Does the Consolidated Feed Matter?

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MOTIVATION

- Current U.S. equities market structure:
  - ▶ Fast: 20% of trades arrive in < 1ms clusters (Menkveld, 2018)
  - ▶ Fragmented: 16 lit markets + dozens of dark pools & broker-dealer internalizers

- Market data is crucial! For market makers, arbitrageurs & buy-side

- Two-tiered market data for U.S. equities:
  - ▶ Consolidated (SIP) feeds: slow, on- & off-exchange trades + top-of-book quotes, relatively cheap, unsophisticated traders
  - ▶ Direct feeds: fast, on-exchange trades + depth-of-book quotes, and more (e.g., odd-lot quotes, auction imbalance), expensive, sophisticated traders such as HFTs

- Fair? Policy debates
  - ▶ U.S.: NMS 1.0 $\Rightarrow$ NMS 2.0 (+five-level depth, +odd-lot quotes, +auction imbalance, $\geq$ 2 SIPs)
  - ▶ Europe: In the making: post-trade or pre-trade or both?

- Question: Does the consolidated feed matter?
  - ▶ No impact due to segregated markets: direct feeds for HFTs. SIP sufficient for "display" traders
  - ▶ About 45% dark pools consume only SIP feeds
  - ▶ More used by algo traders for, e.g., data integrity check (CFTC and SEC, 2010; Aldrich, Grundfest, and Laughlin, 2017)
  - ▶ Off-exchange trades (Ernst, Sokobin, and Spatt, 2021)

- Approach: Standard DiD based on two types of exogenous events:
  - ▶ SIP (speed) upgrade :-)
  - ▶ SIP technical glitches :-(

- Results:
  - ▶ Faster SIP $\Rightarrow$ market liquidity $\downarrow$ (spreads + & price impact +), algorithmic trading activity $\uparrow$ (quote-to-trade ratio +), high-frequency trading activity $\approx$ (strategic runs $\approx$)
  - ▶ No/corrupted SIP $\Rightarrow$ market liquidity $\downarrow$, in particular volume and order-book depth $\downarrow \downarrow$

LITERATURE

- Effect of market data on trading and market quality
  - ▶ **Brogaard, Ringgenberg, and Rösch (2020)**: direct feed charge $\Rightarrow$ market volume ↓ as NBBO time and ISO volume ↓
  - ▶ **Hendershott, Rysman, and Schwabe (2020)**: introduction of NYSE Integrated Feed $\Rightarrow$ share of trading on NYSE ↑
  - ▶ **Ye, Yao, and Gai (2013)**: an older Nasdaq-SIP speed upgrade in 2011 (3 to 1ms) $\Rightarrow$ liquidity $\approx$
  - ▶ *Contribution/difference*: Focus on SIP instead of direct feeds
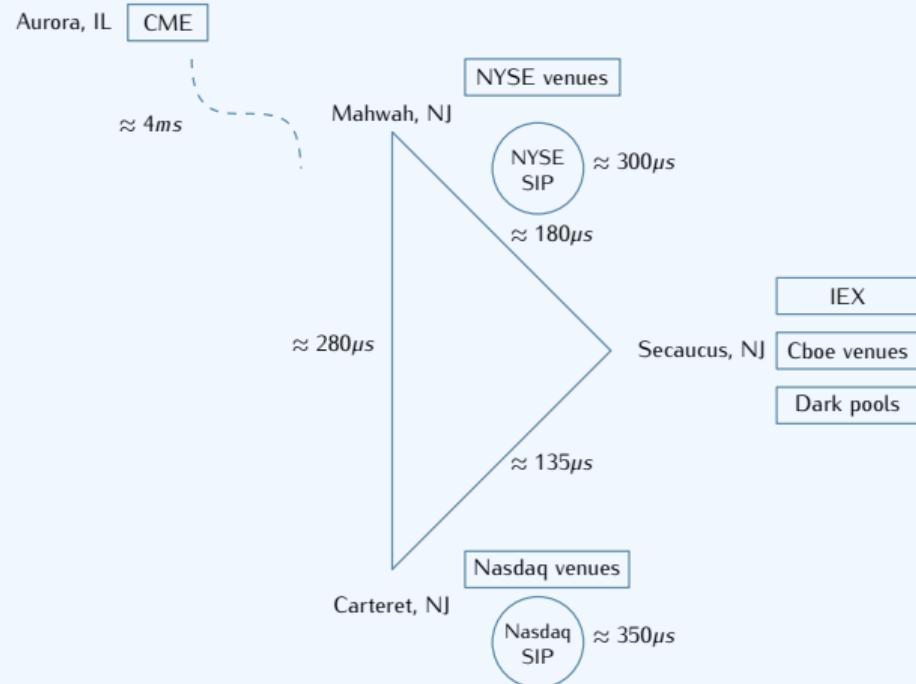
- SIP versus direct feeds
  - ▶ **O'Hara, Yao, and Ye (2014)**: *Odd-lot trades* missing in SIP before 2013. Accounts for a large share of trading volume and quite informed
  - ▶ **Battalio, Corwin, and Jennings (2016)**: Exclusion of *odd-lot quotes* from SIP results in worse executions for high-priced stocks. **Bartlett, McCrary, and O'Hara (2022)**: Odd-lot quotes provide valuable information.
  - ▶ **Ding, Hanna, and Hendershott (2014)**: Dislocations of SIP-NBBOs quite frequent for active stocks but duration short. Cost for low-frequent traders small
  - ▶ **Bartlett and McCrary (2019)**: Profit from direct feed arbitrage not economically significant
  - ▶ **Hasbrouck (2019)**: Information share of direct feeds ≫ SIP at high frequency
  - ▶ *Contribution/difference*: Focus on exogenous real-world events instead of static comparisons

