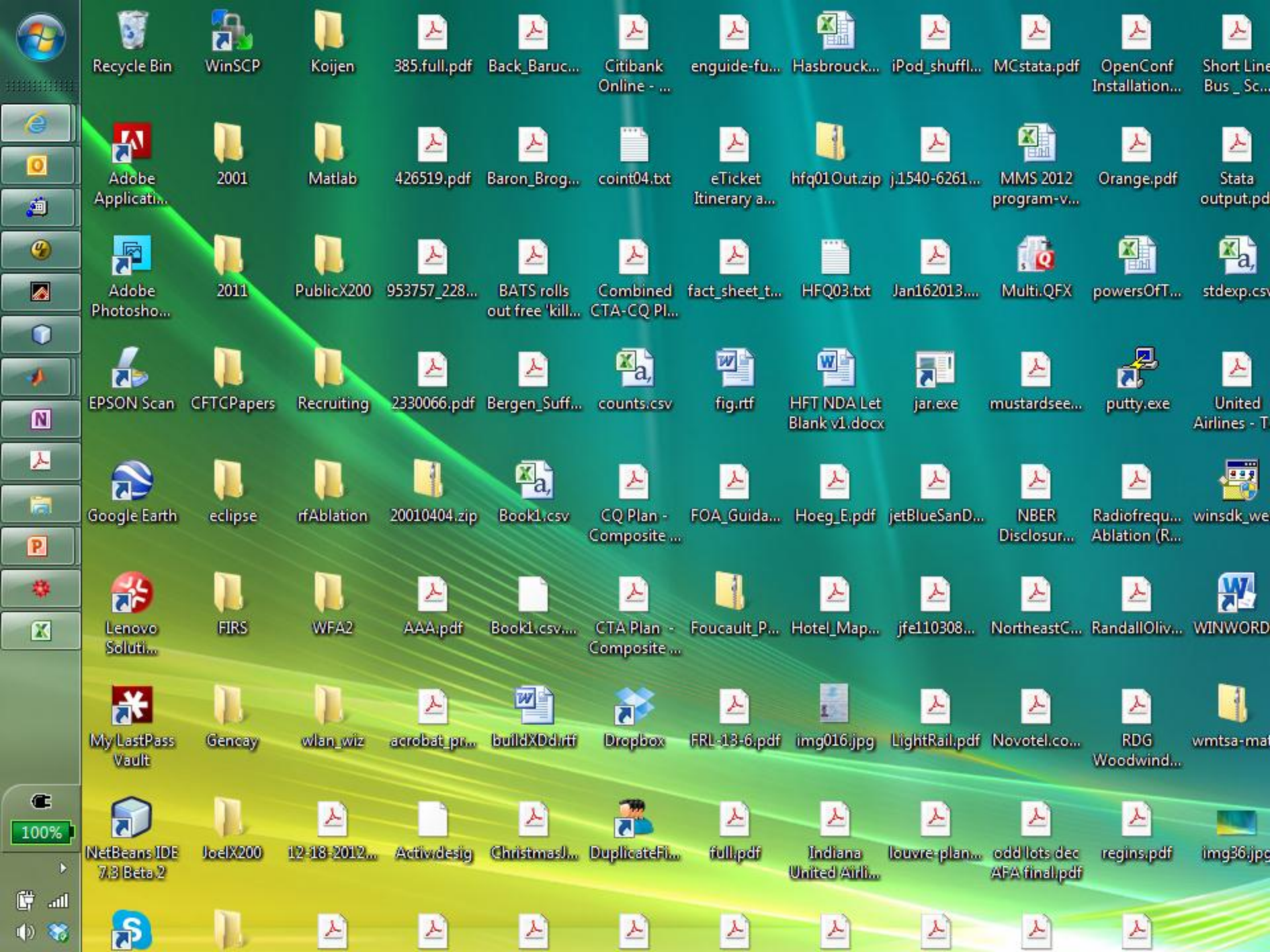
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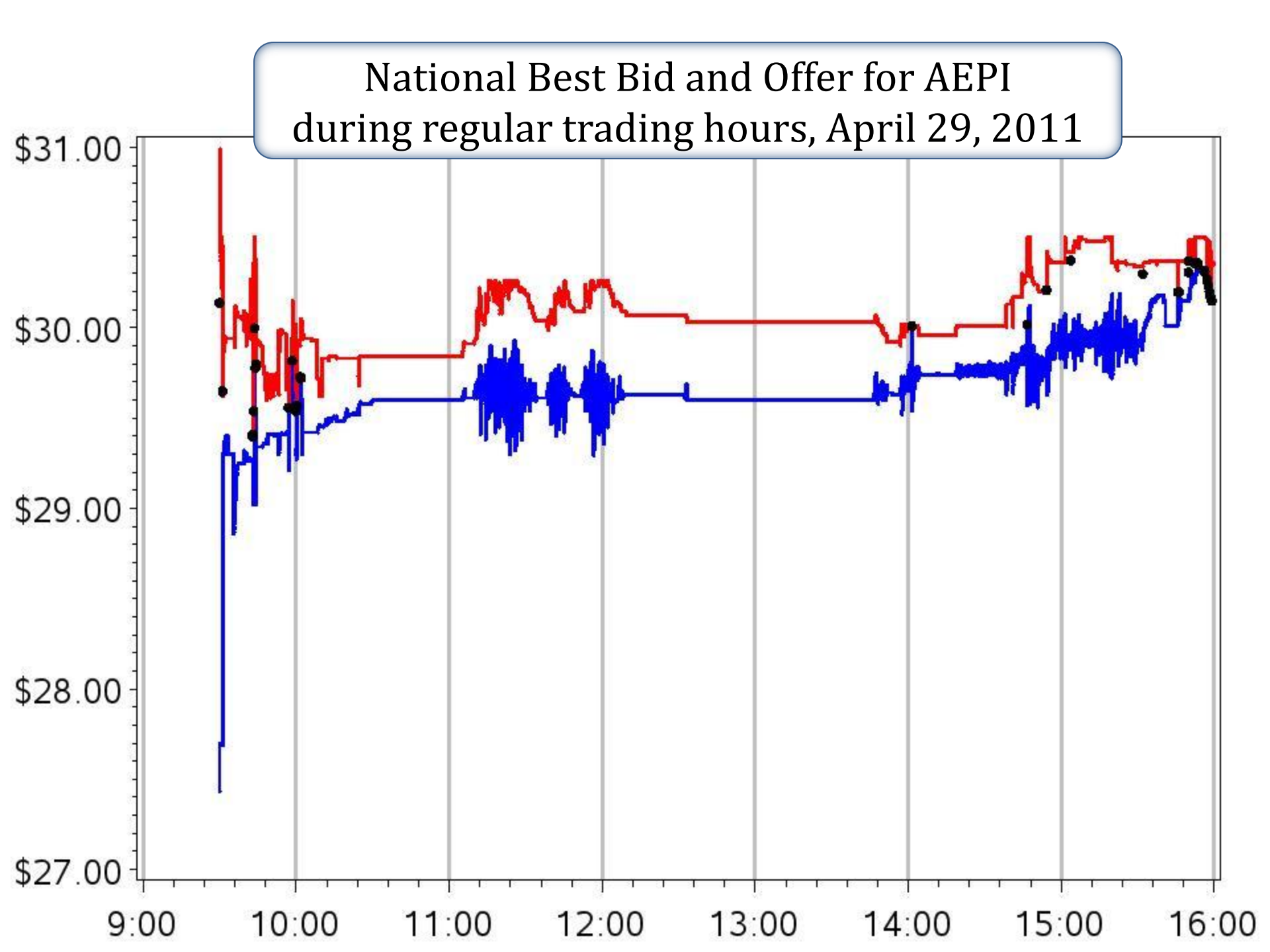
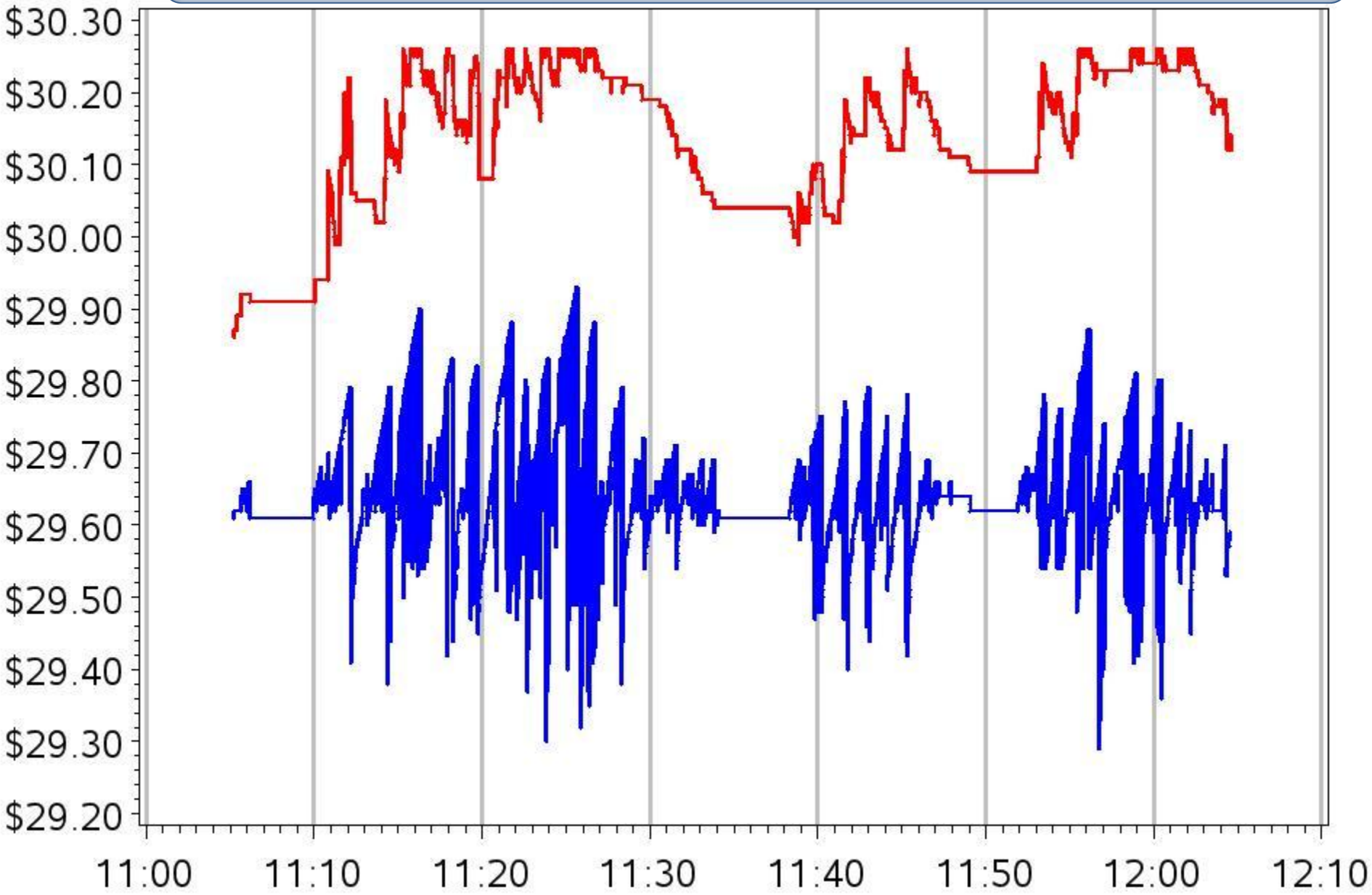
Disclaimers

- 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.

