High Frequency Quoting: Short-Term Volatility in Bids and Offers

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Disclaimers

- I teach in an entry-level training program at a large financial firm that is generally thought to engage in high frequency trading.
- I serve on a CFTC advisory committee that discusses issues related to high frequency trading.
- I accept honoraria for presentations at events sponsored by financial firms.

What does quote volatility look like?

- In US equity markets, bids and offers from all trading venues are consolidated and disseminated in real time.
  - The highest bid is the National Best Bid (NBB)
  - The lowest offer is the National Best Offer (NBO)
- Next slide: the NBBO for AEPI on April 29, 2011

Figure 1. AEPI bid and offer, April 29, 2011

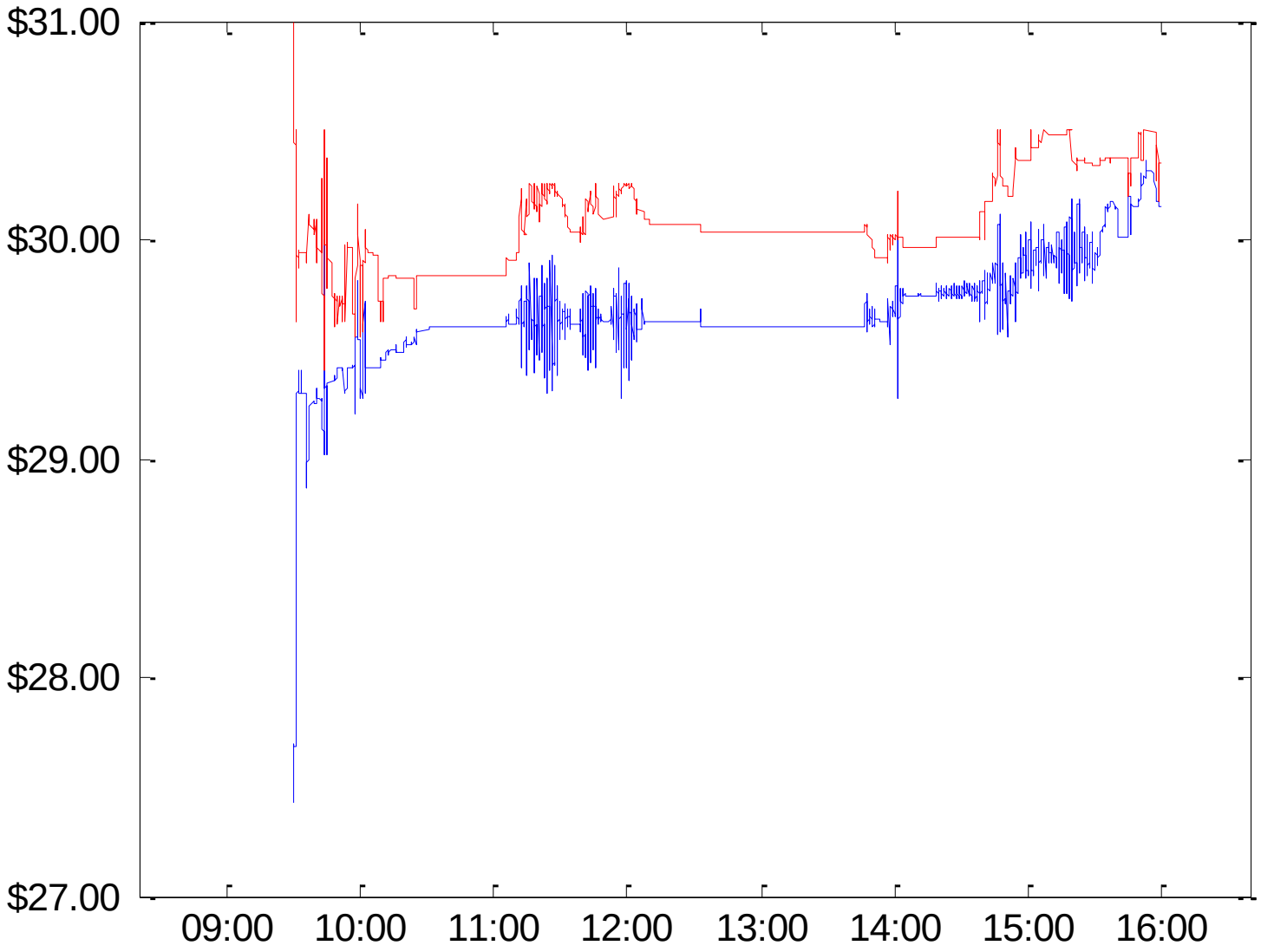
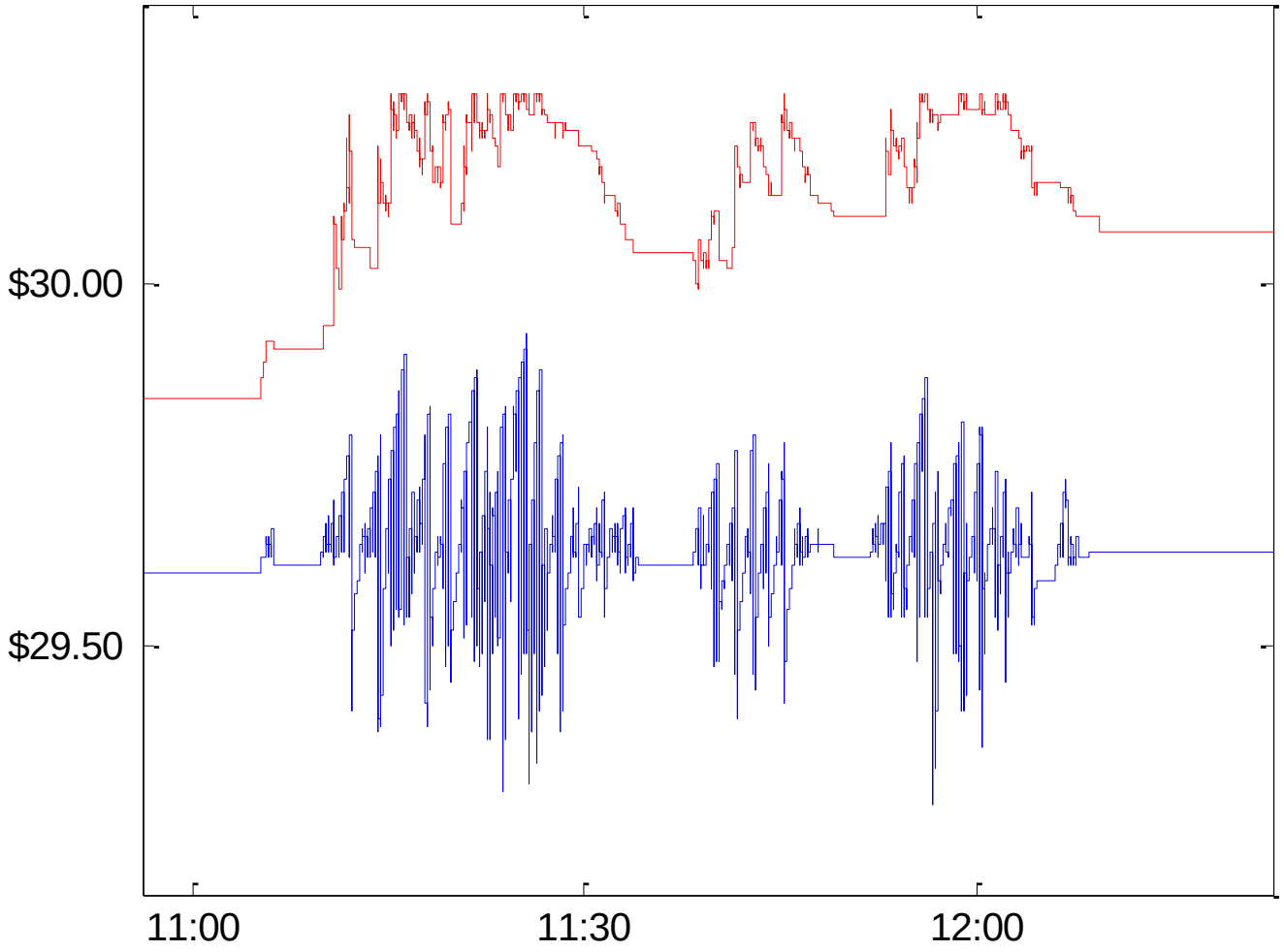
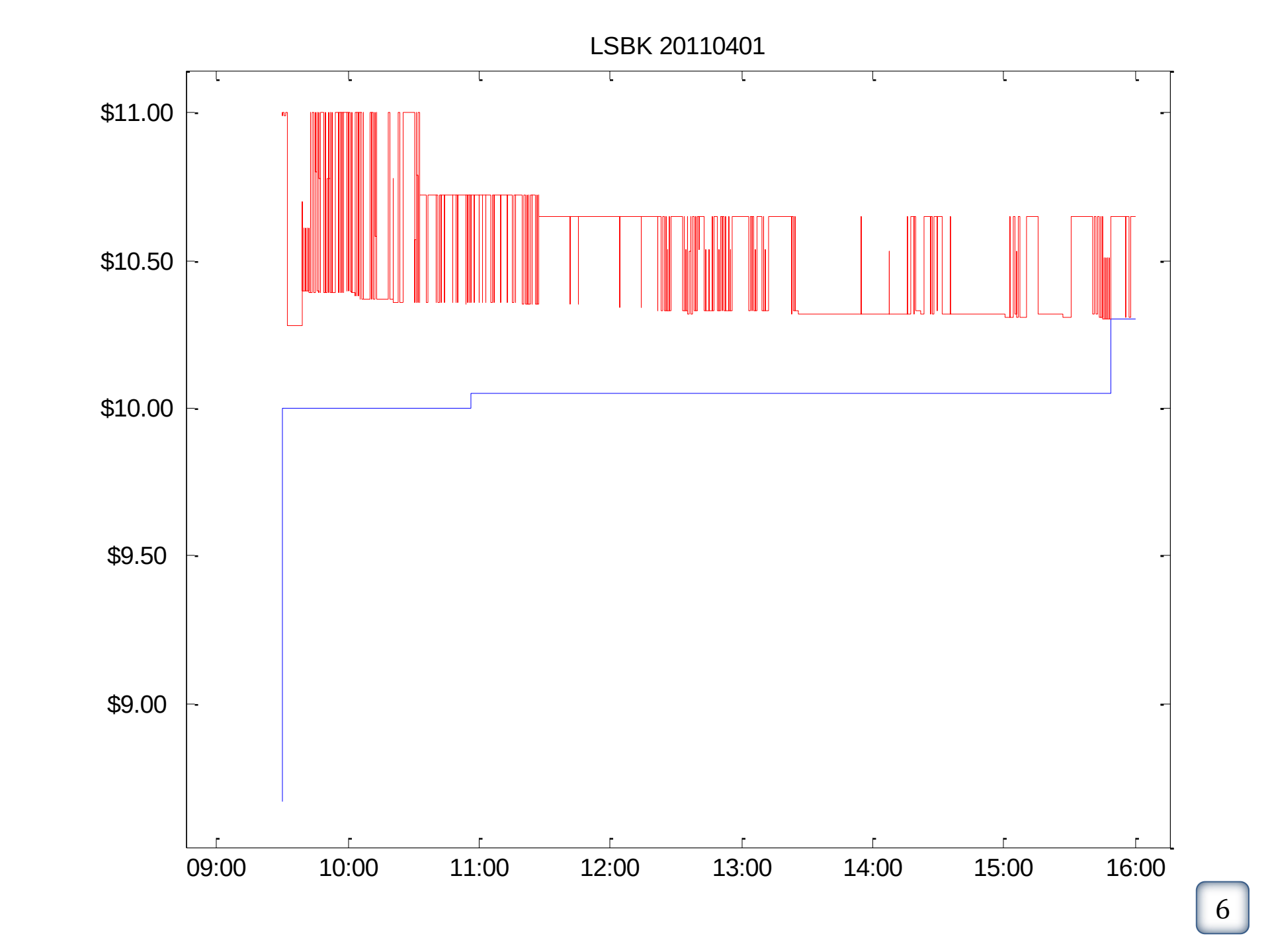