- Impact of trading speed on market quality
  - ▶ Faster HF-Arbs ⟹ market liquidity ↓ **(Biais, Foucault, and Moinas, 2015; Budish, Cramton, and Shim, 2015; Foucault, Hombert, and Roşu, 2016)**
  - ▶ Faster HF-MMs ⟹ market liquidity ↑ **(Hoffmann, 2014; Jovanovic and Menkveld, 2016)**
  - ▶ Market liquidity ↑ when HF-MMs have faster co-location **(Brogaard et al., 2015)** or when HF-Arbs become slower due to microwave network disruptions **(Shkilko and Sokolov, 2020)**
  - ▶ *Contribution/difference*: A unique event where slow traders (e.g., buy-side) become faster
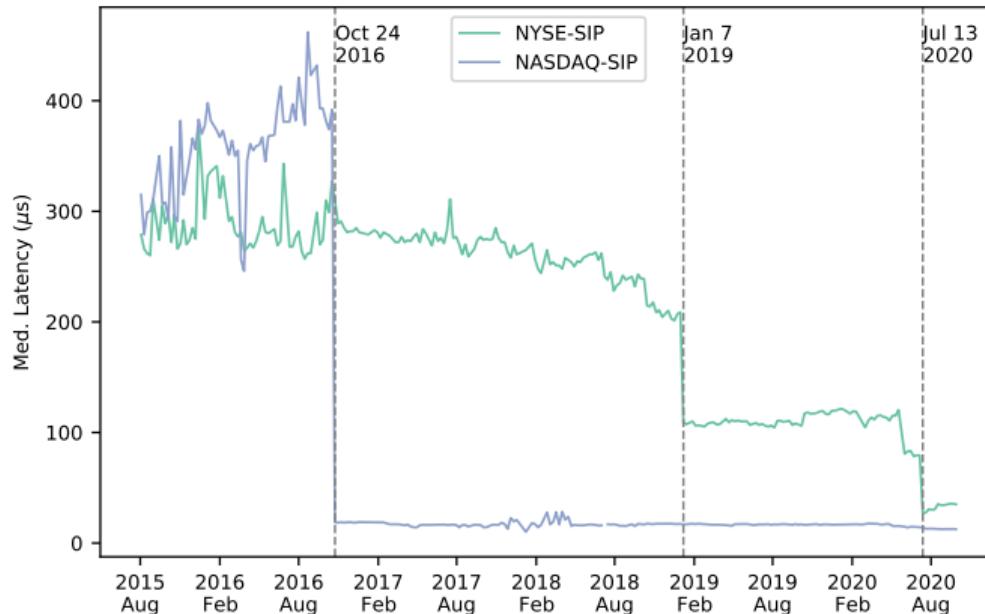
- Consolidated feeds disseminated by Security Information Processors (SIPs)

- Feature #1: two SIPs
  - NYSE-listed stocks $\Rightarrow$ NYSE-SIP
  - Nasdaq-listed stocks $\Rightarrow$ Nasdaq-SIP

- Feature #2: unique geography
  - SIP feed latency = geographical latency + processing latency
  - E.g., for a SIP feed subscriber at Mahwah trading Nasdaq stocks, a quote update from NYSE takes 280×2 (geographical) + 350 (processing) = 910 μs
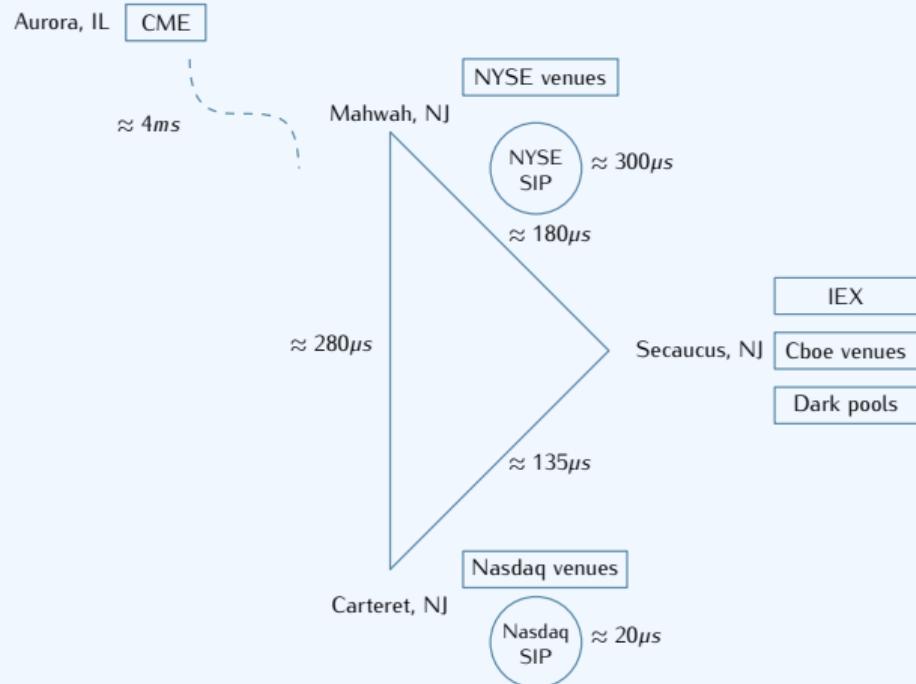
■ Migrated to INET ⟹ speed and capacity ↑ ⟹ processing latency ≈ 350 to < 20 μs

- Implication #1: SIP feeds for Nasdaq stocks faster
- Implication #2: more so for Nasdaq stocks@Nasdaq exchanges
- Nasdaq stocks@Nasdaq venues
  - Björn (direct): < 20 μs
  - Shihao (SIP): $350 \to 20$ μs :-)
- Nasdaq stocks@NYSE venues
  - Björn (direct): < 20 μs
  - Shihao (SIP): $280 \times 2 + 350 \to 280 \times 2 + 20$ μs :-|

Aurora, IL CME

NYSE venues

Mahwah, NJ

NYSE SIP $\approx 300\mu s$

$\approx 4ms$

$\approx 180\mu s$

IEX

$\approx 280\mu s$ Secaucus, NJ Cboe venues

Dark pools

$\approx 135\mu s$

Nasdaq venues

Carteret, NJ

Nasdaq SIP $\approx 20\mu s$

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- A sample of 296 Nasdaq-stocks[1] matched with 296 NYSE-stocks on price, volume, market capitalization and Fama French 12 industry. `▶ PSM score SIP upgrade` `▶ PT1` `▶ PT2`
- Nasdaq-listed stocks vs. NYSE-listed stocks

$$metric_{i,t} = \alpha_i + \beta After_t + \gamma After_t \times NasdaqStock_i + \epsilon_{i,t} \tag{1}$$

- Nasdaq exchange vs. Other exchanges (ARCA, BATS, EDGX)[2]

$$metric_{i,e,t} = \alpha_{i,e} + \beta_t After_t + \gamma_1 After_t \times NasdaqStock_i + \gamma_2 After_t \times NasdaqVenue_e$$
$$+ \gamma_3 After_t \times NasdaqStock_i \times NasdaqVenue_e + \epsilon_{i,e,t} \tag{2}$$

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[1]Stocks involved in the SEC's Tick Size Pilot Program excluded.
[2]Only maker-taker venues. NYSE excluded as it only starts trading Nasdaq stocks since April 2018.

