[1] 115600988 ←  
→  
> C.mon$vlm[ C.mon$sym=='IBM' ]  
[1] 115601000 ←
```

Monthly and daily volumes
match within 12 lots
(rounding to 100)

R data.table

Top 3 much bigger than rest

```
> head(C, 25)
```

	PERMNO	date	TICKER	COMNAM	SHRCLS	PRC	VOL	SHROUT	mktcap
1:	14593	2019-12-31	AAPL	APPLE INC		293.64999	598499300	4443265000	1304764722817
2:	10107	2019-12-31	MSFT	MICROSOFT CORP		157.70000	452022200	7632139000	1203588320300
3:	84788	2019-12-31	AMZN	AMAZON COM INC		1847.83997	68758700	495797000	916153513606
4:	13407	2019-12-31	FB	FACEBOOK INC	A	205.25000	277763900	2406468000	493927557000
5:	14542	2019-12-31	GOOG	ALPHABET INC	C	1337.02002	27552000	343551000	459334564891
6:	47896	2019-12-31	JPM	JPMORGAN CHASE & CO		139.39999	213309900	3136485000	437225977635
7:	90319	2019-12-31	GOOGL	ALPHABET INC	A	1339.39001	28305800	299628000	401318749916
8:	22111	2019-12-31	JNJ	JOHNSON & JOHNSON		145.87000	128925300	2631872000	383911168640
9:	55976	2019-12-31	WMT	WALMART INC		118.84000	98637200	2837175000	337169877000
10:	92611	2019-12-31	V	VISA INC	A	187.89999	160648400	1711838000	321654343082
11:	59408	2019-12-31	BAC	BANK OF AMERICA CORP		35.22000	942301800	8995107000	316807668540
12:	83443	2019-12-31	BRK	BERKSHIRE HATHAWAY INC DEL	B	226.50000	80495600	1383415000	313343497500
13:	18163	2019-12-31	PG	PROCTER & GAMBLE CO		124.90000	137973100	2493812000	311477118800
14:	84398	2019-12-31	SPY	SPDR S & P 500 E T F TRUST		321.85999	1290525600	953832000	307000357982
15:	91233	2019-12-31	MA	MASTERCARD INC	A	298.59000	57874800	997449000	297828296910
16:	11850	2019-12-31	XOM	EXXON MOBIL CORP		69.78000	286704800	4231106000	295246576680
17:	66093	2019-12-31	T	A T & T INC		39.08000	515237500	7305000000	285479400000
18:	92655	2019-12-31	UNH	UNITEDHEALTH GROUP INC		293.98001	60757400	947415000	278521071174
19:	26403	2019-12-31	DIS	DISNEY WALT CO		144.63000	171316800	1802398000	260680822740
20:	59328	2019-12-31	INTC	INTEL CORP		59.85000	419801900	4350000000	260347500000
21:	65875	2019-12-31	VZ	VERIZON COMMUNICATIONS INC		61.40000	240286600	4135784000	253937137600
22:	14888	2019-12-31	BABA	ALIBABA GROUP HOLDING LTD		212.10001	301211100	1135511000	240841894455
23:	17778	2019-12-31	BRK	BERKSHIRE HATHAWAY INC DEL	A	339590.00000	5600	708000	240429720000
24:	66181	2019-12-31	HD	HOME DEPOT INC		218.38000	112416700	1090831000	238215673780
25:	11308	2019-12-31	KO	COCA COLA CO		55.35000	233757900	4284491000	237146576850

2 BRK share classes

2 Alphabet (Google) share classes



What's the Difference Between Berkshire Class A and B Stocks?

Posted by [E. Ellis](#) on 28 April 2017, 12:38 pm

If you're looking to invest in Berkshire Hathaway (and, let's face it, we really can't blame you), then you're probably wondering what is the difference between Berkshire Class A and Class B stocks. The short answer is price.

When the Class B stocks were originally created, they were worth 1/30th of a Class A stock and held 1/10,000th of the voting rights. That means a Class B voter would have to hold 10,000 shares for their votes to have the same weight as a single Class A shareholder.

However, in 2010, Buffett split the stocks again to help pay for the acquisition of BNSF. Right now, the Class B stocks are valued at 1/1500th of a Class A. They retained the same voting rights, however.

Both Class A and Class B stock holders can attend the Berkshire Hathaway Shareholder's Meeting and both can vote on shareholder issues although, as mentioned above, Class B voters will have less voting power than Class A.

GOOG or GOOGL: Which Stock Do You Buy? (GOOG, GOOGL)

By JESSE EMSPAK | Updated Jun 25, 2019

There are two ticker symbols for Alphabet Inc. on the NASDAQ stock exchange: [GOOG](#) and [GOOGL](#). There's little price difference between the two – as of February 15, 2019, it was \$1,113.65 vs. \$1,119.63, respectively – still, what gives?

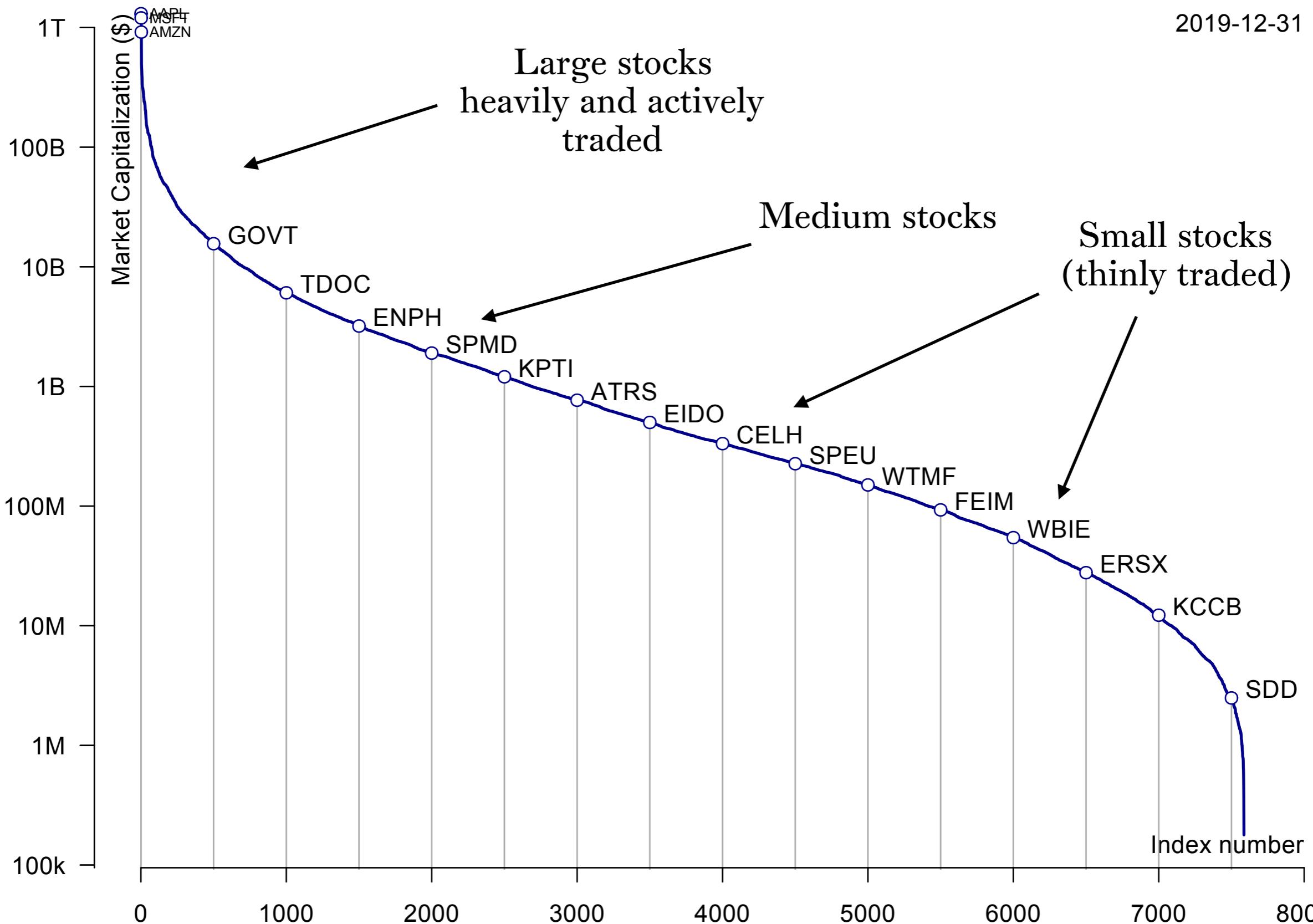
The two tickers represent two different [share classes](#): A (GOOGL) and C (GOOG). The [B shares](#) are owned by [insiders](#) and don't trade on the public markets. It's those B shares that are still in the possession of Brin, Page, Schmidt and a few other directors.

Google split its stock in April 2014, which created the A and C shares. Like any other one-for-one split, the number of shares doubled, and the price dropped in half. There is, however, one crucial difference. A shares receive one vote, C shares receive no votes, and B shares receive 10 votes. Anyone who held A shares at the time of the [split](#) received an equal number of C shares, but their [voting power](#) did not increase.

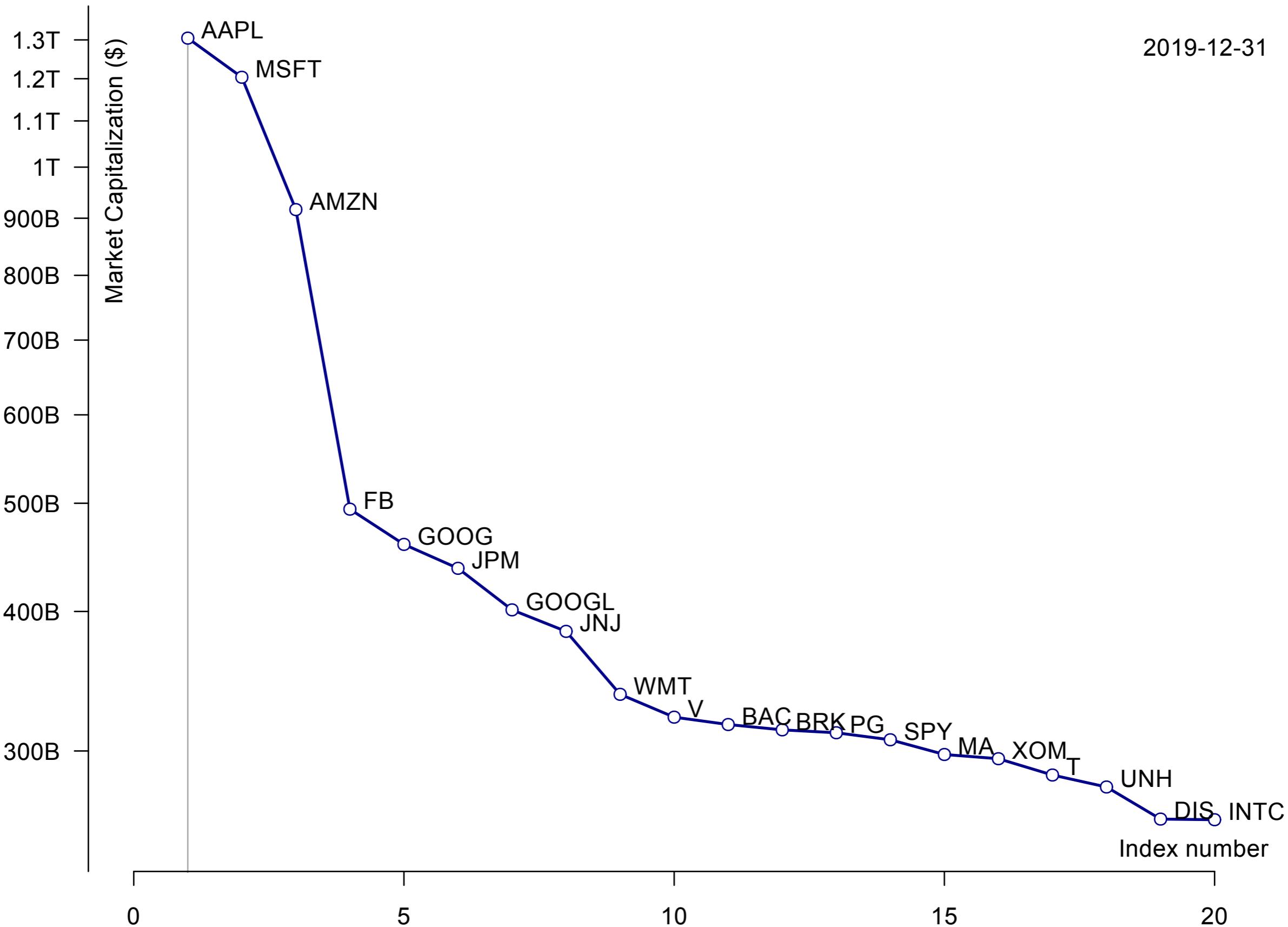
Note that the A shares consistently trade [at a premium](#) to the C shares. The difference is not large – perhaps 2% at most – but it is there.

<https://www.investopedia.com/articles/markets/052215/goog-or-googl-which-google-should-you-buy.asp>

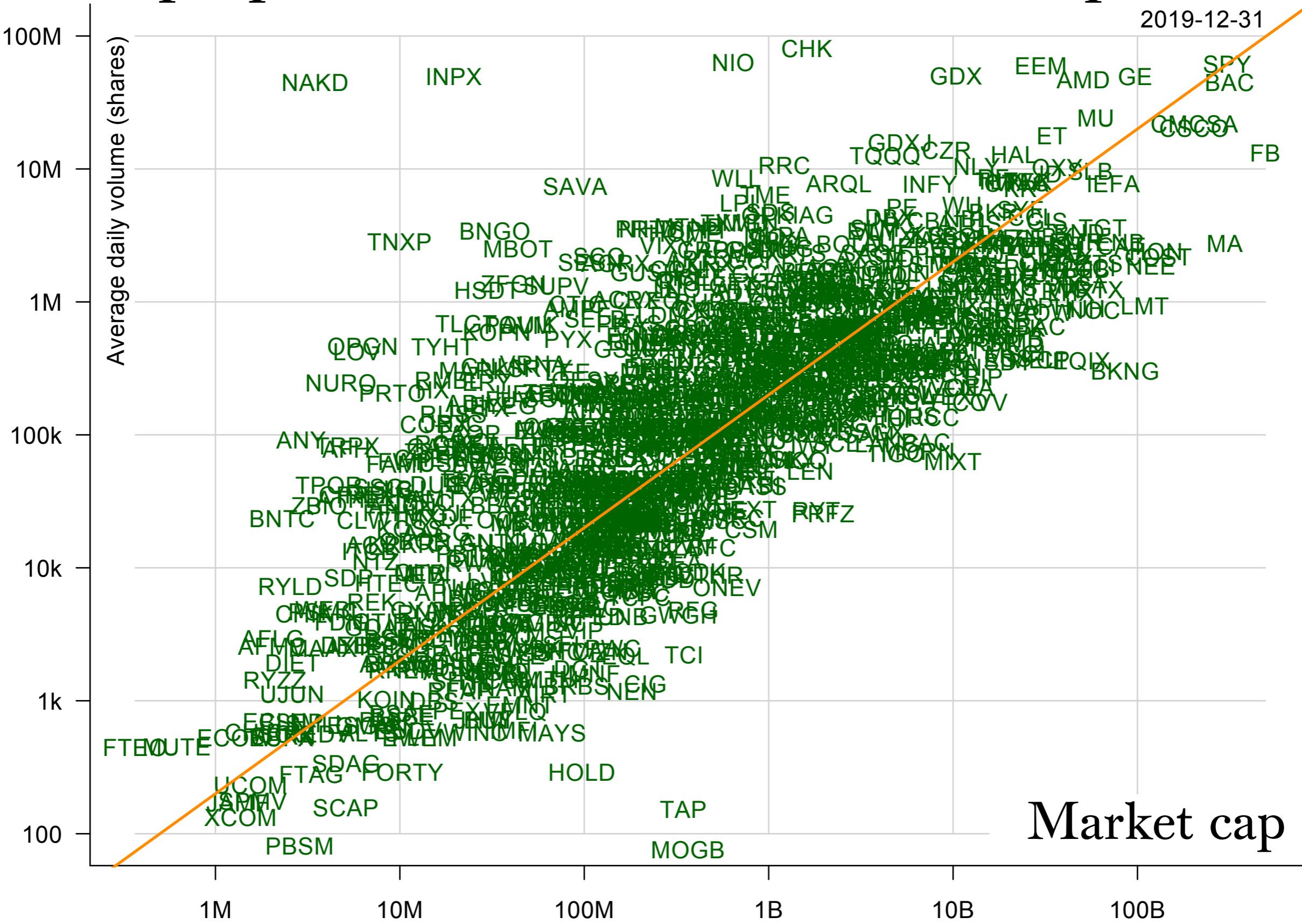
Spectrum of market cap



Large stock detail



Other properties correlate with market cap



Large liquid stocks

2019-12-31

Traded
volume
in one day

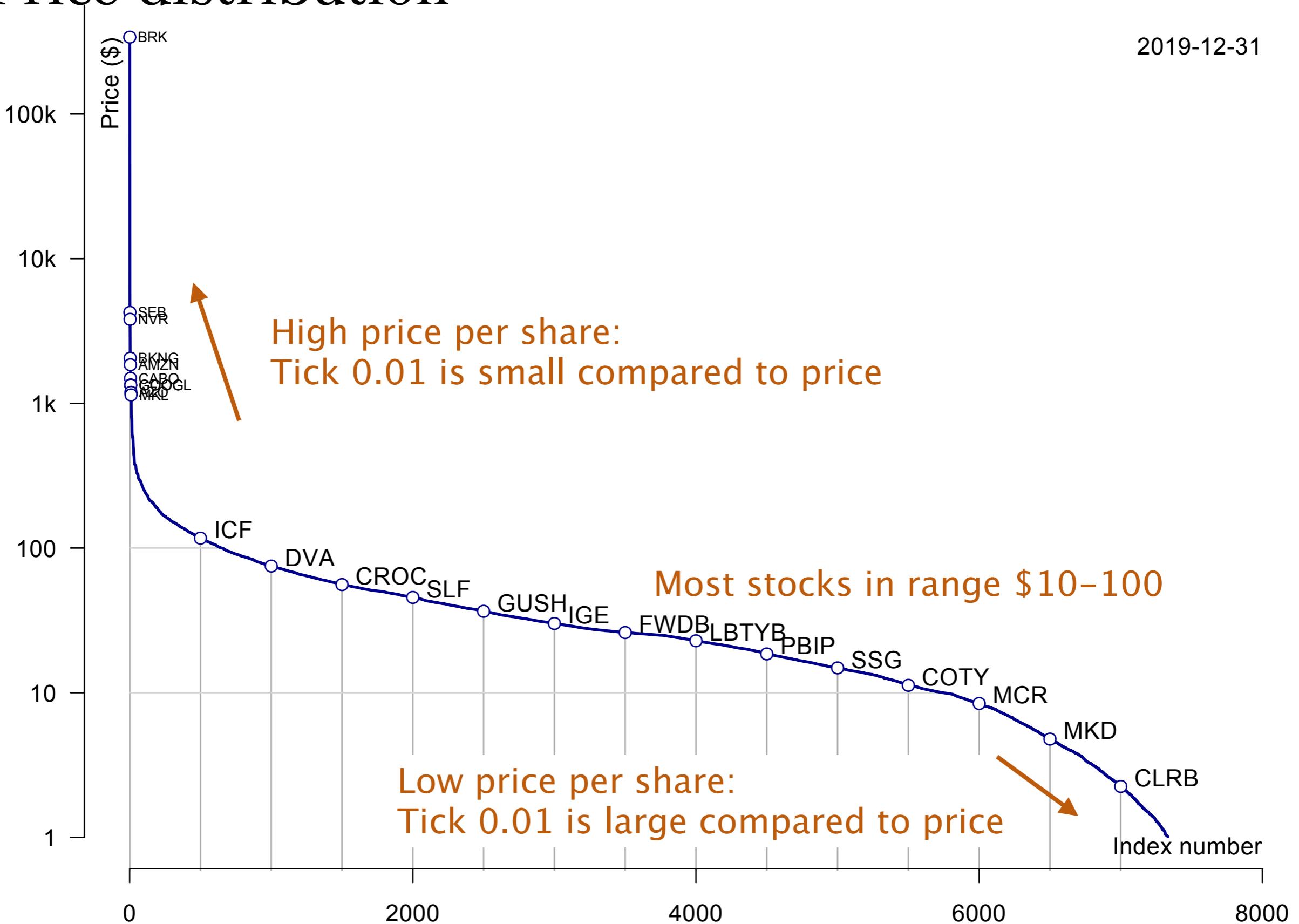
SFET

Average stock
trades 0.5% of float
per day

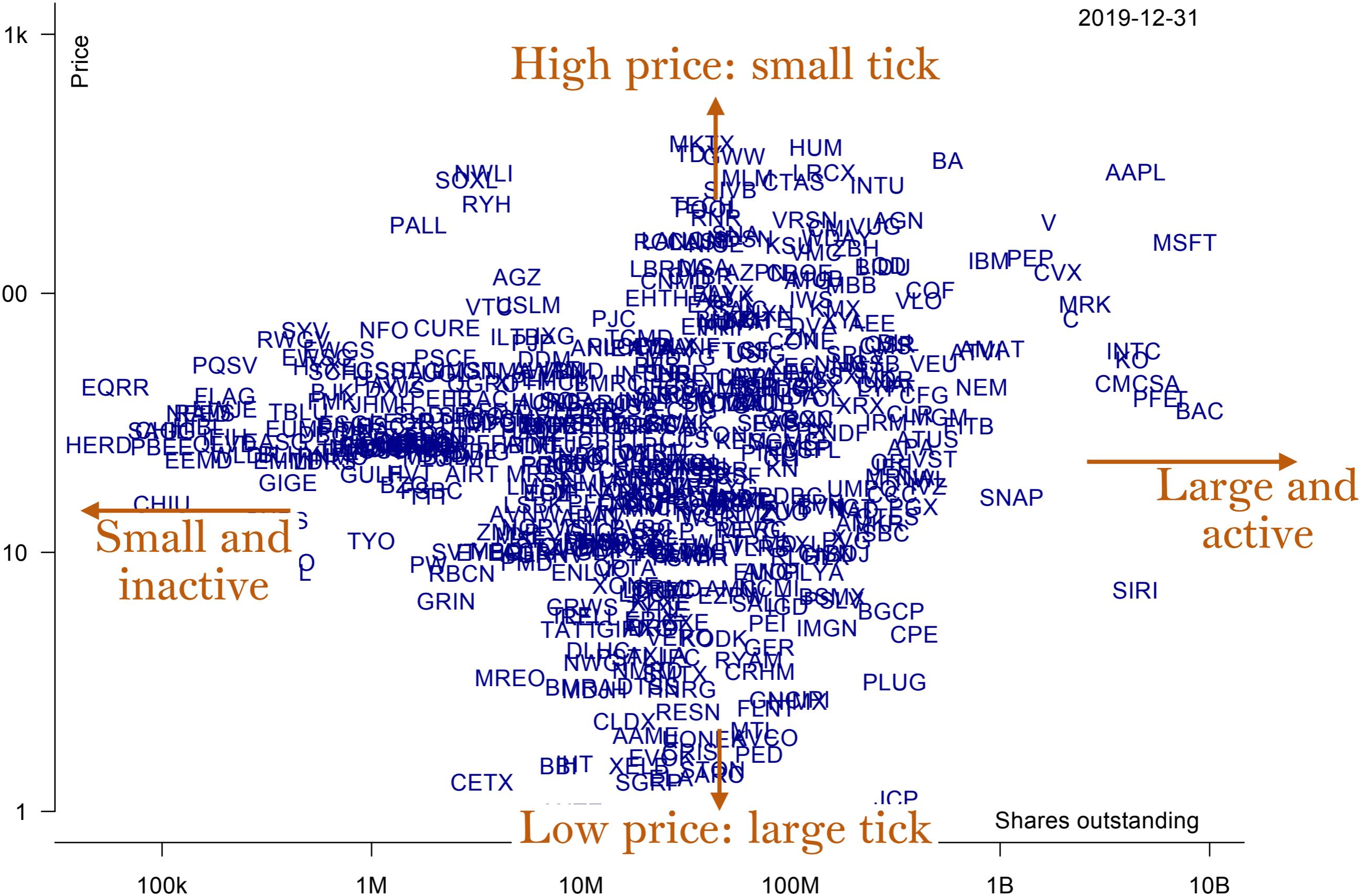
Shares outstanding

Small illiquid stocks

Price distribution



Price vs shares outstanding



Usefulness of these overview statistics

- Stock properties vary quite widely
 - Market cap >\$1T down to \$1MM (million-fold)
 - Traded volumes 100 shares to 100 million
- Trading properties roughly correlate with size
 - typical stock trades 0.5% of its float each day
- To choose a stock to study, pick a place in spectrum
 - large cap / medium cap / small cap

Select stock to look at

NYSE stock,
around #1000
by market cap