Figure 1. AEPI bid and offer on April 29, 2011 (detail)

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10:00
11:00
12:00
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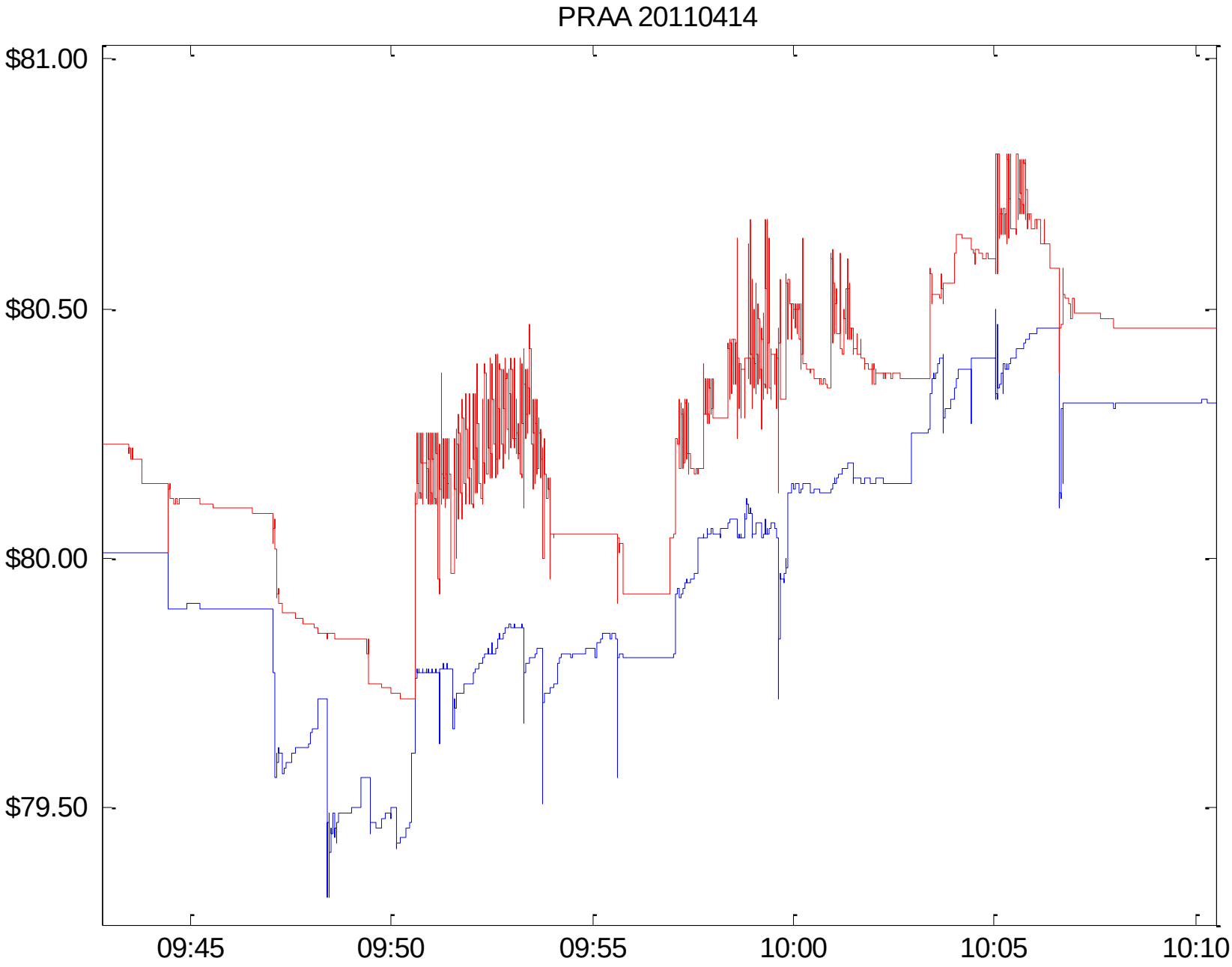
14:00
15:00
16:00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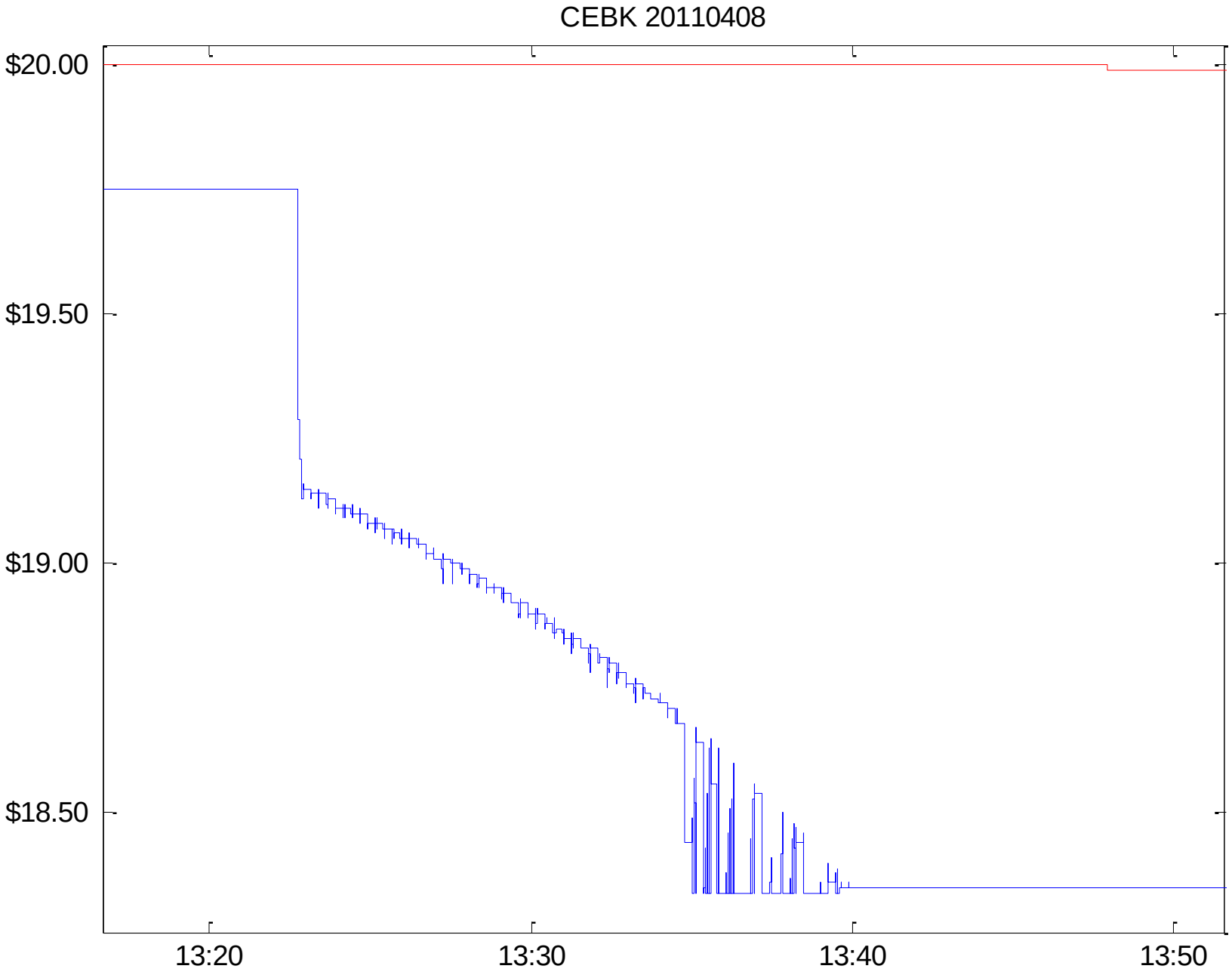