- Nasdaq-SIP (speed) upgrade ▸ SS SIP-upgrade
    - ▸ **Liquidity**: RQS, RES, RRS, depth at NBBO, trading volume, retail trade price improvements (NYSE TAQ)
    - ▸ **Trading**: ISO share, odd-lot share (NYSE TAQ); AT proxies: cancel-to-trade and order-to-trade ratio (SEC MIDAS); HFT proxy: #strategic runs/volume (LOBSTER)
    - ▸ Note that direct-NBBO and direct-BBOs constructed from Participant Timestamps of TAQ (Bartlett and McCrary, 2019). Might differ from SIP-NBBOs and SIP-BBOs. ▸ nbbo-dislocation   ▸ nasdaq-bbo-dislocation

- SIP glitches ▸ SS SIP-glitch
    - ▸ **Liquidity**: RQS, RES, RRS, volume, depth at NBBO, cumulative depth across five best prices (direct feeds from MayStreet due to as no/corrupted consolidated feeds)

- Liquidity ↓:*RQS* +6.32%, *RES* +4.76%, *RPI* +5.53%, *RRS* ≈
- Price impacts ↑ but also transaction costs ↑, market-maker profits ≈

	RQS	RES	RPI	RRS	Depth	Vlm	PrcImp
After	0.63***	0.11***	0.14***	−0.03	−8.97**	25.93***	0.59***
	(0.07)	(0.03)	(0.02)	(0.03)	(3.72)	(2.94)	(0.07)
After x NasdaqStock	0.54***	0.15**	0.13***	0.02	−7.51	−4.02	−0.02
	(0.20)	(0.06)	(0.04)	(0.05)	(13.64)	(6.25)	(0.10)
R^2 (%)	2.13	0.27	0.65	0.00	0.21	0.95	0.89
N	42900	42900	42900	42900	42900	42900	42900
Stock F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes

- ISO share +4.37%; *Cancel/Trade* +12.99%, *Order/Trade* +16.11%; *#Run/Vlm* ≈
- Informed AT activities ↑?

	ISOShr	OddlotShr	Cancel/Trade	Order/Trade	#Run/Vlm
After	−2.16***	0.09	−8.32***	−14.21***	−2.45***
	(0.16)	(0.10)	(0.44)	(0.98)	(0.42)
After x NasdaqStock	1.53***	0.18	3.09***	6.13***	0.08
	(0.24)	(0.14)	(0.53)	(1.08)	(0.61)
R^2 (%)	1.80	0.12	16.16	12.88	1.47
N	42900	42900	42900	42900	42900
Stock F.E.	Yes	Yes	Yes	Yes	Yes

■ Liquidity of Nasdaq stocks@Nasdaq exchange ↓: *RES* +, *RPI* +

	RQS	RES	RPI	RRS	Vlm	Depth
After	3.87***	0.15***	0.21***	−0.06***	1.71***	−1.05**
	(0.54)	(0.02)	(0.03)	(0.02)	(0.20)	(0.44)
After x NasdaqStock	0.55	0.09*	0.12*	−0.03	−0.02	−1.16
	(0.88)	(0.05)	(0.07)	(0.04)	(0.49)	(2.01)
After x NasdaqVenue	−3.35***	−0.03***	0.01	−0.03**	2.73***	1.44***
	(0.54)	(0.01)	(0.02)	(0.01)	(0.22)	(0.27)
After x NasdaqStock x NasdaqVenue	−0.25	0.06**	0.09**	−0.03	1.78**	0.56
	(0.80)	(0.01)	(0.03)	(0.03)	(0.74)	(1.27)
R^2 (%)	0.94	1.05	0.59	0.07	1.02	0.08
N	171600	171597	171597	171597	171597	171600
Stock-Venue F.E.	Yes	Yes	Yes	Yes	Yes	Yes

■ AT activities in Nasdaq stocks@Nasdaq exchange ↑: *Cancel/Trade* +, *Order/Trade* +

	ISOShr	OddlotShr	Cancel/Trade	Order/Trade
After	−1.95***	0.28**	−7.69***	−10.86***
	(0.22)	(0.12)	(0.54)	(0.75)
After x NasdaqStock	1.18***	0.21	0.54	0.07
	(0.31)	(0.16)	(0.78)	(1.16)
After x NasdaqVenue	−0.39***	0.42***	−1.08***	−1.47**
	(0.12)	(0.07)	(0.37)	(0.58)
After x NasdaqStock x NasdaqVenue	0.57***	−0.35***	4.33***	5.85***
	(0.19)	(0.11)	(0.59)	(0.99)
R^2 (%)	1.01	0.29	2.26	0.19
N	171597	171597	171595	171595
Stock-Venue F.E.	Yes	Yes	Yes	Yes

- Shorten window to two month (one month before and one after)
- Exclude US election
- Stock-day fixed effects (for the triple DiD)

SIP GLITCHES

Table 1: Recent market-wide SIP glitches. This table lists some key information about the three market-wide SIP glitch events that happened in recent years.

Date	Start and End Time	Duration	SIP	Market-wide Trading halt
January 3, 2013 ▸Trd ▸Msg	13:33 - 13:51	18 minutes	Nasdaq-SIP	No[a]
October 30, 2014 ▸Trd ▸Msg	13:07 - 13:34	27 minutes[b]	NYSE-SIP	No[c]
August 12, 2019 ▸Trd ▸Msg	15:15 - 15:27	12 minutes[b]	NYSE-SIP	No

[a] There is no market-wide trading halt. EDGX and EDGA halted trading for Nasdaq-listed stocks after 13:42.
[b] In both events, The NYSE shifted operations to its disaster recovery site in Chicago after the glitch was solved.
[c] Some dark pools, including ITG Posit and Goldman Sachs' Sigma X, which uses the NYSE SIP were closed during the glitch period.

- The same DiD identification: ▶ PSM score SIP glitch

$$metric_{i,d,t} = \alpha_{i,d} + \beta After_{d,t} + \gamma After_{d,t} \times Treated_{i,d} + \epsilon_{i,d,t}. \qquad (3)$$

- Liquidity ↓: *RQS* +4.28%, *RES* +11.14%, *Vlm* -17.81%, *DepthNBBO* -21.20%, *Depth5Lvl* -13.80%

	RQS	RES	RRS	Vlm	DepthNBBO	Depth5Lvl
After	0.35*	−0.04	−0.02	2.85	−3.16	−35.01***
	(0.20)	(0.05)	(0.08)	(1.84)	(2.13)	(4.77)
After x Treated	0.59**	0.37***	0.96***	−5.93***	−17.91***	−64.85***
	(0.25)	(0.07)	(0.10)	(2.14)	(6.55)	(23.42)
R^2 (%)	0.22	0.14	0.31	0.01	0.09	0.77
N	235564	129309	129309	235564	235564	235564
Stock-Event F.E.	Yes	Yes	Yes	Yes	Yes	Yes

Table 2: Channel assignment of NASDAQ-SIP and outage order. This table shows the symbol allocation across the six data dessimination channels of the Nasdaq-SIP. Moreover, it shows the starting and ending time of the glitch for trades and quotes in each channel.