```
> C <- crsspread('CRSP-monthly-201912.csv.gz')
```

```
> C <- C[ order(mktcap,decreasing=TRUE), ]
```

```
> C[ 995:1005, ]
```

	PERMNO	date	TICKER	COMMNAME	SHRCLS	PRC	VOL	SHROUT	mktcap
1:	90396	2019-12-31	CUBE	CUBESMART		31.48000	39137100	193555000	6093111400.00
2:	89134	2019-12-31	ECA	ENCANA CORP		4.69000	381417300	1299112000	6092835280.00
3:	12536	2019-12-31	SCHH	SCHWAB STRATEGIC TRUST		45.96000	14423500	132500000	6089700000.00
4:	88397	2019-12-31	EZU	ISHARES INC		41.92000	72576700	145200000	6086784000.00
5:	80069	2019-12-31	ARWR	ARROWHEAD PHARMACEUTICALS INC		63.43000	67540100	95708000	6070758440.00
6:	15585	2019-12-31	TDOC	TELADOC HEALTH INC		83.72000	21164100	72382000	6059821040.00
7:	14752	2019-12-31	TPL	TEXAS PACIFIC LAND TRUST		781.21997	405500	7756000	6059142087.32
8:	27511	2019-12-31	CUZ	COUSINS PROPERTIES INC		41.20000	16784300	146762000	6046594400.00
9:	15724	2019-12-31	PFGC	PERFORMANCE FOOD GROUP CO		51.48000	16737100	117130000	6029852400.00
10:	86121	2019-12-31	GIL	GILDAN ACTIVEWEAR INC		29.53000	15009000	203694000	6015083820.00
11:	71175	2019-12-31	UNM	UNUM GROUP		29.16000	47139200	206268000	6014774880.00

Read in TAQ trade data

CUZ ~ 1000th largest market cap

My own TAQ reading program
data.table summary functionality