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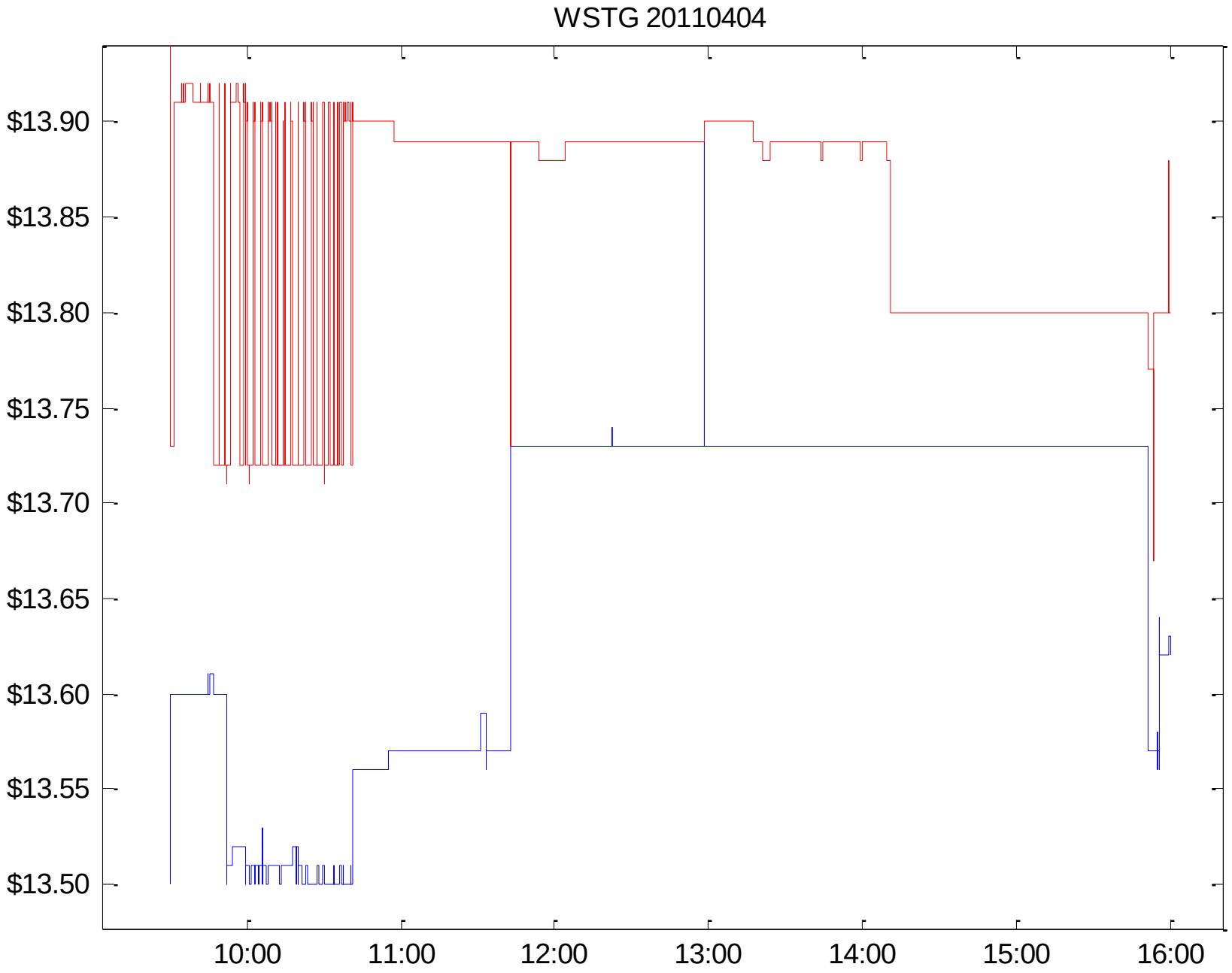
13:30
13:40
13:50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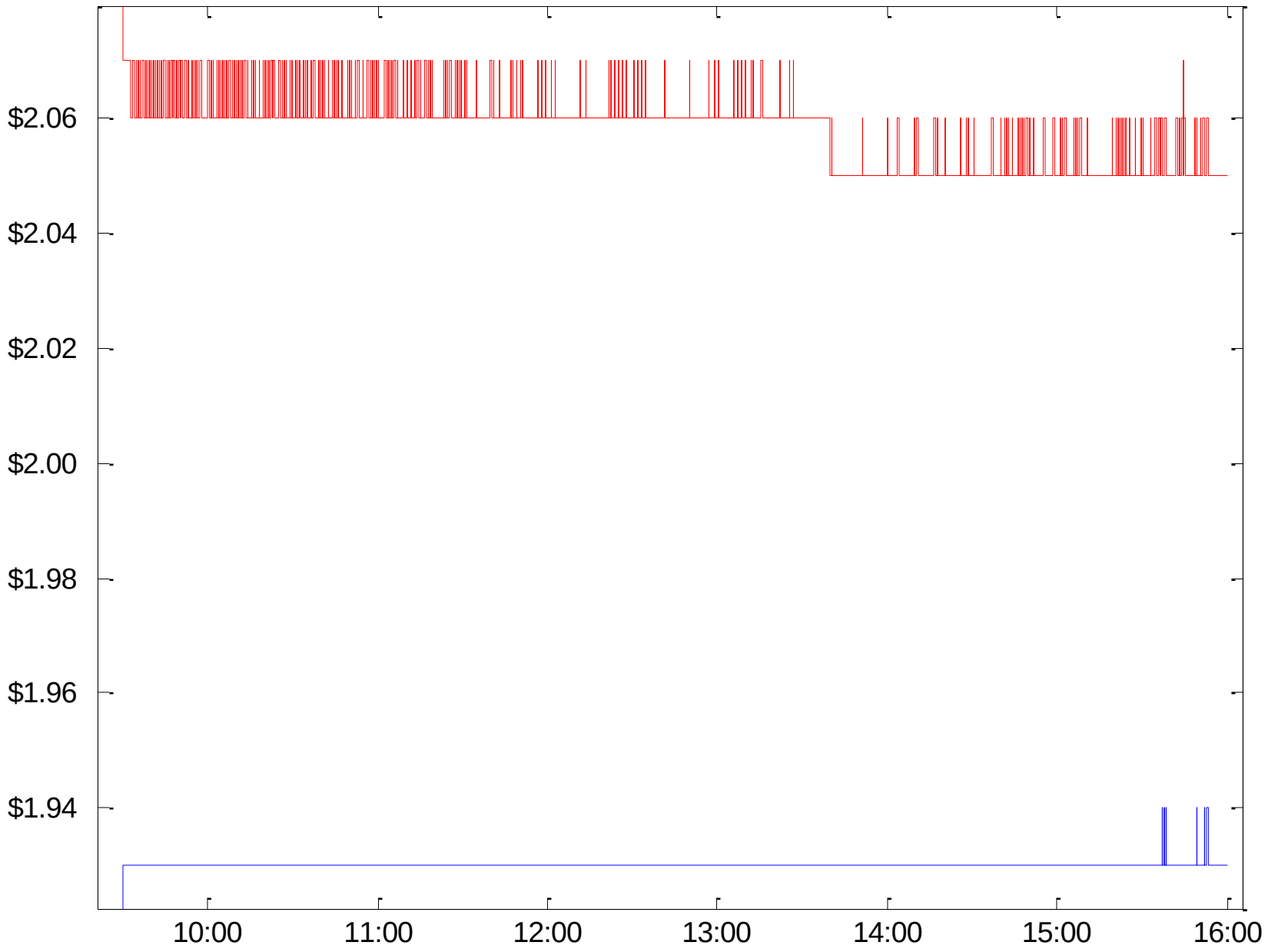
16:00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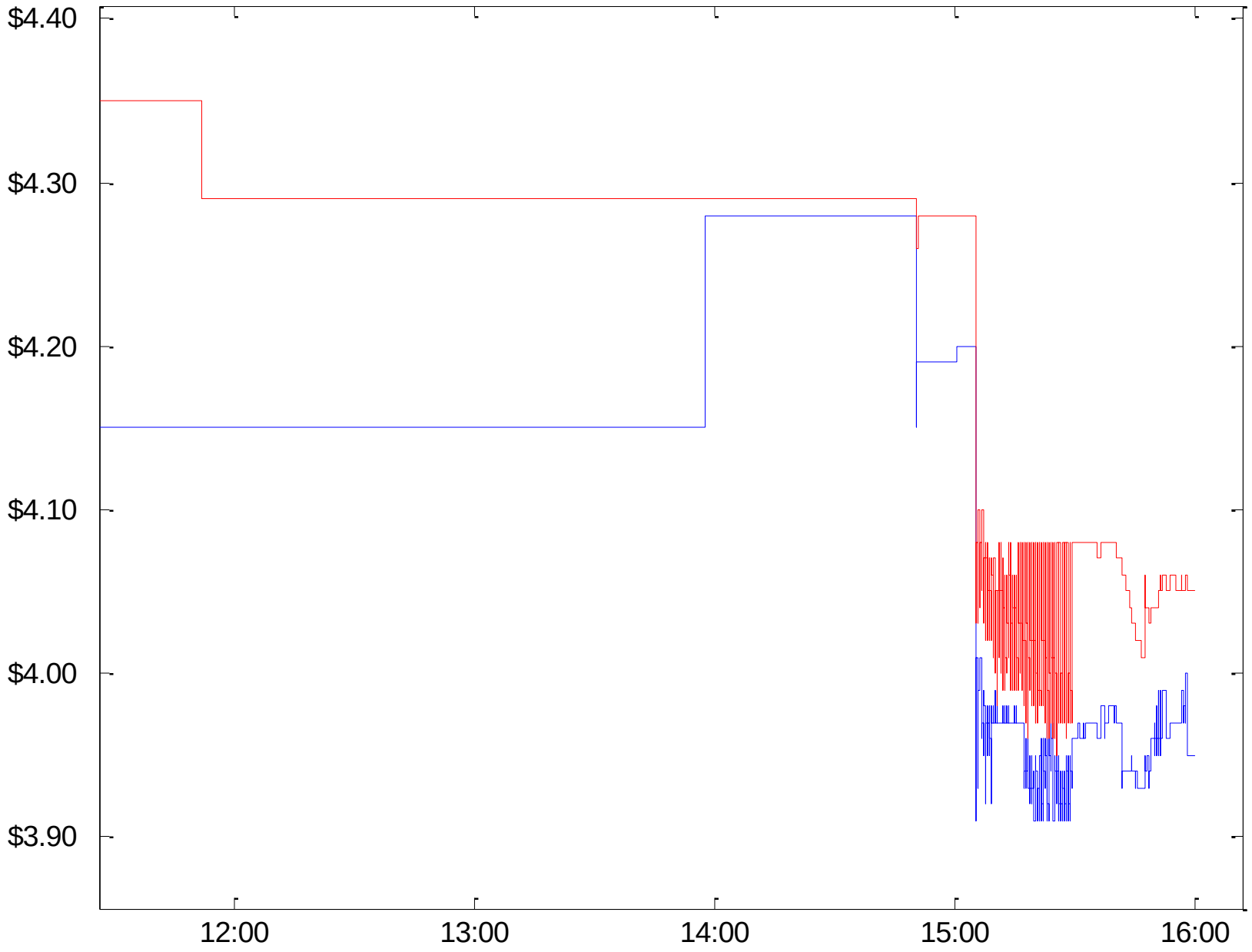
16:00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13:00
14:00
15:00
16:00

