

DOES THE CONSOLIDATED TAPE MATTER?

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- Current US equities market structure:
 - ▶ Fast: 20% of trades arrive in < 1ms clusters (Menkveld, 2018)
 - ▶ Fragmented: 16 lit markets + dozens of dark pools & broker-dealer internalizers
- Data is important! For market makers, arbitrageurs & buy-side algos
- Two types of market data:
 - ▶ SIP feeds: slow (aggregation + geographical latency), top of book
 - ▶ Direct feeds from exchanges: fast, full depth and more
- Fair? Policy debates
 - ▶ US: NMS 1.0 \Rightarrow NMS 2.0 (+some depth, +odd lots, +auction info, ≥ 2 SIPs)
 - ▶ Europe: MiFID II/MiFIR (an European-wide tape in process)

- *Question:* Does the consolidated tape matter?
 - ▶ About 45% dark pools use not consolidated feeds¹
 - ▶ More used by algo traders². Data integrity check (CFTC and SEC, 2010; Aldrich, 2017)
 - ▶ Off-exchange trades (Ernst, Sokobin, and Spatt, 2021)
- *Approach:* Standard DiD based on two types of exogenous events:
 - ▶ Nasdaq-SIP (processing/aggregation) speed upgrade in October 2016
 - ▶ Three SIP outages (two NYSE-SIP outages and one Nasdaq-SIP outage)
- *Results on SIP upgrade:*
 - ▶ Overall market liquidity & Liquidity on Nasdaq: \approx
 - ▶ Low-latency trading activity: \uparrow
- *Results on SIP outages:*
 - ▶ Market liquidity: \downarrow

¹"Dispelling the Complementary Product Theory for Market Data", *Nasdaq*, August 8, 2020.

²"Consolidated Market Data Feeds Gain Traction in Algo Trading and Fixed Income", *Finextra*, January 2019.

- Effect of market data on trading and market quality
 - ▶ **Brogaard and Brugler (2020)**: Direct fee introduction \Rightarrow market volume \downarrow as NBBO time and ISO volume \downarrow
 - ▶ **Hendershott, Rysman, and Schwabe (2020)**: Introduction of NYSE Integrated Feed \Rightarrow share of trading on NYSE \uparrow
 - ▶ **Ye, Yao, and Gai (2013)**: An older Nasdaq-SIP speed upgrade in 2011 \Rightarrow liquidity \approx
 - ▶ *Contribution/difference*: Focus on consolidated feeds instead of direct feeds
- Consolidated feeds 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
 - ▶ **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 \gg SIP at high frequency
 - ▶ *Contribution/difference*: Focus on exogenous real-life events instead of static comparisons
- Impact of trading speed on market quality
- ▶ Market liquidity \uparrow if HF-MMs become faster (**Biais, Foucault, and Moinas, 2015; Budish, Cramton, and Shim, 2015; Foucault, Hombert, and Roşu, 2016**)
 - ▶ Market liquidity \downarrow if HF-Arbs becomes faster (**Hoffmann, 2014; Jovanovic and Menkveld, 2016**)
 - ▶ Market liquidity \uparrow 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, 2017**)
 - ▶ *Contribution/difference*: A unique event where slow traders (e.g., buy-side algos) become faster

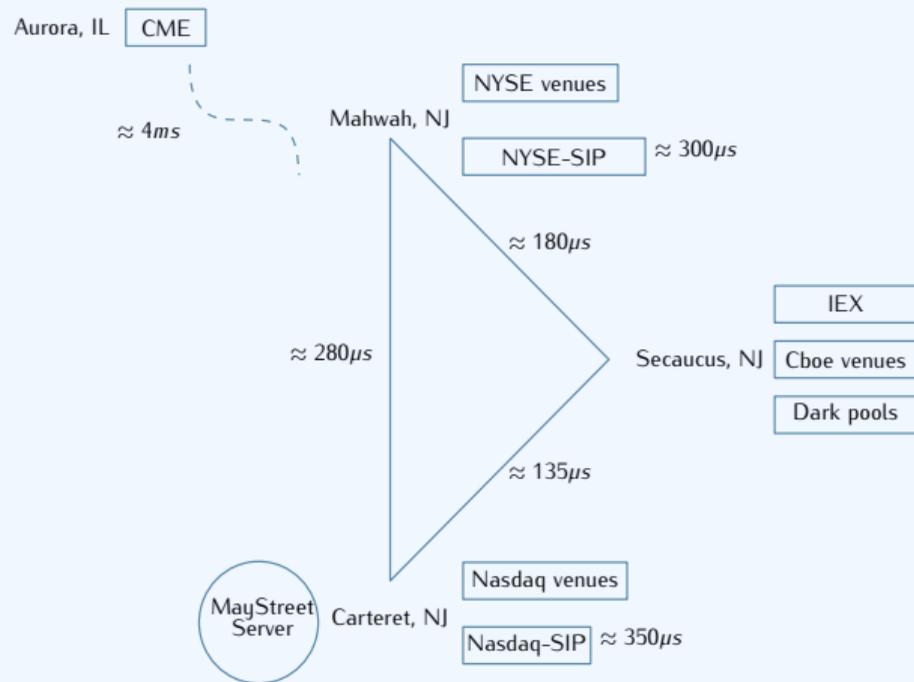
INSTITUTIONAL DETAILS

■ Two SIPs:

