

High-Frequency Trading. Technology, Strategies, Regulations

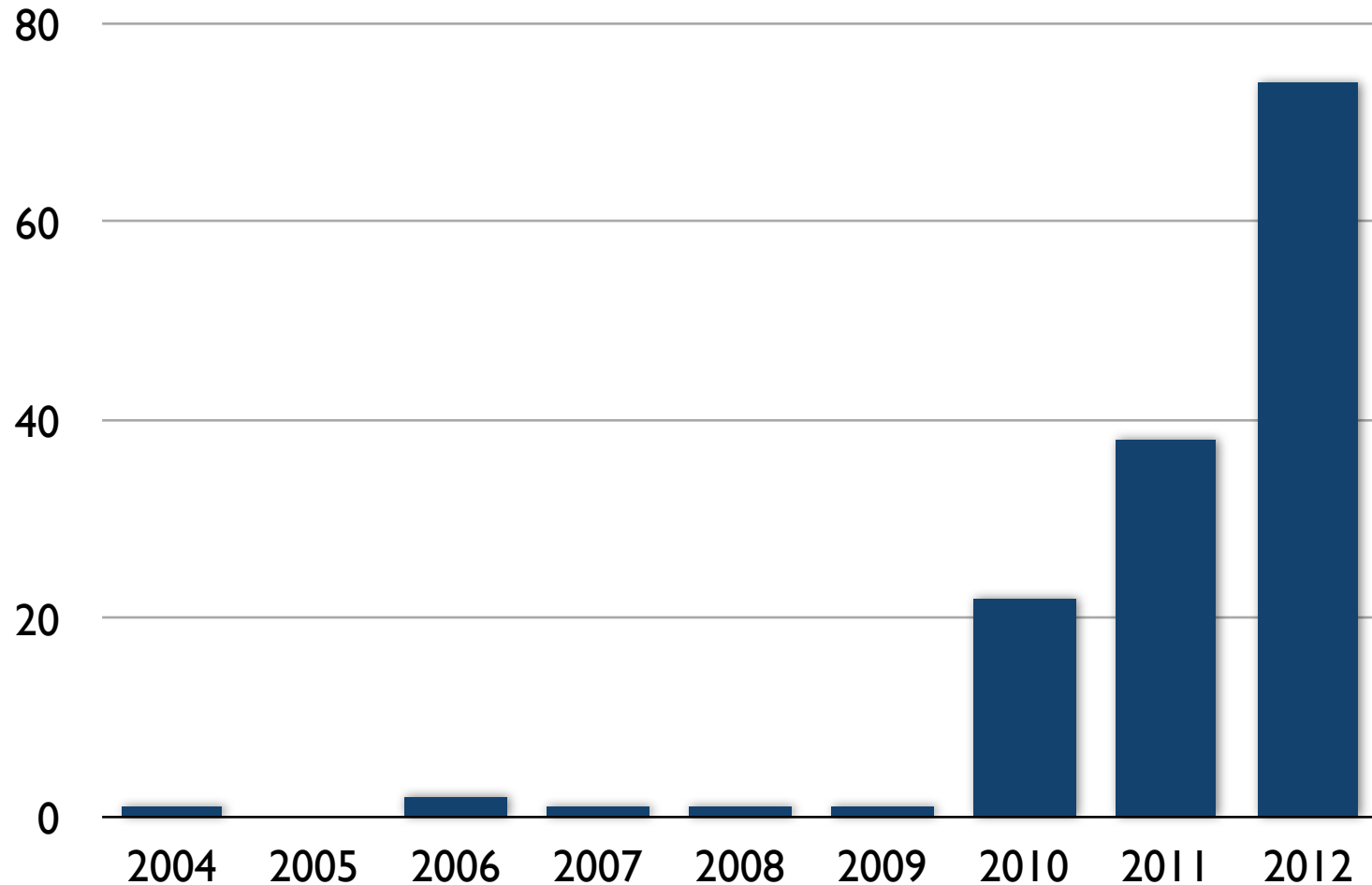
Vladimir Filimonov

ETH Zurich, D-MTEC, Chair of Entrepreneurial Risks



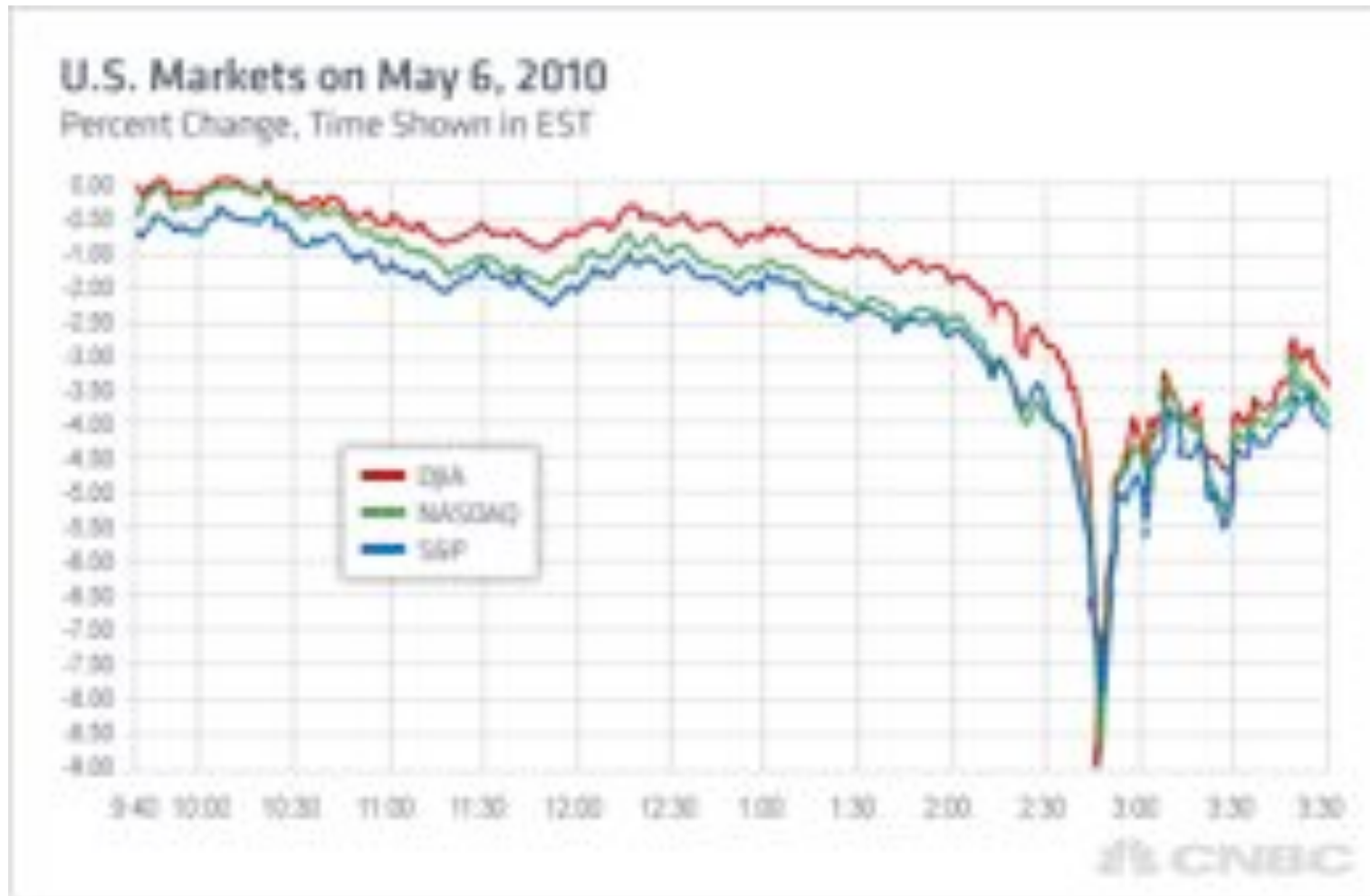
Perm Winter School 2013, Perm, Russia, February 5-7, 2013

Number of papers about HFT posted to SSRN library per year



Based on the search query on website <http://papers.ssrn.com>. Search was performed by the exact phrase “high frequency trading” in title, abstract or keywords and output was filtered by the “Date posted” field

Flash-crash of May 6, 2010



Arbitrage between
Futures and ETF

Arbitrage between
ETF and underlying
stocks

E-mini S&P 500

ETF on S&P 500

S&P 500

What is High-Frequency Trading?