National Best Bid and Offer for AEPI during regular trading hours, April 29, 2011



National Best Bid and Offer for AEPI from 11:00 to 12:10



Questions

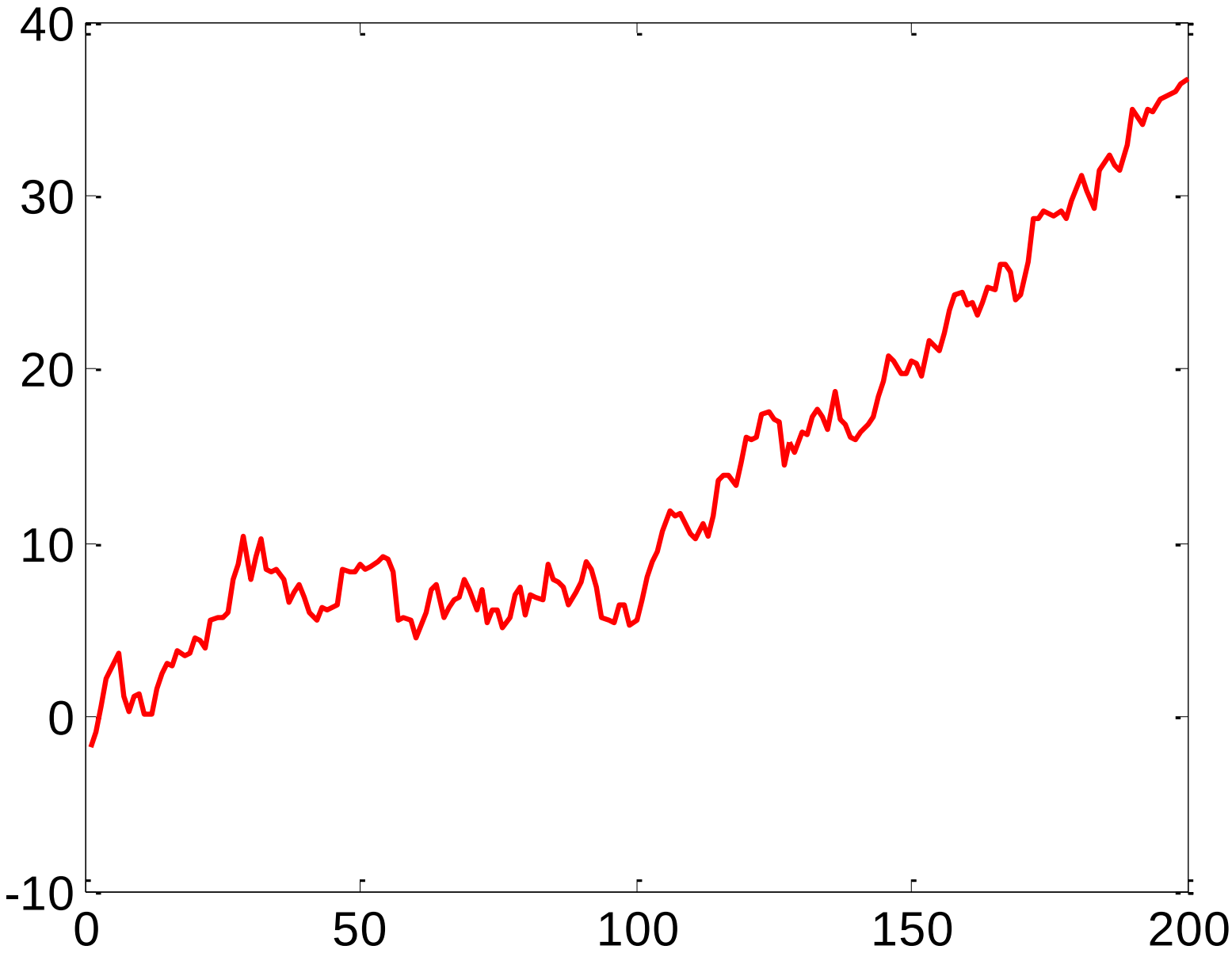
- Is this volatility typical?
- Is the volatility informational?
  - No net price change over the period of volatility.
  - Volatility is mostly on one side of the market.

Who cares?

- Noise degrades the informational value of any price.
- Quote volatility → trade price uncertainty.
  - … when a market sell order hits a volatile bid.
  - … when the bid is being used as a reference to price some other trade ("dark trades")
- Quote volatility can be systematically exploited by intermediaries' look-back options.