- ▶ NYSE-listed stocks \Rightarrow NYSE-SIP
- ▶ Nasdaq-listed stocks \Rightarrow Nasdaq-SIP

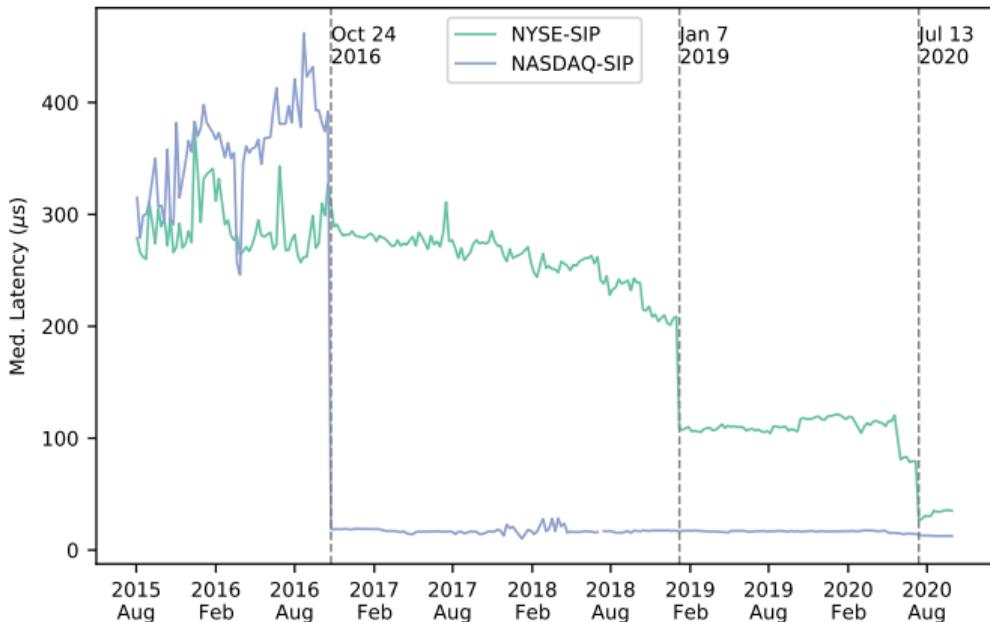
■ SIP latency = geographical latency + processing latency

- ▶ E.g., for a SIP subscriber at Mahwah trading Nasdaq, an quote update from NYSE takes 280×2 (geographical) + 350 (processing) = $910 \mu\text{s}$



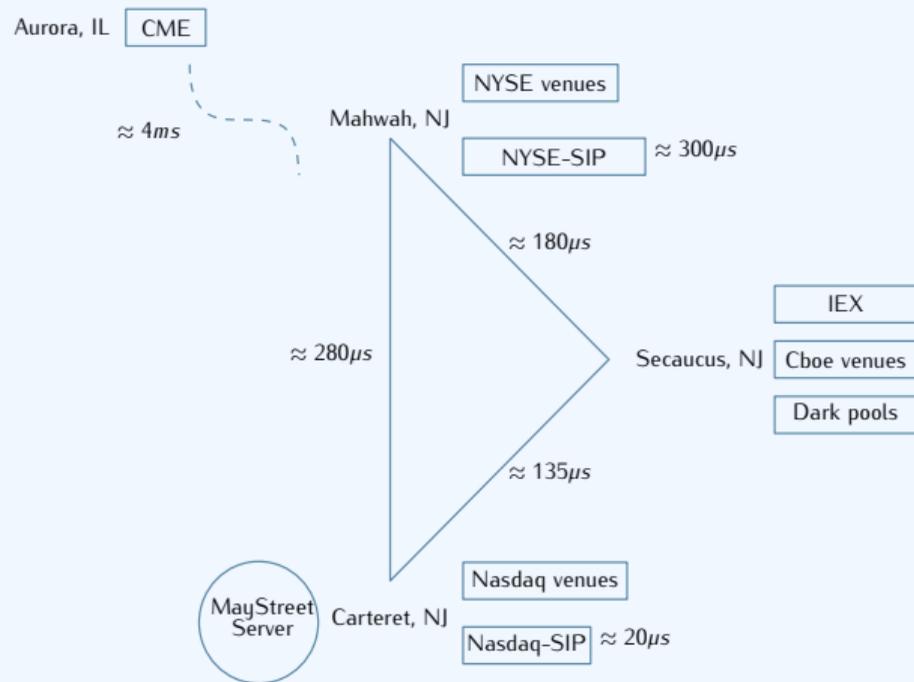
SIP SPEED UPGRADE

- Processing latency of Nasdaq-SIP: $\approx 350 \mu s \Rightarrow < 20 \mu s$



IMPLICATIONS ON THE DIRECT FEED ADVANTAGE

- *Implication #1: SIP feeds for Nasdaq-stocks faster*
- *Implication #2: More so for Nasdaq-stocks on Nasdaq venues*
- @Nasdaq venues trading Nasdaq-stocks
 - ▶ Björn (direct): $< 20 \mu\text{s}$
 - ▶ Shihao (SIP): $350 \rightarrow 20 \mu\text{s} :-)$
- @NYSE venues trading Nasdaq-stocks
 - ▶ Björn (direct): $< 20 \mu\text{s}$
 - ▶ Shihao (SIP): $280 \times 2 + 350 \rightarrow 280 \times 2 + 20 \mu\text{s}$