Quote volatility: the questions

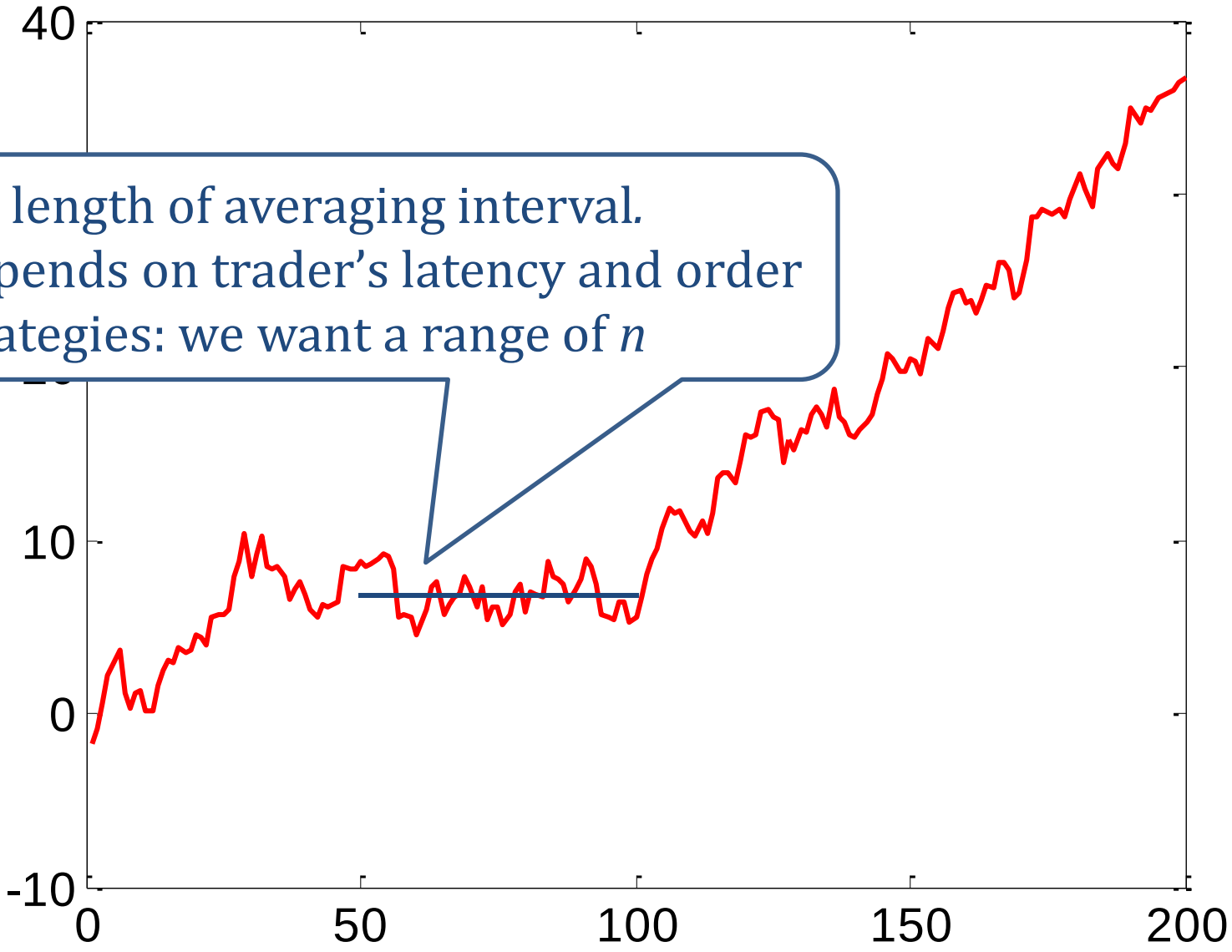
- What is its economic meaning and importance?
- How should we measure it?
- Is it elevated? Relative to what?
- Has it increased along with wider adoption of high-speed trading technology?

Economic consequences of quote volatility

- Noise due to flickering quotes
- Execution price risk
  - For marketable orders
  - For dark trades
- Intermediaries' look-back options
- Quote-stuffing
- Spoofing

Descriptive statistics: computation and interpretation

Local variances about local means



n = length of averaging interval.
Depends on trader's latency and order strategies: we want a range of *n*

Interpretation

- To assess economic importance, I present the (wavelet and rough) variance estimates in three ways.
  - In mils per share
  - In basis points
  - As a short-term/long-term ratio

Mils per share

- Variances are computed on bid and offer price levels.
- Reported volatilities are scaled to $mils/share$.
  - One mil = $0.001
- Most trading charges are assessed per share.
  - Someone sending a marketable order to a US exchange typically pays an "access fee" of about three mils/share.
  - An executed limit order receives a "liquidity rebate" of about two mils/share.

Basis points (One bp = 0.01%)

- Volatilities are first normalized by price (bid-ask average)
- The rough volatility in basis points:
  - $\frac{\sigma_j}{Price} \times 10{,}000$
- "One bp is a one cent bid-offer spread on a $100 stock."

The short/long variance ratio

- For a random walk with per period variance σ^2, the variance of the n-period difference is $n\sigma^2$.
- An conventional variance ratio might be
  - $V = \dfrac{60 \times one\ minute\ return\ variance}{one\ hour\ return\ variance}$
- For a random walk, $V = 1$.
  - Microstructure: we usually find $V > 1$.
- Extensively used in microstructure studies: Barnea (1974); Amihud and Mendelson (1987); etc.