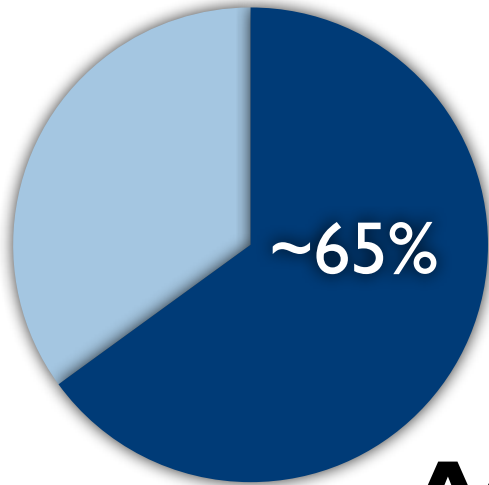
On February 9, 2012, the CFTC announced that the Commission “*has voted to establish a **Subcommittee** on Automated and High Frequency Trading **tasked with developing recommendations regarding the definition of high frequency trading** (“HFT”) in the context of the larger universe of automated trading.*”



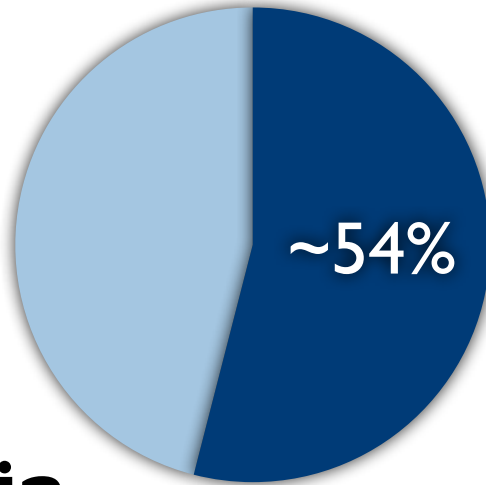
How big is HFT market?

HFT trade volume as % of total market

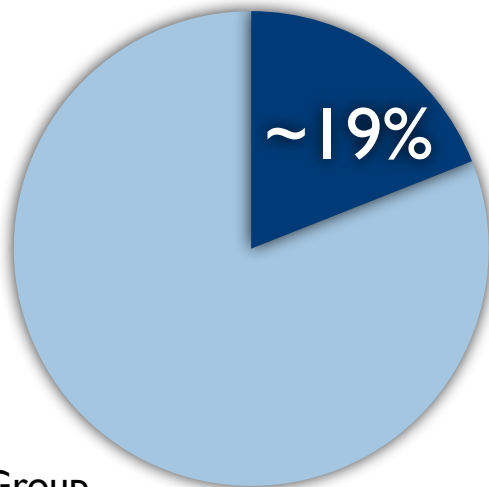
U.S.