Outage order	Channel	Quote outage period	Trade outage period
"Late"channels	Channel 1 (Symbols A-CDZ) Channel 3 (Symbols FE-LKZ) Channel 5 (Symbols PC-SPZ)	13:37:22 - 13:48:19	13:36:51 - 13:51:14
"Early" channels	Channel 2 (Symbols CE-FDZ) Channel 4 (Symbols LL-PBZ) Channel 6 (Symbols SQ-ZZZ)	13:33:11 - 13:48:21	13:33:11 - 13:51:15

- DiD specification for the 1st period:

$$metric_{i,t} = \alpha_i + \beta Period1_{i,t} + \gamma_1 Period1_{i,t} \times EarlyChannel_{i,t} + \gamma_2 Period1_{i,t} \times LateChannel_{i,t} + \epsilon_{i,t} \tag{4}$$

- Liquidity ↓: in particular *Vlm* -27.66%

	RQS	RES	RRS	Vlm	DepthNBBO	Depth5Lvl
Period1	0.04	−0.03	0.06	−1.38**	3.35	−7.89
	(0.15)	(0.05)	(0.08)	(0.67)	(4.05)	(6.14)
Period1 x EarlyChannel	0.19	0.31*	0.96***	−2.31**	−8.27	−47.03**
	(0.35)	(0.17)	(0.19)	(1.12)	(5.35)	(22.66)
Period1 x LateChannel	0.43	0.01	−0.02	0.45	−0.12	4.08
	(0.31)	(0.09)	(0.16)	(1.18)	(5.01)	(8.53)
R^2 (%)	0.09	0.08	0.31	0.04	0.05	0.61
N	80886	21803	21803	80886	80886	80886
Stock F.E.	Yes	Yes	Yes	Yes	Yes	Yes
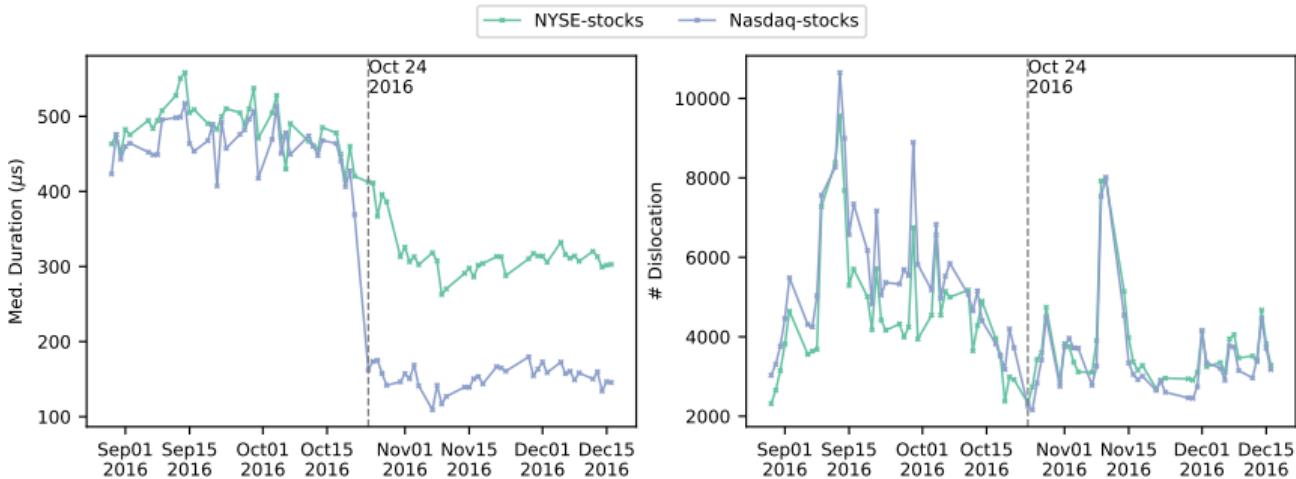
- Empirically study two exogenous events to SIPs: Nasdaq-SIP speed upgrade and technical glitches

- Faster SIP:
  - ▶ Liquidity: ↓
  - ▶ Informed AT activity: ↑

- No/corrupted SIP:
  - ▶ Liquidity: ↓

- Implications for NMS 2.0:
  - ▶ Speeding up the single SIP does not seem to help the market. Competing SIPs? More wasteful arm race?
 - ▶ More content? Odd-lot quotes, depth-of-book, auction imbalances

Data & Variables
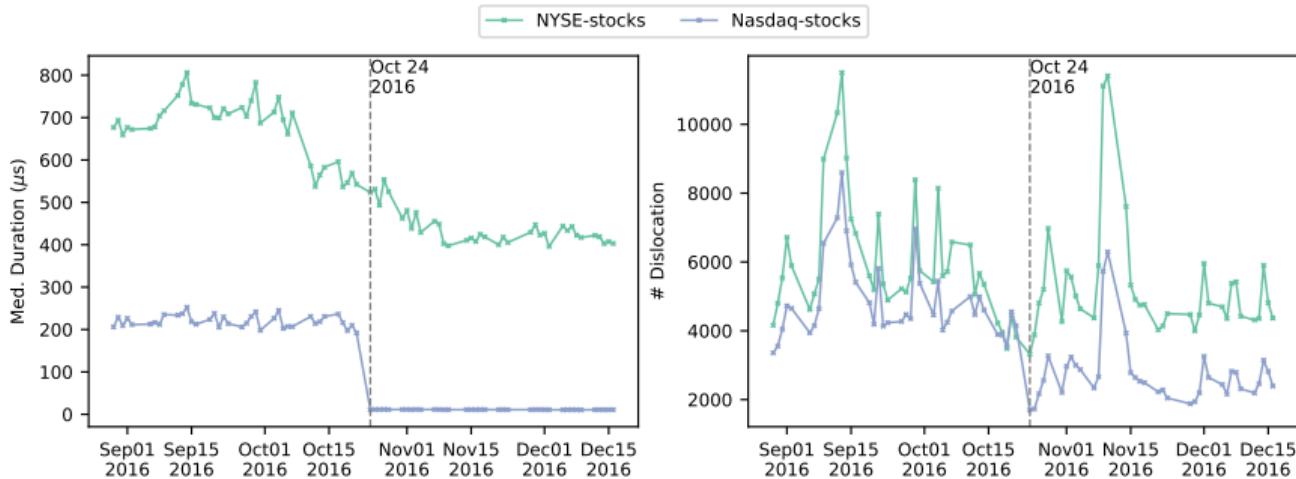
■ # NBBO dislocations in Nasdaq-stocks ↓ 1013 (18.72%) *relative to* NYSE-stocks.