The empirical analysis

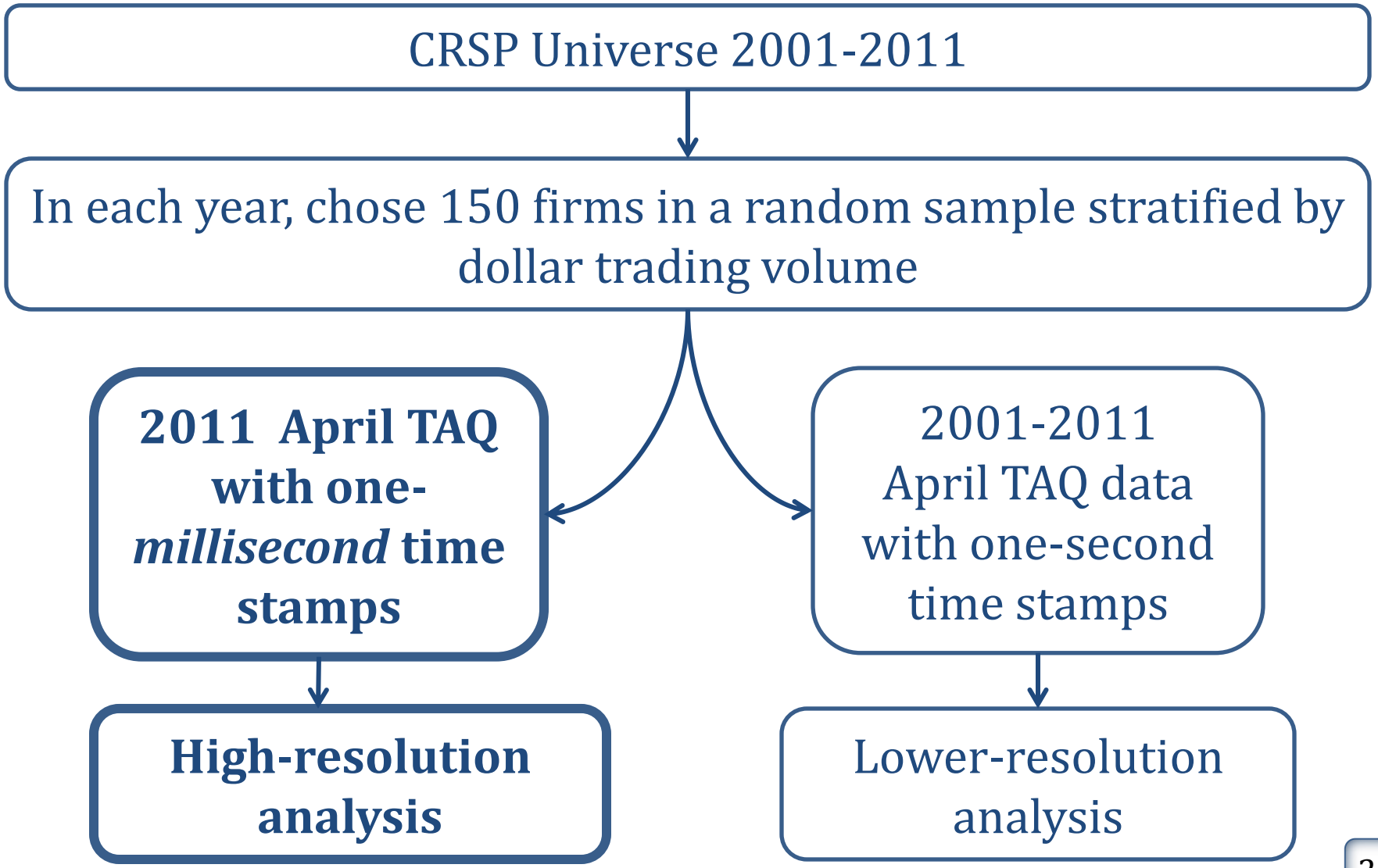


Table 1. Summary Statistics, 2011

		Dollar trading volume quintile				
	Full sample	1 (low)	2	3	4	5 (high)
No. of firms	150	30	30	30	30	30
NYSE	47	0	5	7	16	19
Amex	6	2	2	0	1	1
NASDAQ	97	28	23	23	13	10
Avg. daily trades	1,331	31	431	1,126	3,478	16,987
Avg. daily quotes	***23,928***	***967***	***7,706***	***24,026***	***53,080***	***181,457***
Avg. daily NBBO records	7,138	328	3,029	7,543	16,026	46,050
Avg. daily NBB changes	1,245	120	511	1,351	2,415	4,124
Avg. daily NBO changes	1,164	103	460	1,361	2,421	4,214
Avg. price	$15.62	$4.87	$5.46	$17.86	$27.76	$51.60
Market capitalization of equity, $ Million	$683	$41	$202	$747	$1,502	$8,739

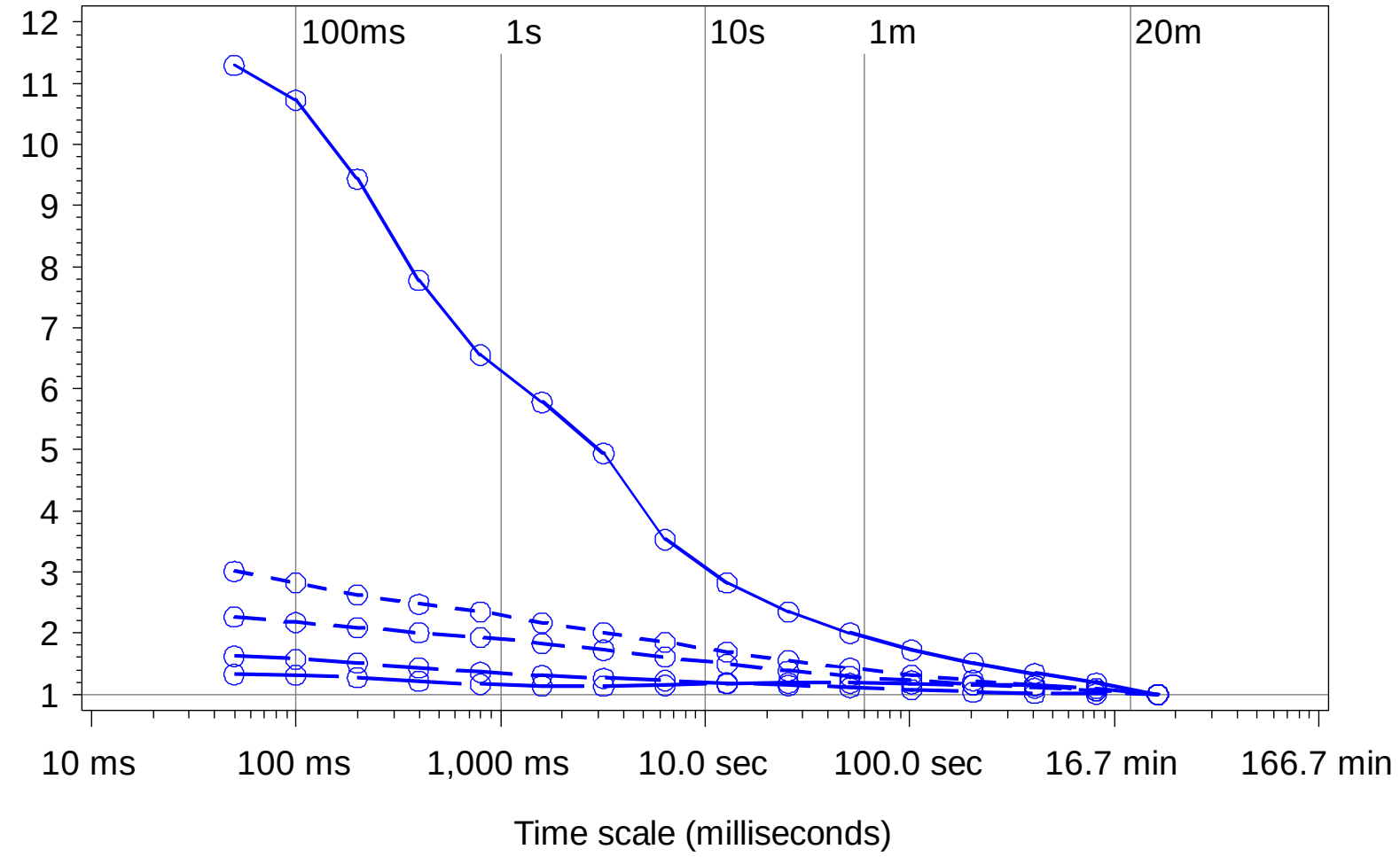
Table 2. Time scale variance estimates, 2011

	Rough volatilities, σ_j			Wavelet variances, ν_j^2			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Time scale	σ_j, mils	σ_j, bp	Variance ratio	$\sqrt{\nu_j^2}$, mils	$\sqrt{\nu_j^2}$, bp	Variance ratio	Bid-Offer Corr
< 50 ms	0.28	0.16	4.22				
50 ms	0.39	0.22	3.99	0.2			
100 ms	0.55	0.31	3.79	0.3			
200 ms	0.76	0.43	3.53				
400 ms	1.05	0.59	3.21				
800 ms	1.46	0.83	2.90				
1,600 ms	2.02	1.14	2.64	1.			
3.2 sec	2.80	1.58	2.40	1.9			
6.4 sec	3.90	2.18	2.12	2.7			
12.8 sec	5.43	2.99	1.88	3.7			
25.6 sec	7.54	4.10	1.70	5.2			
51.2 sec	10.48	5.61	1.54	7.2			
102.4 sec	14.53	7.68	1.42	10.0			
3.4 min	20.12	10.51	1.32	13.8			
6.8 min	27.88	14.40	1.23	19.22			
13.7 min	38.55	19.70	1.16	26.45	13.33	1.08	0.88
27.3 min	52.84	26.79	1.08	35.73	17.91	1.00	0.90

A trader who faces time uncertainty of 400 ms incurs price risk of 1.05 *mils/share* or 0.59 *basis points*.

At a time scale of 400 ms., the rough variance is 3.21 times the value implied by a random walk with variance calibrated to 27.3 minutes.

Figure 2. Wavelet variance ratios across time scale and dollar volume quintiles



The 2011 results: a summary

- Variance ratios: short term volatility is much higher than we'd expect relative to a random-walk.
- In mils per share or basis points, *average* short term volatility is economically meaningful, but small.