Europe

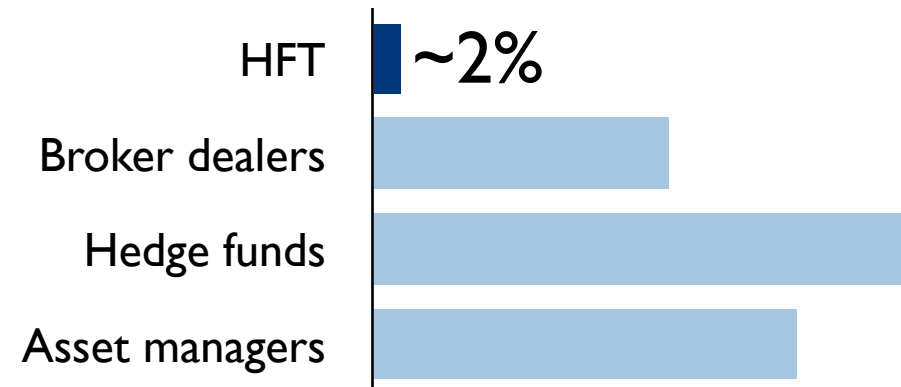


Asia

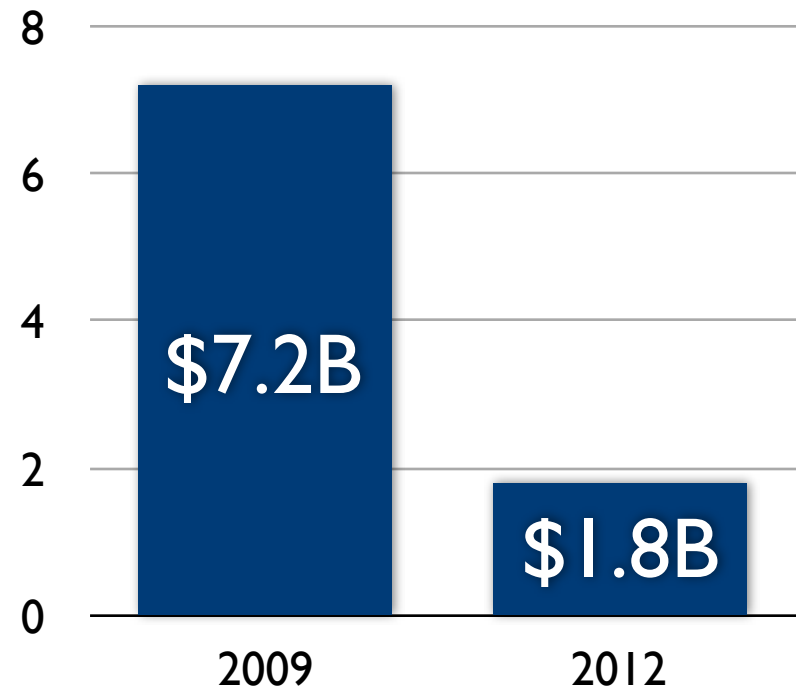


Source: Aite Group

Relative number of HFT firms



HFT firms' revenue



Source: TABB Group

1844 Invention of telegraph

1867 First stock ticker (Nov. 15)

1871 Universal Stock Ticker by
Thomas Edison

1858 First transatlantic cable

1875 Invention of telephone

1915 Invention of radio

1927 Transatlantic Radio-based
telephone service

1956 First transatlantic telephone
cable



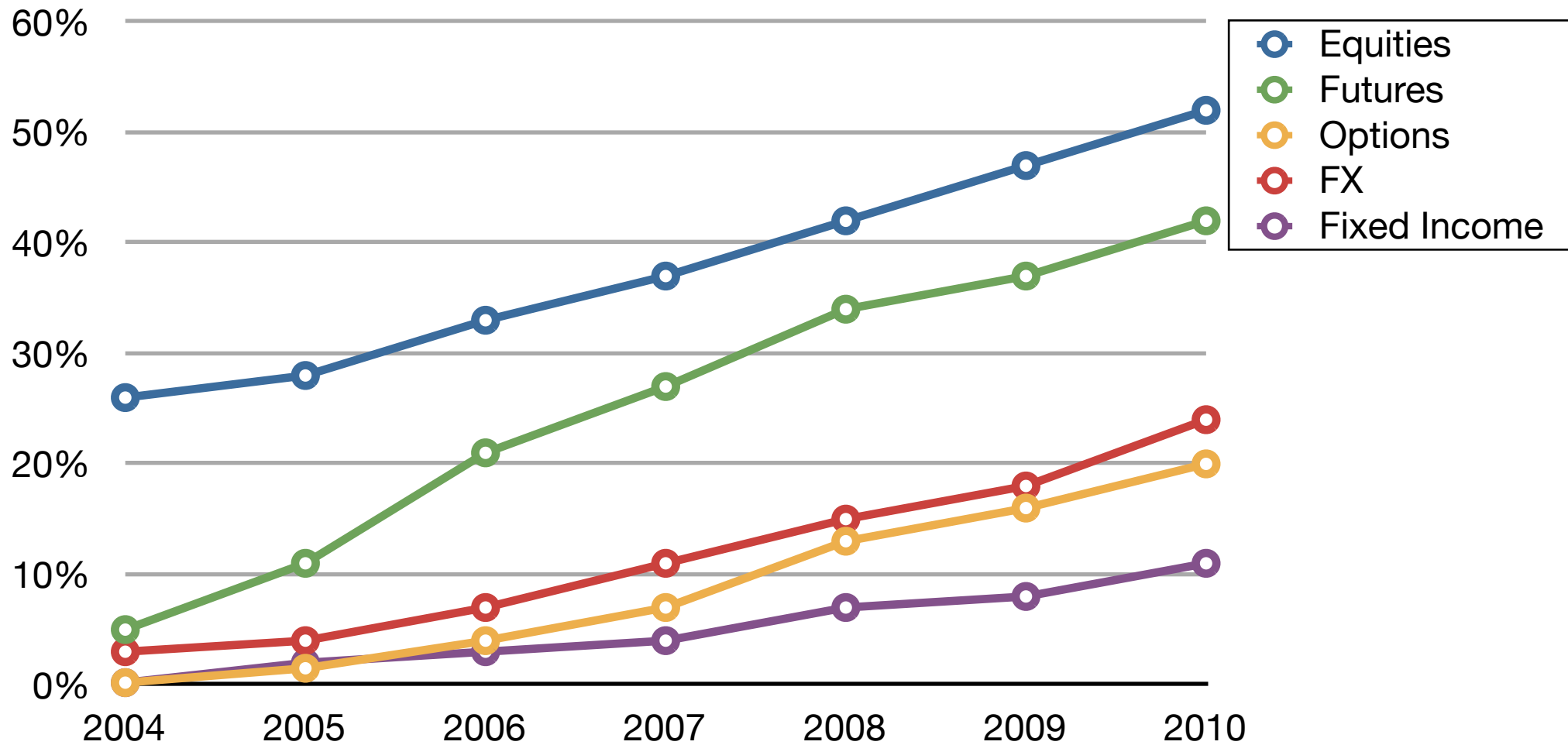
Thomas Edison's
Universal Stock Ticker

Source: Museum of American Finance

Some milestones of electronic trading

- 1960s** “Paper crisis”. from 1960 to 1969 the NYSE daily volume tripled to 14 million shares
- 1963** The first automated trading system was created by Davidsohn Computer Services.
- 1969** Instinet’s “Institutional Networks” started, allowing electronic block-trading.
- 1971** NASDAQ - first fully electronic board, including OTC trading of stocks.
- 1976** NYSE’s Designated Order Turnaround (DOT) system routes small orders.
- 1977** Toronto Stock Exchange introduces Computer Assisted Trading System (CATS)