- A sample of 60 Nasdaq-stocks from S&P 500 matched with 60 NYSE-stocks on price, volume, market capitalization and Fama French 12 industry. ▶ PSM score ▶ PT1 ▶ PT2
- Nasdaq-listed stocks vs. NYSE-listed stocks

$$metric_{i,t} = \alpha_i + \beta After_{i,t} + \gamma After_{i,t} \times NasdaqStock_{i,t} + \epsilon_{i,t} \quad (1)$$

- Nasdaq exchange vs. Other exchanges (ARCA, BATS, EDGX)³

$$metric_{i,e,t} = \alpha_{i,e} + \beta_t + \gamma_1 After_{i,e,t} \times NasdaqStock_{i,e,t} + \gamma_2 After_{i,e,t} \times NasdaqVenue_{i,e,t} + \gamma_3 After_{i,e,t} \times NasdaqStock_{i,e,t} \times NasdaqVenue_{i,e,t} + \epsilon_{i,e,t} \quad (2)$$

³Only maker-taker venues. NYSE excluded as it only starts trading Nasdaq stocks since April 2018.

QUESTIONS?

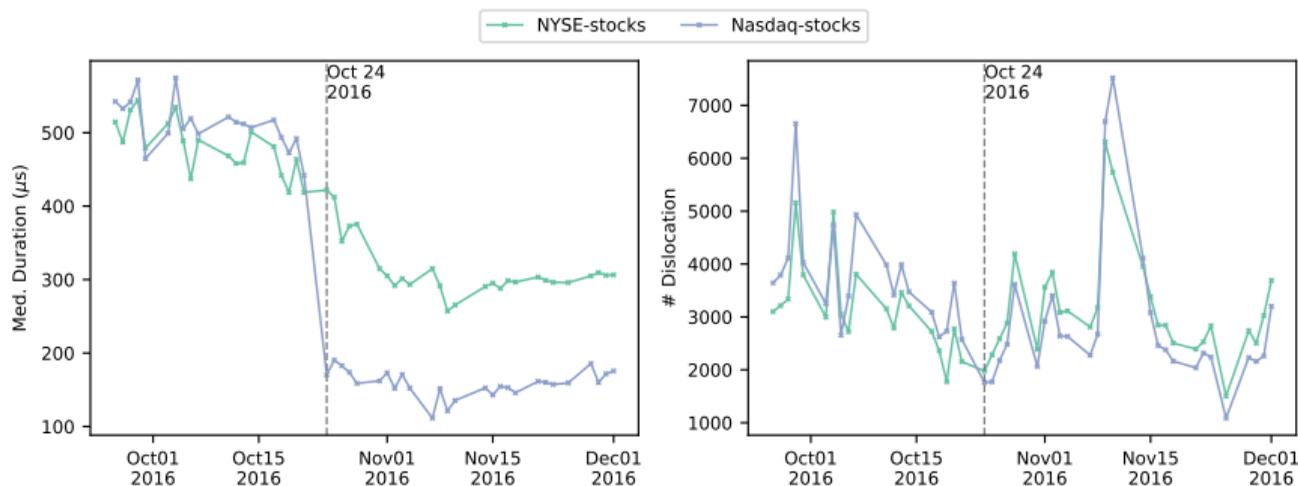


- “Direct-NBBO” constructed from Participant Timestamps of TAQ (Bartlett and McCrary, 2019), based on which I compute all TAQ-related measures [▶ Summary statistics](#)
- Liquidity measures during SIP outages computed from direct feeds from MayStreet

Liquidity & Trading metrics	Approach source	Data source
<i>RQS, RES, RRS</i>		NYSE TAQ
<i>DollarDepth</i>		NYSE TAQ
<i>Vlm</i>		NYSE TAQ
<i>Prclmp</i>	Boehmer et al. (2021)	NYSE TAQ
<i>ISOShr</i>		NYSE TAQ
<i>OddlotShr</i>		NYSE TAQ
<i>Cancel/Trade</i>		SEC MIDAS
<i>Order/Trade</i>		SEC MIDAS
<i>#Run/Vlm</i>	Hasbrouck and Saar (2013)	LOBSTER