Historical analysis

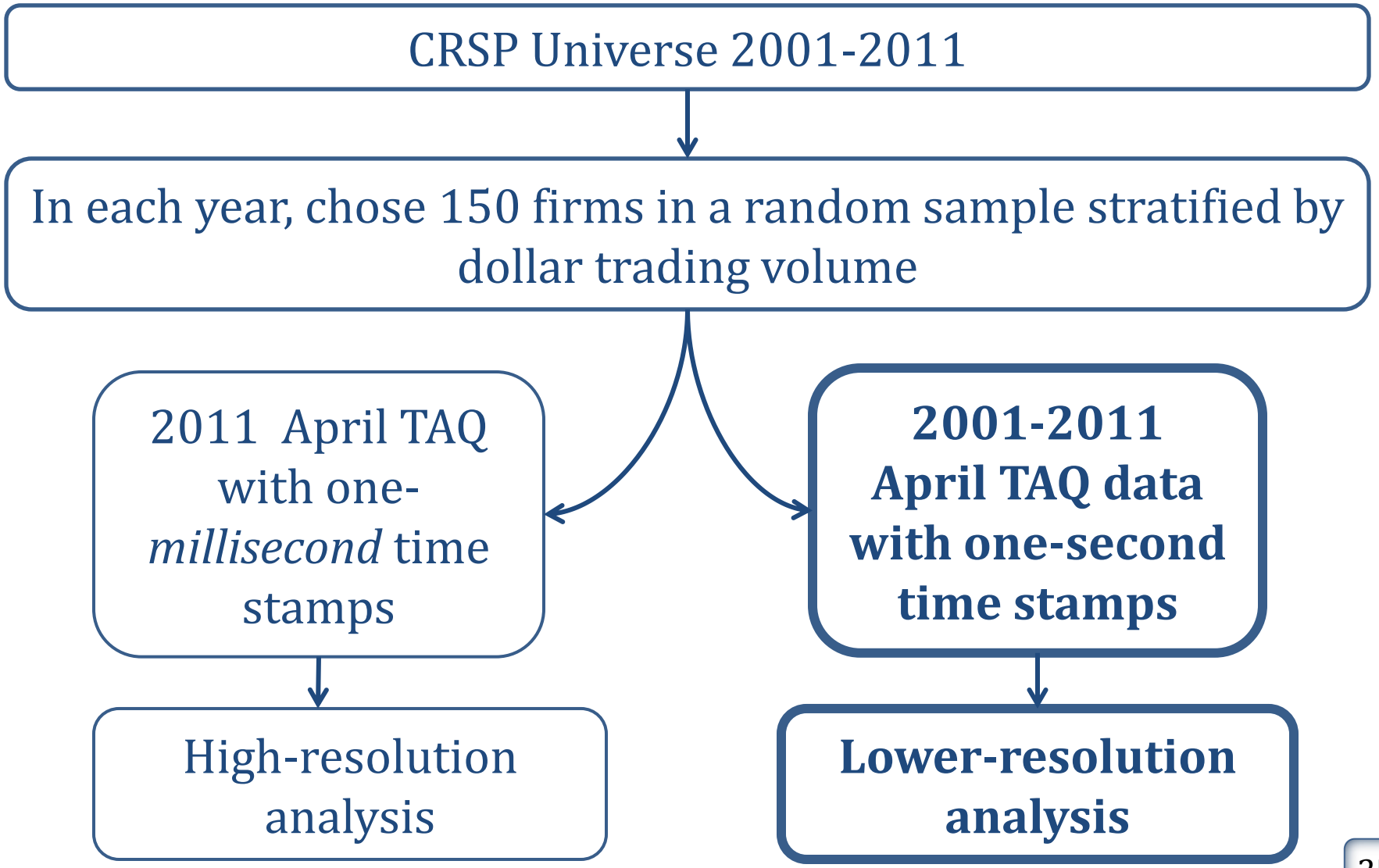


Table 5. Summary statistics, historical sample, 2001-2011 (*only odd numbered years are shown)*

	2001	2003	2005	2007	2009	2011
No. firms	146	150	150	150	150	150
NYSE	108	51	48	55	56	47
Amex	22	11	8	14	5	6
NASDAQ	16	88	94	81	89	97
Avg. daily trades	142	187	425	970	1,790	1,331
Avg. daily quotes	1,078	1,299	5,828	12,521	39,378	23,928
Avg. daily NBB changes	103	203	596	772	1,618	1,210
Avg. daily NBO changes	103	213	729	789	1,731	1,126
Avg. price	$18.85	$14.83	$16.10	$15.81	$10.72	$15.62
Market equity cap $ Million	$745	$189	$325	$480	$316	$683

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Amex	22	11	8	14	5	6
NASDAQ	16	88	94	81	89	97
Avg. daily trades	142	187	25% CAGR		1,790	1,331
Avg. daily quotes	1,078	1,299	36% CAGR		29,279	23,928
Avg. daily NBB changes	103	203	596	772	1,618	1,210
Avg. daily NBO changes	103	213	729	789	1,731	1,126
Avg. price	$18.85	$14.83	$16.10	$15.81	$10.72	$15.62
Market equity cap $ Million	$745	$189	$325	$480	$316	$683

What statistics to consider?

- Long-term volatilities changed dramatically over the sample period.
- Variance ratios (normalized to long-term volatility) are the most reliable indicators of trends.

Table 6. Wavelet variance ratios for bids and offers, 2001-2011

Panel A: Computed from *unadjusted* bids and offers

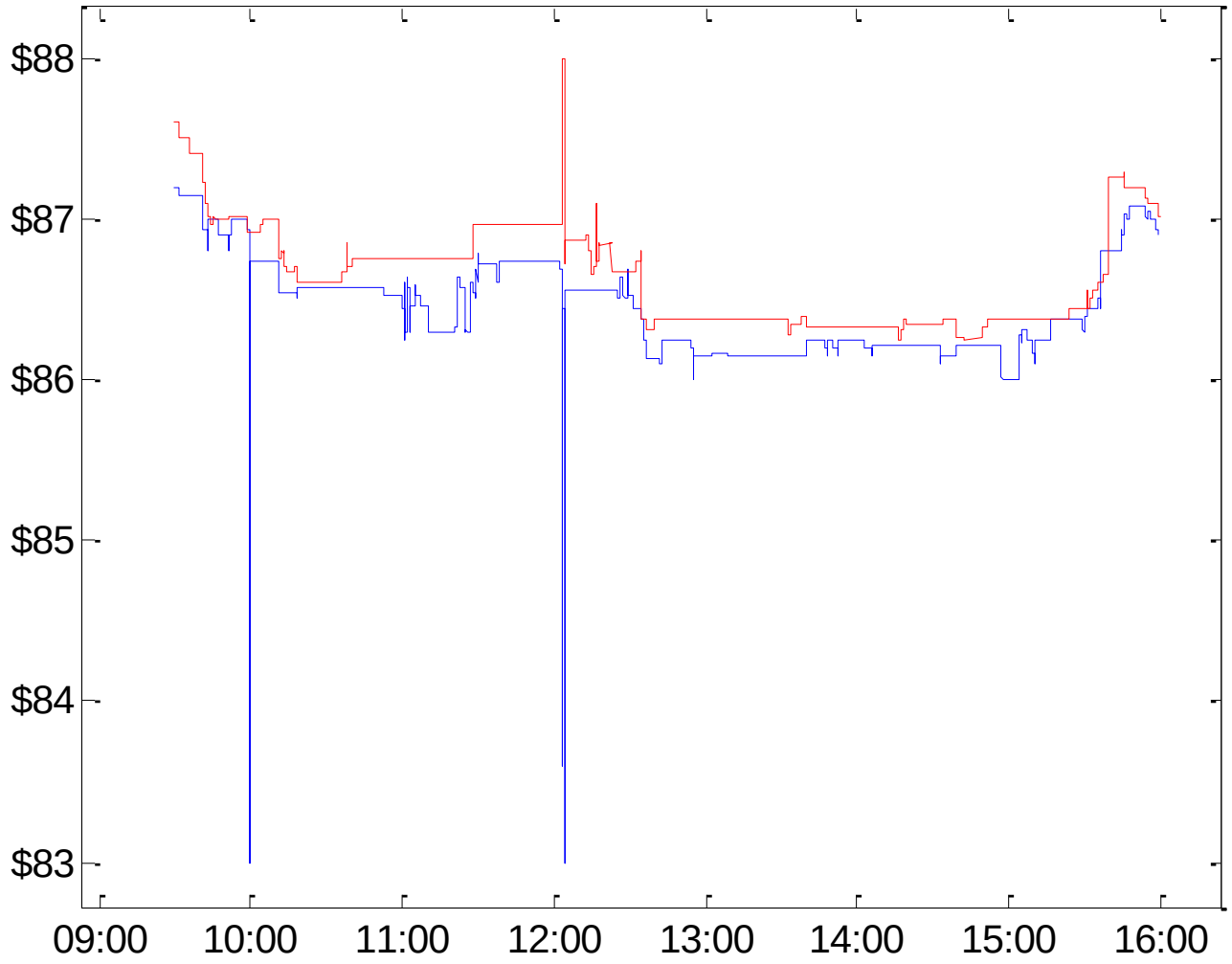
Time scale	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
50 ms	5.22	7.16	6.03	10.28	6.69	8.57	6.96	6.06	4.52	7.08	4.70
100 ms	5.44	6.58	5.28	9.69	6.51	8.07	6.27	5.38	4.12	6.26	4.32
200 ms	5.28	6.28	5.13	9.03	6.22	7.34	5.33	4.64	3.68	5.40	3.74
400 ms	4.59	5.23	5.00	8.16	5.75	6.30	4.25	3.84	3.21	4.53	3.07
800 ms	3.12	4.04	3.93	5.57	5.03	5.10	3.41	3.11	2.76	3.71	2.56
1,600 ms	2.11	2.55	3.25	4.11	4.14	4.05	2.89	2.59	2.43	3.04	2.23
3.2 sec	1.98	2.24	2.93	3.38	3.48	3.37	2.56	2.29	2.17	2.53	2.01
6.4 sec	1.94	2.11	2.62	2.91	2.93	2.92	2.35	2.08	1.95	2.16	1.82