Analyzing price volatility

- Usual approach
  - First-difference the price series.
  - Specify a parametric model for variance dynamics.
- This study
  - *Non-parametric* analysis of variances of price *levels*
- Illustration for simulated random walks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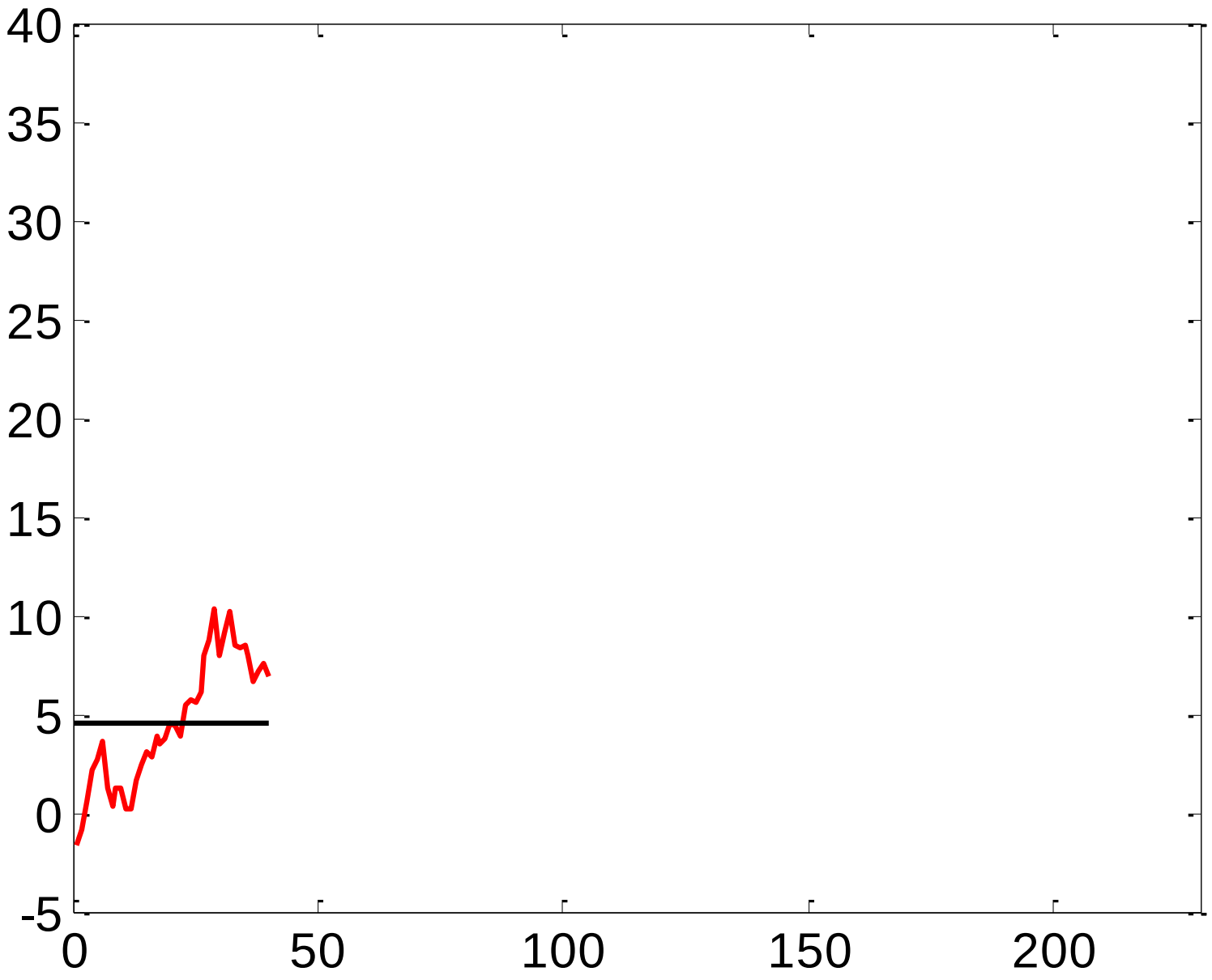