◀ Data & Variables

■ # Nasdaq-BBO dislocations in Nasdaq-stocks ↓ 1354 (28.43%) *relative to* NYSE-stocks
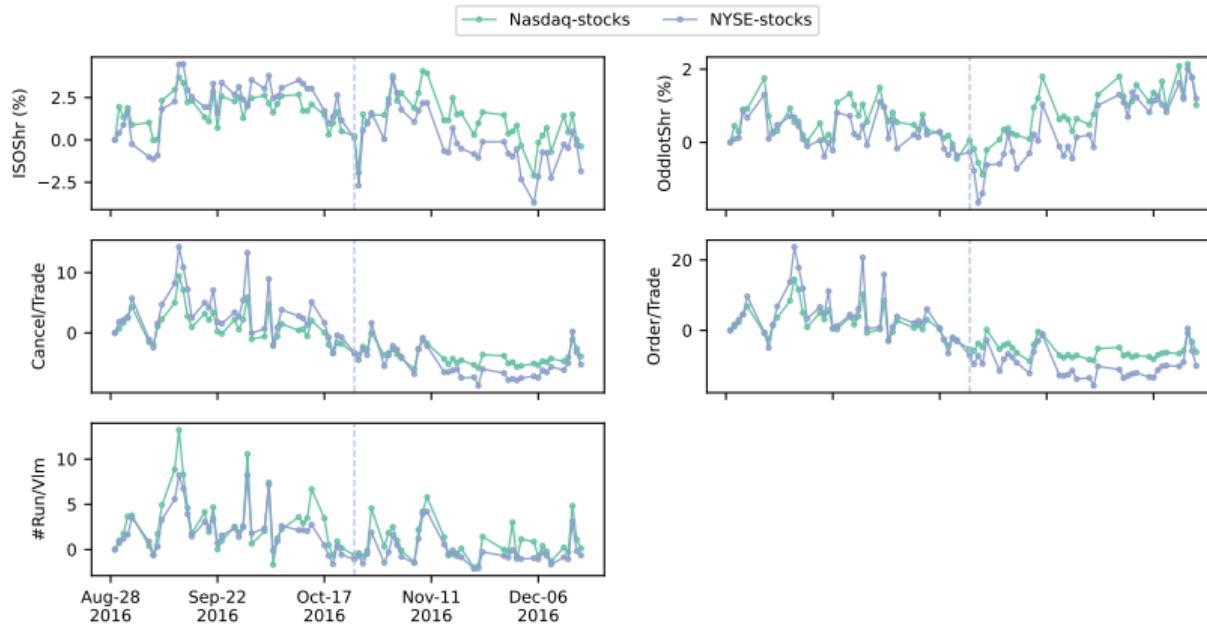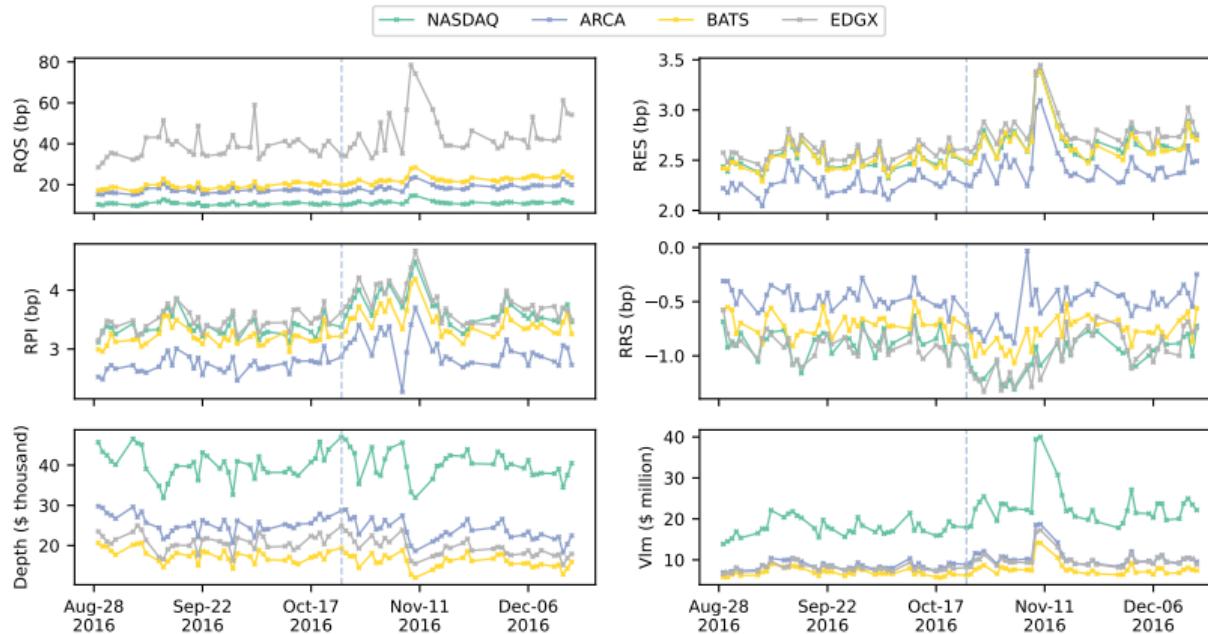
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◀ DiD
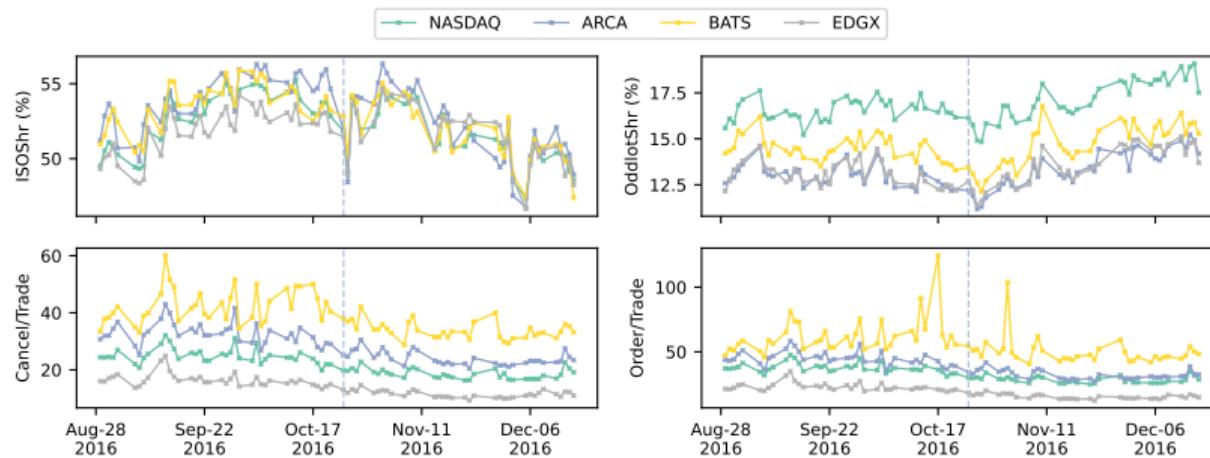
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Propensity matching results: SIP upgrade