```
> trade <- Tread('trade-CUZ-202001.csv.gz',exchexcl=c())  
[1] parse1: 0.699 sec  
> trade[,sum(siz),exch][order(V1,decreasing=TRUE)]  
   exch      V1  
1: N 10334970  
2: D 4989494 ← Large fraction of volume on "D"  
3: T 1656997  
4: Z 1123761  
5: V 890577  
6: J 762816  
7: P 631715  
8: Y 260634  
9: C 253384  
10: K 250071  
11: X 178051  
12: B 163585  
13: A 44361  
14: M 1949
```



Alternative Display Facility (ADF)

The Alternative Display Facility (ADF) is an SRO display only facility that is operated by FINRA. The ADF provides members with a facility for the display of quotations, the reporting of trades, and the comparison of trades. ADF best bid and offer and trade reports are included in the consolidated data stream for Nasdaq and CQS listed securities. As an SRO display only facility, ADF does not provide automated order routing functionality, execution facilities, or linkages between ADF trading centers. ADF trading centers are required by FINRA rule to provide direct electronic access to all other ADF trading centers and provide such access to all FINRA members that request it. All FINRA members in good standing are eligible to participate in ADF, pending execution of appropriate contracts and meeting specific requirements as set forth by FINRA.

Recommend to exclude "D" trades
since not relevant for exchange trading

Opening process

O = "Market Center Opening Trade"

Q = "Market Center Official Open"

I = "Odd Lot Trade" (<100 shares)

09:30 = 34200 sec

	date	time	exch	sym	prc	siz	cond	corr	seq	src	rf
1:	2020-01-31	34200.4357013	N	CUZ	41.10	2736	O	0	388601	C	
2:	2020-01-31	34200.4357196	N	CUZ	41.10	2736	Q	0	388701	C	
3:	2020-01-31	34200.9837554	T	CUZ	40.99	32	I	0	420801	C	
4:	2020-01-31	34200.9837915	T	CUZ	40.99	32	Q	0	420901	C	
5:	2020-01-31	34236.8359323	V	CUZ	41.26	1	I	0	721401	C	
6:	2020-01-31	34240.8932185	V	CUZ	41.25	3	I	0	745101	C	
7:	2020-01-31	34288.8959532	V	CUZ	41.23	2	I	0	1142901	C	
8:	2020-01-31	34304.7241854	V	CUZ	41.23	1	I	0	1262401	C	
9:	2020-01-31	34322.4222367	Y	CUZ	41.22	1	I	0	1394501	C	
10:	2020-01-31	34342.3655995	Y	CUZ	41.20	2	I	0	1563801	C	
11:	2020-01-31	34351.2556287	T	CUZ	41.20	3	F I	0	1625101	C	
12:	2020-01-31	34351.2556363	T	CUZ	41.20	96	F I	0	1625201	C	
13:	2020-01-31	34351.8217306	N	CUZ	41.10	3	I	0	1631401	C	
14:	2020-01-31	34351.8908971	P	CUZ	41.20	1	I	0	1631501	C	
15:	2020-01-31	34351.8909134	P	CUZ	41.20	1	Q	0	1631601	C	
16:	2020-01-31	34354.4632066	Y	CUZ	41.11	1	I	0	1704801	C	
17:	2020-01-31	34358.4781019	N	CUZ	41.20	2	I	0	1744101	C	
18:	2020-01-31	34360.6842602	V	CUZ	41.20	1	I	0	1770501	C	
19:	2020-01-31	34377.6934852	N	CUZ	41.21	2	F I	0	1968301	C	
20:	2020-01-31	34395.0052788	N	CUZ	41.11	100	0	2215801	C		

16:00 = 57600 sec

> tail(T, 20)

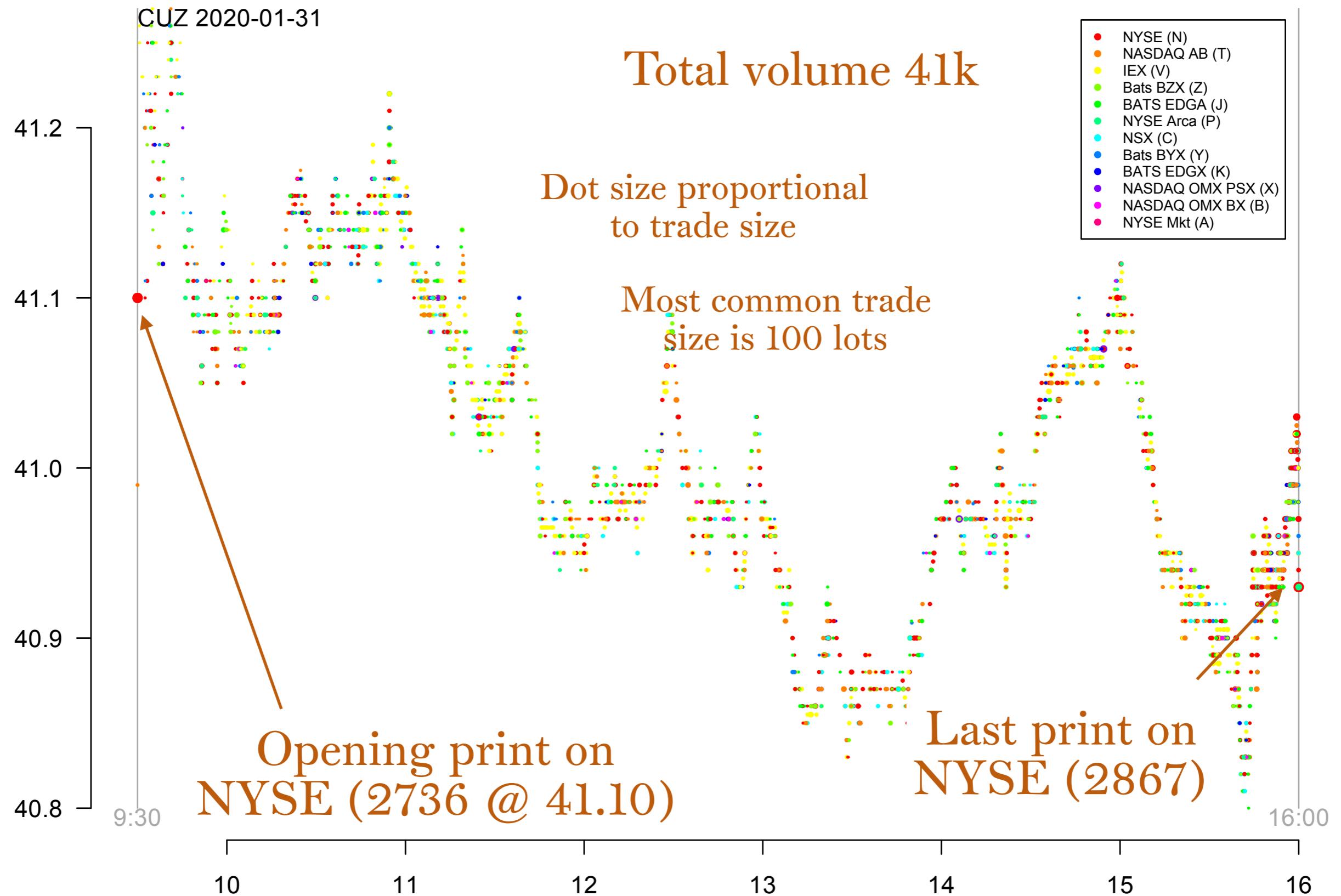
	date	time	exch	sym	prc	siz	cond	corr	seq	src	rf
1:	2020-01-31	57598.6881286	N	CUZ	40.93	7	I	0	185344801	C	
2:	2020-01-31	57598.6884825	V	CUZ	40.93	400		0	185345001	C	
3:	2020-01-31	57599.0161977	X	CUZ	40.93	102		0	185362901	C	
4:	2020-01-31	57599.0173528	X	CUZ	40.93	111		0	185363301	C	
5:	2020-01-31	57599.0212388	X	CUZ	40.93	101		0	185364701	C	
6:	2020-01-31	57599.0249982	X	CUZ	40.93	110		0	185365801	C	
7:	2020-01-31	57599.0959426	X	CUZ	40.93	100		0	185372401	C	
8:	2020-01-31	57599.9246485	N	CUZ	40.93	2867		0	185437201	C	
9:	2020-01-31	57599.9933436	N	CUZ	40.93	209		0	185456401	C	
10:	2020-01-31	57599.9933514	N	CUZ	40.93	700		0	185456501	C	
11:	2020-01-31	57599.9987250	X	CUZ	40.93	750	F	0	185466501	C	
12:	2020-01-31	57600.0006158	N	CUZ	40.93	2100	F	0	185467203	C	
13:	2020-01-31	57600.0436265	P	CUZ	40.93	700	M	0	185472001	C	
14:	2020-01-31	57600.4853087	T	CUZ	40.95	100	M	0	185507401	C	
15:	2020-01-31	57703.5860015	N	CUZ	40.93	125079	6	0	185583401	C	
16:	2020-01-31	57703.5866919	N	CUZ	40.93	125079	M	0	185583501	C	
17:	2020-01-31	58200.0064975	N	CUZ	40.93	0	9	0	185812209	C	
18:	2020-01-31	58200.0065047	N	CUZ	40.93	125079	M	0	185812309	C	
19:	2020-01-31	66600.0068776	N	CUZ	40.93	0	9	0	186063904	C	
20:	2020-01-31	66600.0068776	N	CUZ	40.93	125079	M	0	186063911	C	

M = "Market Center Official Close"

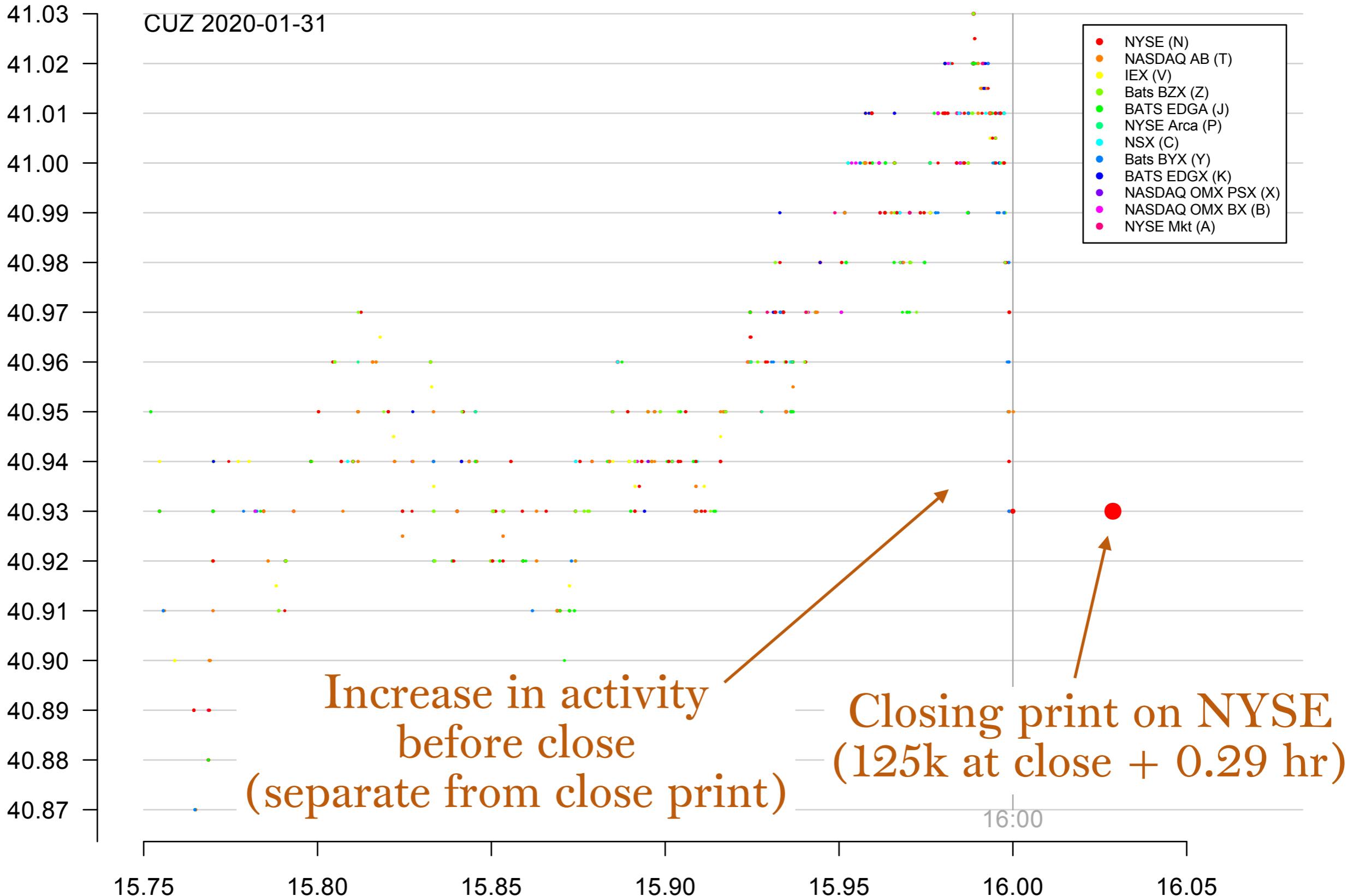
9 = "Corrected Consolidated Close Price per the Listing Market"

6 = "Market Center Closing Trade"

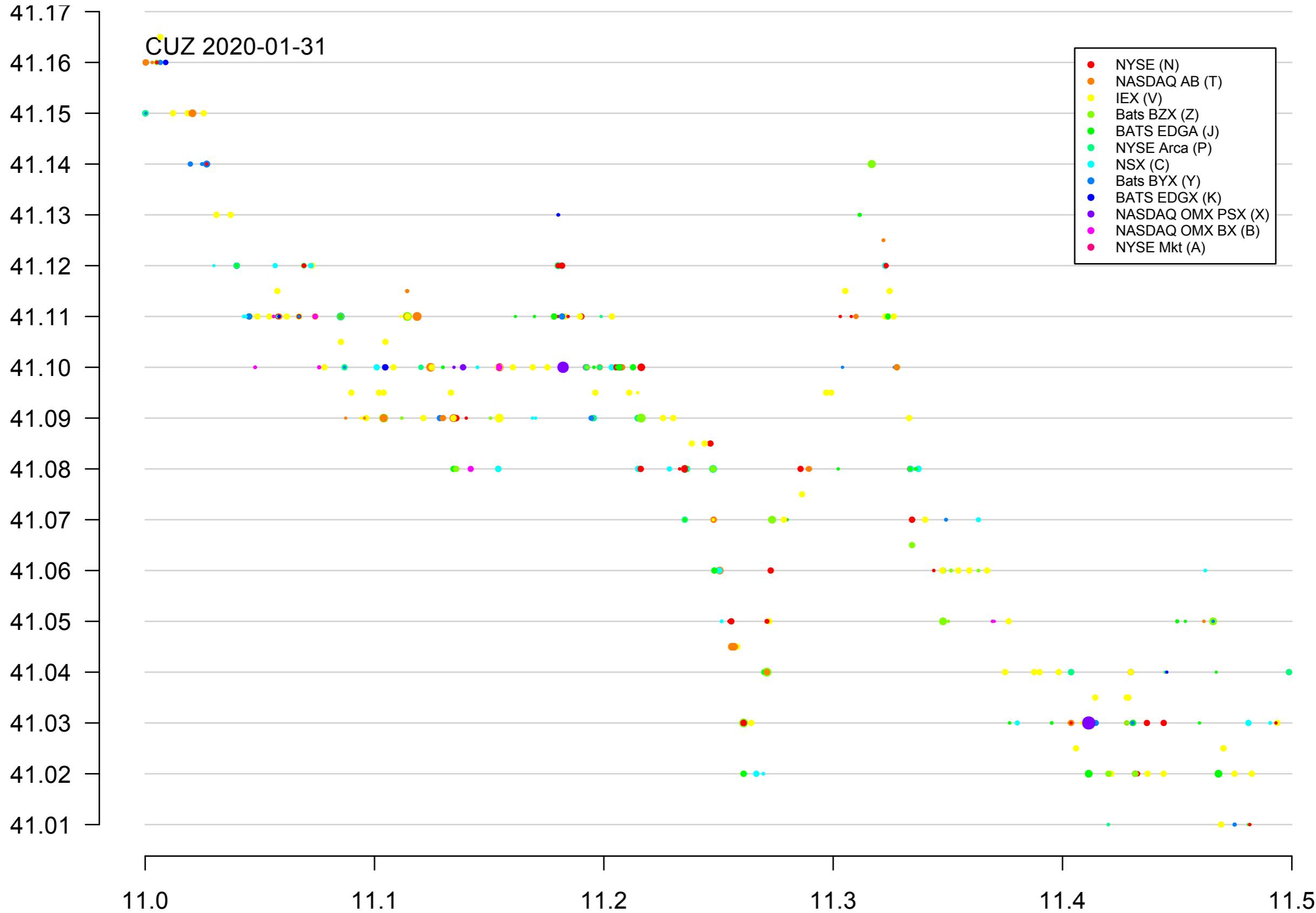
Review of TAQ trade data



Last 15 minutes



Typical intraday detail



Volume curves

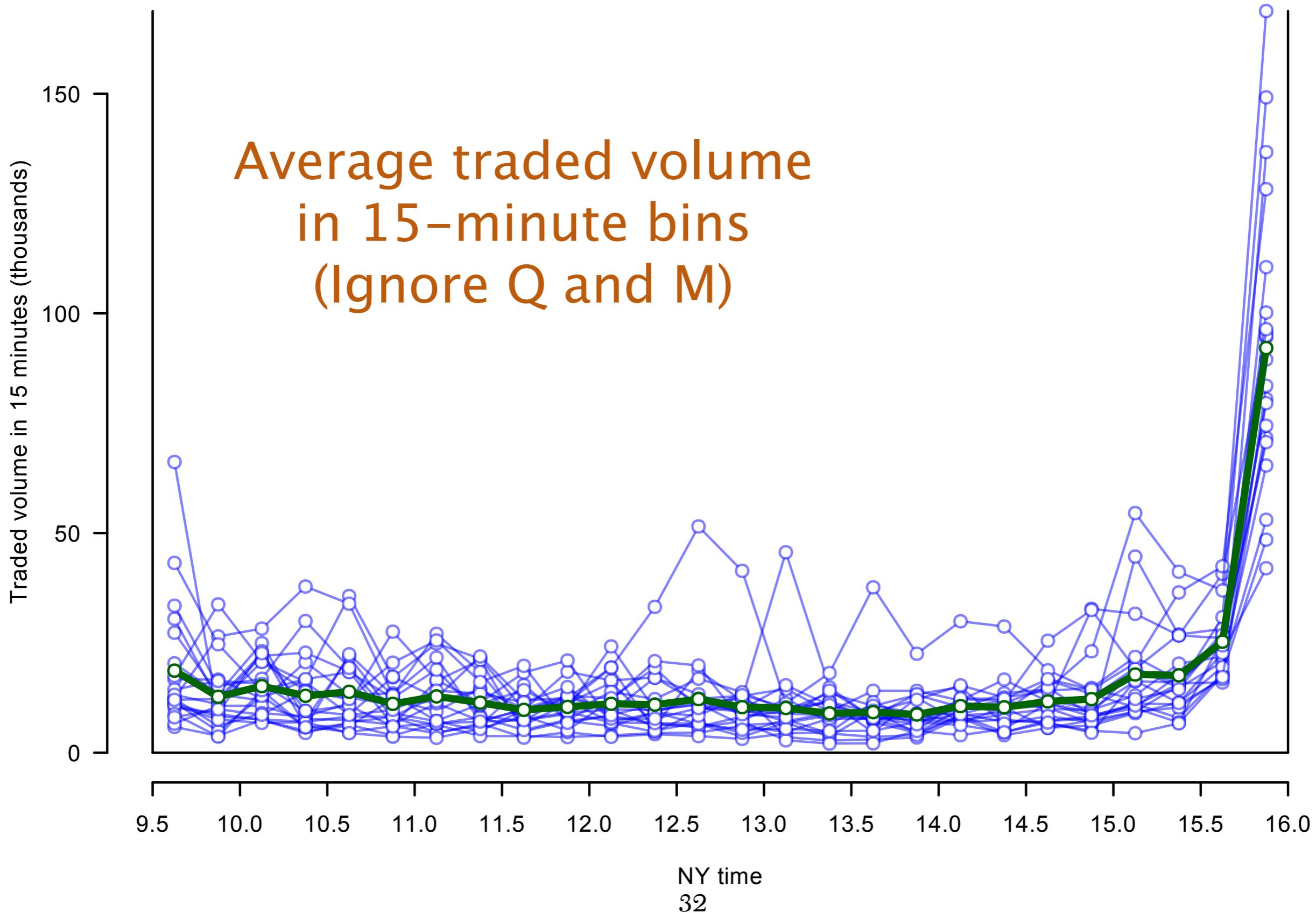
- How much volume trades at different times of day
- Historical: how has trading happened?
- Predictive: how shall we plan trading today?
- Other curves of interest:

volatility

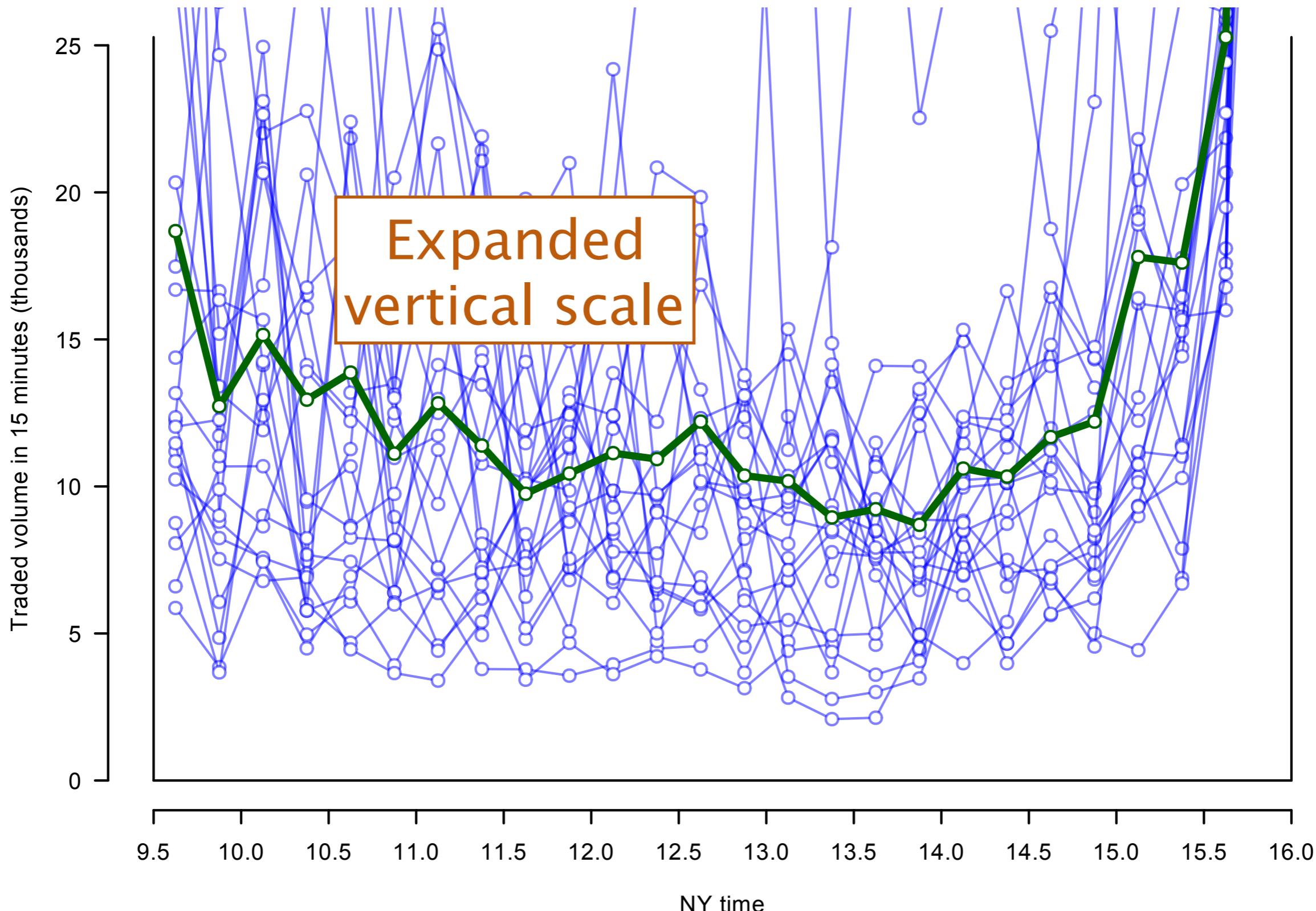
quote quality: bid-ask spread and quote size

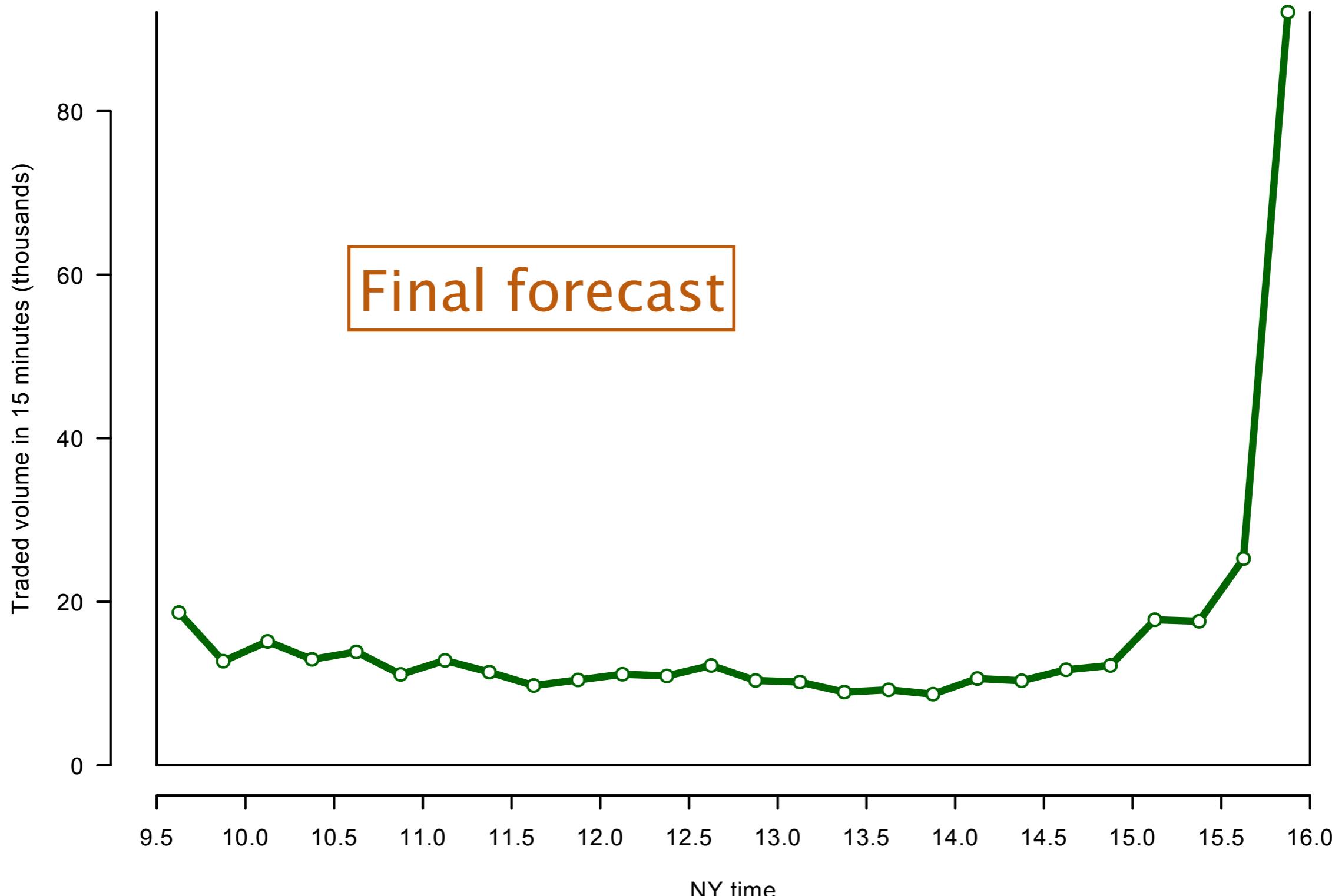
etc

Average traded volume
in 15-minute bins
(Ignore Q and M)



CUZ / 2020-01-02 to 2020-01-31



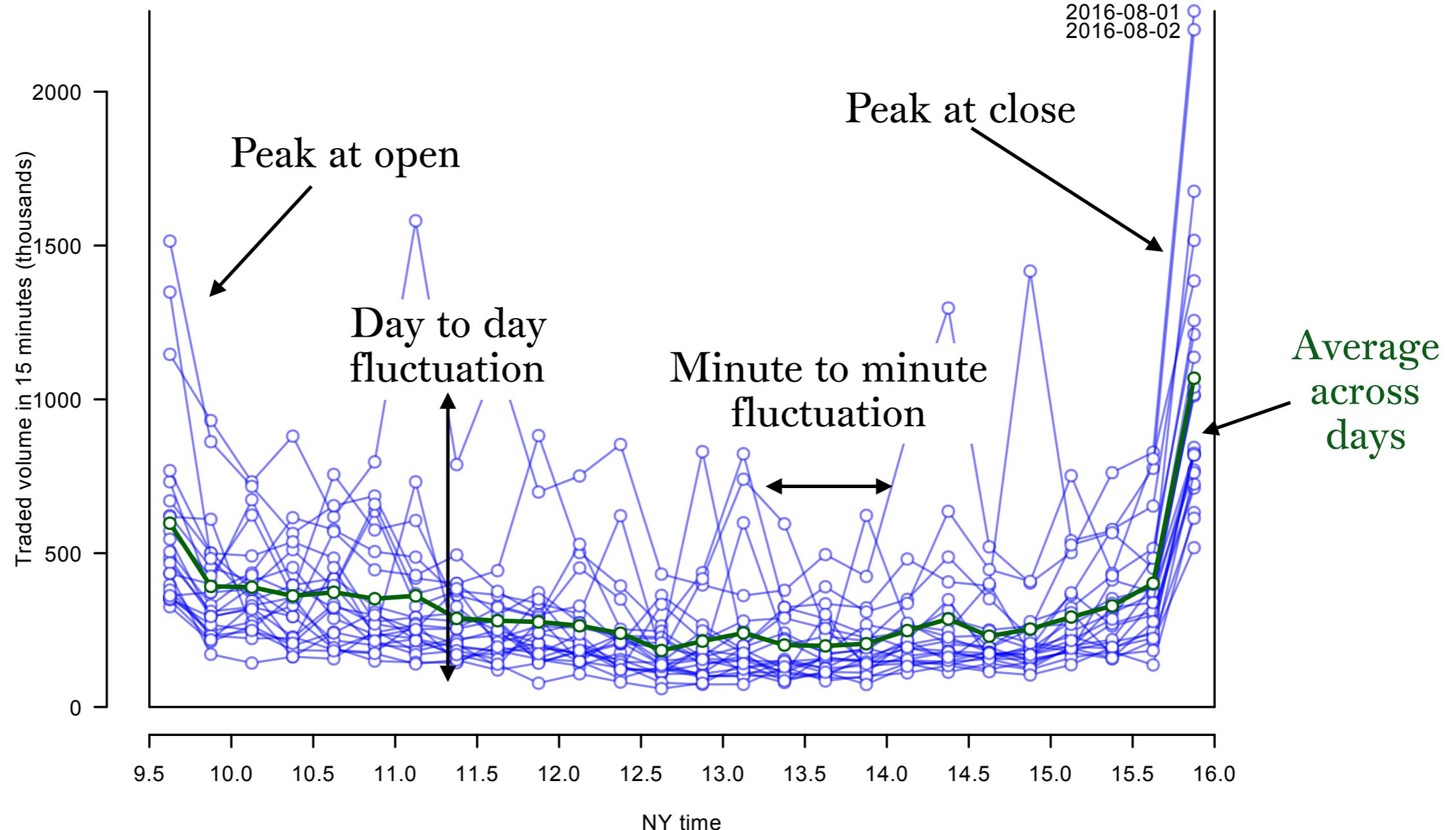


Fluctuations in volume curves

- XOM "Exxon Mobil"
 - #3 on list
 - NYSE-listed \$375B
 - ~ 10 million shares per day
- MHO "MI Homes"
 - #3000 on list
 - NYSE-listed \$600MM

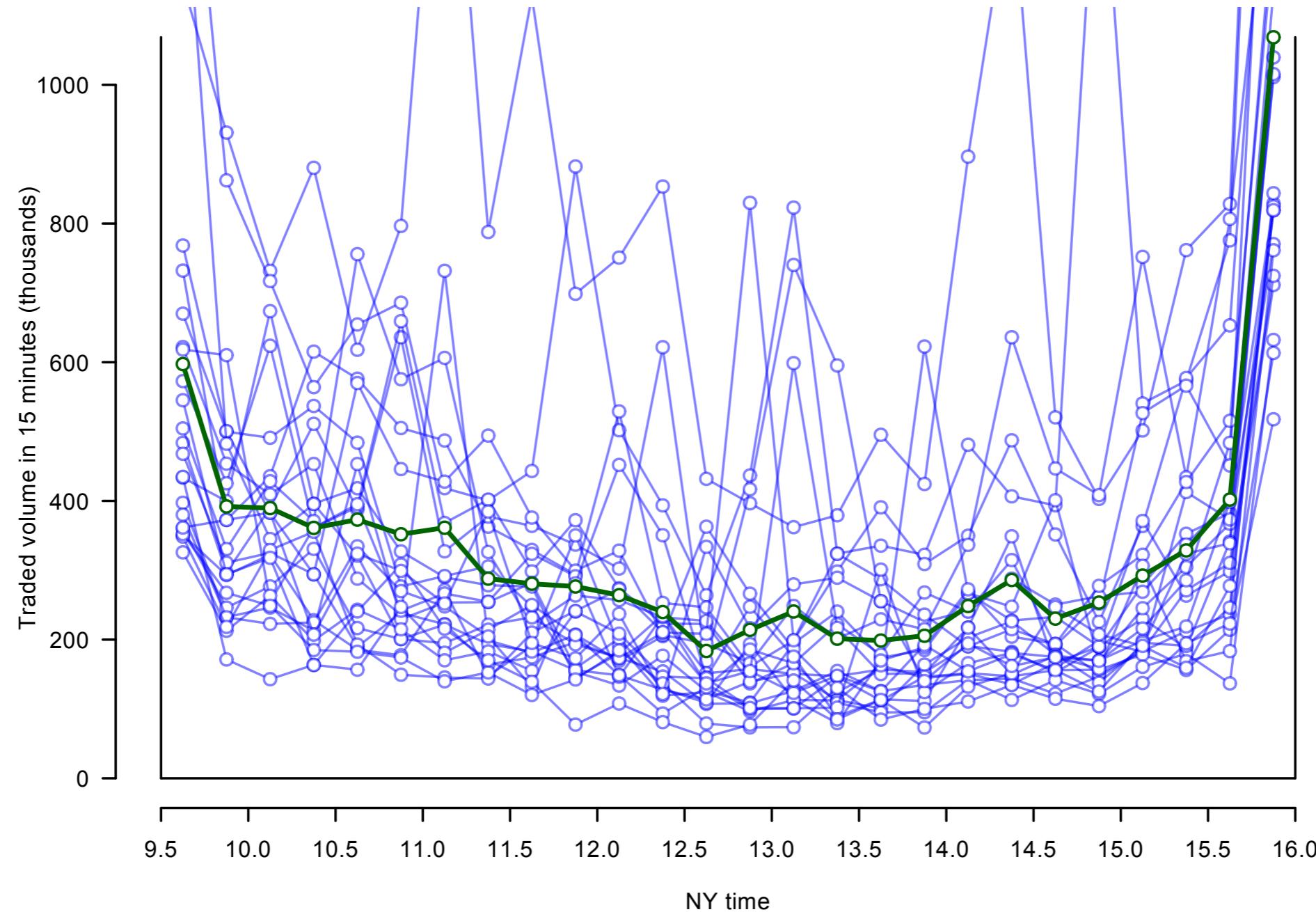
XOM (very large cap) Aug 2016

XOM / 2016-08-01 to 2016-08-31



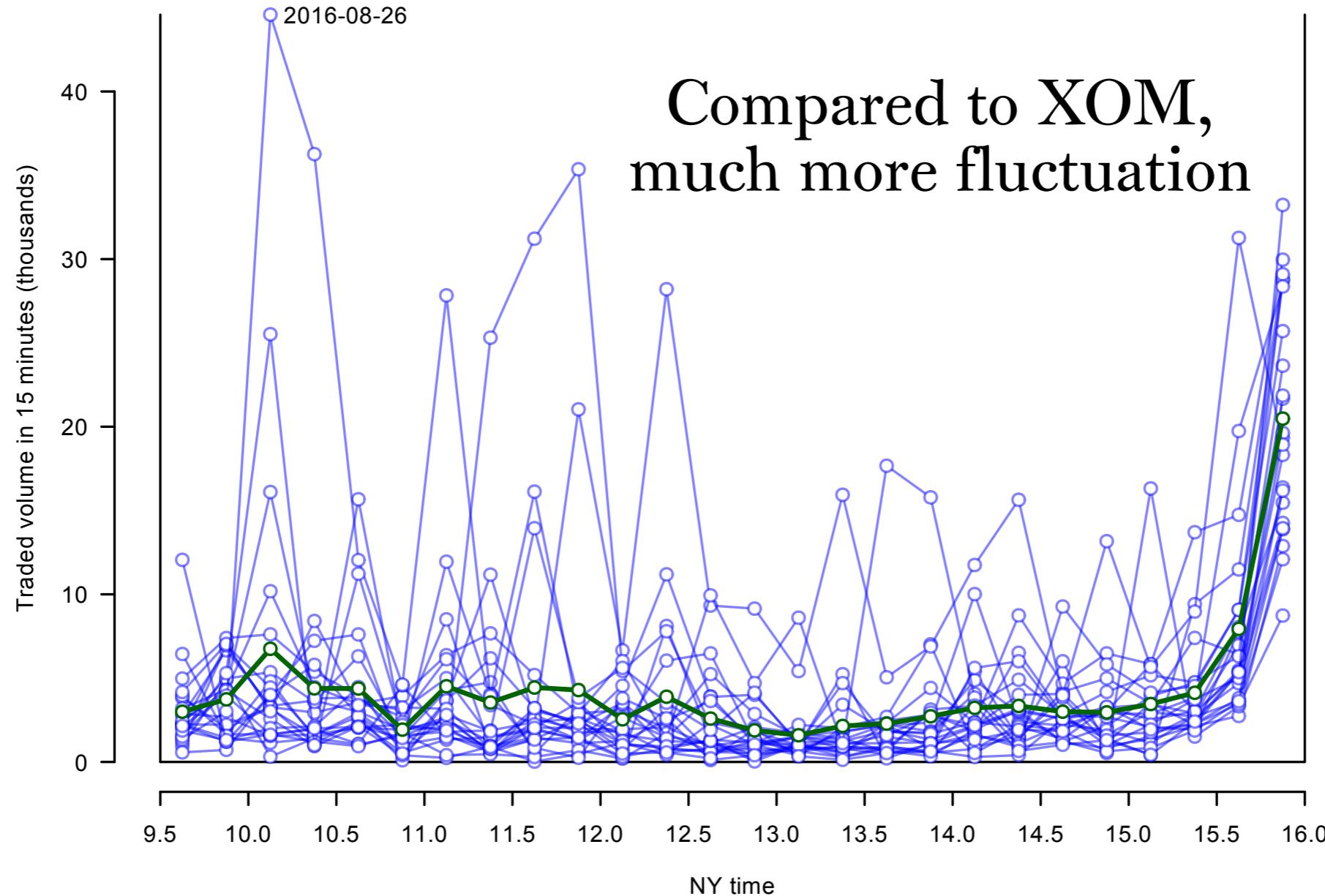
XOM Aug 2016 (detail)

XOM / 2016-08-01 to 2016-08-31



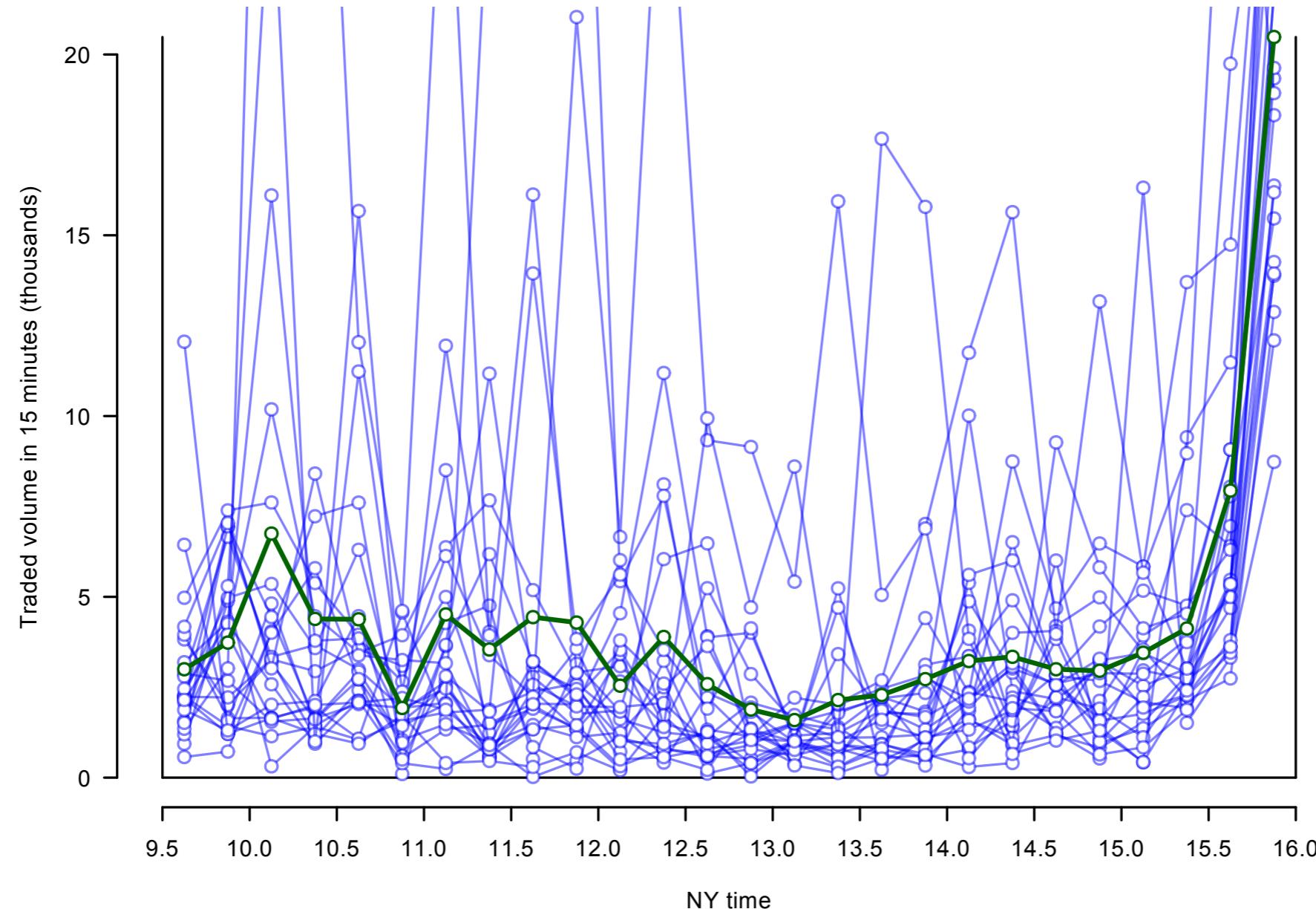
MHO (med-cap) Aug 2016

MHO / 2016-08-01 to 2016-08-31

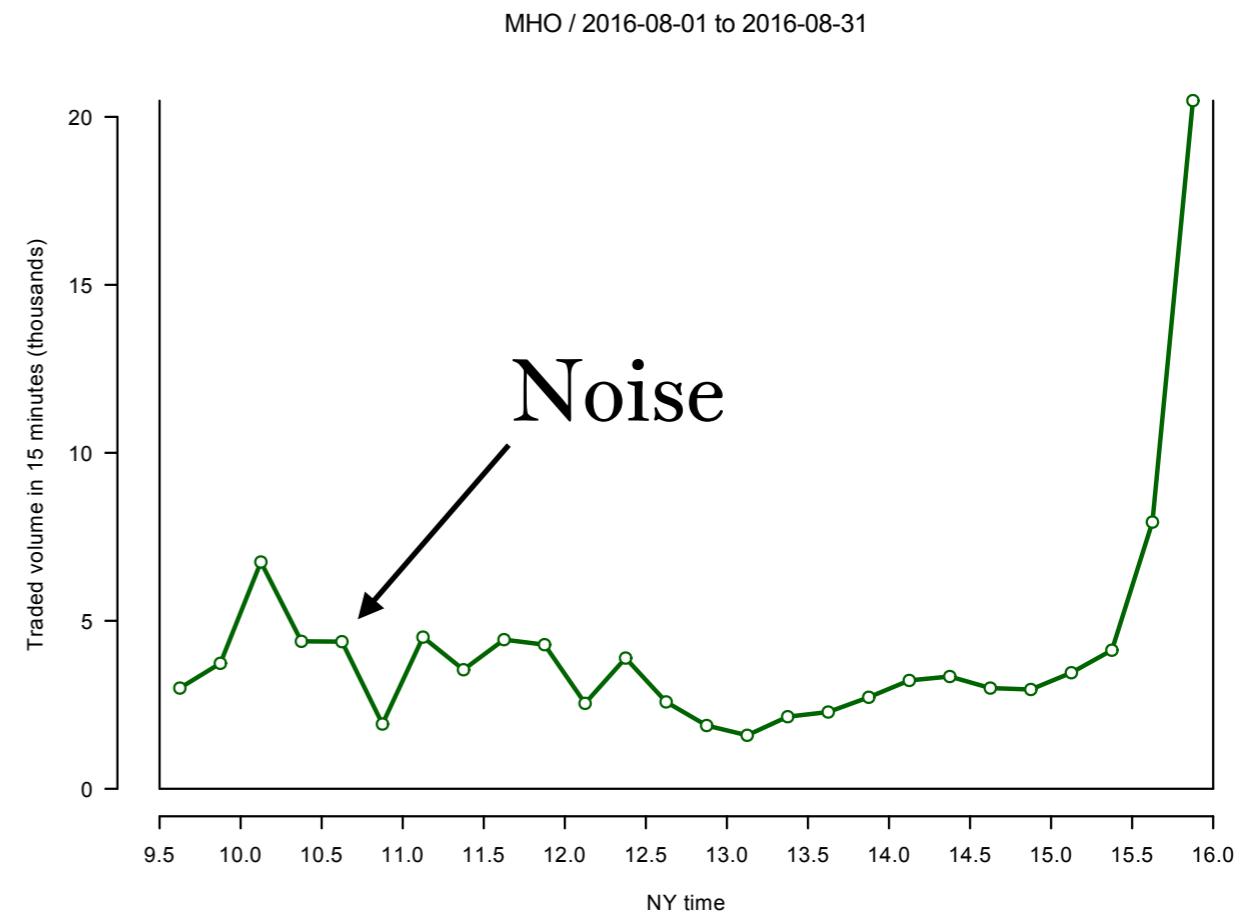
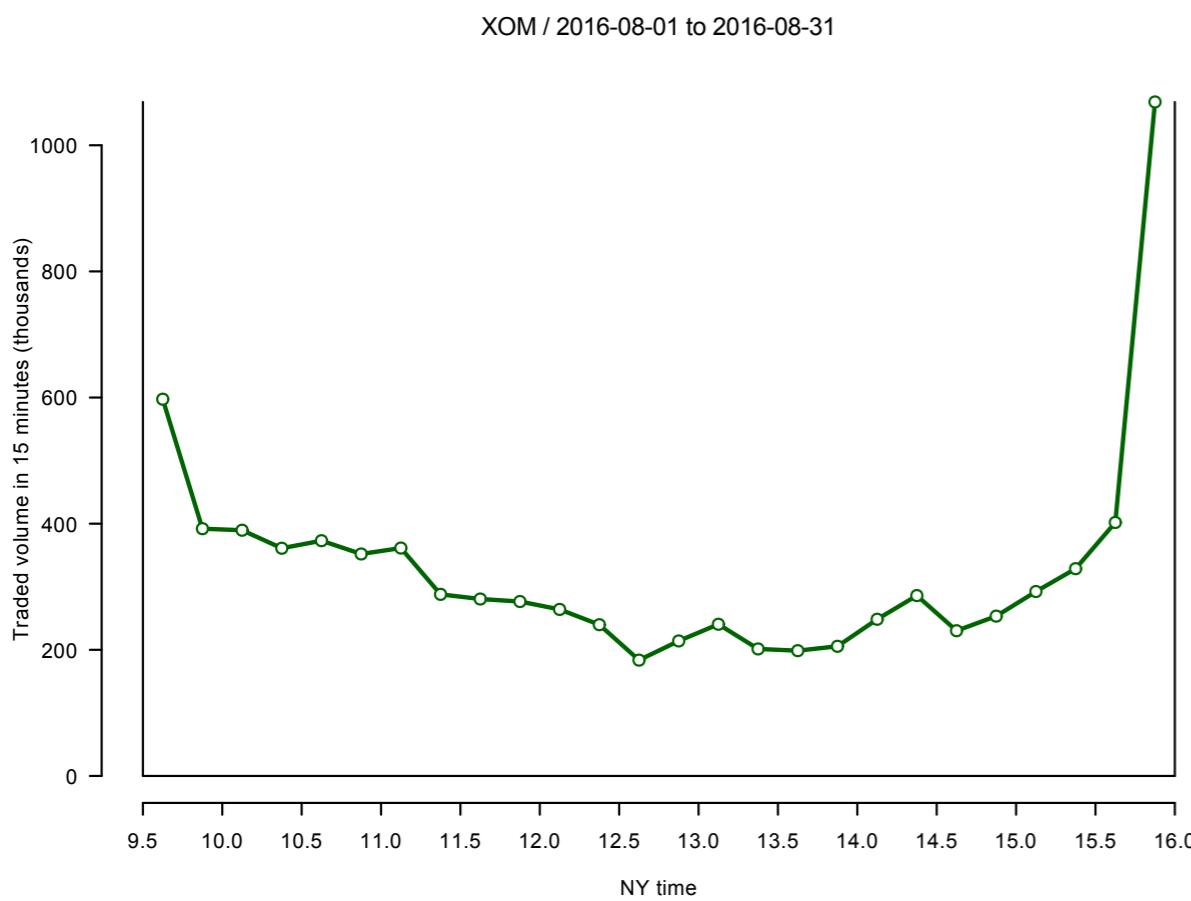


MHO Aug 2016 detail

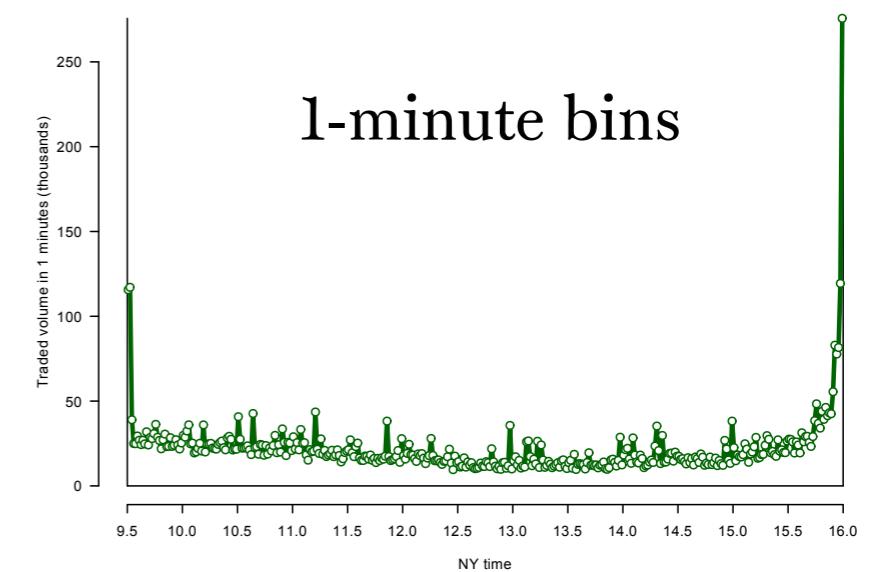
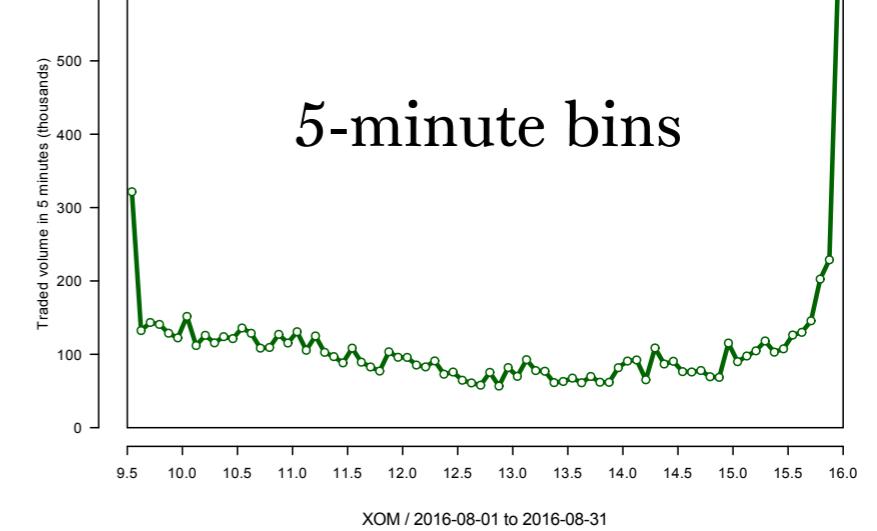
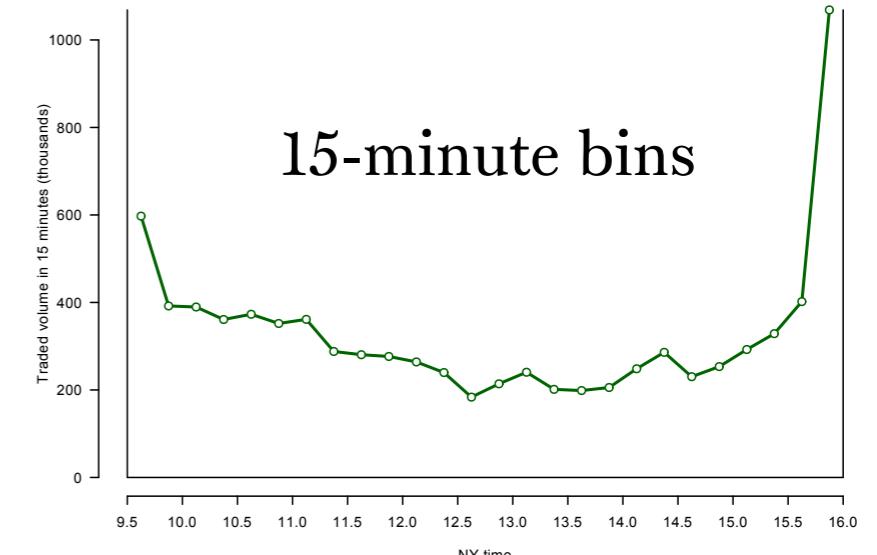
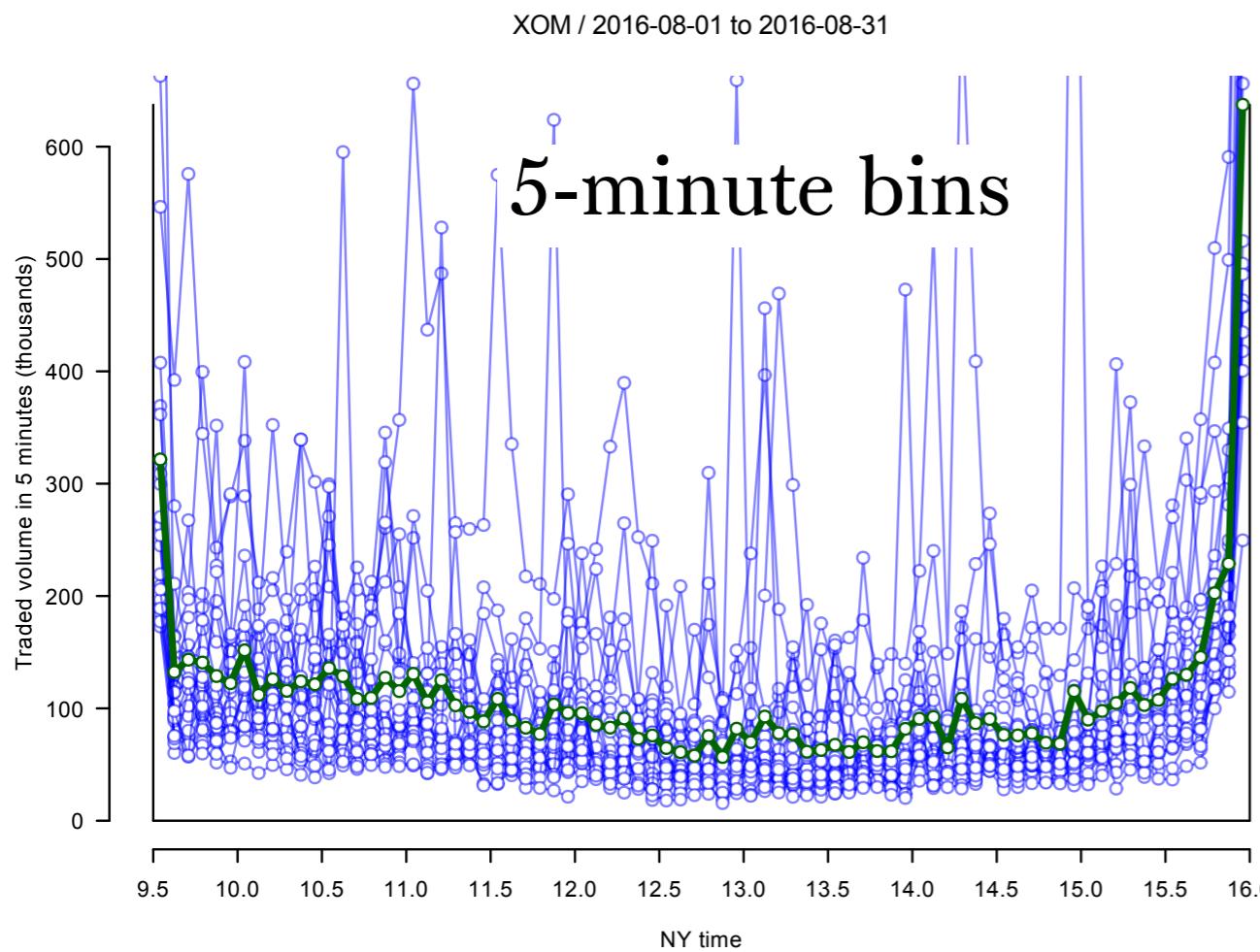
MHO / 2016-08-01 to 2016-08-31



Use average as a predicted curve



Try 5-minute bins

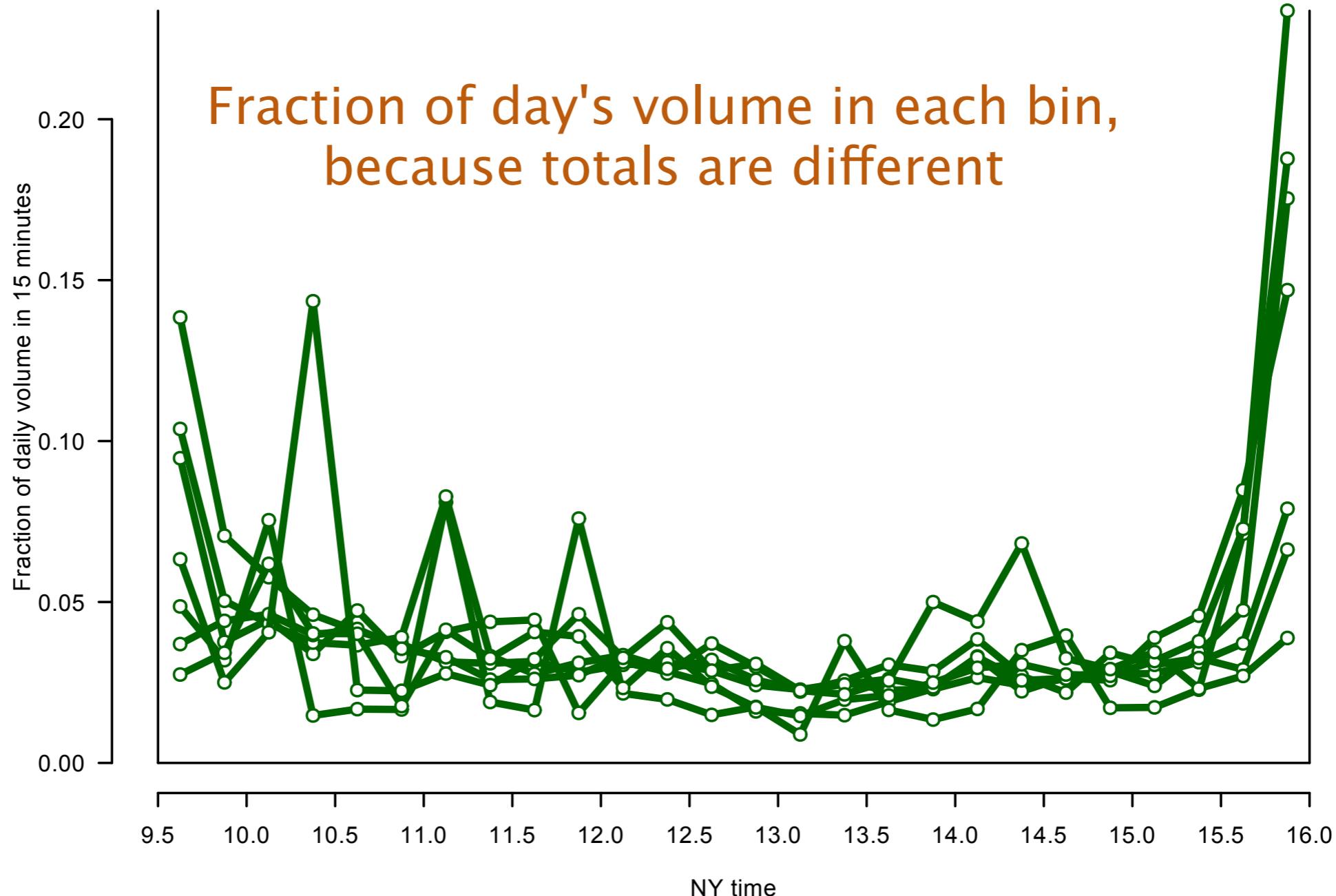


Challenges with volume curves

- Noisiness of data
 - worse for smaller cap stocks
 - worse for finer bins
 - reduce by taking longer time but does not vanish
- Outliers
 - scheduled information events
 - unscheduled events
- Non-stationarity
- Combine different stocks into one curve

Multi-stock averaging

AAPL,CNHI,EBSB,ETY,GRA,MHO,VIS / 2016-08-01 to 2016-08-31



Non-stationarity

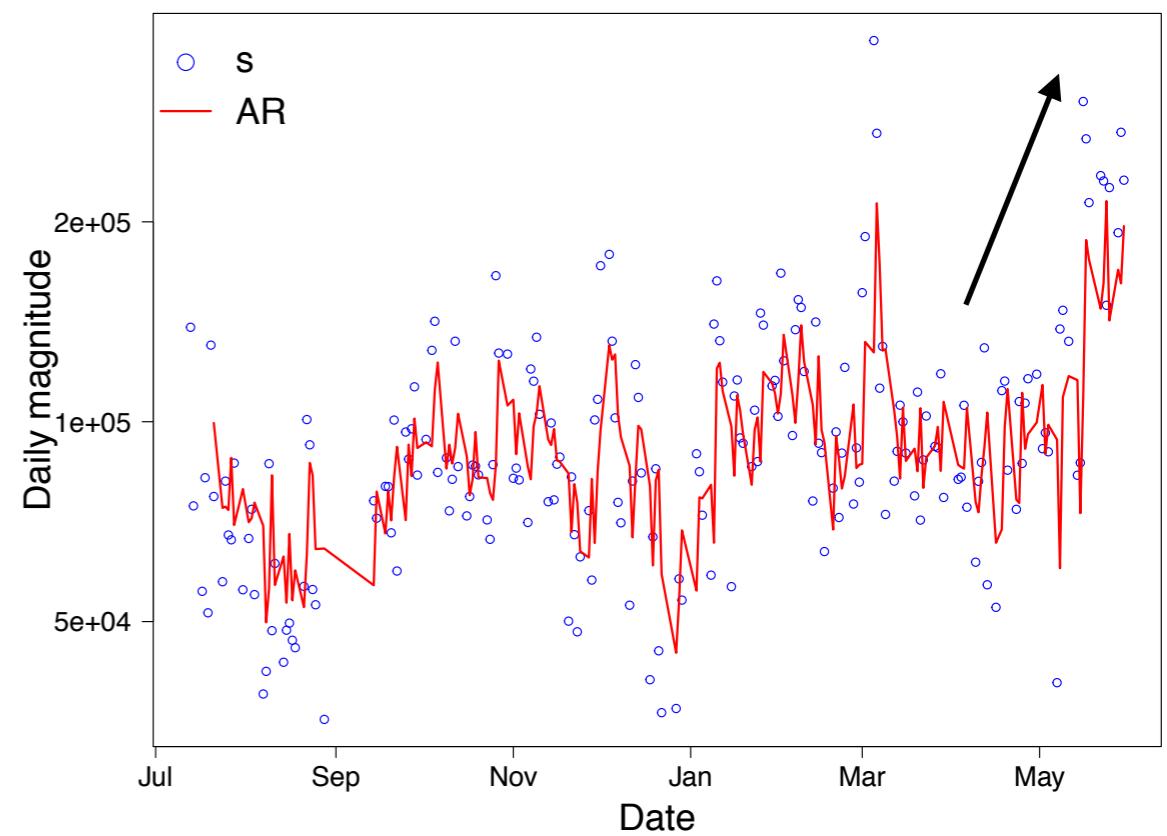
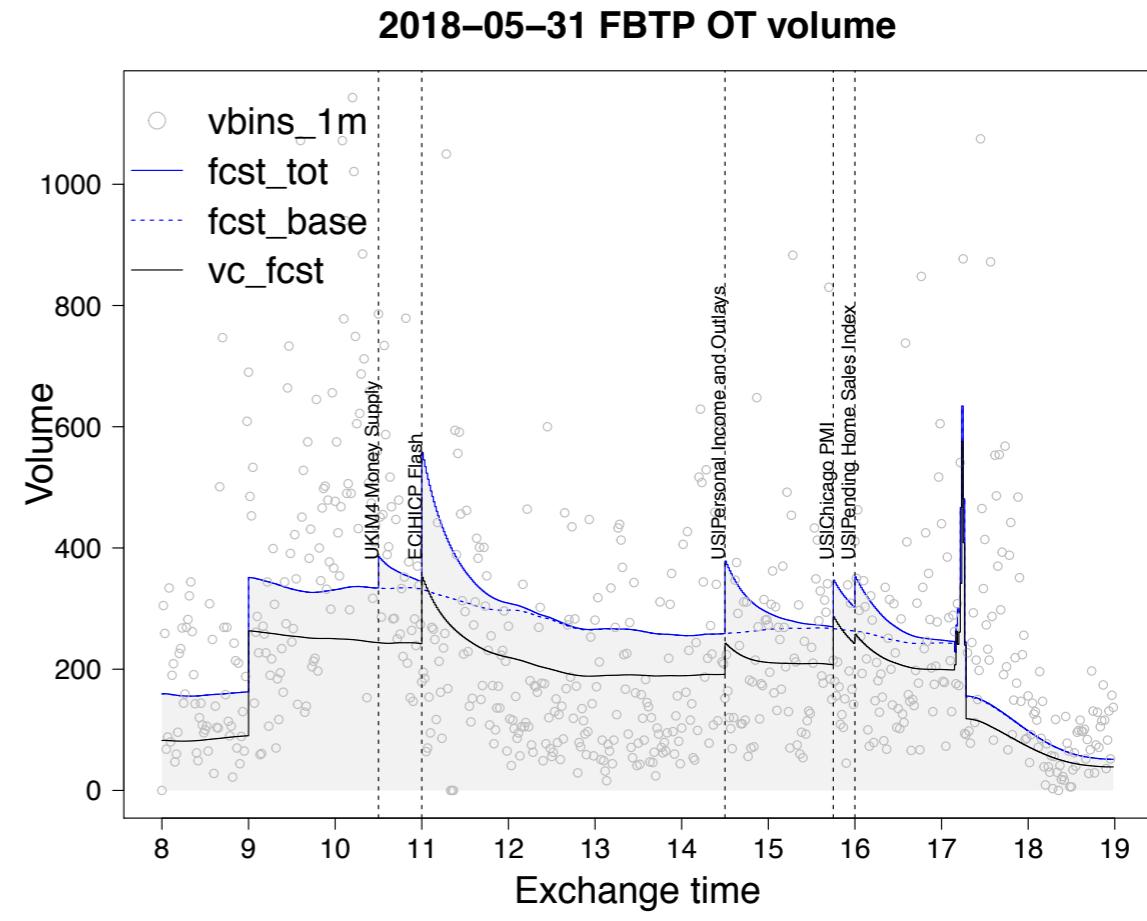


VOLUME CURVES II
- SHAPES, MAGNITUDES
AND EVENTS

YING LIU

AUGUST 29, 2018

Volume on each day and bin
= product of
intraday profile
and daily factor



Information events

- Information released and other events:
 - Employment numbers
 - usually pre-open
 - Economic numbers
 - usually pre-open
 - Earnings announcements
 - usually post-close
 - FOMC minutes