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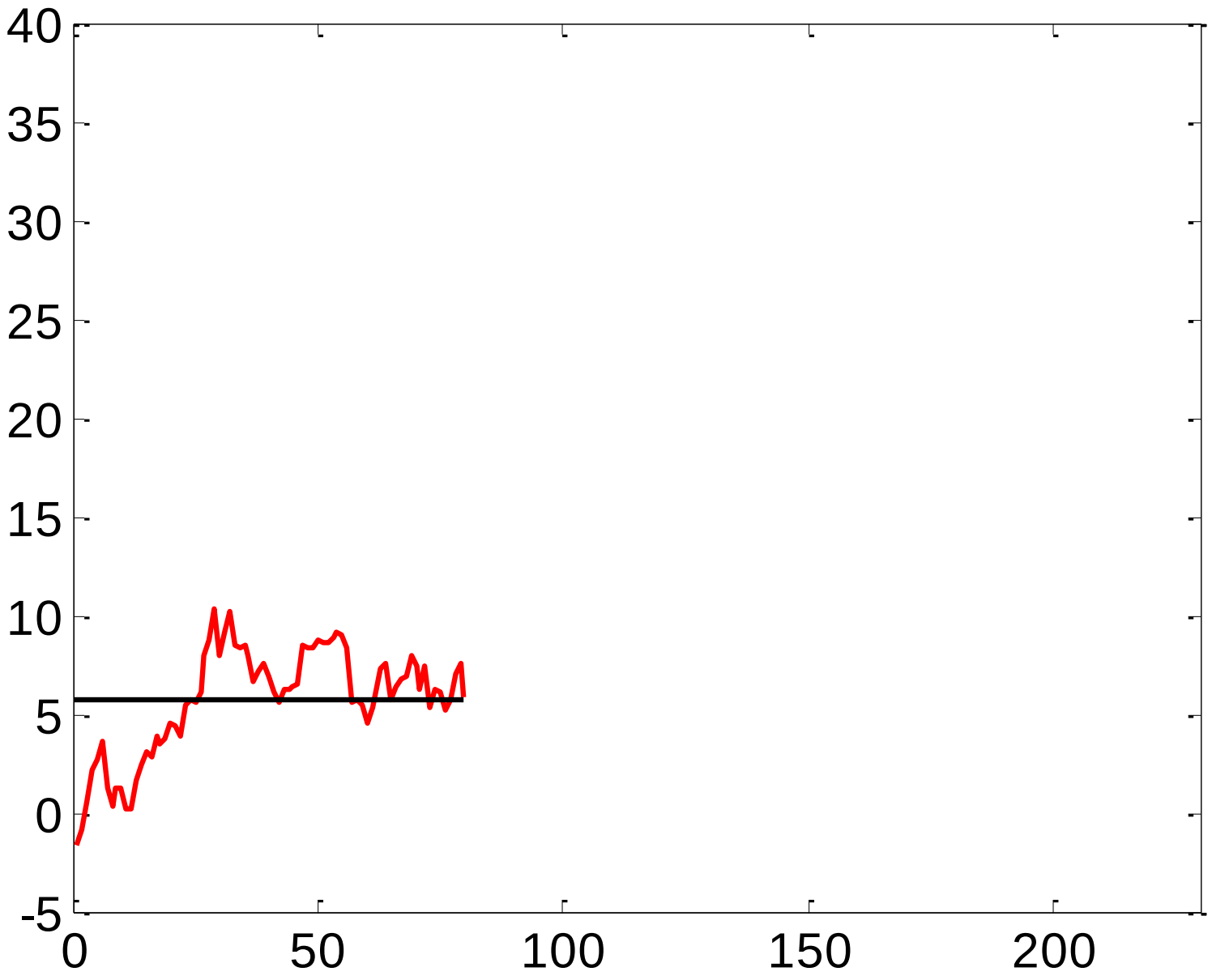
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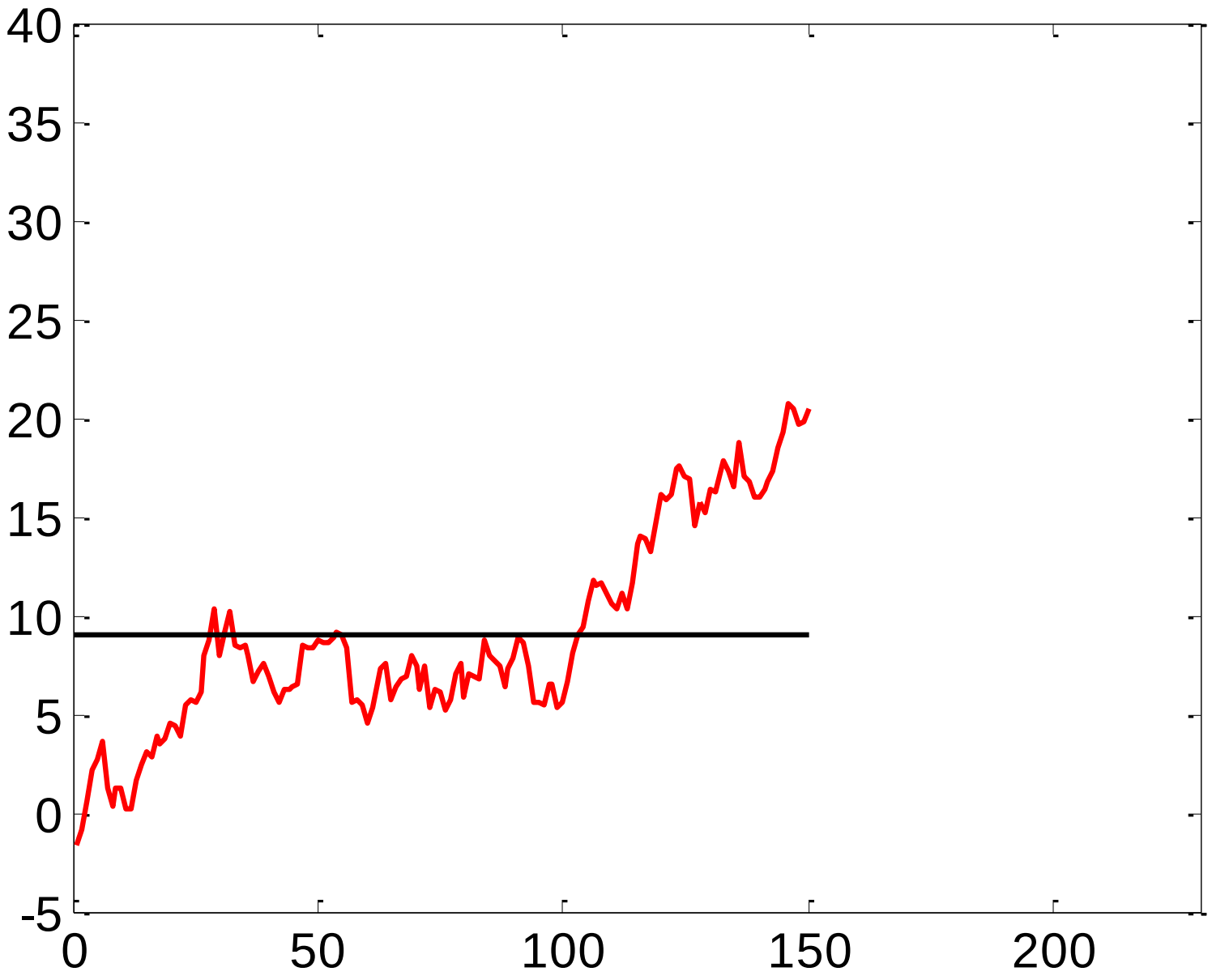
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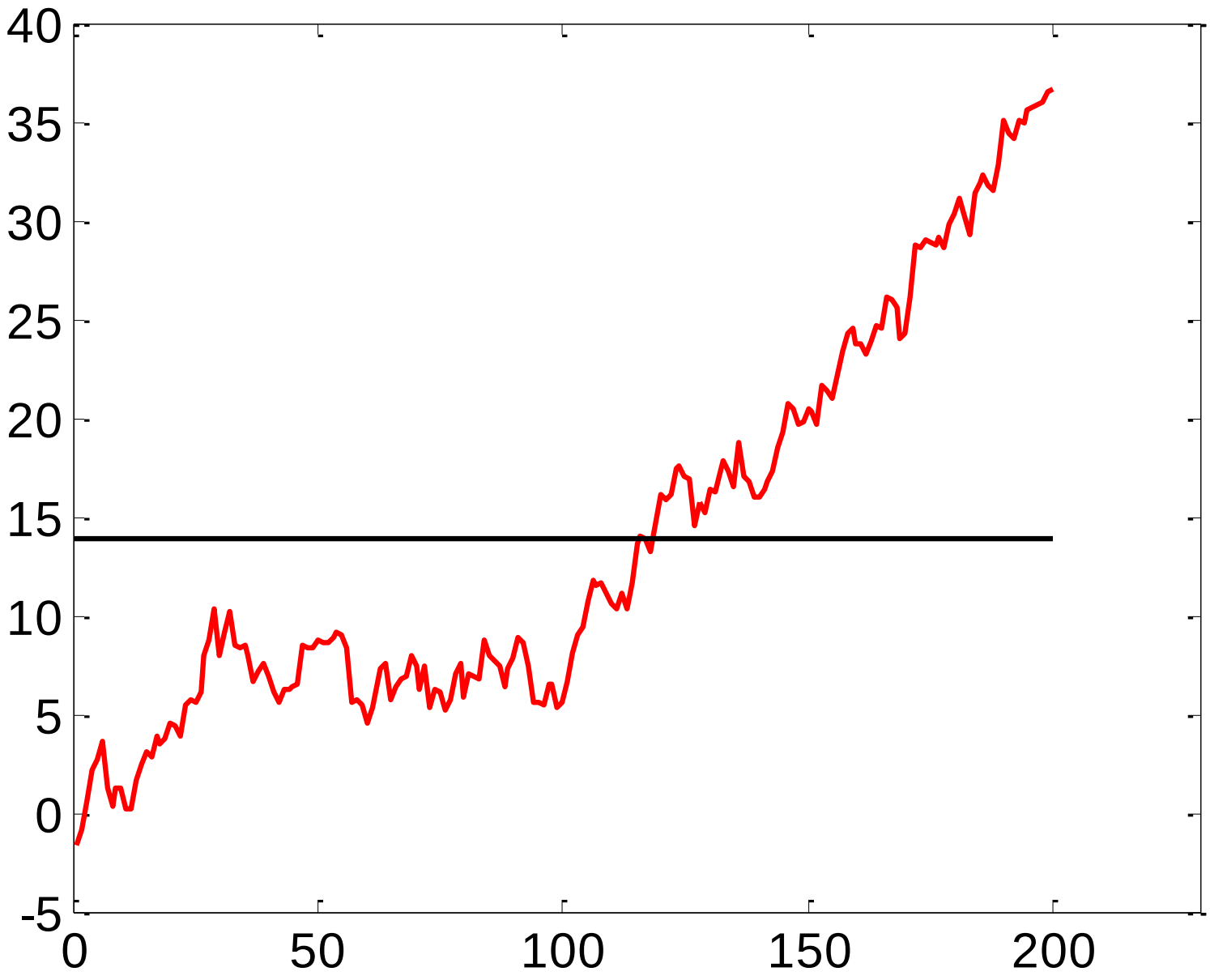
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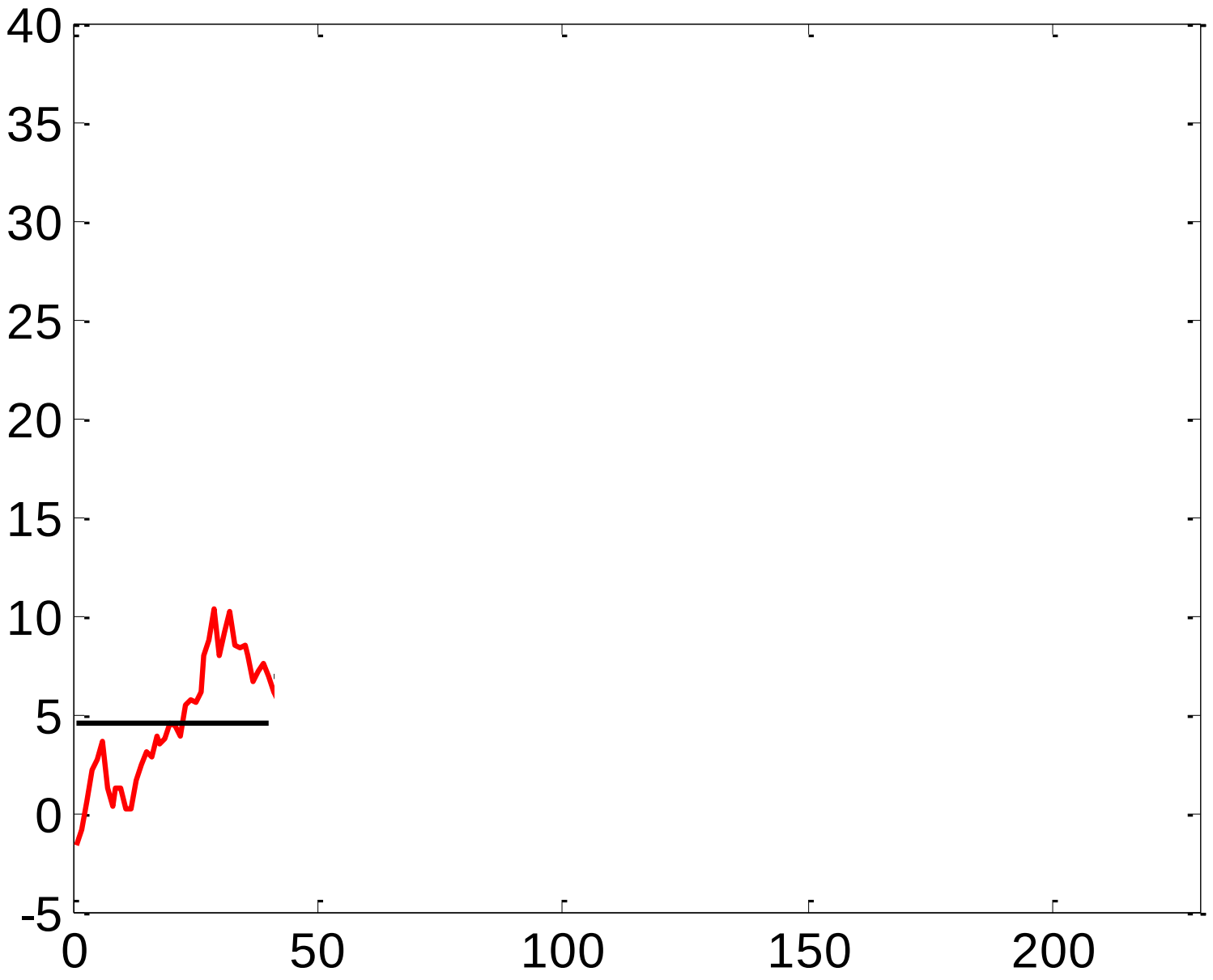
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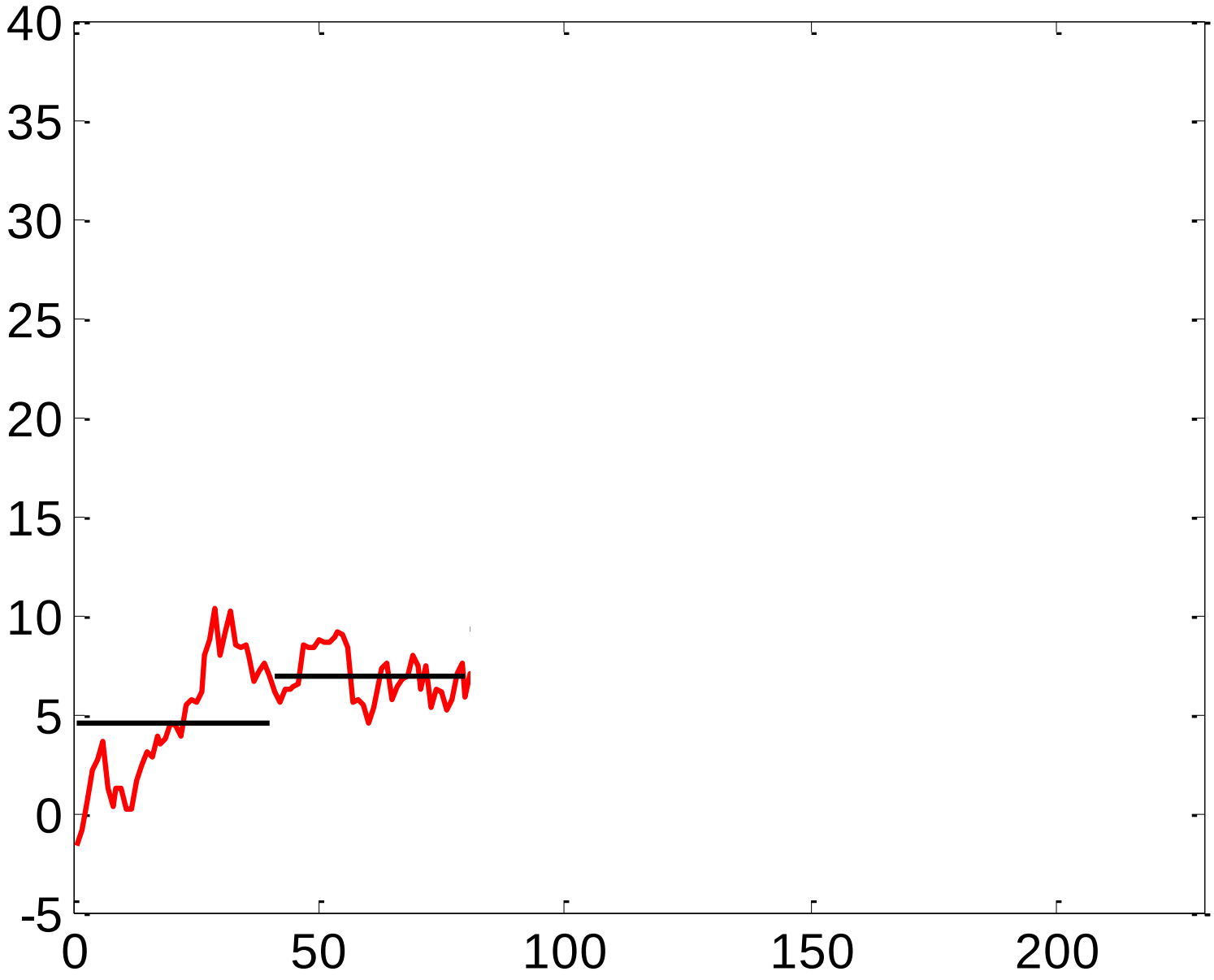