Table 3: Propensity score matching: SIP speed upgrade.

Variable	Sample	N	Mean	SD	10%	25%	50%	75%	90%
Price ($)	Control	296	62.03	54.25	14.67	25.52	47.14	79.53	130.23
	Treatment	296	67.35	110.38	10.01	22.08	45.14	79.68	119.85
MarketCap ($ billion)	Control	296	15.32	26.43	1.93	3.35	6.07	15.24	33.27
	Treatment	296	16.95	51.23	1.28	3.08	4.93	11.57	30.06
DollarVolume ($ million)	Control	296	109.34	160.25	15.92	28.75	64.12	124.99	229.15
	Treatment	296	114.08	241.66	13.74	24.99	48.36	102.09	242.71
PSM Score	Control	296	0.41	0.15	0.25	0.29	0.46	0.51	0.61
	Treatment	296	0.44	0.16	0.25	0.30	0.48	0.55	0.62

PROPENSITY MATCHING RESULTS: SIP GLITCHES

Table 4: Propensity score matching: SIP glitches.

Variable	Sample	N	Mean	SD	10%	25%	50%	75%	90%
Price ($)	Control	1200	49.02	63.62	12.15	21.16	34.66	57.20	92.17
	Treatment	1200	46.87	81.55	11.59	18.47	31.16	50.06	86.91
MarketCap ($ billion)	Control	1200	8.42	20.10	0.76	1.36	2.77	7.00	18.07
	Treatment	1200	6.47	34.86	0.60	0.80	1.42	3.56	9.11
DollarVolume ($ million)	Control	1200	69.48	132.87	4.14	9.86	25.81	71.78	168.24
	Treatment	1200	60.06	277.91	2.63	4.93	13.24	39.49	113.75
PSM Score	Control	1200	0.53	0.15	0.28	0.44	0.57	0.65	0.70
	Treatment	1200	0.54	0.16	0.28	0.44	0.60	0.68	0.71

SUMMARY STATISTICS: SIP UPGRADE

Table 5: Summary statistics of the matched sample for the Nasdaq-SIP upgrade event on October 24. 2016.

Variable	N	Mean	SD	Min	50%	Max
RQS (bp)	42900	8.55	9.01	0.85	6.19	310.27
RES (bp)	42900	2.65	3.15	0.28	1.85	204.06
RPI (bp)	42900	2.35	2.08	-12.02	1.83	100.72
RRS (bp)	42900	0.29	2.12	-44.76	0.01	128.58
Depth ($ thousand)	42900	160.11	505.77	6.94	76.59	14241.81
Vlm ($ million)	42900	104.23	238.14	0.20	46.24	11120.27
PrcImp (¢/100Shr)	42900	14.55	3.31	1.00	14.68	34.71
ISOShr (%)	42900	35.03	7.23	3.66	34.96	89.36
OddlotShr (%)	42900	10.75	6.72	0.06	9.65	56.24
Cancel/Trade	42900	23.79	11.98	3.84	21.14	252.44
Order/Trade	42900	38.04	23.76	5.48	32.31	443.62
#Run/Vlm	42900	14.77	14.46	0.00	10.70	519.25

SUMMARY STATISTICS: SIP GLITCHES

‹ Data & Variables

Table 6: Summary statistics of SIP glitches pooled.

	N	Mean	SD	Min	50%	Max
RQS (bp)	235564	13.80	18.45	0.52	9.08	730.64
RES (bp)	129309	3.32	4.81	0.00	2.04	319.86
RRS (bp)	129309	1.38	6.62	-366.81	0.94	323.56
Vlm ($ million)	235564	33.30	201.72	0.00	1.82	45054.15
DepthNBBO ($ thousand)	235564	84.50	347.56	0.07	32.52	34608.91
Depth5Lvl ($ thousand)	235564	470.26	1387.41	4.25	149.43	42915.56

◄ Data & Variables
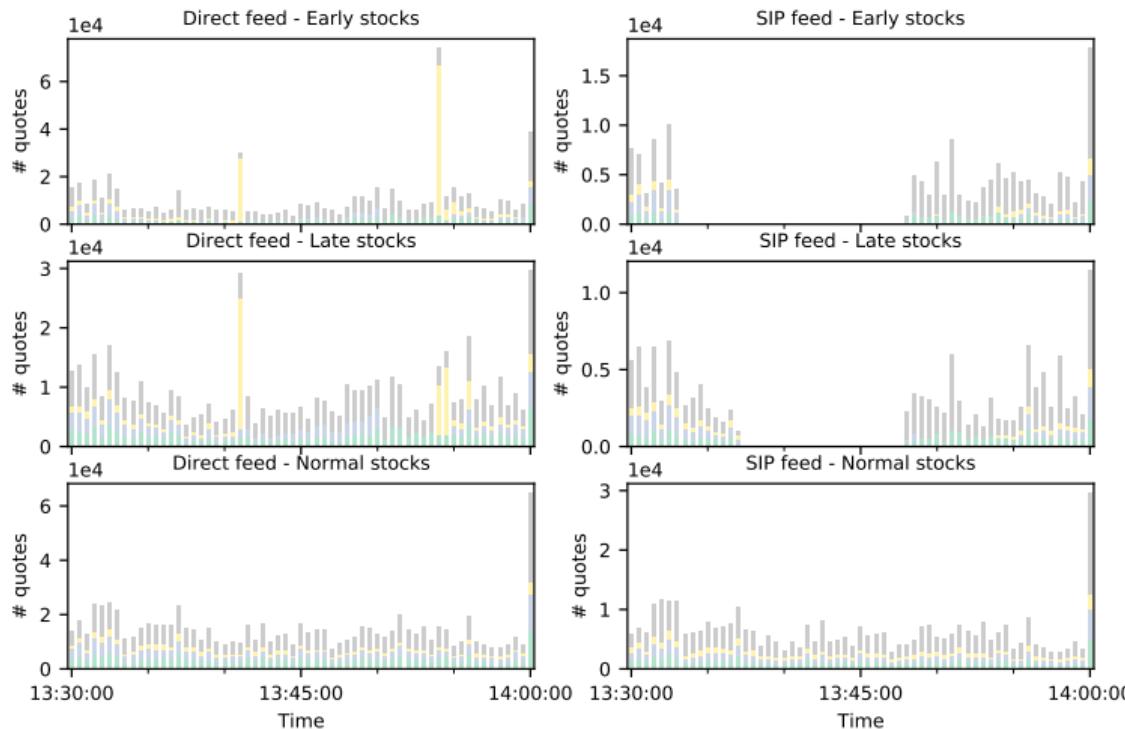
Table 7: Summary statistics of the Nasdaq-SIP glitch.