- 1978** U.S. Intermarket Trading System (ITS) established, providing an electronic link between NYSE and the other U.S. stock exchanges.
- 1981** Reuters pioneered electronic monitor dealing service for FX.
- 1982** Tokyo Stock Exchange introduces Computer-assisted Order Routing & Execution System (CORES).
- 1986** London Stock Exchange’s “The Big Bang” shifts to screen trading. Paris Bourse introduced an electronic trading system.
- 1988** MTS platform created electronic secondary market for Italian government bonds.
- 1992** CME launches first version of GLOBEX electronic futures platform.
- 1993** EBS (Electronic Brokers System) adds competition for spot FX.
- 1997** U.S. SEC order handling rules change results in the creation of Arca, Brut, Island and Bloomberg Tradebook ECNs.
- 1998** Eurex offers the first fully electronic exchange for futures.
- 2000s** “Volume boom” - average daily volume explodes from 302 million shares a day in 1990 to 3.2 billion in 2001

Adoption of algorithmic execution by asset classes



Source: Aite Group

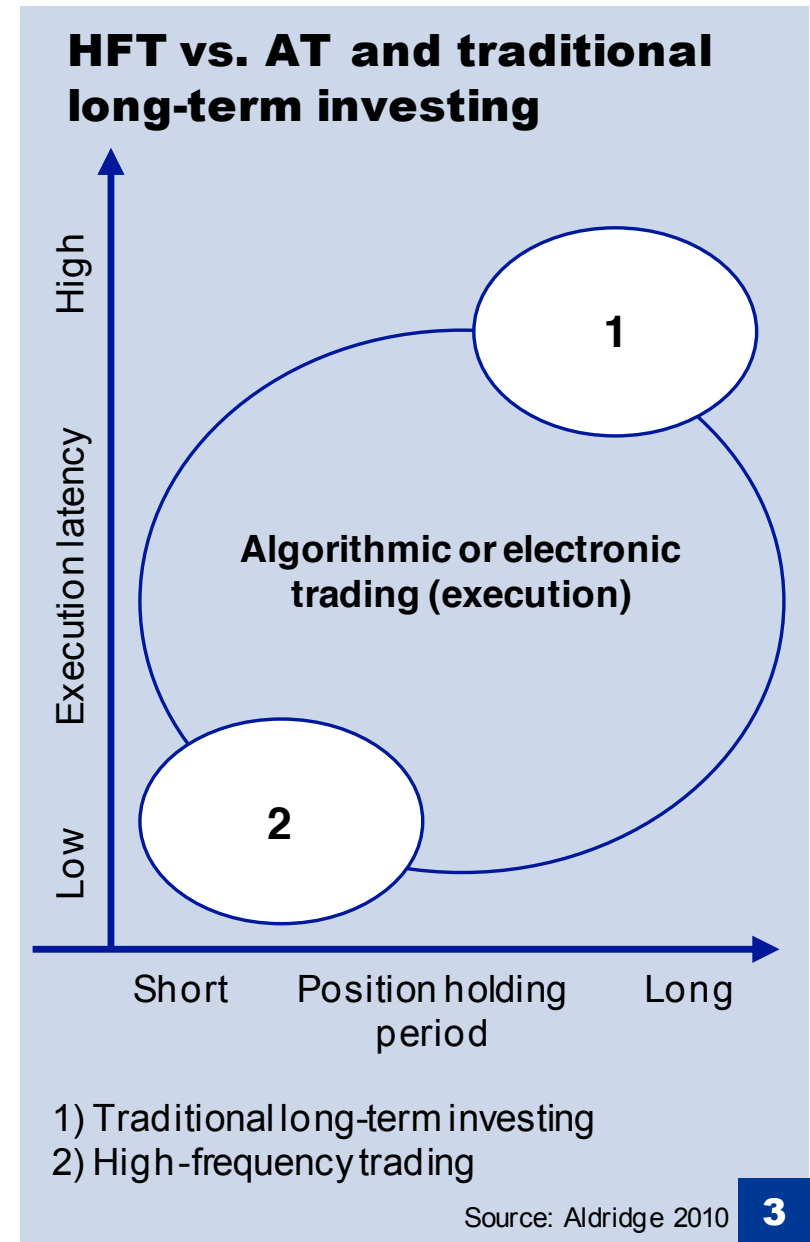
What is High-Frequency Trading?