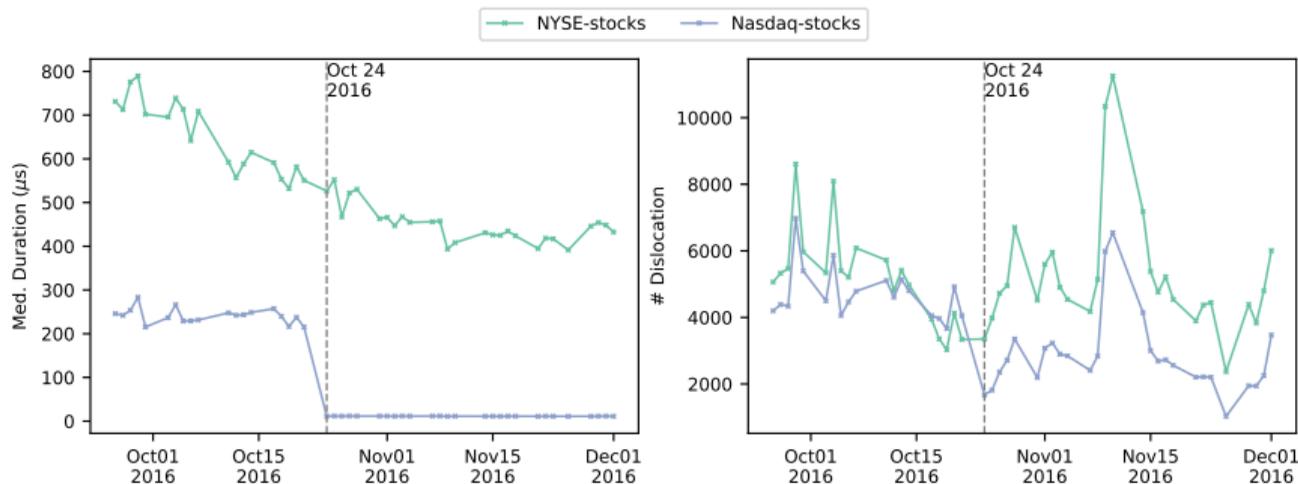
NBBO DISLOCATIONS

- # Dislocations of SIP-NBBO in Nasdaq-stocks ↓ 746 (15%) *relative to NYSE-stocks.*



NASDAQ-BBO DISLOCATIONS

- # Dislocations of SIP-Nasdaq-BBO in Nasdaq-stocks ↓ 1854 (41%) *relative to* NYSE-stocks



DID RESULTS: LIQUIDITY IMPACT OF NASDAQ-SIP UPGRADE

■ No impact on liquidity

	RQS	RES	RRS	DollarDepth	Vlm	Prclmp
After	0.53*** (0.09)	0.23*** (0.06)	0.00 (0.05)	-26.27* (15.07)	64.09*** (12.44)	0.00 (0.00)
After x NasdaqStock	0.06 (0.14)	-0.10 (0.08)	-0.07 (0.07)	7.10 (18.61)	3.59 (30.33)	0.00 (0.00)
R ² (%)	7.67	1.14	0.10	0.78	2.84	0.12
N	4408	4408	4408	4408	4408	4408
Stock F.E.	Yes	Yes	Yes	Yes	Yes	Yes

DID RESULTS: TRADING IMPACT OF NASDAQ-SIP UPGRADE

- ISO share \uparrow 3%: More flows from informed institutions? (Chakravarty et al., 2012)
- Low-latency measures \uparrow : Both algo measures, *Cancel/Trade* (\uparrow 16%) & *Order/Trade* (\uparrow 15%), and HFT measure *#Run/Vlm* (\uparrow 13%) [▶ Graph](#)

	ISOShr	OddlotShr	Cancel/Trade	Order/Trade	#Run/Vlm
After	-1.89*** (0.33)	-0.52** (0.21)	-6.39*** (0.84)	-10.20*** (1.60)	-0.12*** (0.03)
After x NasdaqStock	1.26** (0.50)	0.00 (0.31)	3.79*** (0.98)	5.71*** (1.79)	0.08** (0.04)
R^2 (%)	2.01	1.04	12.16	9.40	2.81
N	4408	4408	4370	4370	4325
Stock F.E.	Yes	Yes	Yes	Yes	Yes

TRIPLE DID RESULTS: LIQUIDITY IMPACT OF NASDAQ-SIP UPGRADE

■ Again, no impact on liquidity

	RQS	RES	RRS	DollarDepth	Vlm
After	0.77 (0.61)	0.14*** (0.03)	-0.11*** (0.02)	-2.91 (1.88)	4.47*** (0.87)
After x NasdaqStock	0.87 (0.68)	-0.01 (0.04)	-0.01 (0.04)	0.96 (2.23)	1.77 (2.37)
After x NasdaqVenue	-0.09 (0.56)	0.00 (0.01)	0.00 (0.01)	0.52 (0.98)	5.14*** (0.86)
After x NasdaqStock x NasdaqVenue	-0.95 (0.62)	0.02 (0.01)	-0.02 (0.02)	-0.18 (1.63)	6.08 (3.77)
R ² (%)	0.36	3.43	0.95	0.28	3.00
N	17632	17632	17632	17632	17632
Stock-Venue F.E.	Yes	Yes	Yes	Yes	Yes

TRIPLE DID RESULTS: TRADING IMPACT OF NASDAQ-SIP UPGRADE

- ISO share ↑; Odd-lot share ↓
- Low-latency measures ↑. Both also measure (*Cancel/Trade* & *Cancel/Trade*)

	ISOshr	OddlotShr	Cancel/Trade	Order/Trade
After	-2.45*** (0.44)	-0.44* (0.25)	-6.14*** (0.84)	-8.43*** (1.08)
After x NasdaqStock	1.00* (0.56)	0.12 (0.33)	2.45** (1.13)	2.60* (1.46)
After x NasdaqVenue	-0.35 (0.24)	0.03 (0.14)	-2.03*** (0.58)	-3.93*** (0.91)
After x NasdaqStock x NasdaqVenue	0.67* (0.35)	-0.66*** (0.21)	3.68*** (0.79)	6.17*** (1.18)
R^2 (%)	2.89	0.53	5.84	6.43
N	17632	17632	17480	17480
Stock-Venue F.E.	Yes	Yes	Yes	Yes

- Stock-day fixed effects (for the triple DiD)
- Exclude US election
- Include VIX

QUESTIONS?