 - 2 PM NY time -- middle of trading day

Economic announcements

- Employment Situation
 - Most important: "Change in nonfarm payrolls"
the "jobs number"
- First Friday of every month 8:30 AM
- Very significant effect on markets, but equity markets are closed



Economic News Release

Employment Situation Summary

Transmission of material in this release is embargoed until
8:30 a.m. (EST) Friday, February 3, 2017

USDL-17-0141

Technical information:

Household data: (202) 691-6378 * cpsinfo@bls.gov * www.bls.gov/cps
Establishment data: (202) 691-6555 * cesinfo@bls.gov * www.bls.gov/ces

Media contact: (202) 691-5902 * PressOffice@bls.gov

THE EMPLOYMENT SITUATION -- JANUARY 2017

Total nonfarm payroll employment increased by 227,000 in January, and the unemployment rate was little changed at 4.8 percent, the U.S. Bureau of Labor Statistics reported today. Job gains occurred in retail trade, construction, and financial activities.

Schedule of Releases for the Employment Situation

Reference Month	Release Date	Release Time
October 2016	Nov. 04, 2016	08:30 AM
November 2016	Dec. 02, 2016	08:30 AM
December 2016	Jan. 06, 2017	08:30 AM
January 2017	Feb. 03, 2017	08:30 AM
February 2017	Mar. 10, 2017	08:30 AM
March 2017	Apr. 07, 2017	08:30 AM
April 2017	May 05, 2017	08:30 AM
May 2017	Jun. 02, 2017	08:30 AM
June 2017	Jul. 07, 2017	08:30 AM
July 2017	Aug. 04, 2017	08:30 AM
August 2017	Sep. 01, 2017	08:30 AM
September 2017	Oct. 06, 2017	08:30 AM
October 2017	Nov. 03, 2017	08:30 AM
November 2017	Dec. 08, 2017	08:30 AM

THE WALL STREET JOURNAL.

English Edition ▾ | February 10, 2020 | Print Edition | Video

Unexplained Trading in Pound Last Month Wasn't a First

Data show unusual trading activity in the pound before Bank of England announcements in January, December

By [Anna Isaac](#) and [Caitlin Ostroff](#)

Feb. 9, 2020 5:00 am ET

On Dec. 19, in the 10 seconds before the bank released its decision to keep interest rates steady, trading volumes for three-month futures tied to the pound against the dollar spiked to more than 300 contracts changing hands in one second, from single digits. At the same time, pound futures ticked as high as \$1.3113 from \$1.3090 10 seconds before the announcement, according to data and academic analysis.

At the BOE, reporters are allowed to take one electronic device into an underground room about two hours before the scheduled release of the monetary-policy announcement. There, they are given freshly printed documents with the central bank's decision. When the release becomes public at noon London time, a staff person flips a switch that turns on internet access inside the room and the lock-in, as it is called, ends.

Unlike the Fed and the European Central Bank, which make their decisions public on the day they are made, the Bank of England reveals its decision a day later.

The U.S. Labor Department, which releases market-moving jobs and inflation data, said recently it plans to [end the practice of giving reporters an early peek at data](#) at a secure facility controlled by the government. Under that system, it would allow the reporters to publish articles at the same time that the data was publicly disclosed.

The change was engineered in part to remove the potential advantage that media organizations and their clients had over the broader public.

<https://www.wsj.com/articles/unexplained-trading-in-pound-last-month-wasnt-a-first-11581242400>

It's the End of Jobs Day as We Know It. Traders Feel Fine.

New limits on data reporting are set to take effect next month. High-speed algorithms are already fastest, and that won't change.

By Brian Chappatta

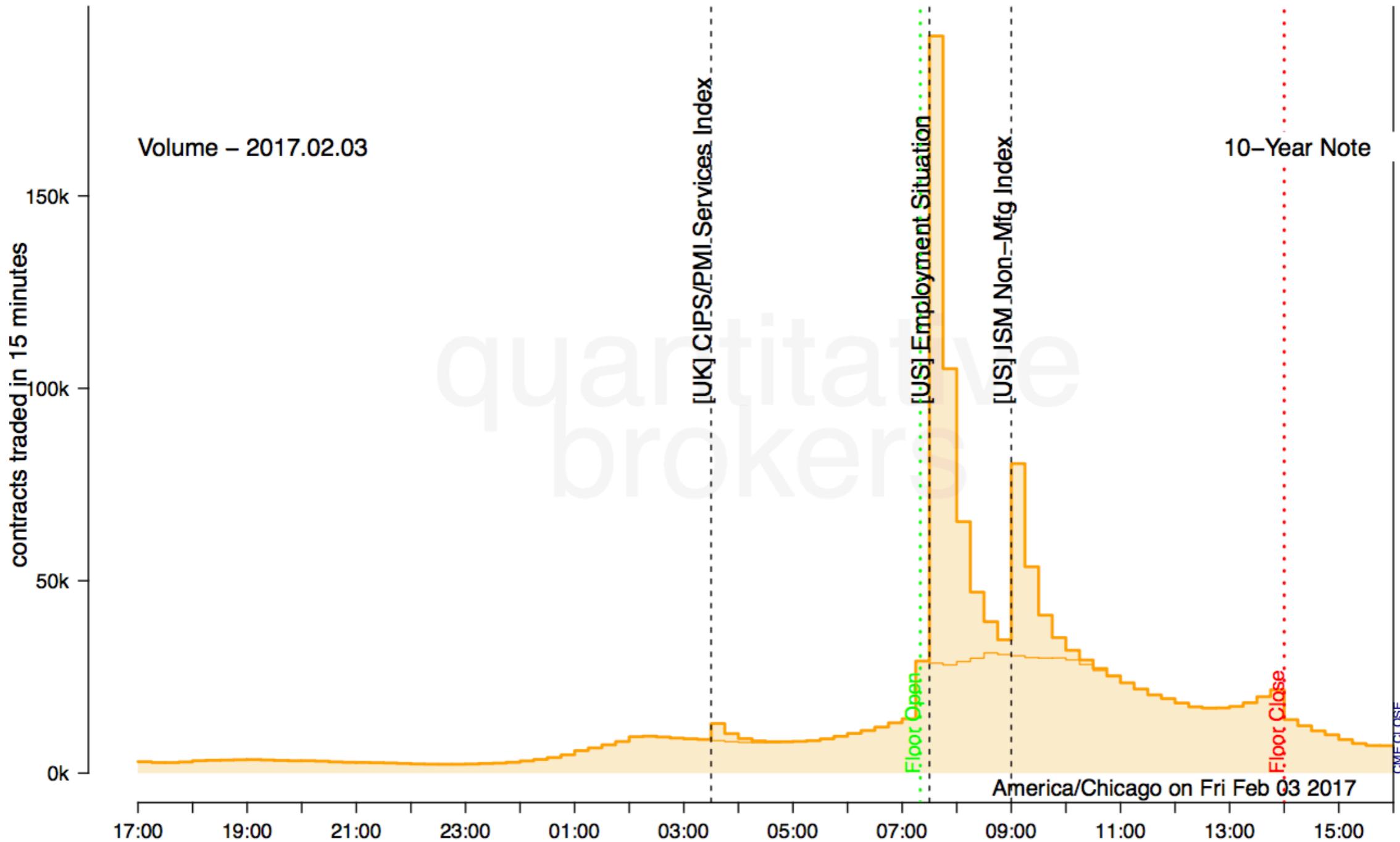
February 7, 2020, 10:00 AM UTC *Updated on February 7, 2020, 1:50 PM UTC*

When the next payrolls report rolls around on March 6, the market swings might be even bigger. The Labor Department's new ban on computers is set to take effect March 1, a move that will most likely leave news services slightly behind the official release on the government's website. The Commerce Department, which is responsible for distributing major reports like gross domestic product and retail sales through the same lockups, has signaled it will follow the changes.

Talk to bond traders, on the other hand, and you'd hardly know anything was afoot. Their rationale? High-speed algorithmic traders are fastest under the current system, and they'll be just as quick under the new one. Some speculate that these firms already scrape the Labor Department's website anyway to inform their jobs day trades, possibly on top of key words from headlines. So, in that sense, not much will truly change: Algos will get the first crack at the market, and the rest of Wall Street will react soon afterward.

<https://www.bloomberg.com/opinion/articles/2020-02-07/it-s-the-end-of-jobs-day-as-we-know-it-traders-feel-fine>

- Employment Situation for interest rate futures



FOMC announcement



Meeting calendars, statements, and minutes (2012-2017)

The FOMC holds eight regularly scheduled meetings during the year and other meetings as needed. Links to policy statements and minutes are in the calendars below. The minutes of regularly scheduled meetings are released three weeks after the date of the policy decision. Committee membership changes at the first regularly scheduled meeting of the year.

2016 FOMC Meetings

January	26-27	Statement: PDF HTML Implementation Note	Longer-Run Goals and Policy Strategy Minutes: PDF HTML (Released February 17, 2016)
March	15-16*	Statement: PDF HTML Implementation Note	Press Conference Projections Materials: PDF HTML Minutes: PDF HTML (Released April 6, 2016)
April	26-27	Statement: PDF HTML Implementation Note	Minutes: PDF HTML (Released May 18, 2016)

FEDERAL RESERVE press release



For release at 2 p.m. EDT

September 21, 2016

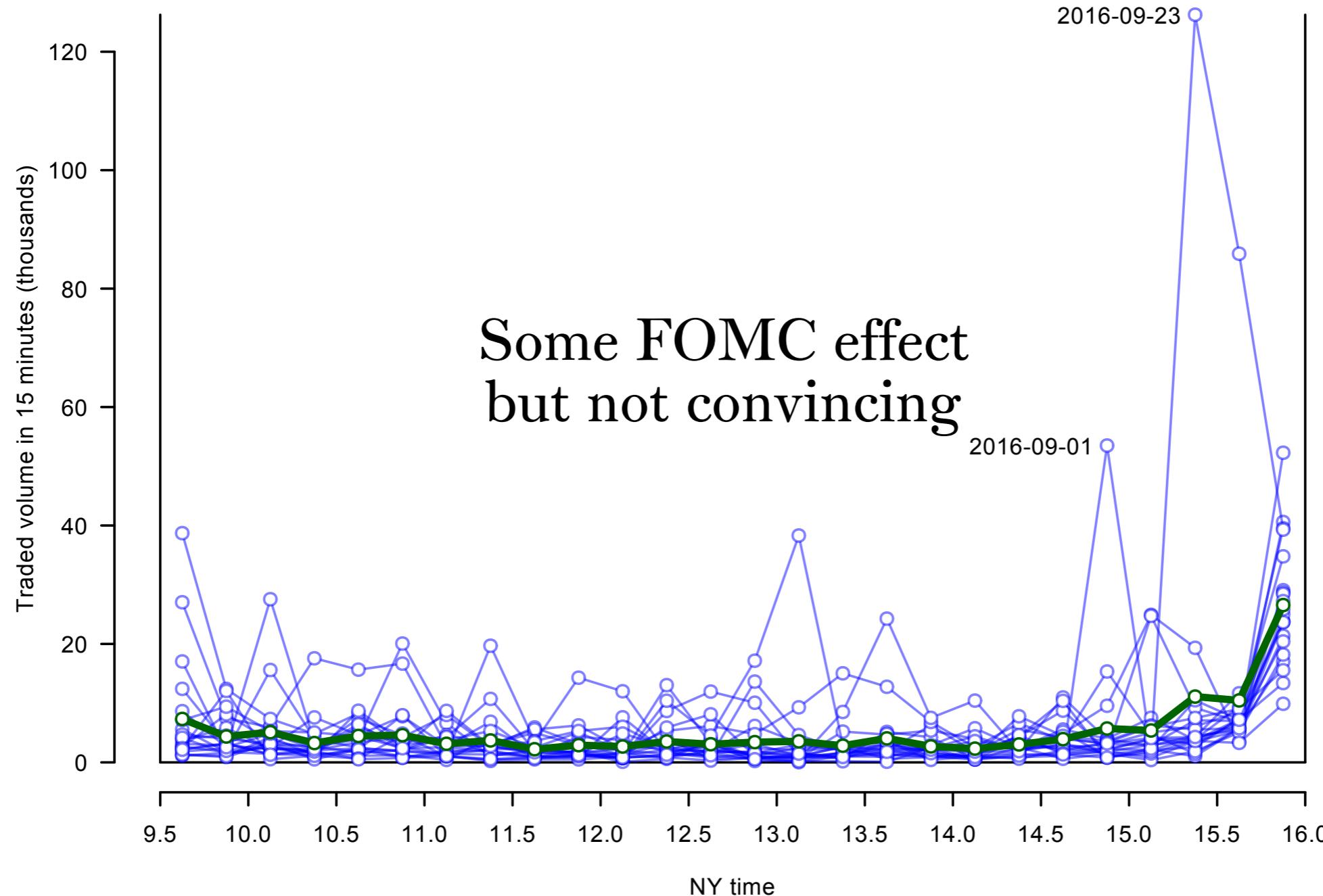
Information received since the Federal Open Market Committee met in July indicates that the labor market has continued to strengthen and growth of economic activity has picked up from the modest pace seen in the first half of this year. Although the unemployment rate is little changed in recent months, job gains have been solid, on average. Household spending has been growing strongly but business fixed investment has remained soft. Inflation has continued to run below the Committee's 2 percent longer-run objective, partly reflecting earlier declines in energy prices and in prices of non-energy imports. Market-based measures of inflation compensation remain low; most survey-based measures of longer-term inflation expectations are little changed, on balance, in recent months.