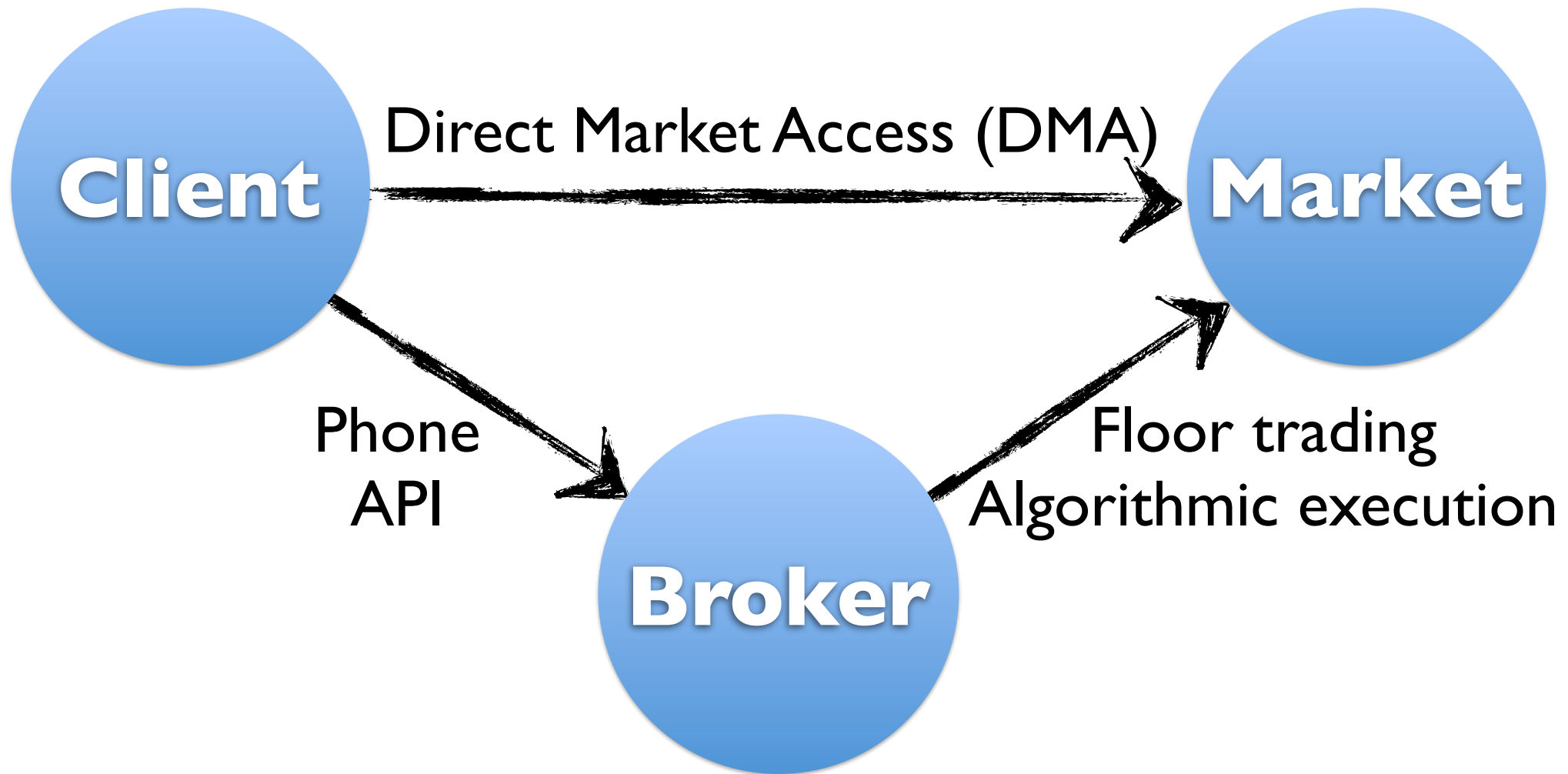
HFT typically is used to refer to professional traders acting in a proprietary capacity that engage in strategies that generate a large number of trades on a daily basis.