Table 1: Recent major SIP glitches.

Date	Time	Duration	SIP	Trading halt
January 3, 2013	13:33 - 13:51	18 minutes	Nasdaq-SIP	No ^a
October 30, 2014	13:07 - 13:34	27 minutes ^b	NYSE-SIP	No
August 12, 2019	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.

DID RESULTS: ALL THREE SIP GLITCHES POOLED

- DiD specification; Similar matching as before

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

- All liquidity measures ↓: *RQS* (↑10.7%), *RES* (↑7.7%), *DollarVlm* (↓40%), *NBBODepth* (↓15%)

	RQS	RES	RRS	DollarVlm	DepthNBBO	Depth5lvl
After	0.04 (0.07)	-0.02 (0.03)	-0.01 (0.07)	26.72*** (9.39)	-16.70 (11.54)	-124.56*** (36.17)
After x Treated	0.46*** (0.12)	0.11** (0.04)	0.51*** (0.09)	-41.39*** (11.18)	-34.83** (14.88)	-143.40** (58.98)
R ² (%)	1.72	0.12	0.53	0.18	1.93	6.10
N	34964	30497	30497	34964	34964	34964
Stock-Event F.E.	Yes	Yes	Yes	Yes	Yes	Yes

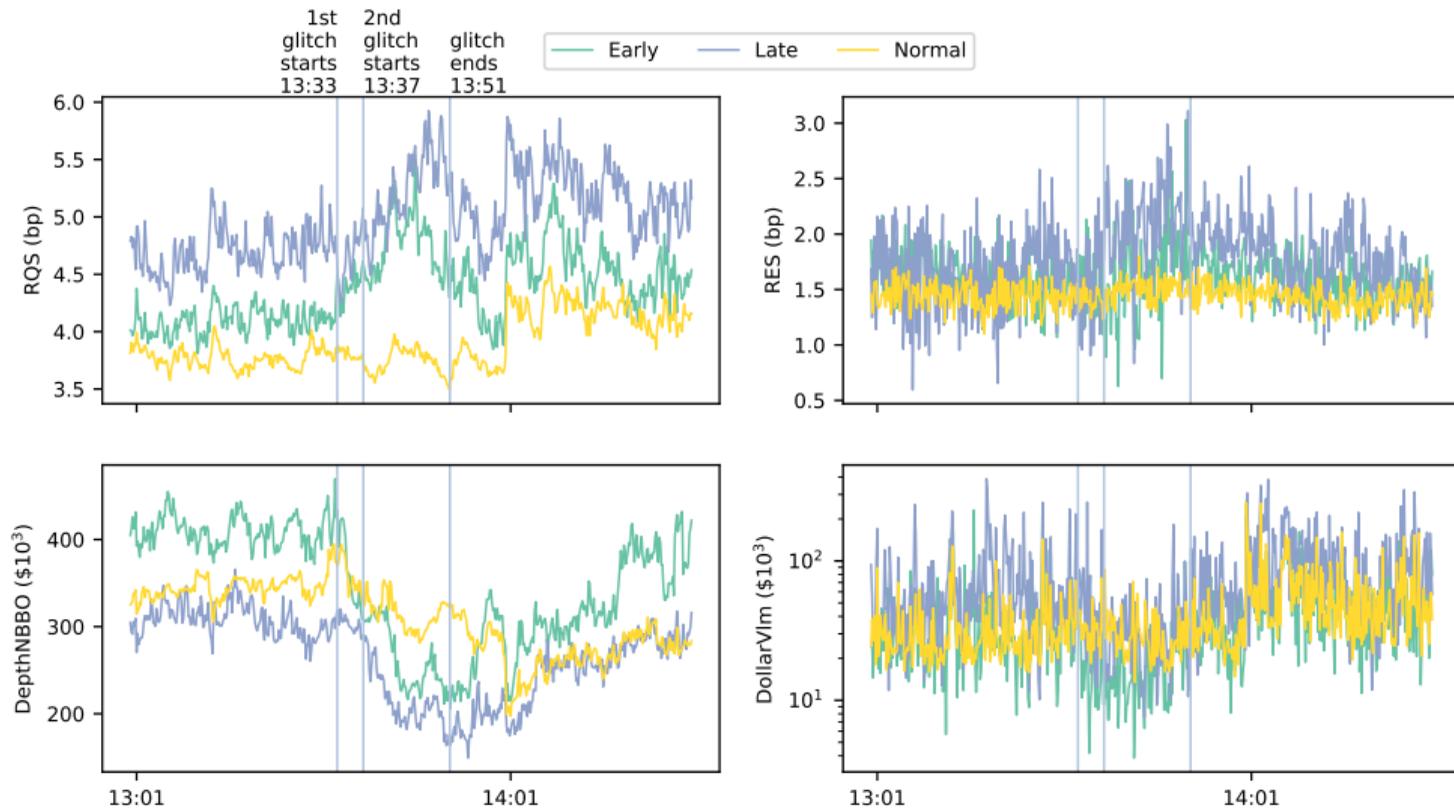
ZOOM IN ONTO THE SIP OUTAGE ON JAN 3, 2013