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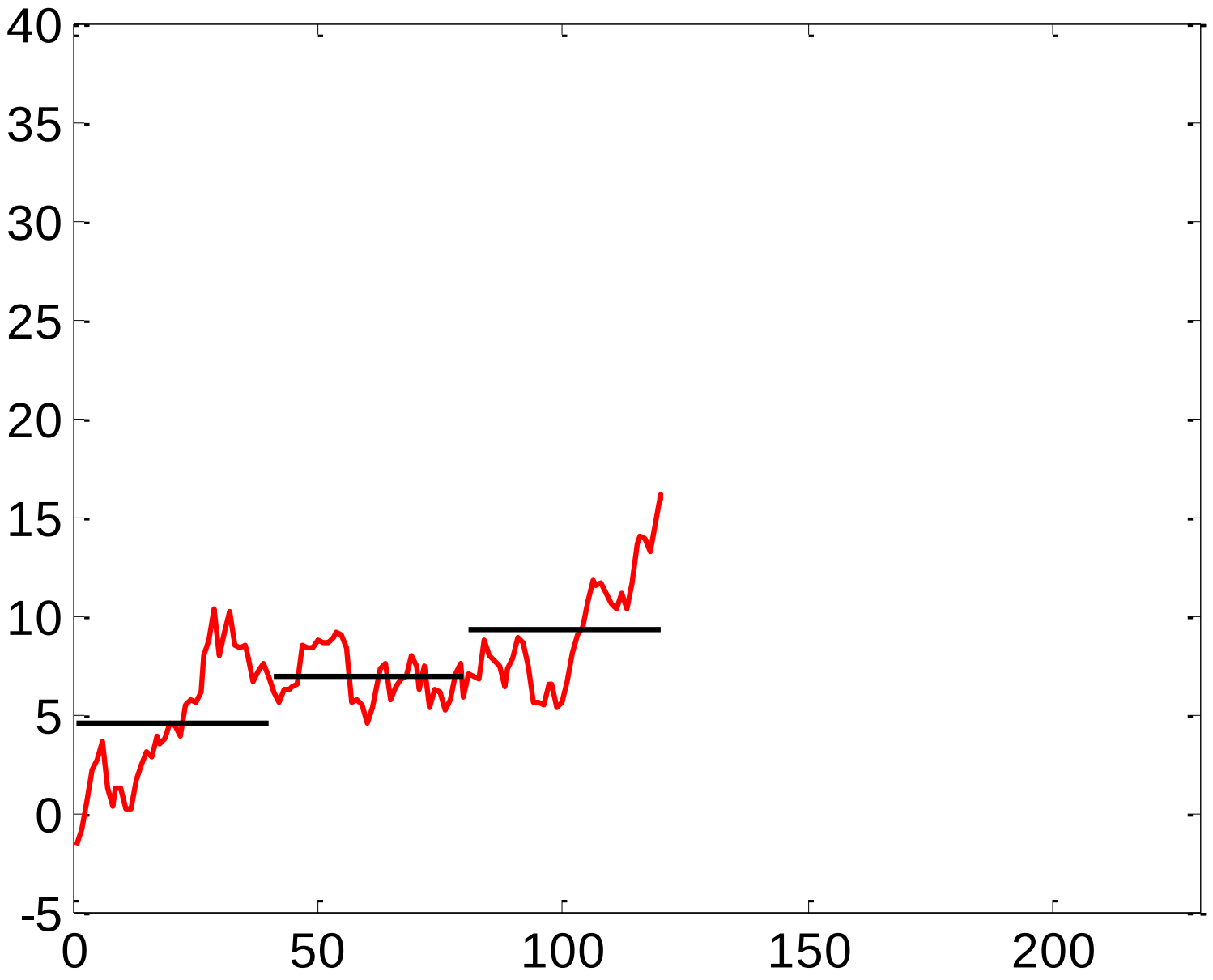
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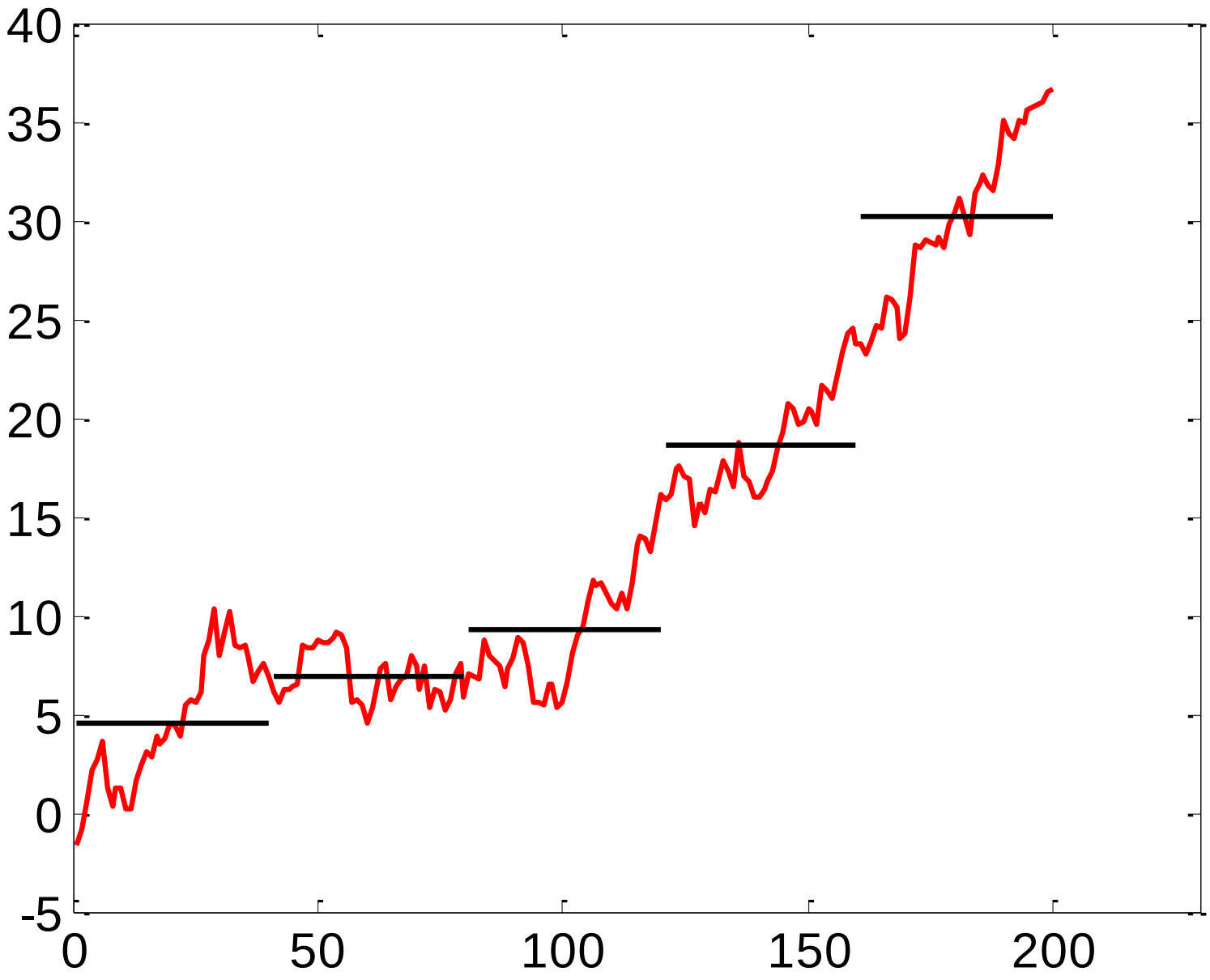
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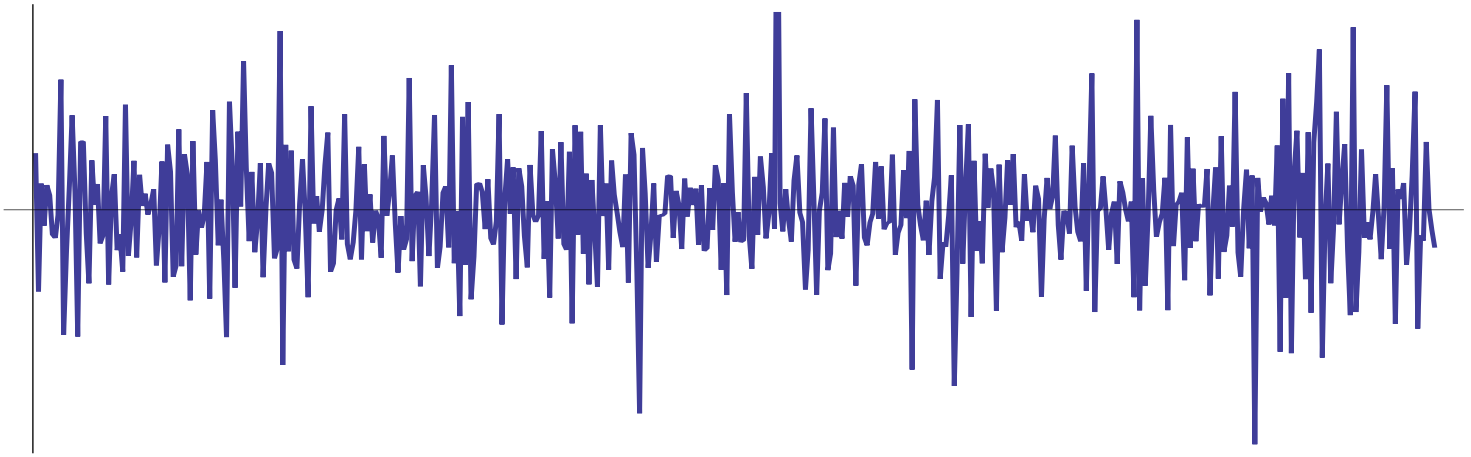
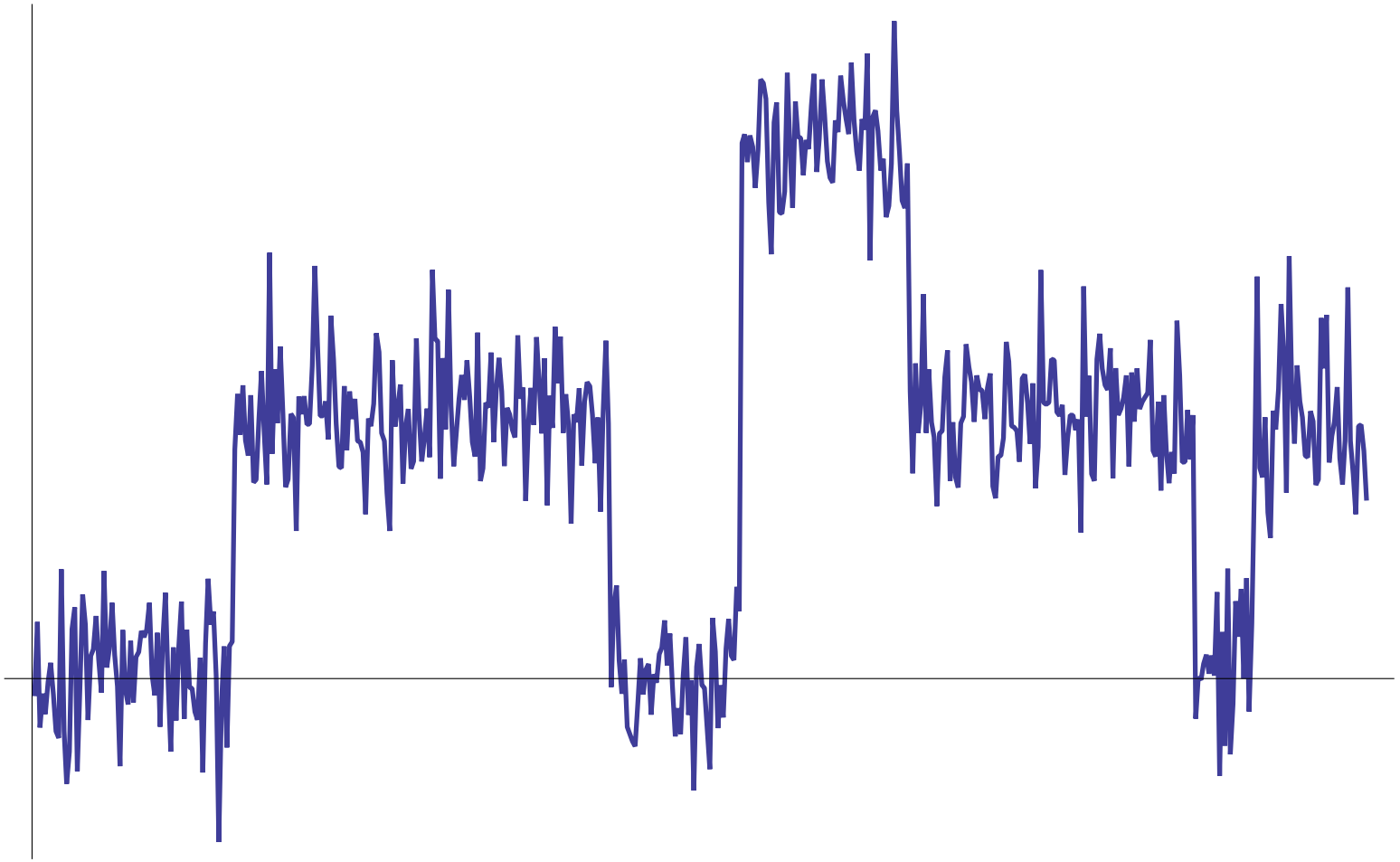
What's lost by first-differencing?