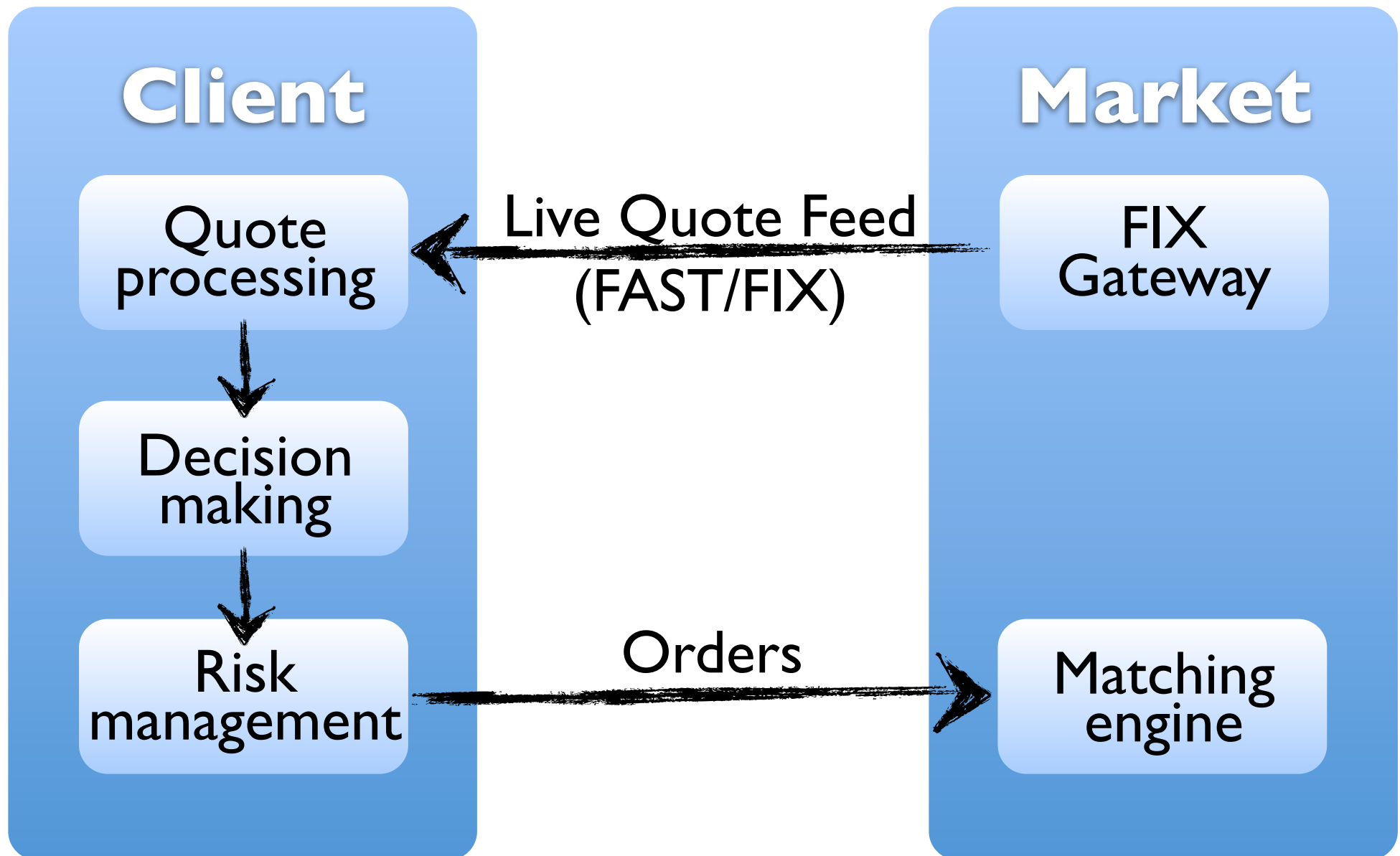
Other characteristics often attributed to proprietary firms engaged in HFT are:

- the use of extraordinarily high-speed and sophisticated computer programs for generating, routing, and executing orders;
- use of co-location services and individual data feeds offered by exchanges and others to minimize network and other types of latencies;
- very short time-frames for establishing and liquidating positions;
- the submission of numerous orders that are cancelled shortly after submission; and
- ending the trading day in as close to a flat position as possible (that is, not carrying significant, unhedged positions over-night).

SEC (2010)







Quote processing

Due to complexity of FAST/FIX protocol, its decoding is quite computationally expensive ($\sim 10\text{-}20\ \mu\text{S}$).