No trend in quote volatilities?

- Maybe …
  - "Flickering quotes" aren't new.
  - Recent concerns about high frequency trading are all media hype.
  - The good old days weren't really so great after all.

- What *did* quote volatility look like circa 2001?

Figure 4 Panel A. Bid and offer for PRK, April 6, 2001.



Compare

- PRK in 2001 vs. AEPI in 2011
  - AEPI: low amplitude, intense oscillation.
  - PRK: large amplitude, no oscillation.
- PRK-type noise is called “pop” noise
- It can be filtered out by clipping
  - I clip the short-run noise to

$$Max(1.5 \times spread, \$0.25)$$

Figure 4 Panel B. PRK, April 6, 2001, Rough component of the bid

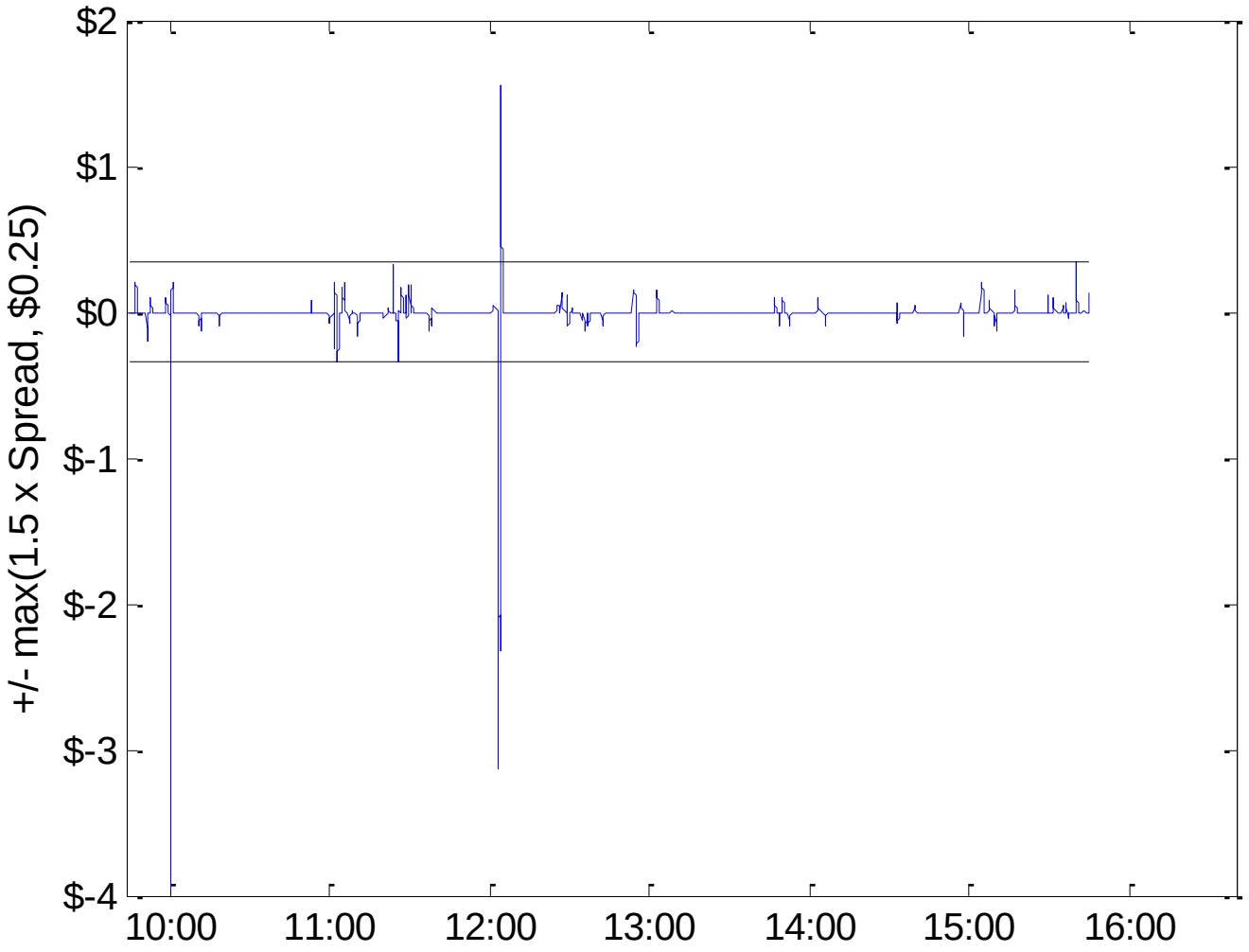


Table 6. Wavelet variance ratios for bids and offers, 2001-2011

Panel B. Computed from *denoised* bids and offers

Time scale	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
50 ms	1.60	2.37	3.15	7.02	6.09	8.24	6.56	5.83	4.20	6.79	4.46
100 ms	1.57	2.32	3.09	6.82	5.89	7.76	5.89	5.17	3.83	6.00	4.07
200 ms	1.56	2.27	3.03	6.48	5.61	7.04	4.99	4.45	3.41	5.18	3.57
400 ms	1.55	2.23	2.94	5.90	5.16	6.02	3.96	3.68	2.97	4.36	3.00
800 ms	1.57	2.19	2.83	5.00	4.47	4.82	3.13	2.98	2.56	3.58	2.52
1,600 ms	1.64	2.20	2.71	3.99	3.60	3.79	2.63	2.51	2.27	2.94	2.20
3.2 sec	1.81	2.30	2.62	3.44	3.02	3.16	2.33	2.23	2.04	2.46	2.00
6.4 sec	2.11	2.51	2.59	3.20	2.65	2.75	2.15	2.04	1.86	2.11	1.82

So has quote volatility increased?

- Apples vs. oranges
  - The nature of quotes has changed.
- Quote volatility has changed
  - From infrequent large changes to frequent (and oscillatory) small changes.
- Possibly a overall small increase,
  - But nothing as strong as the trend implied by the growth in quote messaging rates.