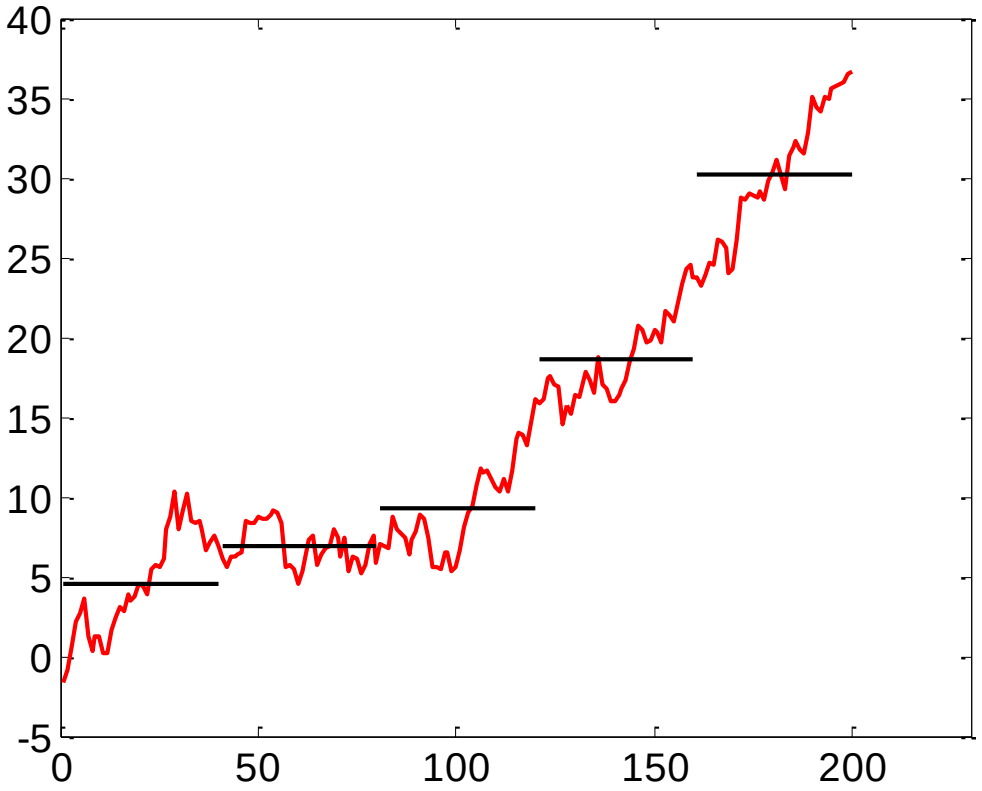


- First difference plot of a simulated series.

… and the integrated series



How should we implement these calculations?



- The intervals …
  - How wide?
  - How aligned?

Time-scale decompositions

- A time series = sum of components
  - Each component is associated with a particular time scale ("horizon")
    - 1 ms, 2 ms, 4 ms, 8 ms, …
      4,194,302 ms (≈ 70 minutes)
  - Each component is associated with a variance.
- Horizons and components are constructed systematically using wavelet transforms
  - These transforms average over all alignments.

Sources

- Percival, Donald B., and Andrew T. Walden, 2000. *Wavelet methods for time series analysis (Cambridge University Press, Cambridge).*
- Gençay, Ramazan, Frank Selçuk, and Brandon Whitcher, 2002. *An introduction to wavelets and other filtering methods in finance and economics (Academic Press (Elsevier), San Diego).*

Wavelet methods

- Strengths
  - Isolate features associated with particular time-horizons.
  - Localized
  - Computationally efficient
- Weaknesses
  - Not part of the usual academic financial econometricians' toolkit.
  - No easy connection to forecasting or innovations representations.

The questions

- What is the current level of high-frequency quote volatility?
- Since 2000, trading technology has changed markedly.
  - Has HF quote volatility increased?

The plan of the analysis

CRSP Universe 2001-2011. (Shrcd 10 or 11; average price in March between $2 and $1,000)

In each year, firms randomly chosen in sample stratified by dollar trading volume

2001-2011 April TAQ data with one-second time stamps

2011 April TAQ with one-*millisecond* time stamps

Lower-resolution wavelet analysis

High-resolution wavelet analysis

Gauging the magnitude of the volatility

- Normalized by share price (basis points)
- $ per share
  - Access fees are about $0.003 (“3 mils”) per share
- Relative to long-term (“fundamental”) volatility.
  - Volatility in excess of what we’d expect from a random-walk.

NBBO volatility, mils per share (Table 2 Panel A *excerpt)*

Time scale	Volatility ($0.001/share)
64 ms	0.4
128 ms	0.6
256 ms	0.8
512 ms	1.1
1,024 ms	1.6
4.1 sec	3.0
32.8 sec	8.0

NBBO volatility, basis points (0.01%)
Table 2 Panel B *excerpt*

Time scale	Volatility, bp (0.01%)
64 ms	0.3
128 ms	0.4
256 ms	0.6
512 ms	0.8
1,024 ms	1.2
4.1 sec	2.2
32.8 sec	5.6

NBBO variance ratios, "short/long" (Table 3, excerpt)

Time scale τ_j	Variance ratio
1 ms	5.36
8 ms	4.18
64 ms	3.25
128 ms	3.03
1,000 ms	2.56
2,048 ms	2.36
8.0 sec	1.97
32.0 sec	1.60
4.3 min	1.24
34.1 min	1.00

The 2011 results: a summary

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

High-resolution analysis … … with low resolution data

- TAQ with millisecond time stamps only available from 2006 onwards
- TAQ with second time stamps available back to 1993.
- Can we draw inferences about *subsecond* variation from second-stamped data?

Simulating the time stamps

Quote A	10:01:35
Quote B	10:01:35
Quote C	10:01:35

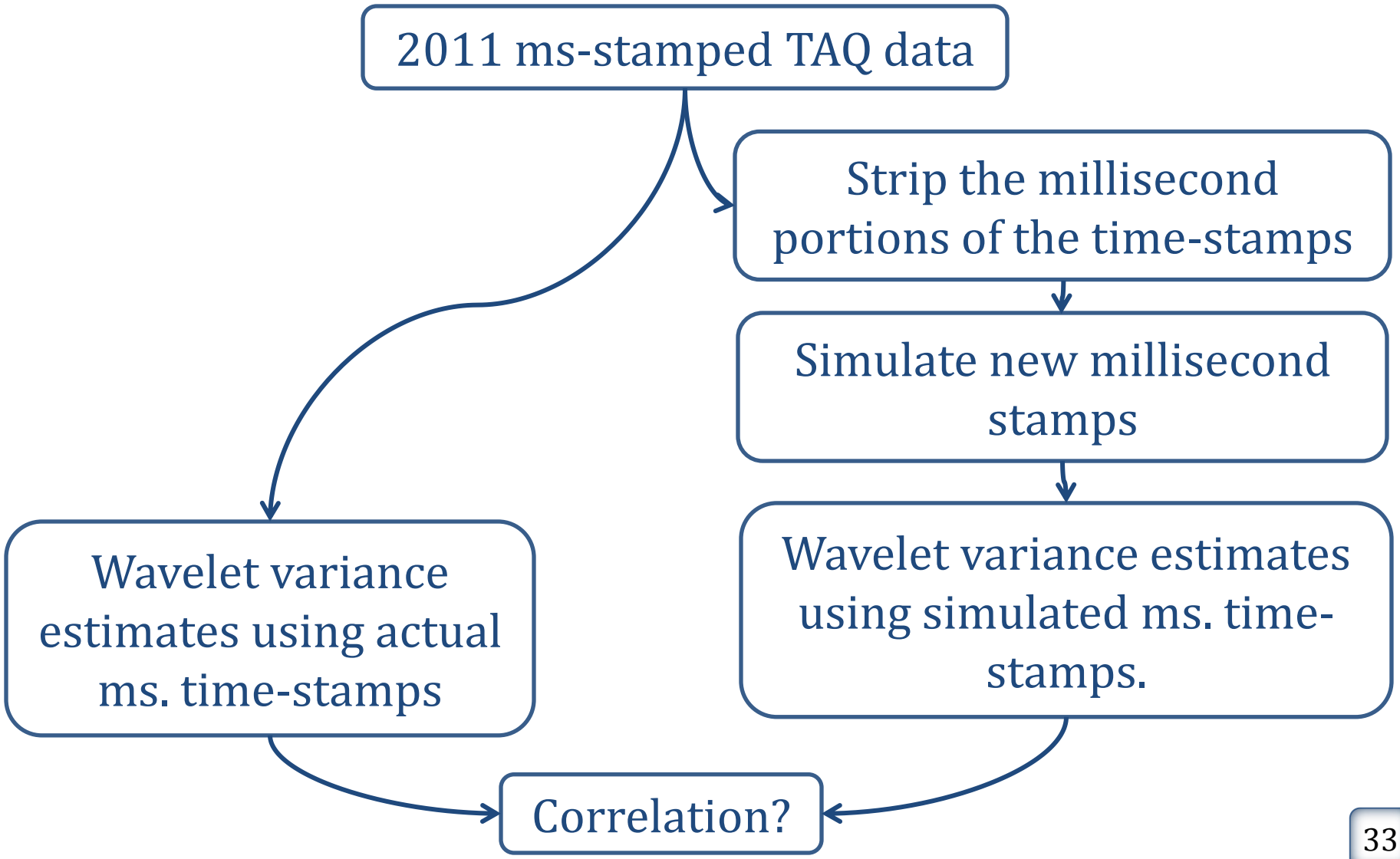
- Where, within the second did these quotes actually occur?
- Assume
  - Quotes are correctly sequenced.
  - Arrival intensities are time-homogeneous Poisson
- Then the joint distribution of the fractional (sub-second) arrival times =
  the joint distribution of the order statistics from a draw of three uniform random variables.

Simulating the time stamps

Quote A	10:01:35.*243*
Quote B	10:01:35.*347*
Quote C	10:01:35.*912*

- Where, within the second did these quotes actually occur?
- Assume
  - Quotes are correctly sequenced.
  - Arrival intensities are time-homogeneous Poisson
- Then the joint distribution of the fractional (sub-second) arrival times =
  the joint distribution of the order statistics from a draw of three uniform random variables.

Does this really work?



Correlations between wavelet variances based on actual and simulated time-stamps

Time Scale	All
1 ms	0.991
…	
16 ms	0.967
…	
256 ms	0.975
…	
4.1 sec	1.000
…	
32.8 sec	1.000

Summary statistics, historical sample (Table 6, excerpt)

	Year					
	2001	2003	2005	2007	2009	2011
No. of firms	30	30	30	30	30	30
Avg. daily trades	97	65	276	889	869	1,341
Avg. daily quotes	807	814	4,846	12,383	18,305	17,989

NBBO Volatility
mils ($0.001) / share; (Table 7, excerpt)

	Year					
Time scale	2001	2003	2005	2007	2009	2011
64 ms	0.5	0.4	0.7	0.4	0.5	0.3
128 ms	0.7	0.5	1.0	0.5	0.7	0.5
256 ms	0.9	0.7	1.3	0.7	0.9	0.6
512 ms	1.3	1.0	1.9	0.9	1.2	0.9
1,024 ms	1.9	1.4	2.5	1.3	1.6	1.2
4.1 sec	3.6	2.8	4.6	2.3	3.0	2.2
32.8 sec	10.1	7.2	11.3	6.3	7.7	5.8

Given the increased quote traffic, why didn't short-term quote volatility explode?