Consistent with its statutory mandate, the Committee seeks to foster maximum employment and price stability. The Committee expects that, with gradual adjustments in the stance of monetary policy, economic activity will expand at a moderate pace and labor market conditions will strengthen somewhat further. Inflation is expected to remain low in the near term, in part because of earlier declines in energy prices, but to rise to 2 percent over the medium term as the transitory effects of past declines in energy and import prices dissipate and the labor market strengthens further. Near-term risks to the economic outlook appear roughly balanced. The Committee continues to closely monitor inflation indicators and global economic and financial developments.

Against this backdrop, the Committee decided to maintain the target range for the federal funds rate at 1/4 to 1/2 percent. The Committee judges that the case for an increase in the federal funds rate has strengthened but decided, for the time being, to wait for further evidence of continued progress toward its objectives. The stance of monetary policy remains accommodative, thereby supporting further improvement in labor market conditions and a return to 2 percent inflation.

(more)

MHO / 2016-09-01 to 2016-09-30



Information events for stocks

time	date	NYtime	UKtime	GEtime	src	region	event
2020.01.03T15:30:00.000	2020.01.03	10:30	15:30	16:30	energy	US	EIA Natural Gas Report
2020.01.03T16:00:00.000	2020.01.03	11:00	16:00	17:00	energy	US	EIA Petroleum Status Report
2020.01.07T21:30:00.000	2020.01.07	16:30	21:30	20:30	energy	US	API Report (WSB)
2020.01.08T15:30:00.000	2020.01.08	10:30	15:30	16:30	energy	US	EIA Petroleum Status Report
2020.01.09T15:30:00.000	2020.01.09	10:30	15:30	16:30	energy	US	EIA Natural Gas Report
2020.01.14T21:30:00.000	2020.01.14	16:30	21:30	20:30	energy	US	API Report (WSB)
2020.01.15T15:30:00.000	2020.01.15	10:30	15:30	16:30	energy	US	EIA Petroleum Status Report
2020.01.16T15:30:00.000	2020.01.16	10:30	15:30	16:30	energy	US	EIA Natural Gas Report
2020.01.22T21:30:00.000	2020.01.22	16:30	21:30	20:30	energy	US	API Report (WSB)
2020.01.23T15:30:00.000	2020.01.23	10:30	15:30	16:30	energy	US	EIA Natural Gas Report
2020.01.23T16:00:00.000	2020.01.23	11:00	16:00	17:00	energy	US	EIA Petroleum Status Report
2020.01.28T21:30:00.000	2020.01.28	16:30	21:30	20:30	energy	US	API Report (WSB)
2020.01.29T15:30:00.000	2020.01.29	10:30	15:30	16:30	energy	US	EIA Petroleum Status Report
2020.01.30T15:30:00.000	2020.01.30	10:30	15:30	16:30	energy	US	EIA Natural Gas Report



Petroleum status:
Might have effect
on oil companies

[SEE ALL PETROLEUM REPORTS](#)

Weekly Petroleum Status Report

Data for week ending January 31, 2020 | Release Date: February 5, 2020 | Next

Release Date: February 12, 2020 | [full report](#)

The petroleum supply situation in the context of historical information and selected prices.

Released after

10:30 a.m. 1:00 p.m.

[Previous Issues](#)

Week: February 5, 2020

[Release schedule](#)[Automated retrieval policy](#)[Sign up for email updates](#)[Webinars](#)**Highlights**[Weekly Petroleum Status Report Highlights](#)[PDF](#)[Data Overview \(Combined Table 1 and Table 9\)](#)**RELEASE SCHEDULE**

The wpsrsummary.pdf, overview.pdf, and Tables 1-14 in CSV and XLS formats, are released to the web site **after 10:30 a.m. (Eastern Time) on Wednesday**. All other PDF and HTML files are released to the web site **after 1:00 p.m. (Eastern Time) on Wednesday**. For some weeks which include holidays, releases are delayed by one day.

Summary of Weekly Petroleum Data for the week ending January 31, 2020

U.S. crude oil refinery inputs averaged 16.0 million barrels per day during the week ending January 31, 2020, which was 48,000 barrels per day more than the previous week's average. Refineries operated at 87.4% of their operable capacity last week.

Gasoline production increased last week, averaging 9.9 million barrels per day. Distillate fuel production decreased last week, averaging 5.0 million barrels per day.

U.S. crude oil imports averaged 6.6 million barrels per day last week, down by 46,000 barrels per day from the previous week. Over the past four weeks, crude oil imports averaged about 6.6 million barrels per day, 12.3% less than the same four-week period last year. Total motor gasoline imports (including both finished gasoline and gasoline blending components) last week averaged 676,000 barrels per day, and distillate fuel imports averaged 194,000 barrels per day.

<https://www.eia.gov/petroleum/supply/weekly/>

Privacy Statement and Security Policy

Privacy statement

This website (<http://www.eia.gov/>) is provided as a public energy information service of the U.S. Energy Information Administration.

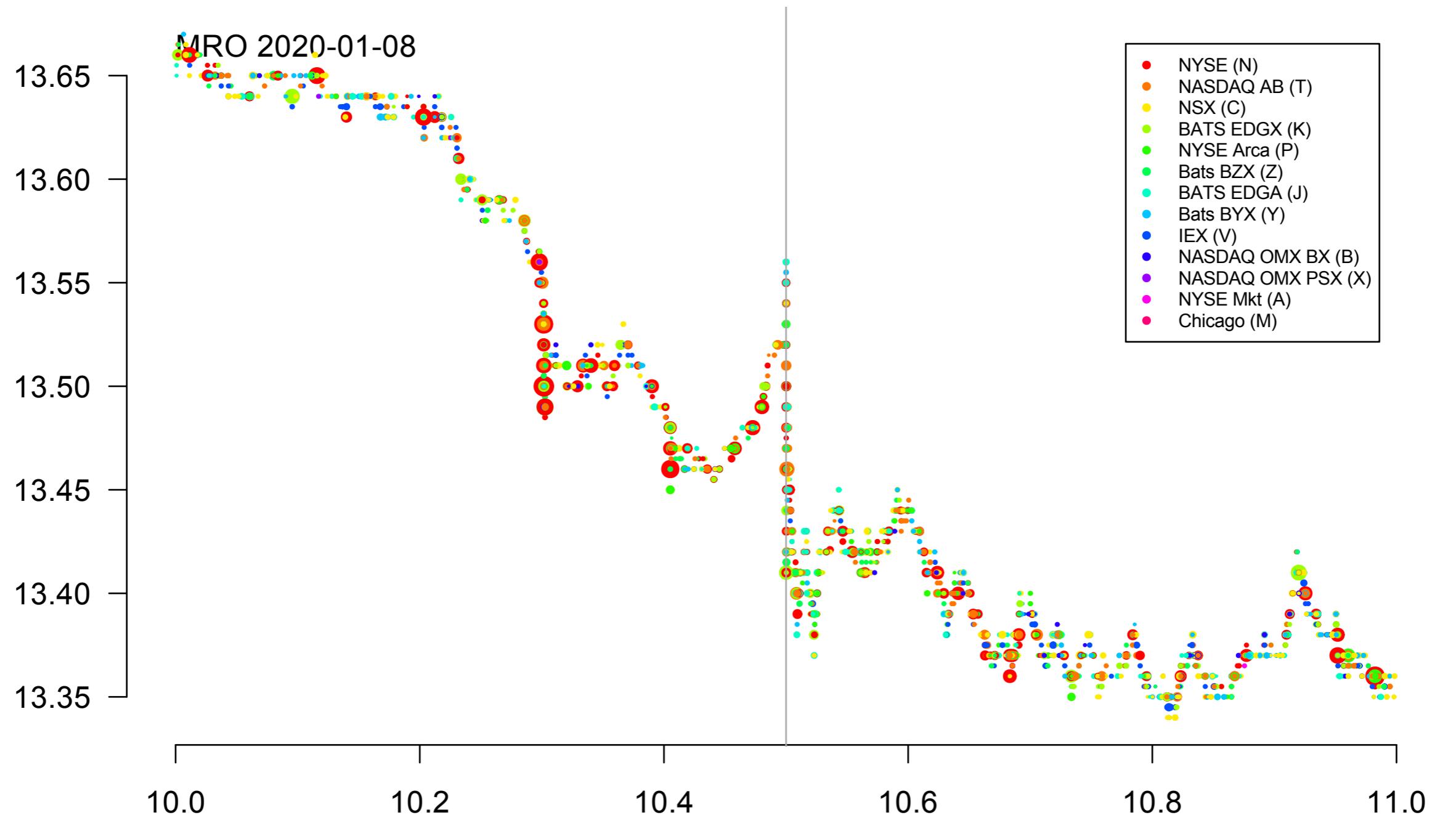
EIA.gov utilizes web measurement software tools in order to improve the efficiency of our website and to provide a better user experience for our customers. If you visit this site to read or download information, you should know that EIA collects and stores a standard set of Internet-related information, such as an Internet Protocol (IP) address, the date and time, the type of browser and operating system used, the page(s) visited, and if you linked to the EIA website from another website, the address of that website.

**Automated retrieval program (robot) activity**

EIA is committed to providing data promptly and according to established schedules. Therefore any automated retrieval program (commonly referred to as a "robot" or "bot") that excessively accesses information from EIA's website is prohibited. Excessive robot activity on EIA's website can cause delays and interfere with other customers' timely access to information.

EIA will block robots that are accessing the website in any way that EIA considers excessive or malicious, including robots that attempt to access or download survey information multiple times per second with resulting degradation of service to others. EIA also reserves the right to block robots that do not contain contact information that can be used to contact the owner. Blocking may occur in real time.

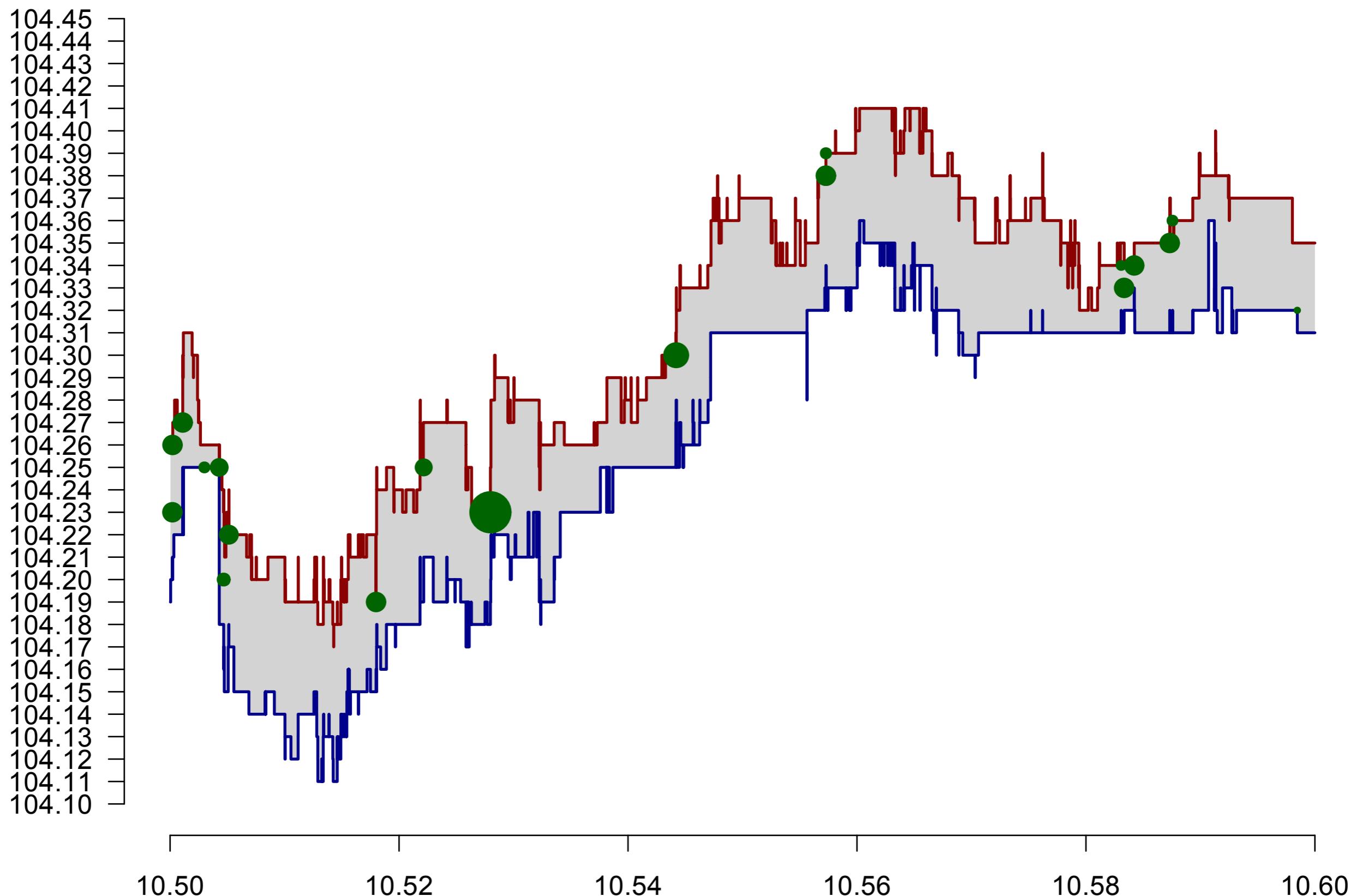
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> C[ TICKER=='MRO', ]
  PERMNO      date TICKER      COMNAME SHRCLS     PRC      VOL    SHROUT      mktcap
1: 15069 2019-12-31    MRO MARATHON OIL CORP      13.58 212144400 799929000 10863035820
```