▸ Trades ▸ Messages

Table 2: Channel assignment of NASDAQ-SIP and outage order. This table shows the symbol allocation across the six data dissemination 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)	13:37:22 - 13:48:19	13:36:51 - 13:51:14
	Channel 3 (Symbols FE-LKZ)		
	Channel 5 (Symbols PC-SPZ)		
“Early” channels	Channel 2 (Symbols CE-FDZ)	13:33:11 - 13:48:21	13:33:11 - 13:51:15
	Channel 4 (Symbols LL-PBZ)		
	Channel 6 (Symbols SQ-ZZZ)		

SIP GLITCH ON JAN 3, 2013



DiD: SIP OUTAGE ON JAN 3, 2013, 1ST PERIOD

- DiD specification for the 1st period

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

- Liquidity ↓ & Only stocks in the early channel affected

	RQS	RES	RRS	DollarVlm	DepthNBBO	Depth5lvl
Period1	-0.01 (0.02)	-0.03 (0.02)	0.08*** (0.03)	-2.21 (2.64)	30.94 (28.66)	-37.83 (47.41)
Period1 x EarlyChannel	0.28*** (0.11)	-0.02 (0.09)	0.36*** (0.10)	-25.88*** (4.70)	-85.86** (38.57)	-367.08*** (129.29)
Period1 x LateChannel	-0.10 (0.09)	-0.05 (0.07)	0.06 (0.09)	-21.88 (14.25)	-35.72 (30.06)	-76.57 (55.22)
R ² (%)	0.16	0.01	0.08	0.04	0.14	1.04
N	55596	55596	55596	55596	55596	55596
Stock F.E.	Yes	Yes	Yes	Yes	Yes	Yes

DiD: SIP OUTAGE ON JAN 3, 2013, 2ND PERIOD

- DiD specification for the 2nd period

$$metric_{i,t} = \alpha_i + \beta Period2_{i,t} + \gamma Period2_{i,t} \times LateChannel_{i,t} + \epsilon_{i,t} \quad (5)$$

- Liquidity ↓ & control stocks affected as well

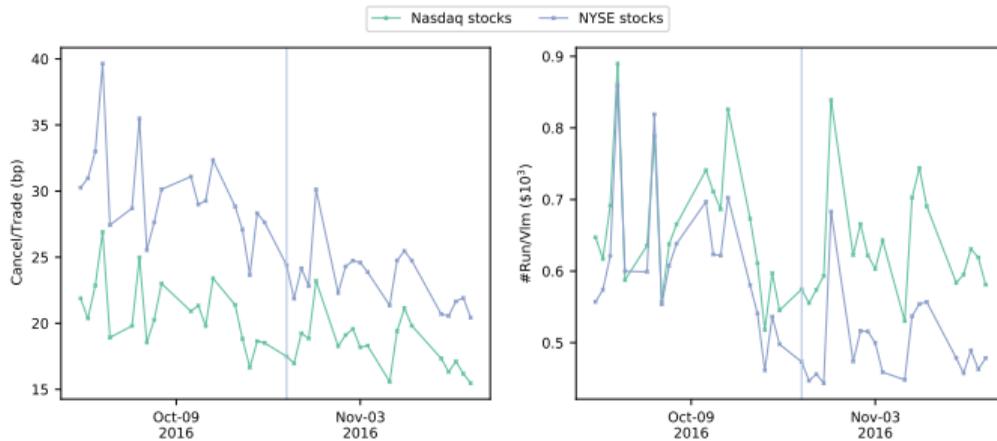
	RQS	RES	RRS	DollarVlm	DepthNBBO	Depth5lvl
Period2	-0.02 (0.03)	0.07** (0.03)	0.05 (0.04)	1.40 (3.11)	-47.36*** (16.37)	-241.36*** (37.81)
Period2 x LateChannel	0.43*** (0.13)	0.17 (0.13)	0.47*** (0.16)	-35.99* (18.53)	-9.49 (23.32)	-20.95 (122.22)
R ² (%)	0.80	0.23	0.29	0.16	0.54	9.34
N	12265	12265	12265	12265	12265	12265
Stock F.E.	Yes	Yes	Yes	Yes	Yes	Yes

- Nasdaq-SIP (processing) speed upgrade
 - ▶ Low-latency activity: ↑
 - ▶ Overall market liquidity: ≈
 - ▶ Liquidity on Nasdaq: ≈
- SIP outages
 - ▶ Market liquidity: ↓
- Implications for NMS 2.0
 - ▶ Speeding up the single SIP does not seem to help the market. Competing SIPs? More wasteful arm race?
 - ▶ Perhaps more content? Odd-lot quotes, depth, auction imbalances