- The good old days weren't really that good.
  - With no automatic execution, no penalty for erroneous quotes.
- Maybe the present state of affairs isn't so awful.

The elements of the story

- There is a presumption that HF activity has increased over the 2000's
  - Strong trend in quote traffic
- Short-term volatility (mils per share) does *not* show a clear increase.
- Variance ratios show increase relative to 2001 (but not uniformly)

Connection to high frequency trading

- Brogaard (2012), Hendershott and Riordan (2012) use Nasdaq HFT dataset: trades used to define a set of high frequency traders.
- Hendershott, Jones and Menkveld (2011): NYSE message traffic
- Hasbrouck and Saar (2012): strategic runs / order chains
- General consensus: HF activity enhances market quality and lowers volatility.
- Quote volatility results are less uniform.

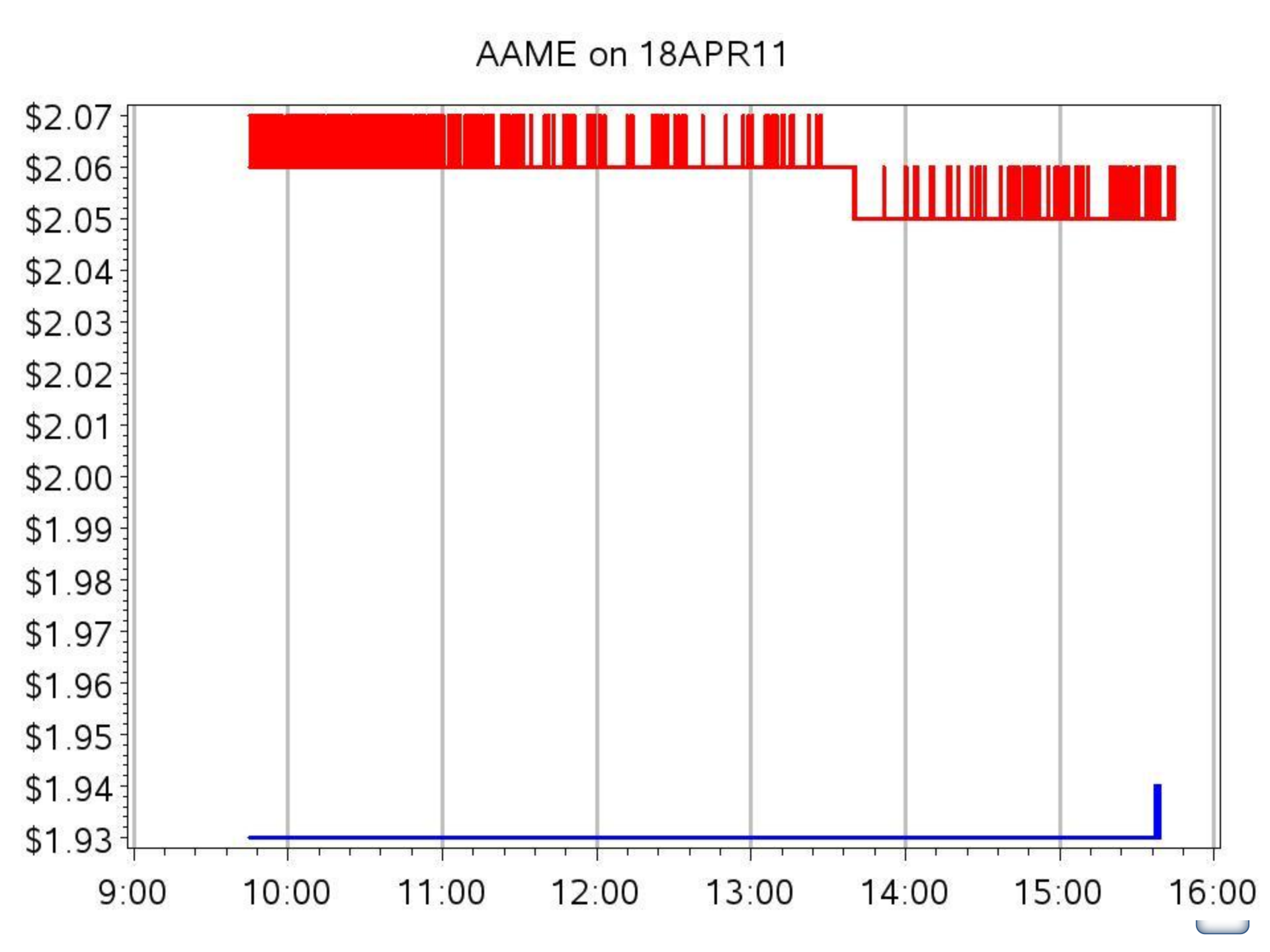
Connection to realized volatility literature

- Realized volatility = summed (absolute/squared) price changes.
  - Andersen, Bollerslev, Diebold and Ebens (2001), and others
- Hansen and Lunde (2006) advocate pre-averaging to eliminate microstructure noise.
- Present study: “Don’t throw out the noise!”

Open questions

- Analysis in this study focuses on average HFQ volatility.
  - But there are extreme and interesting outliers.
- What are the strategies?
  - Are the HFQ episodes unstable algos?
  - Are they sensible strategies to detect and access liquidity?
- Wavelet methods show great promise in isolating strategic microstructure effects from long-term informational noise.