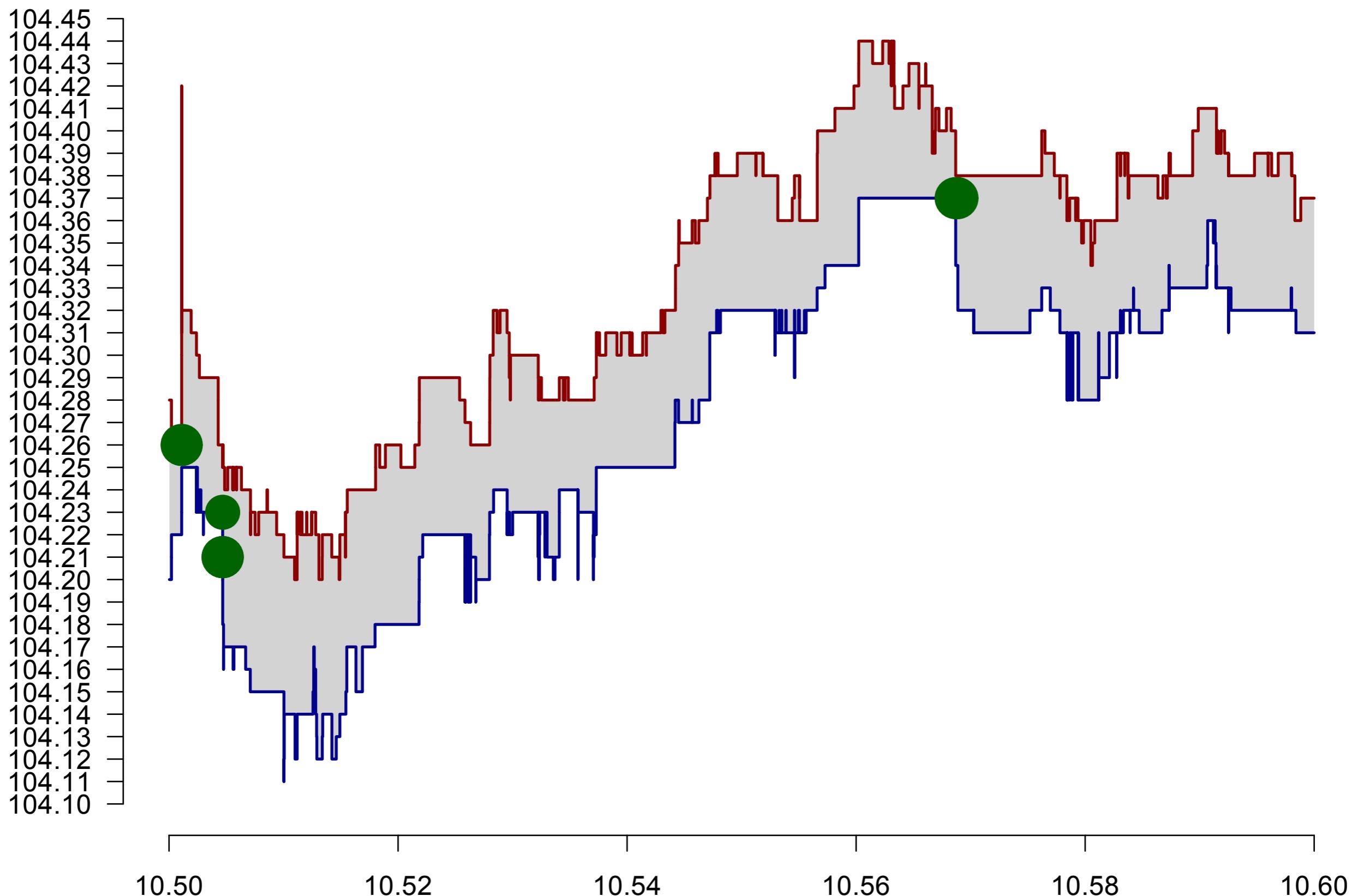
Quote data

- Much more volume than trade data
- Time stamps may be different
- Matching trades and quotes is not easy