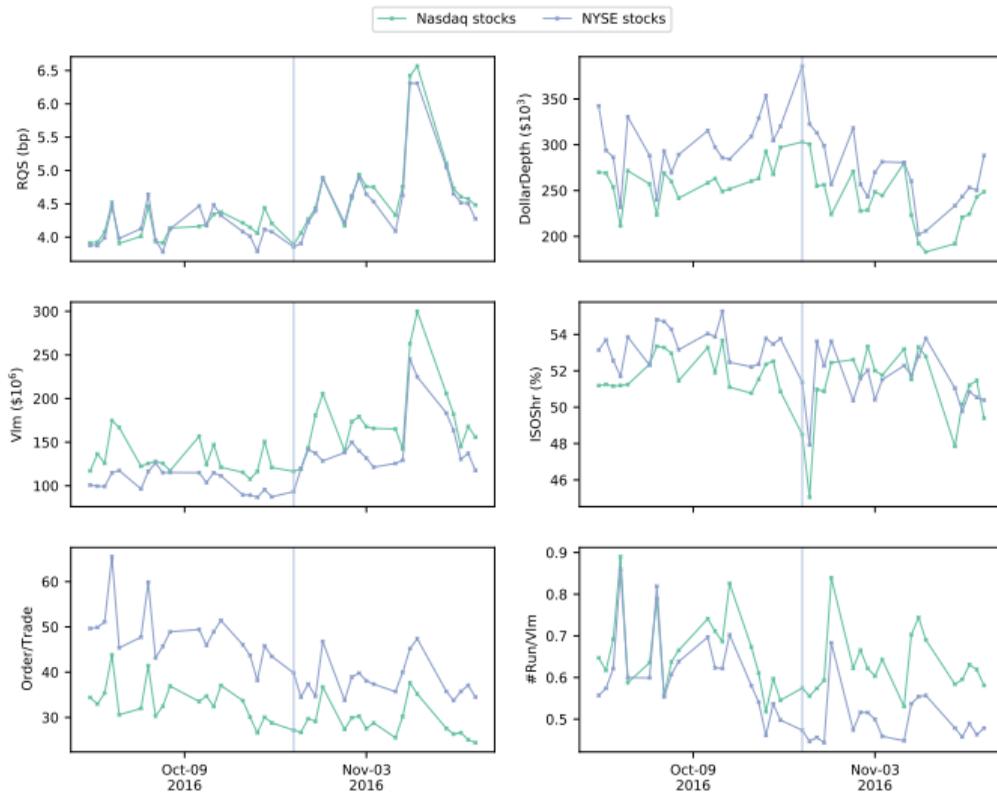
PARALLEL TRENDS: SIP UPGRADE, LOW-LATENCY MEASURES

◀ DiD



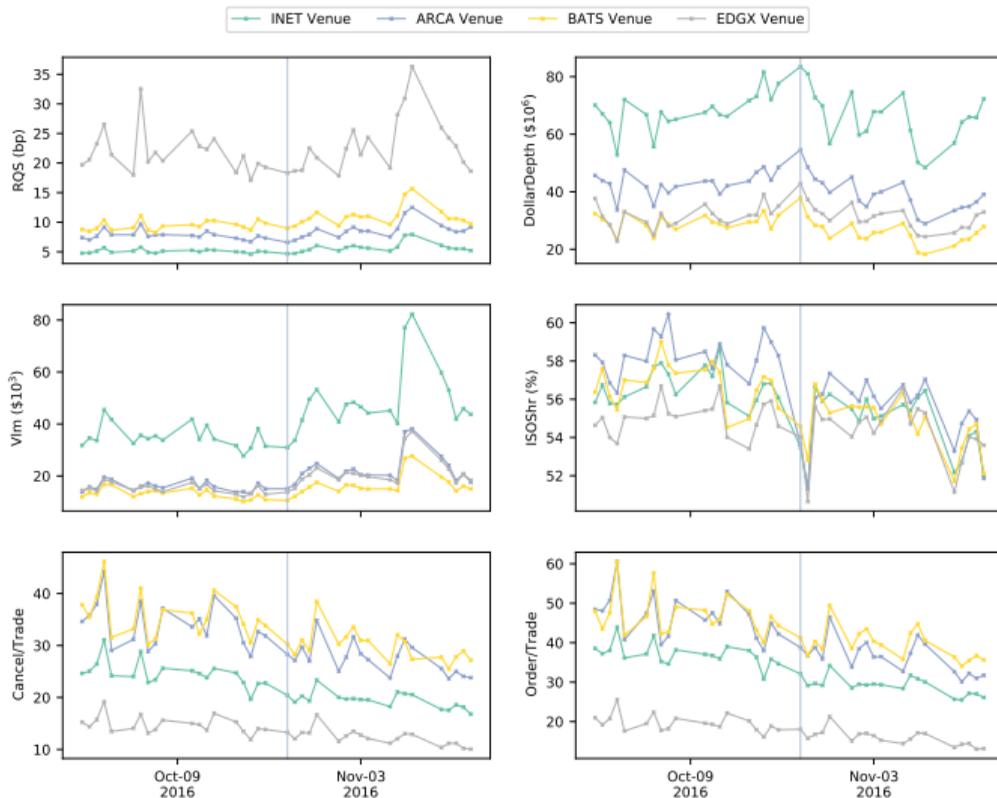
PARALLEL TRENDS: SIP UPGRADE

◀ DiD



PARALLEL TRENDS: SIP UPGRADE, EXCHANGE

◀ DiD



PROPENSITY MATCHING RESULTS: SIP UPGRADE

◀ DiD

Table 3: Propensity score matching: SIP speed upgrade.