More pictures from the National (High Frequency) Portrait Gallery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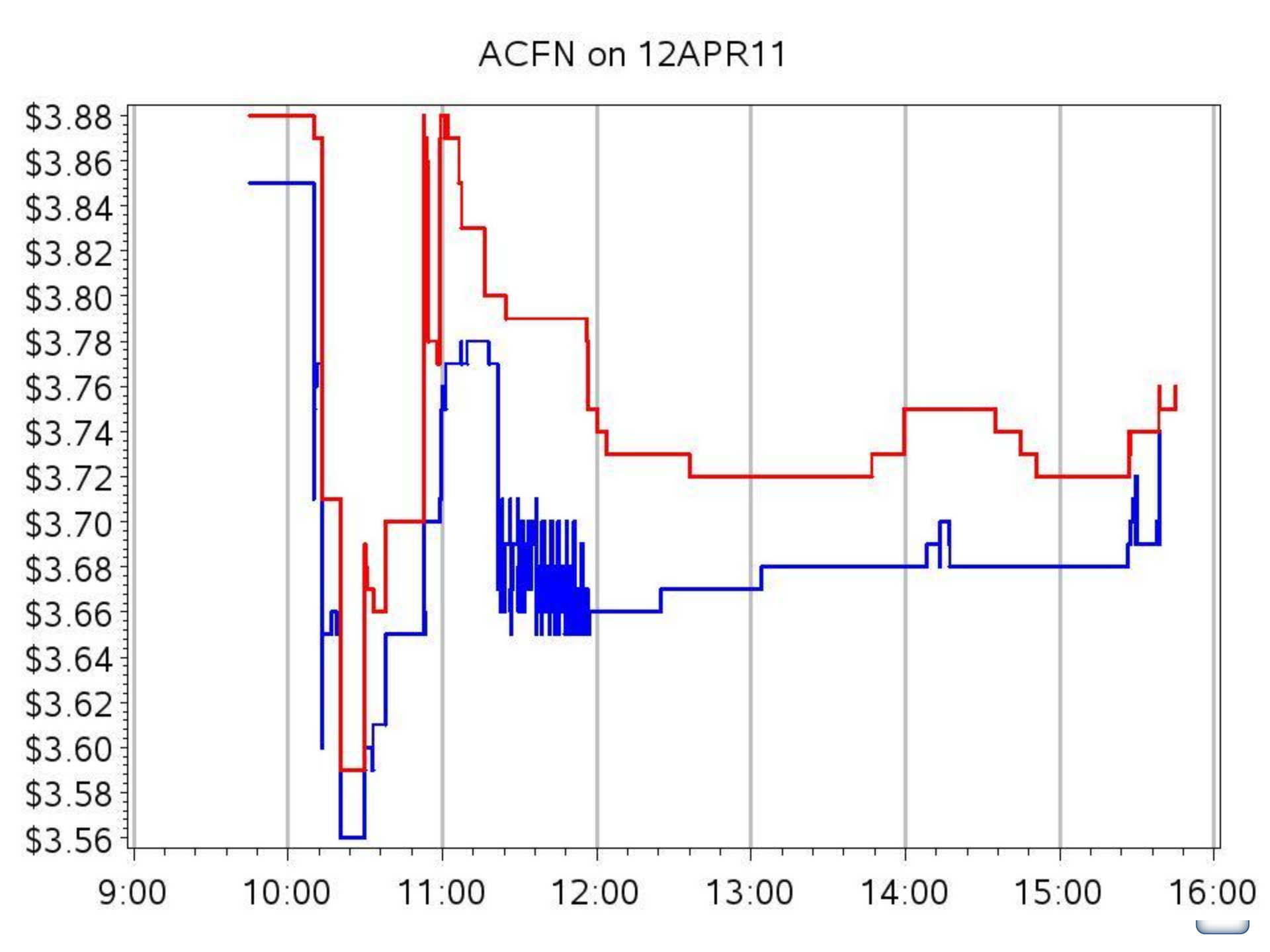
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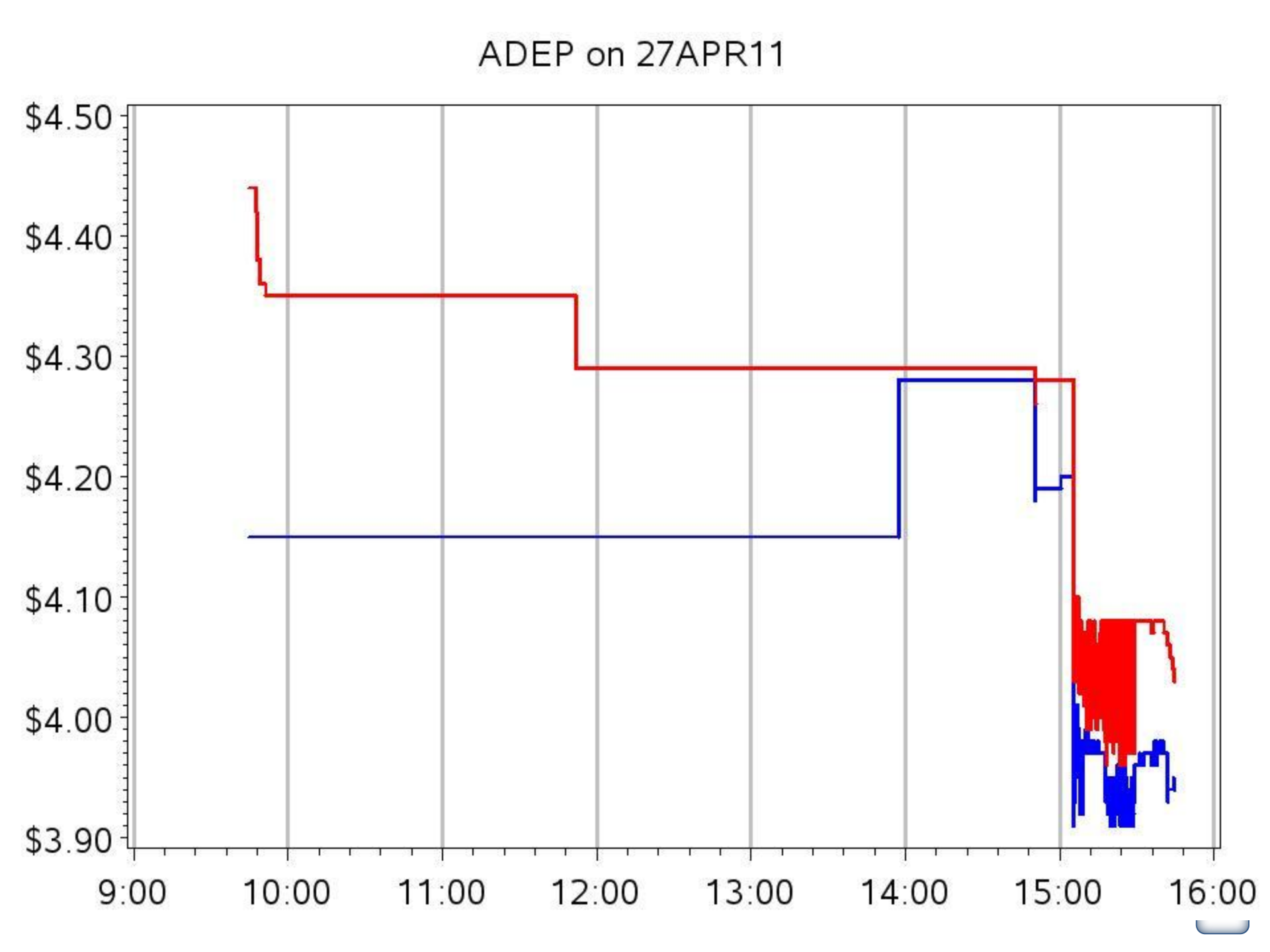
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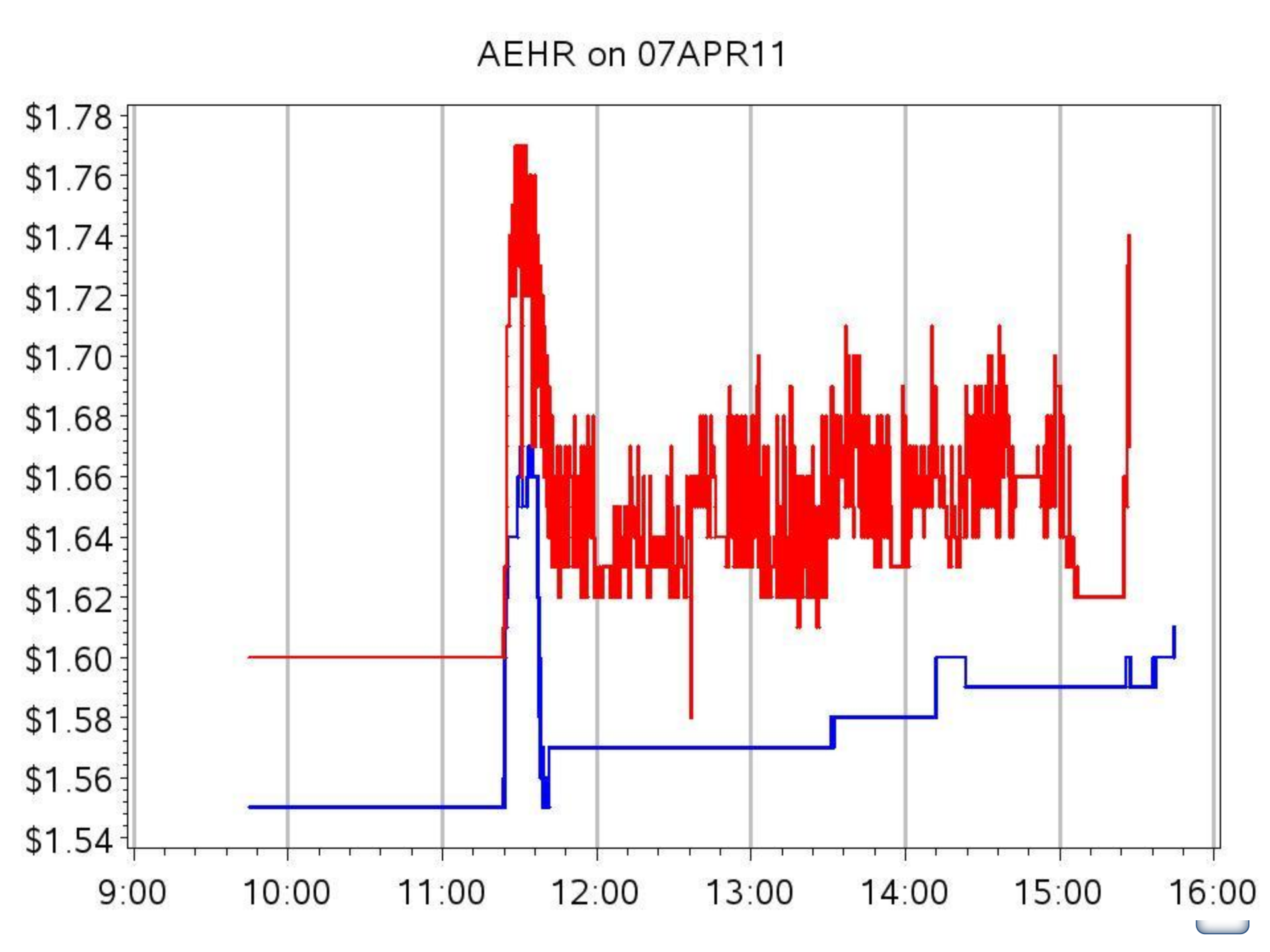
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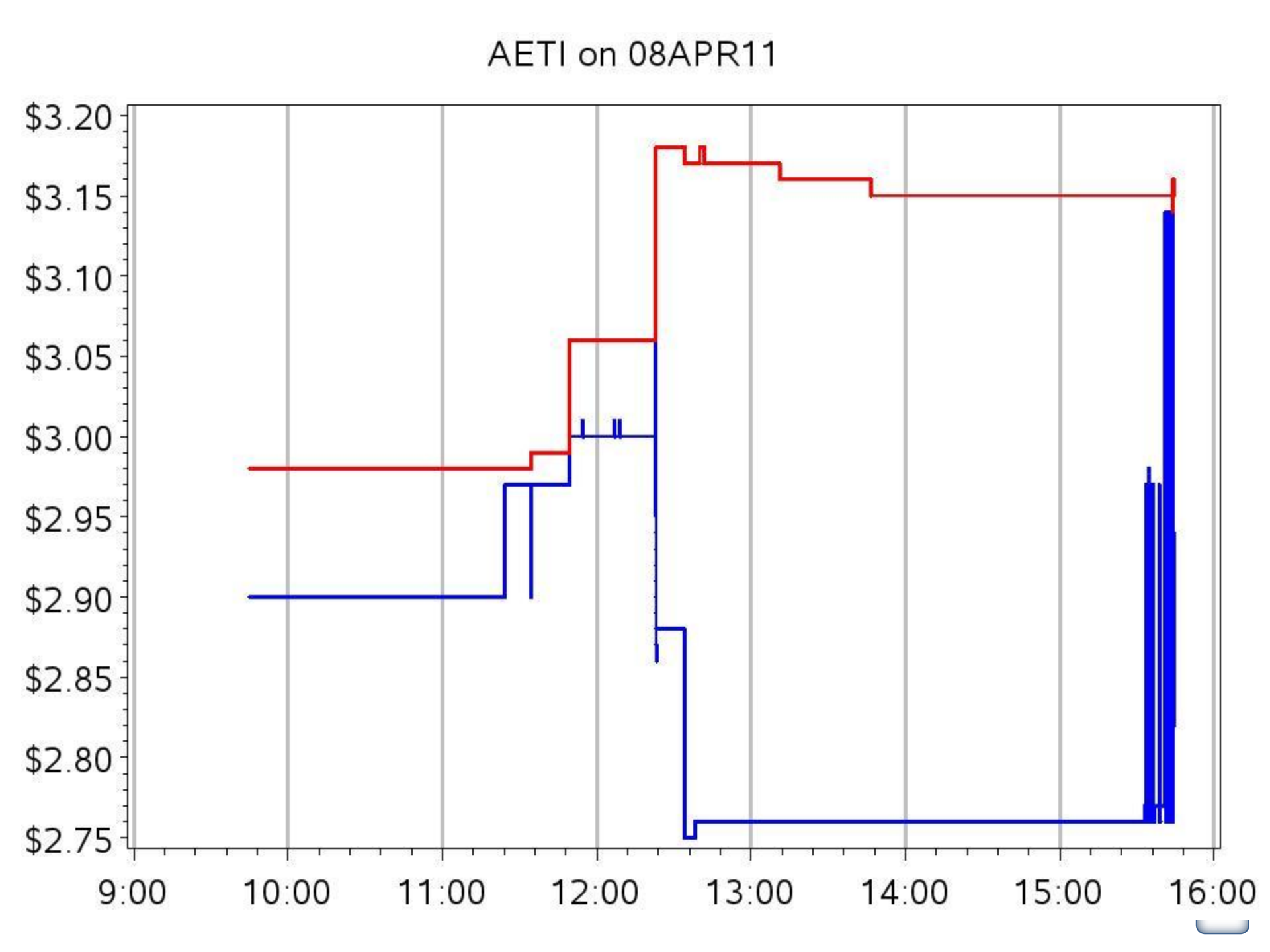
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