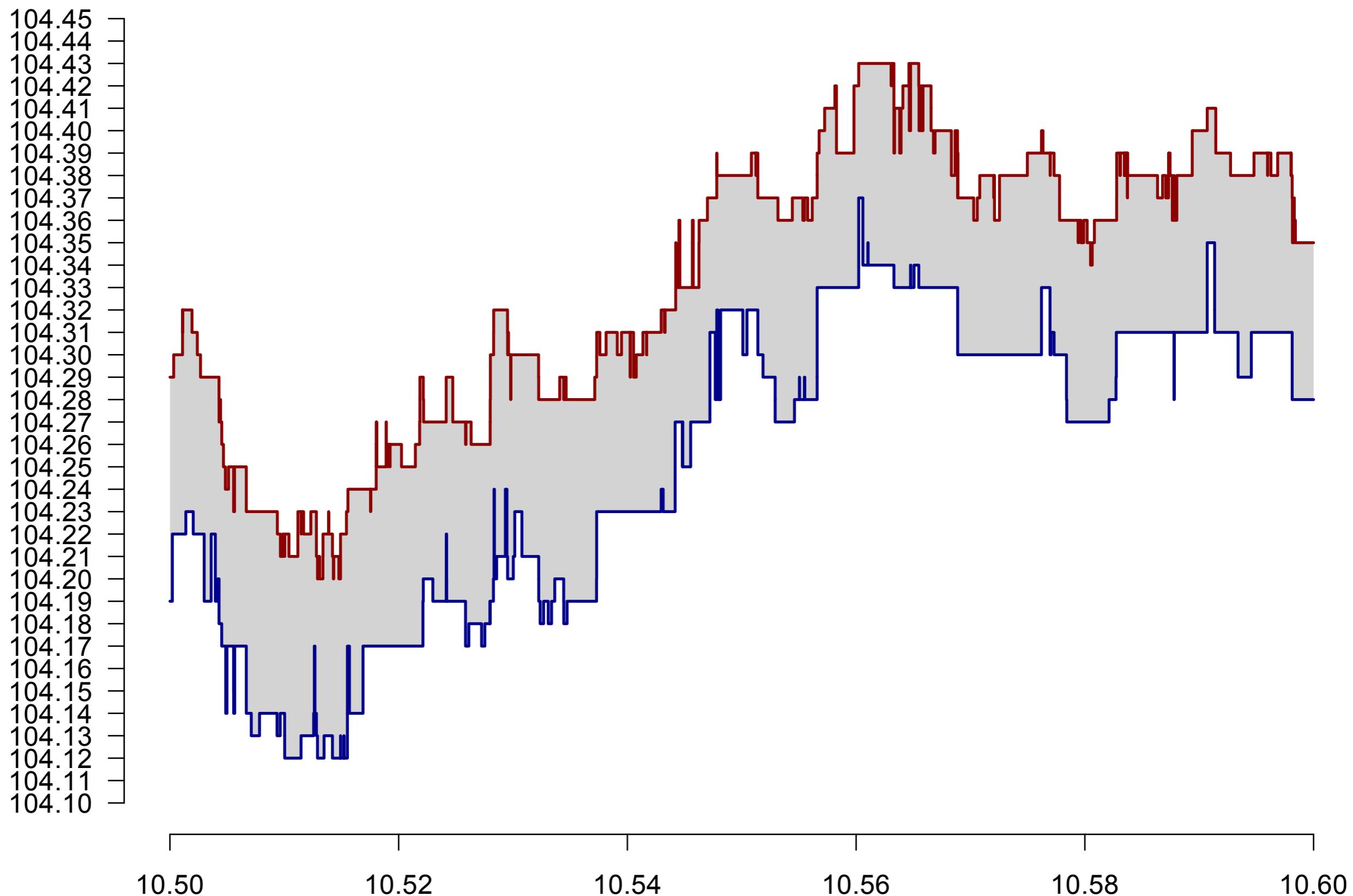
SAP 2019-01-23 NASDAQ AB (T)



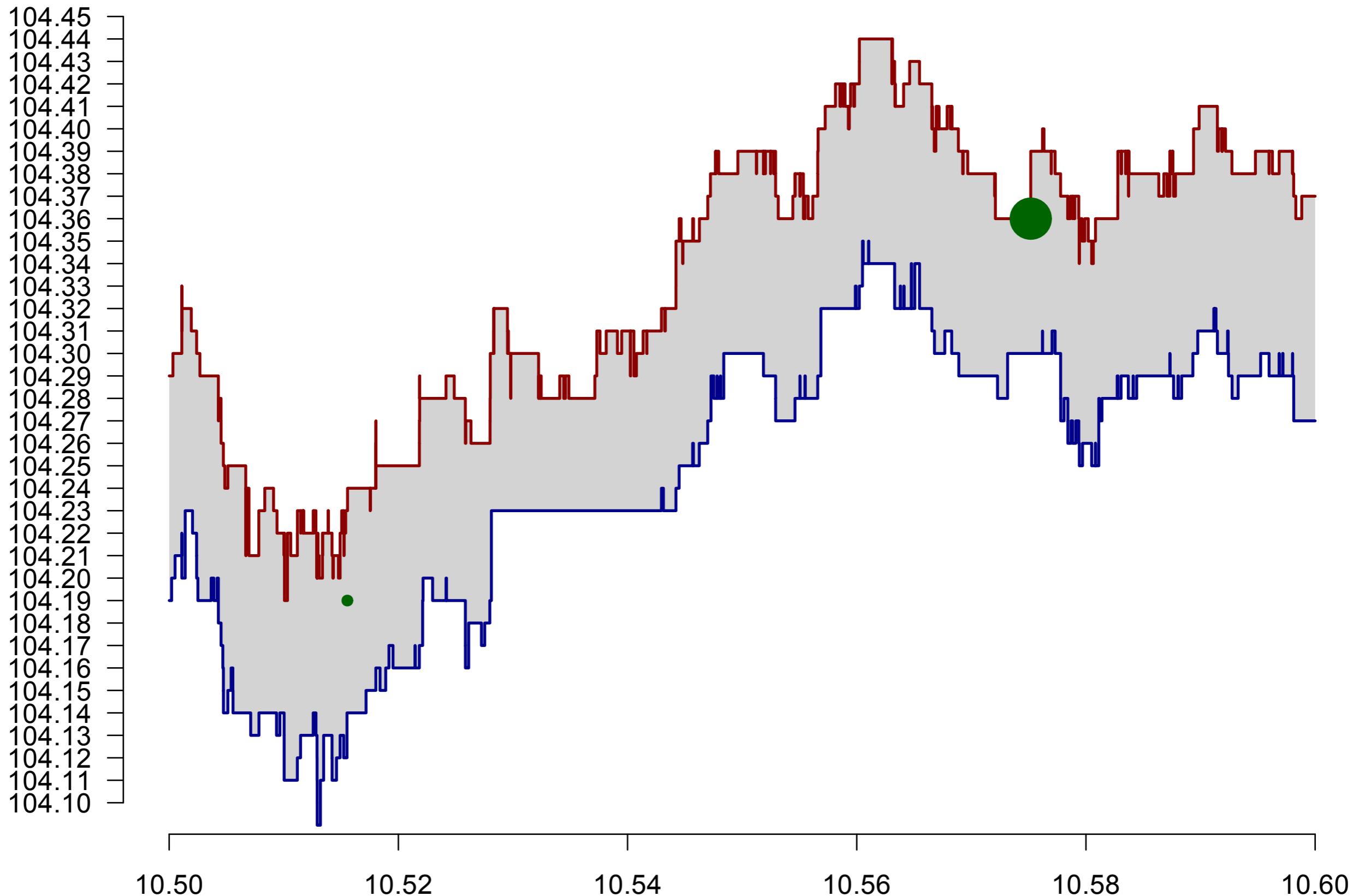
SAP 2019-01-23 NYSE (N)



SAP 2019-01-23 Bats BZX (Z)

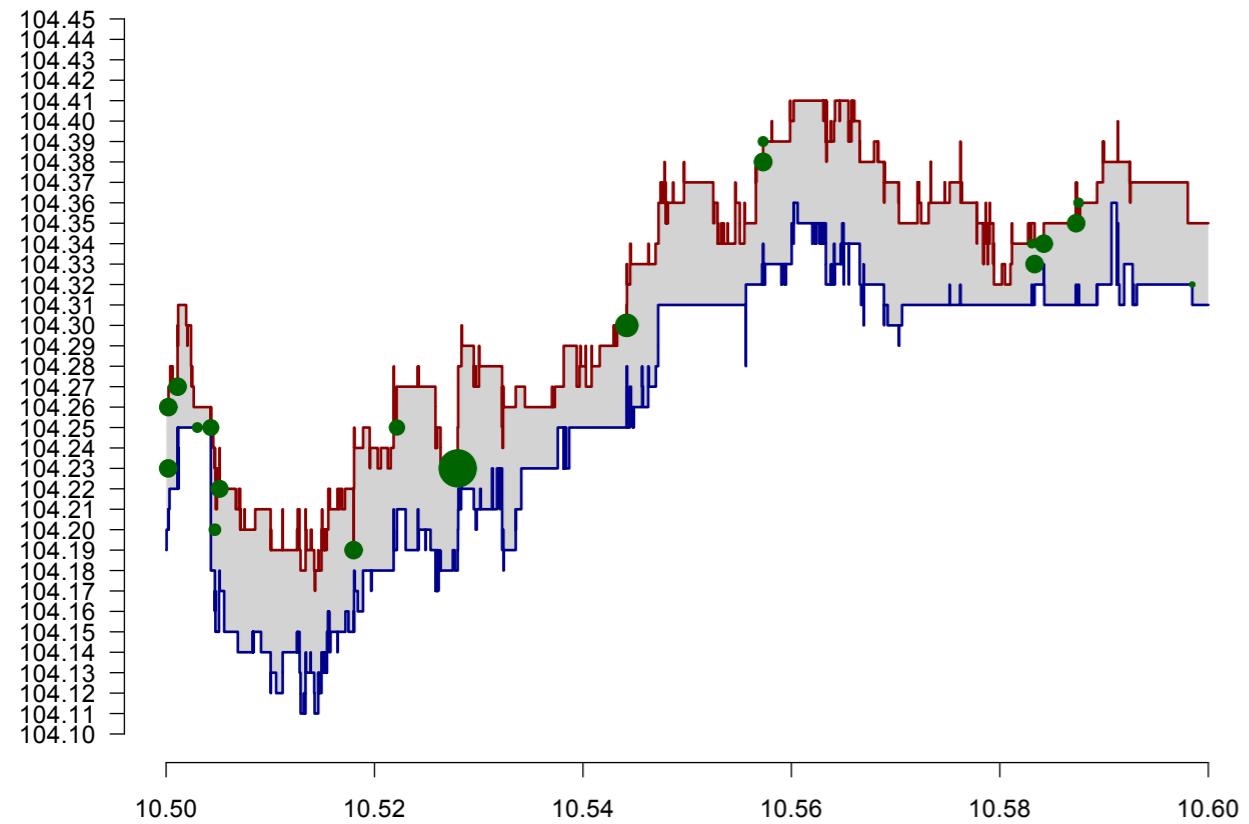


SAP 2019-01-23 NYSE Arca (P)

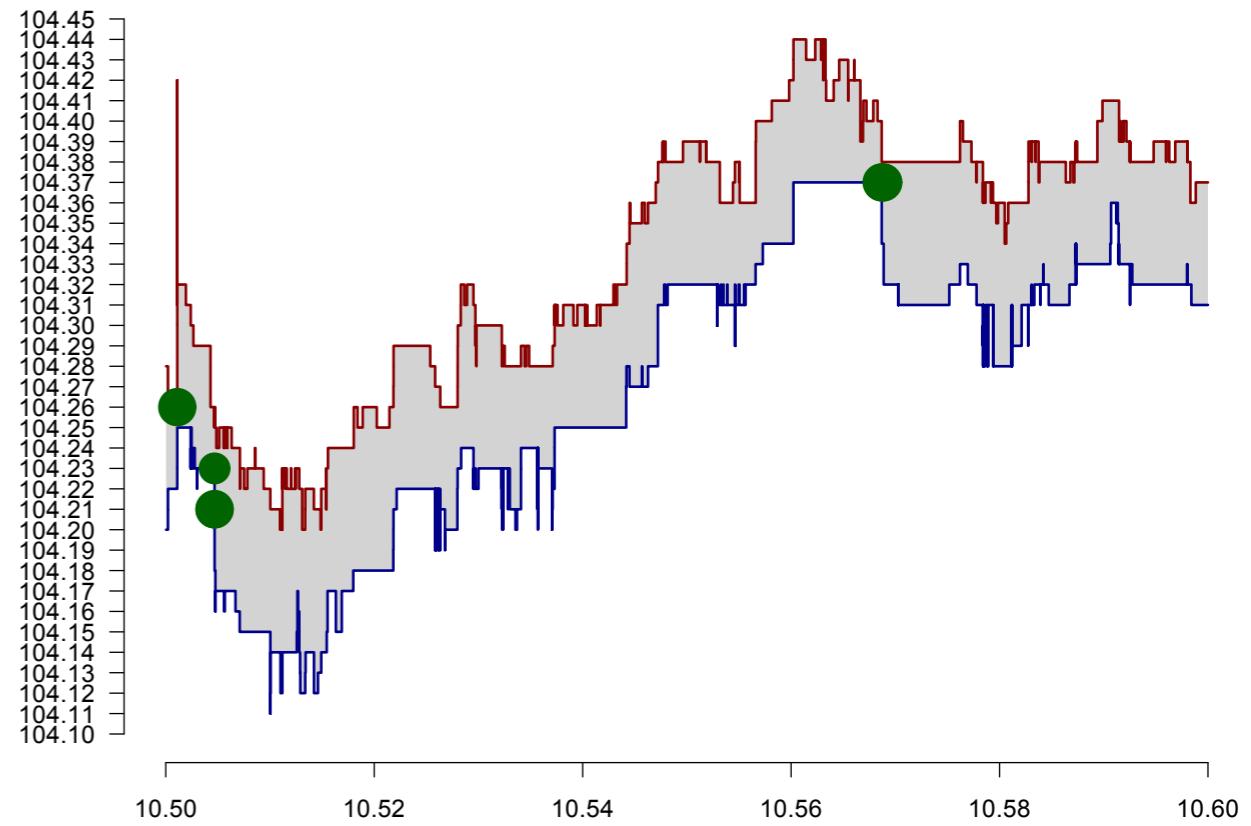


How to combine these together?

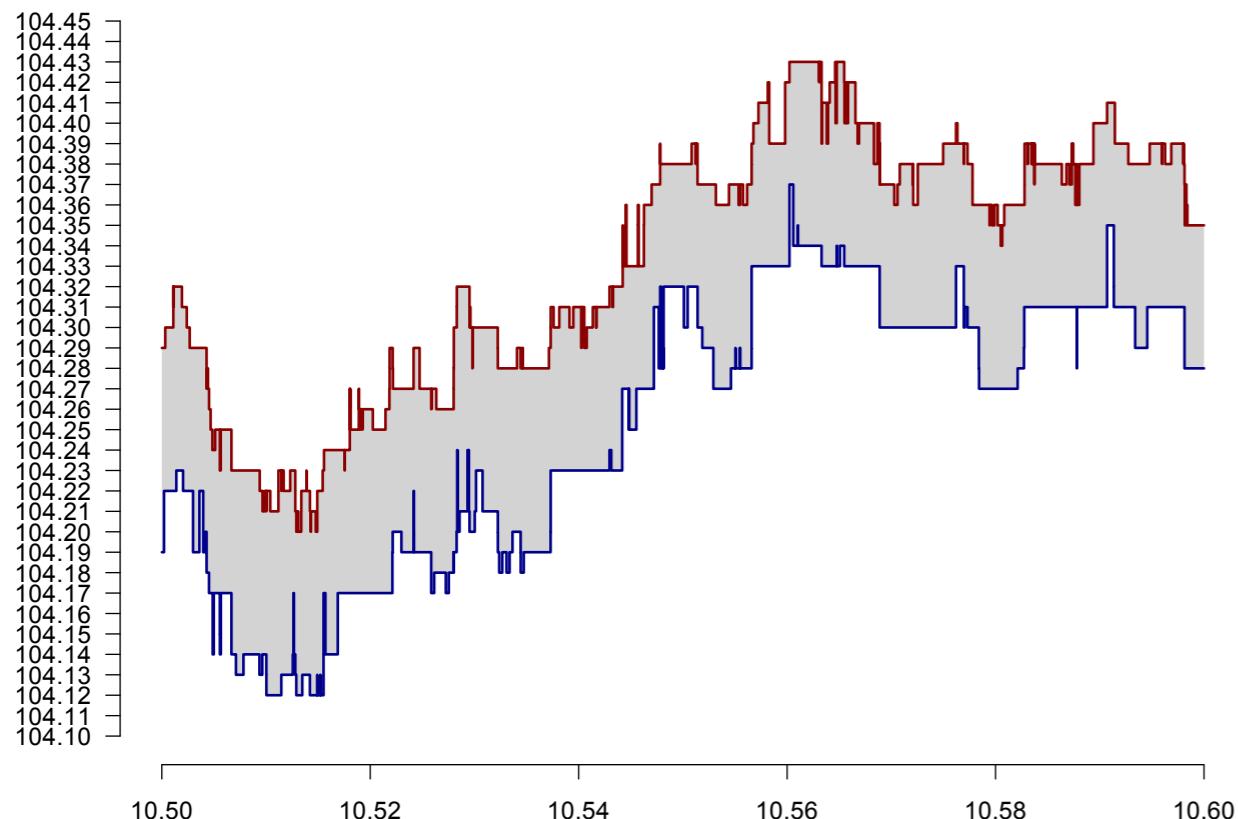
SAP 2019-01-23 NASDAQ AB (T)