Variable	Sample	N	Mean	SD	10%	25%	50%	75%	90%
Price	Control	60	92.19	78.49	26.62	46.32	70.47	118.16	177.15
	Treatment	60	91.44	113.88	28.83	39.57	64.74	90.74	119.90
MarketCap	Control	60	37.39	48.35	8.90	12.77	23.61	33.12	66.91
	Treatment	60	38.31	54.77	7.01	11.33	19.08	40.98	89.70
DollarVolume	Control	60	224.68	203.55	60.38	95.47	143.72	263.84	503.85
	Treatment	60	265.42	327.89	49.12	79.16	166.70	272.31	579.30
PSM Score	Control	60	0.35	0.16	0.15	0.27	0.32	0.54	0.57
	Treatment	60	0.36	0.17	0.15	0.27	0.32	0.54	0.59

SUMMARY STATISTICS: SIP UPGRADE SAMPLE

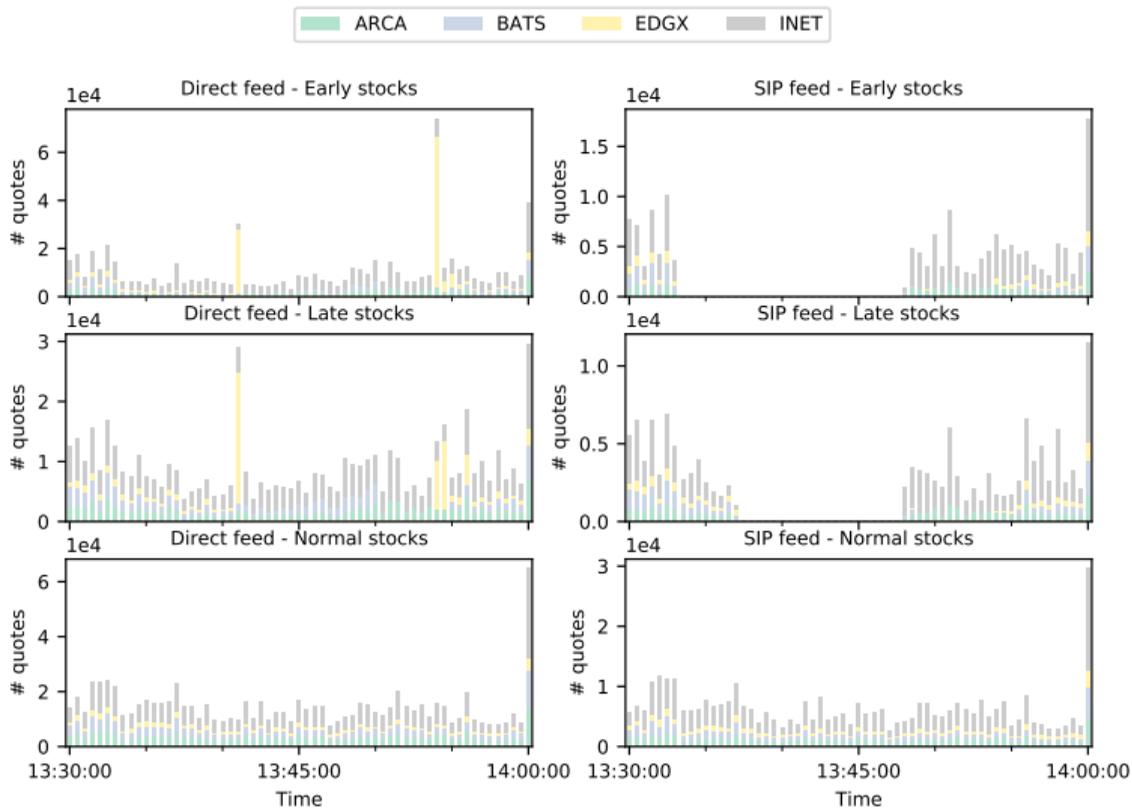
◀ DiD

Table 4: Summary statistics of the matched sample for the Nasdaq-SIP upgrade event on October 24, 2016.

Variable	N	Mean	SD	Min	10%	25%	50%	75%	90%	Max
RQS	4408	4.42	3.38	1.18	1.94	2.50	3.43	5.11	7.84	31.67
RES	4408	1.59	1.39	0.40	0.72	0.89	1.21	1.74	2.75	25.69
RRS	4408	0.19	0.95	-6.87	-0.41	-0.18	0.02	0.33	0.82	15.18
DollarDepth	4408	267.46	504.98	32.50	71.83	91.26	128.89	214.86	474.68	7529.71
Vlm	4408	210.97	349.57	10.20	47.94	74.16	127.08	237.66	413.89	8827.11
Prclmp	4408	0.15	0.03	0.01	0.12	0.13	0.15	0.17	0.18	0.32
ISOShr	4408	37.01	6.17	12.93	29.16	32.80	37.04	41.18	44.76	77.96
OddlotShr	4408	11.05	6.54	0.18	3.44	6.15	9.90	15.12	20.56	35.81
Cancel/Trade	4370	23.13	9.38	6.00	13.72	16.94	21.38	27.28	34.40	122.87
Order/Trade	4370	37.35	18.18	8.89	20.84	25.96	33.54	43.76	56.46	262.08
#Run/Vlm	4325	0.60	0.33	0.08	0.29	0.39	0.53	0.73	0.96	4.75

SIP GLITCH ON JAN 3, 2013

◀ Channel



SIP GLITCH ON JAN 3, 2013

← Channel