Variable	N	Mean	SD	Min	50%	Max
RQS (bp)	80886	10.87	9.66	0.88	8.11	140.60
RES (bp)	21803	2.87	3.14	0.00	1.89	54.18
RRS (bp)	21803	1.61	4.15	-48.50	1.30	45.16
Vlm ($ million)	80886	8.35	49.19	0.00	0.00	2878.37
DepthNBBO ($ thousand)	80886	126.78	344.84	0.19	37.12	5985.11
Depth5Lvl ($ thousand)	80886	707.78	1796.72	11.97	196.50	23383.85

SIP glitch on Jan 3, 2013

SIP glitches

ARCA BATS EDGX INET

Direct feed - Early stocks
SIP feed - Early stocks
Direct feed - Late stocks
SIP feed - Late stocks
Direct feed - Normal stocks
SIP feed - Normal stocks

SIP glitch on October 30, 2014

SIP glitch on Jan 3, 2013
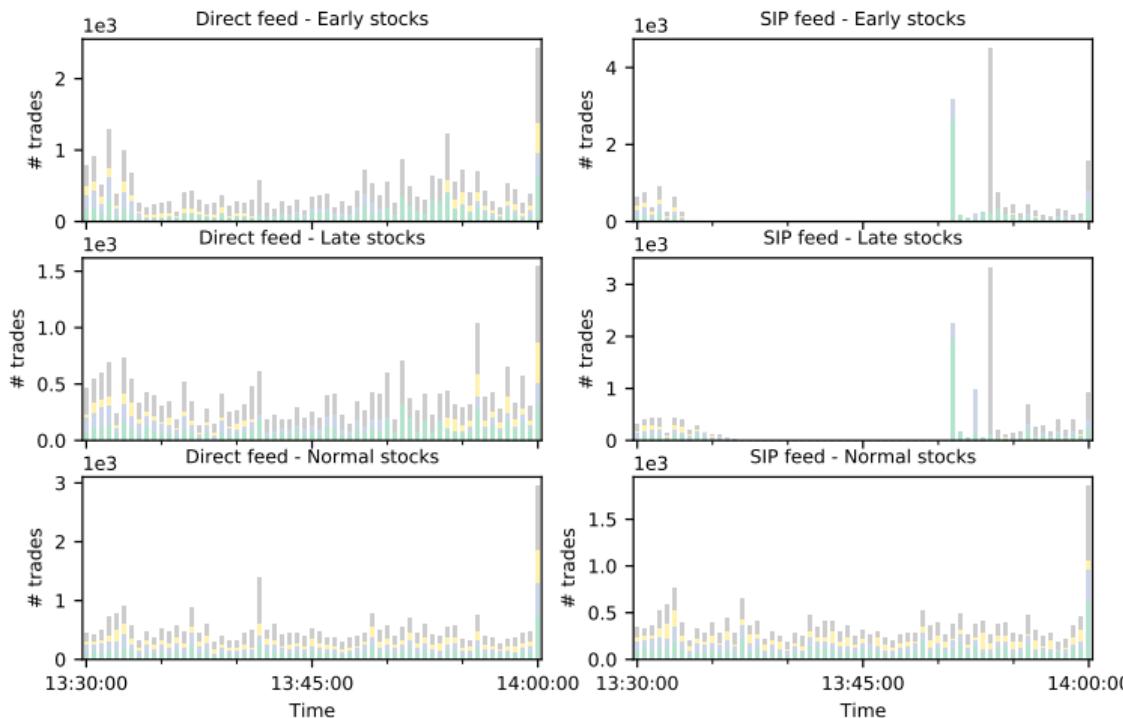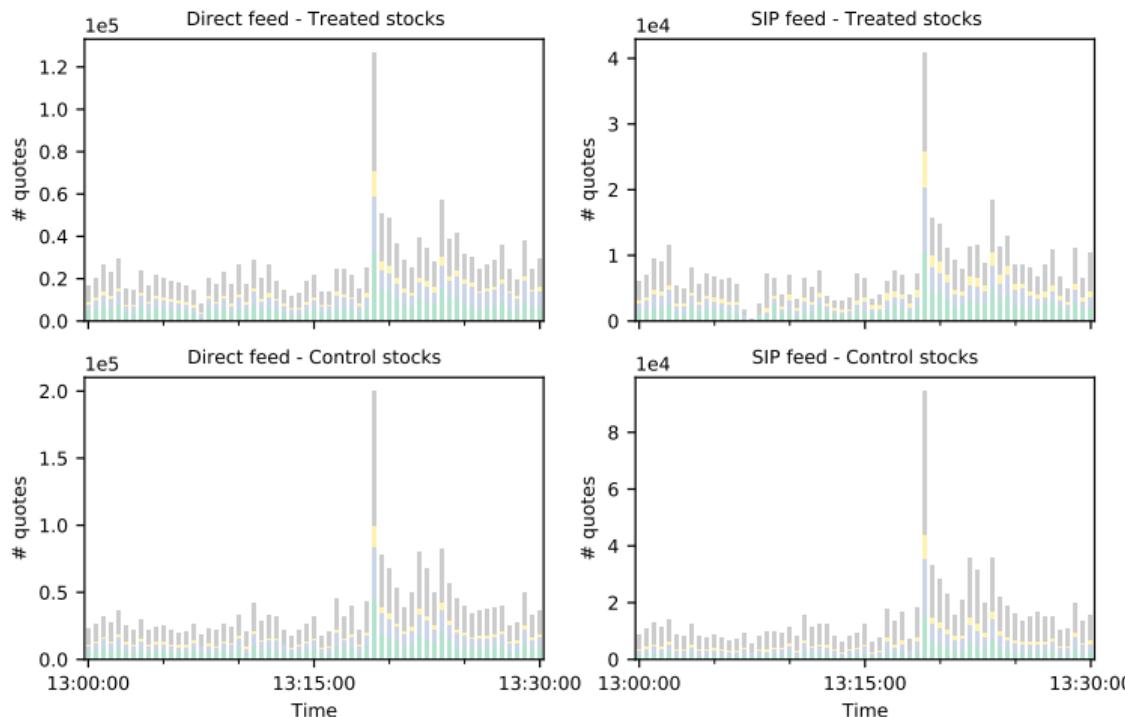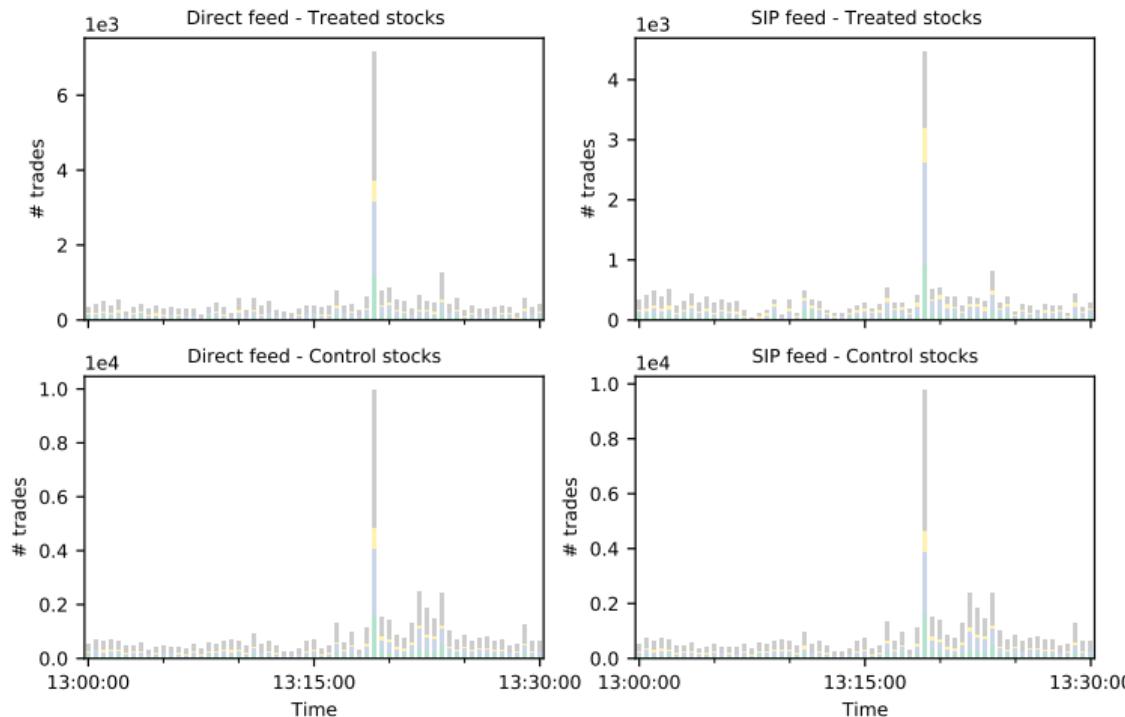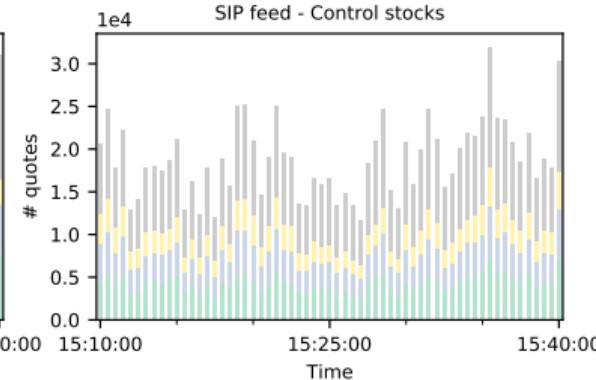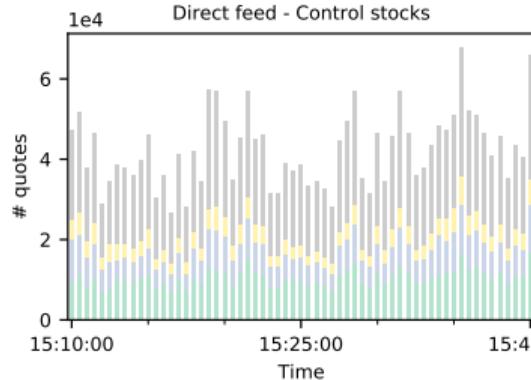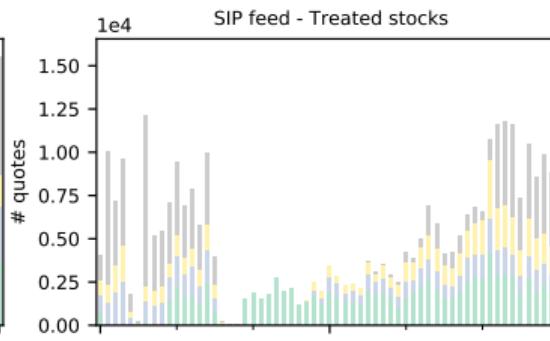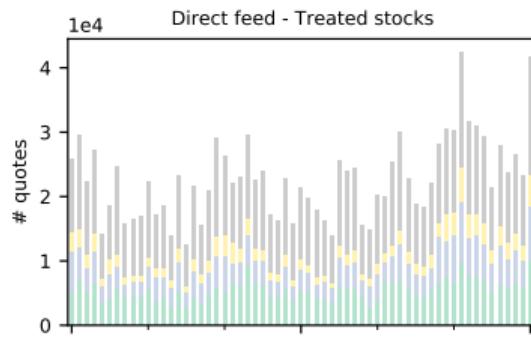
Legend: ARCA, BATS, EDGX, INET

SIP glitch on August 12, 2019

SIP glitch on Jan 3, 2013