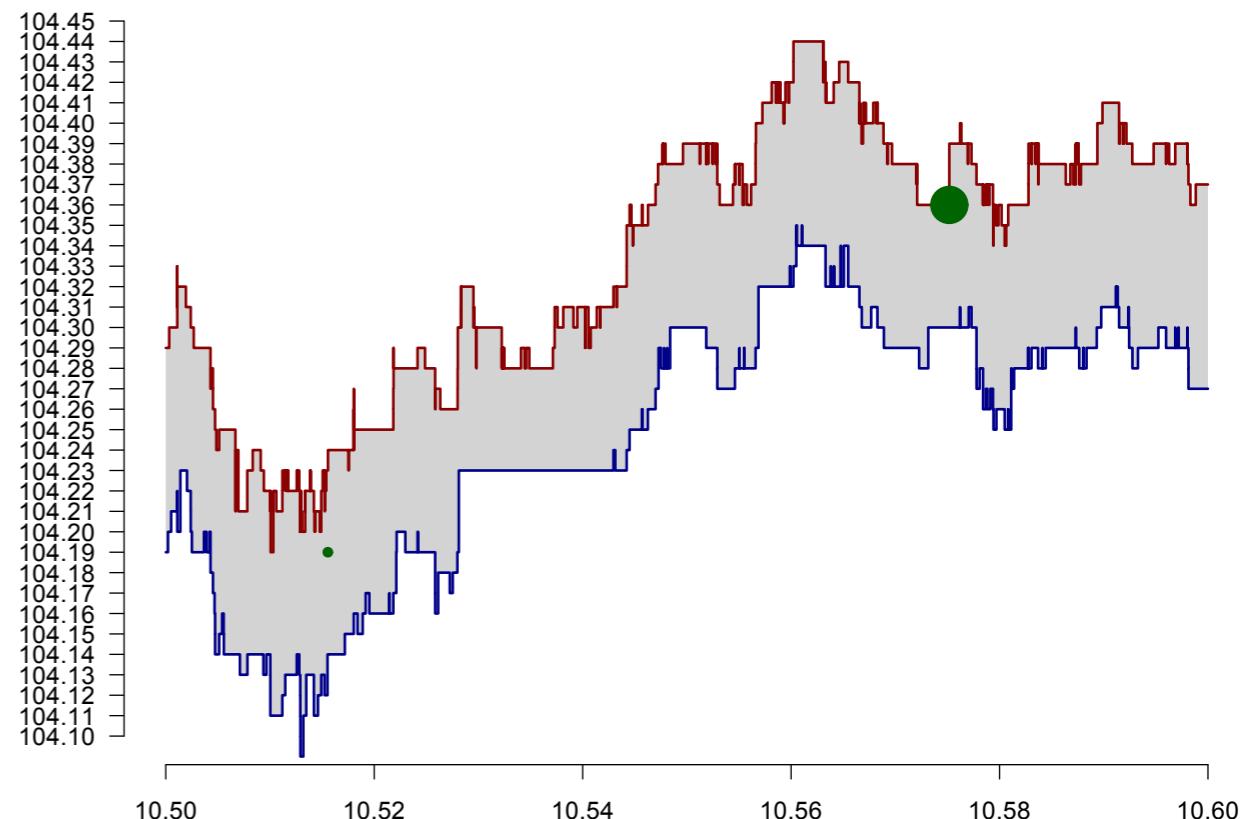
SAP 2019-01-23 NYSE (N)



SAP 2019-01-23 Bats BZX (Z)



SAP 2019-01-23 NYSE Arca (P)



SECURITIES AND EXCHANGE COMMISSION

17 CFR PARTS 200, 201, 230, 240, 242, 249, and 270

[Release No. 34-51808; File No. S7-10-04]

RIN 3235-AJ18

REGULATION NMS

AGENCY: Securities and Exchange Commission.

ACTION: Final rules and amendments to joint industry plans.

SUMMARY: The Securities and Exchange Commission ("Commission") is adopting rules under Regulation NMS and two amendments to the joint industry plans for disseminating market information. In addition to redesignating the national market system rules previously adopted under Section 11A of the Securities Exchange Act of 1934 ("Exchange Act"), Regulation NMS includes new substantive rules that are designed to modernize and strengthen the regulatory structure of the U.S. equity markets. First, the "Order Protection Rule" requires trading centers to establish, maintain, and enforce written policies and procedures reasonably designed to prevent the execution of trades at prices inferior to protected quotations displayed by other trading centers, subject to an applicable exception. To be protected, a quotation must be immediately and automatically accessible. Second, the "Access Rule" requires fair and non-discriminatory access to quotations, establishes a limit on access fees to harmonize the pricing of quotations across different trading centers, and requires each national securities exchange and national securities association to adopt, maintain, and enforce written rules that prohibit their members from engaging in a pattern or practice of displaying quotations that lock or cross automated quotations. Third, the "Sub-Penny Rule" prohibits market participants from accepting, ranking, or displaying orders, quotations, or indications of interest in a pricing

Reg NMS

increment smaller than a penny, except for orders, quotations, or indications of interest that are priced at less than \$1.00 per share. Finally, the Commission is adopting amendments to the "Market Data Rules" that update the requirements for consolidating, distributing, and displaying market information, as well as amendments to the joint industry plans for disseminating market information that modify the formulas for allocating plan revenues ("Allocation Amendment") and broaden participation in plan governance ("Governance Amendment").

DATES: Effective Date: August 29, 2005.

Compliance Dates: For specific phase-in dates for compliance with the final rules and amendments, see section VII of this release.

MEMORANDUM

TO: SEC Market Structure Advisory Committee

FROM: SEC Division of Trading and Markets¹

DATE: April 30, 2015

RE: Rule 611 of Regulation NMS

II. Rule 611 Requirements and Exceptions

A. Intermarket Price Protection

The core of Rule 611 is paragraph (a)(1), which promotes intermarket price protection of orders by restricting the execution of trades on one venue at prices that are inferior to displayed quotations at another venue. Specifically, it requires a “trading center” to implement policies and procedures that are reasonably designed to prevent “trade-throughs” on that trading center of “protected quotations” that do not fall within one of the exceptions set forth in paragraph (b) of the Rule. The terms marked by quotation marks are defined separately in Rule 600(b) of Regulation NMS.

Trading center is defined broadly to include all of the types of venues that execute trades in today’s equity market structure, including registered exchanges, ATSs (both dark pools and ECNs), off-exchange market makers, and any other broker-dealers that execute trades internally, whether as principal or agent.

A trade-through is defined as the purchase or sale of an “NMS stock” during “regular trading hours” (9:30 a.m. to 4:00 p.m. ET), either as agent or principal, at a price that is lower than a protected bid or higher than a protected offer. An NMS stock generally means any exchange-listed security (other than listed options) for which consolidated market data is disseminated.

<https://www.sec.gov/spotlight/emsac/memo-rule-611-regulation-nms.pdf>

Nasdaq proposes exclusive exchange trading for illiquid stocks

By John McCrank NEW YORK, Feb 5 (Reuters) - Nasdaq Inc asked regulators on Wednesday to allow issuers of thinly-traded stocks listed on its exchange to trade almost exclusively on Nasdaq, as part of a broader plan to boost trading in small- and mid-sized companies. There are 13 U.S. stock exchanges, with at least two more preparing to launch, and a company's shares can be traded on any of them, regardless of whether they are listed on the Intercontinental Exchange Inc's New York Stock Exchange, or Nasdaq.

Concentrating all the orders for a stock on a single exchange would help bring buyers and sellers together, while reducing market complexity and lowering trading costs, Nasdaq said in a filing with the SEC on Wednesday.

"Nasdaq proposes to establish a tier nestled within the U.S. public equity markets that is better tailored and far more hospitable to thinly-traded securities than is the all-purpose, undifferentiated market environment in which they suffer today," the New York-based company said.

For instance, exempting thinly-traded stocks from a rule that says trades must happen at the best displayed bid or offer in the market, would allow the exchange operator to use on-demand auctions to further pool liquidity. And allowing issuers to pay market makers to maintain quotes on their stock could lead to more attractive spreads and more orderly openings and closings of the stock.

Cboe Global Markets, which operates four U.S. stock exchanges, but does not have a corporate listings program, said in a Dec. 20 letter to the SEC that allowing companies to trade on a single exchange would dampen competition and innovation among exchanges.

Those who support the move "criticize the 'one-size-fits-all' market structure in place today," Cboe said. "Their proposed fix is to limit trading to a single national securities exchange, offering a single market structure. The irony of this solution is not lost on Cboe."

<https://www.nasdaq.com/articles/nasdaq-proposes-exclusive-exchange-trading-for-illiquid-stocks-2020-02-05>

Order Types and Modifiers

Delivering a Comprehensive Suite of Innovative Order Types & Modifiers

Execute transactions with order types and modifiers that are designed to optimize cost, reduce risk and create efficiencies on our U.S. equities exchanges: The Nasdaq Stock Market (Nasdaq), Nasdaq BX (BX) and Nasdaq PSX (PSX).

ORDER TYPES

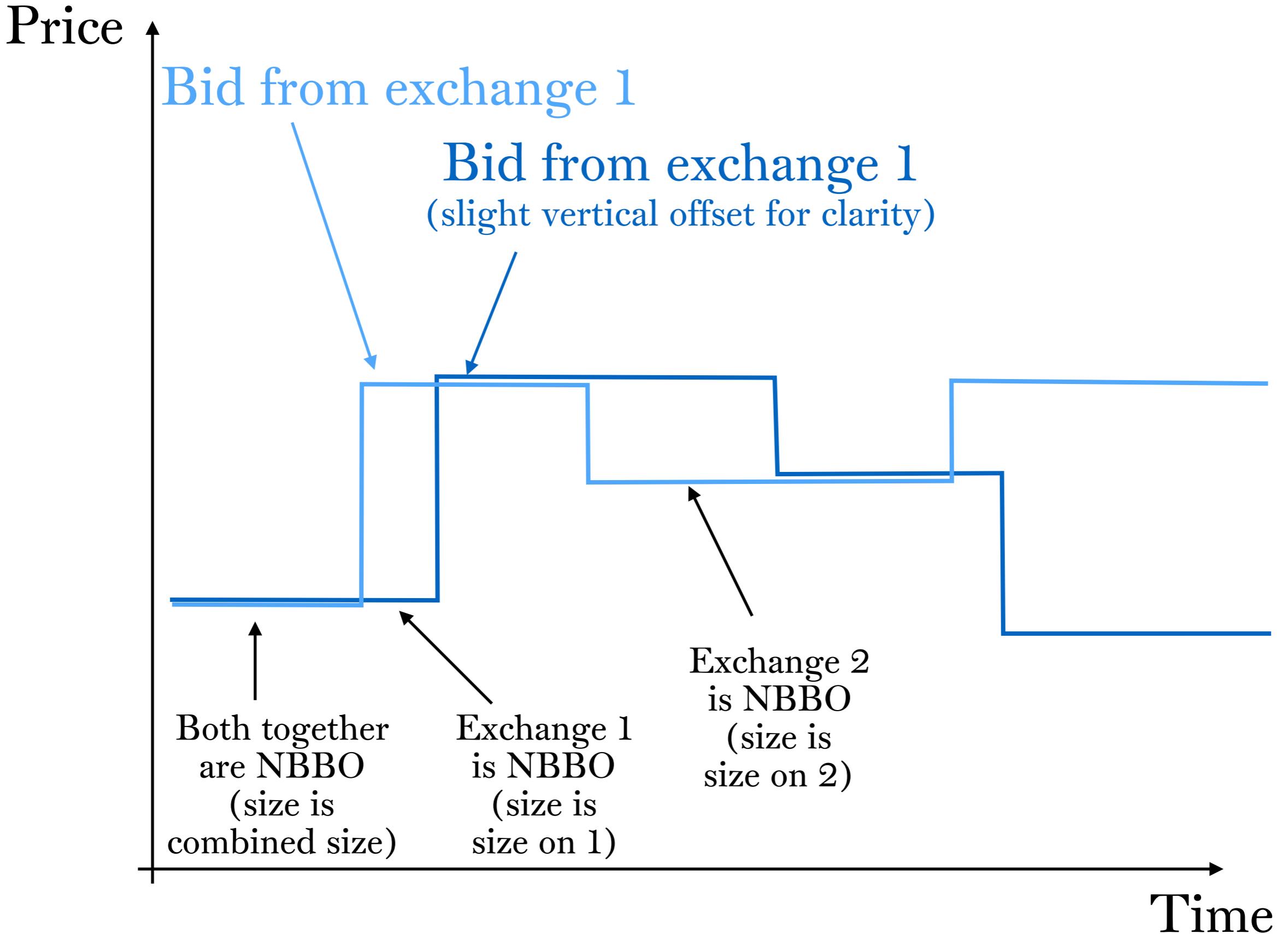
ORDER TYPE	DESCRIPTION	NASDAQ	BX	PSX
INTERMARKET SWEEP ORDERS (ISO)	An order designated as ISO indicates that the entering firm has already checked all other protected quotes before coming to the Exchange. This order will not route. It will trade at the best prices on the Exchange regardless of prices in other market centers.	X	X	X
POST-ONLY ORDERS	The Post-Only order is designed to promote displayed liquidity and provide users control over trading costs. Post-Only orders that would lock the Exchange book will be posted on the book one tick away from the best price on the opposite side of the market. Post-Only orders that would cross the Exchange book will be executed at the price of the resting order (i.e. the incoming Post-Only order would receive price improvement). Nasdaq will allow incoming Post-Only orders, entered at the same limit price as a resting contra-side non-displayed order on the Exchange book, to post and display at the locking price on NQ and BX	X	X	X
PRICE-TO-COMPLY ORDERS	Price-To-Comply Orders comply with the Reg NMS Order Protection Rule and Locked and Crossed market rule by re-pricing to the NBBO. Buy orders will be priced at the inside offer and displayed one tick lower than the inside offer. Sell orders will be priced at the inside bid and displayed one tick higher than the inside bid. If the previously impermissible price becomes available due to an NBBO update, participants have three choices as to how their orders will be treated (based on a port configuration): 1. Default; order remains on the book as a non-display order at the previously locking price, maintaining its time stamp but remains prioritized as non-display 2. Order is cancelled back to firm so they may re-enter as displayed order resulting in a new time stamp but with displayed priority 3. Order is automatically displayed at the previously locking price (with a new time stamp)	X	X	X

GLOBAL TRADING AND MARKET SERVICES

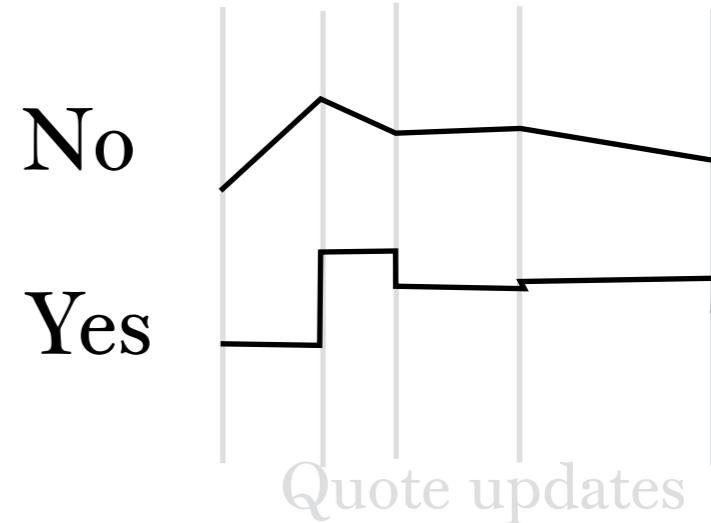
ORDER TYPE	DESCRIPTION	NASDAQ	BX	PSX
SUPPLEMENTAL ORDERS	Non-displayed orders that add liquidity only and always execute at the NBBO. Orders will only execute against incoming routable orders that are the same size or smaller than the aggregate Supplemental Order interest at the price level, and are only eligible for execution during regular market hours. This order type has a lower priority at a given price level than displayed or other non-displayed orders.	X	NA	NA
ON-OPEN ORDERS	On-Open Orders specifically request an execution at the opening price <ul style="list-style-type: none"> • Can be limit-on-open or market-on open. • Accepted beginning at 4:00 a.m., ET, each day. 	X	NA	NA
ON-OPEN IMBALANCE-ONLY ORDERS	On-Open Imbalance-Only Orders provide liquidity intended to offset on-open orders during the Opening Cross. <ul style="list-style-type: none"> • Must be priced (limit); no market imbalance-only orders. • Imbalance-only buy/sell orders only execute at or above/below the 9:30 a.m., ET, offer/bid. Accepted beginning at 4:00 a.m., ET, each day.	X	NA	NA
ON-CLOSE ORDERS	On-Close Orders specifically request an execution at the closing price. <ul style="list-style-type: none"> • Can be limit-on-close or market-on-close. • Accepted beginning at 4:00 a.m., ET, each day. 	X	NA	NA
ON-CLOSE IMBALANCE-ONLY ORDERS	On-Close Imbalance-Only Orders provide liquidity intended to offset on-close orders during the Closing Cross. <ul style="list-style-type: none"> • Must be priced (limit); no market imbalance-only orders. • Imbalance-only buy/sell orders only execute at or above/below the 4:00 p.m., ET, bid/ask. Accepted beginning at 4:00 a.m., ET, each day.	X	NA	NA
ANONYMOUS	Anonymous orders are posted without attribution.	X	X	X
ATTRIBUTION	Attributable orders are displayed in the system data feed with the MPID of the firm entering the order.	X	X	X
PRICE-TO-DISPLAY ORDERS	Price-To-Display Orders comply with the Reg NMS Order Protection Rule and Locked and Crossed market rule by repricing based on the NBBO. Buy Price-To-Display orders will be repriced and displayed to one tick below the best offer. Sell Price-To-Display orders will be repriced and displayed to one tick above the best bid. All orders with attribution (see above) are Price-To-Display Orders. All orders without Attribution are Price-To-Comply Orders.	X	X	X
RESERVE	Reserve orders allow participants to display only a fraction of the entire order. <ul style="list-style-type: none"> • Have a round lot display size and corresponding non-display size. • Incoming order flow has access to both the display and non-display portion of a booked reserve order. • Minimum share quantity for a displayed order is 100 shares; this amount is replenished when the amount falls below 100 shares. 	X	X	X
PEGGING	Pegging allows clients to price orders relative to the current market price for a security. <ul style="list-style-type: none"> • Only supported between 9:30 a.m. and 4:00 p.m., ET. • Offsets allow a client to peg an order with an incremental difference, in \$0.01 increments, from the NBBO and can be either positive (higher price) or negative (lower price). • There are three types of pegged orders: Primary Peg: Peg an order to the same side of the market. • Market Peg: Peg an order to the opposite side of the market. • Mid-Point Peg: Peg an order to the mid-point of the market. These orders will peg in half-penny increments in the event of an odd spread. 	X	X	X

NBBO

- National Best Bid and Offer
- Highest bid, and lowest ask across all exchanges
 - perhaps exclude obscure exchanges ("FINRA")
but these usually have poor quotes anyway
- Seems not to be easily accessible in WRDS TAQ
 - There is a TAQ NBBO data set but WRDS does not have
 - Need to compute ourselves
- Essential for modeling market dynamics



Notes on BBO computation



- Quotes are piecewise constant functions
 - Each quote is in effect until modified or cancelled
 - Never plot with diagonal lines
- Time stamps of quotes are essential
- Market should not cross but might in practice
- NBBO bid and ask may be on different time sets
 - must combine to compute midpoint and spread
- Computing inside prices easier than computing size

The Best Bid and Offer: A Short Note on Programs and Practices

Joel Hasbrouck*

First draft: August 4, 2010

This draft: October 14, 2010

This note describes how to determine the best bid and offer (BBO) from the NYSE's monthly TAQ data, the source that underlies most academic research. At a given point in time the best bid is the maximum bid, taken over the set of current bids posted by all venues. This value persists until one of the bids posted by any of the venues changes. Then the maximum is recomputed. The best offer is computed in a similar fashion. This differs significantly, however, from the BBO defined and computed in Wharton Research Data System (WRDS) documentation and sample programs distributed prior to October 2010.

Furthermore, the BBO calculation relies on correct ordering of the quote records. Incorrect sequencing within a reporting exchange's records is much more serious than incorrect sequencing between exchanges. This note explains these problems and makes some summary recommendations.

B. Time-stamps

The time-stamps on the consolidated data used by practitioners are given to the millisecond.

These data are described on the NYSE's website as the Daily TAQ data, available via ftp. Most academic researchers, however, will use the Monthly TAQ data, which are time-stamped only to the second.

By matching recent Inet data to corresponding consolidated data, I've tentatively concluded that the TAQ time-stamps are those reported by the venue. In principle this is the time when the trade occurred, as opposed to the time when the report was received by the consolidator.

Since the data channel from a reporting venue to the consolidator is a serial mechanism, it seems reasonable to assume that quote data from a single venue are correctly sequenced. Different venues, however, will use different channels, with varying degrees of latency. It therefore seems unlikely that the relative ordering of quote records between venues is reliable.

<http://people.stern.nyu.edu/jhasbrou/Research/Working%20Papers/CompNBBO02.pdf>

SAP 2019-01-23