Best solution: implementations on FPGA ($\sim 2\text{-}5\ \mu\text{S}$).

Decision making

Typically exploiting linear models or nonlinear with pre-calculated parameters. FPGA solutions sufficiently decrease computational time.

Risk management

Run-time system, typically based on pre-calculated parameters that are regularly updated (e.g. once in an hour).

“The speed-of-light limitation is getting annoying”

Andrew Bach

Head of network services at *NYSE Euronext*
European Conference on Optical Communications
Geneva, Switzerland, September 2011

Exchanges provide high-quality data centers with all infrastructure (security, cooling, backup power generators) and high-speed 40G Ethernet Network for trading companies.

Round-trip of order-to-ack and market data order-to-tick latency is usually less than 40-50 microseconds.



Source: NASDAQ OMX

Path	Distance	Theoretical limit	Fiber optics
NY - Chicago	1145 km	7.63 mS	13.33 mS
NY - Washington	328 km	2.18 mS	3.71 mS
Chicago - Washington	956 km	6.44 mS	10.81 mS
NY - Toronto	553 km	3.69 mS	6.34 mS
NY - London	5567 km	37.14 mS	65 mS
London - Frankfurt	636 km	4.24 mS	7.26 mS
Frankfurt - Paris	479 km	3.20 mS	5.48 mS
London - Zurich	776 km	5.18 mS	7.79 mS

Theoretical limit for **round trip** is calculated based on the distance and speed of light (299.8 km/mS)
Latencies in fiber optics include all technological overhead



Source:Wired (March 8, 2012)



Source: Bloomberg Businessweek (March 29, 2012)

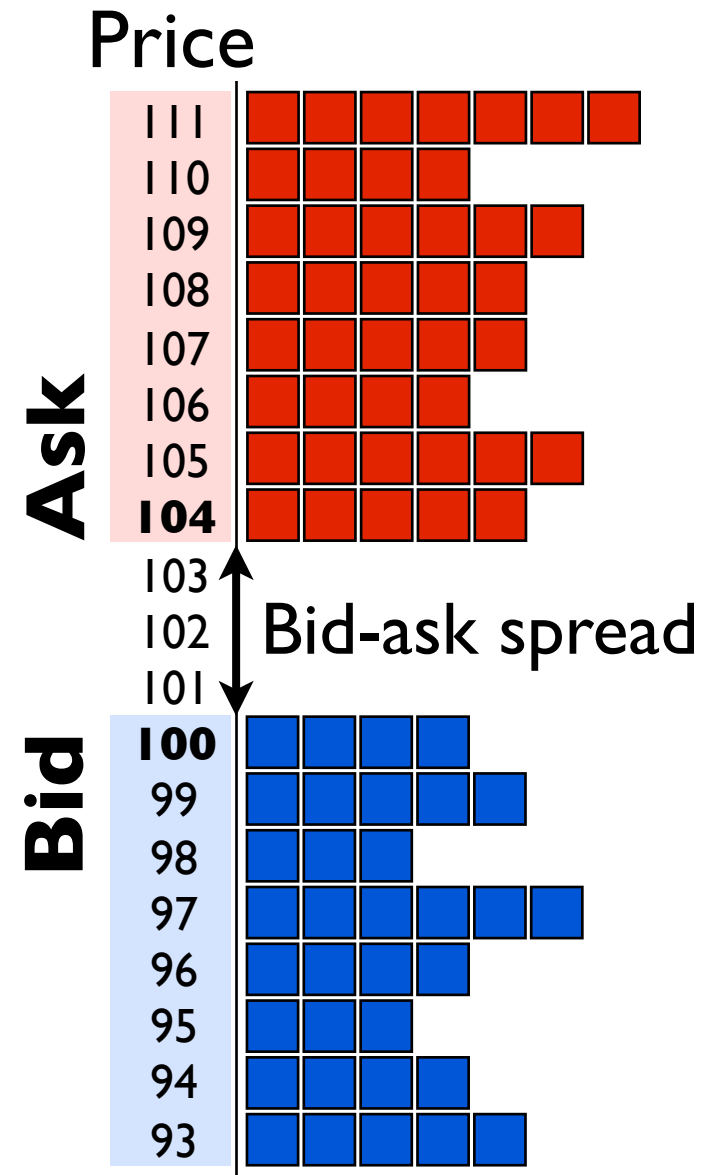
Hibernia. Project “Express”
Estimated costs: **\$300M**
Expected decrease of latency: **6 mS**
To be finished: summer 2013



Market making
Liquidity providing
Statistical arbitrage
Event arbitrage
Cross-market arbitrage
Exploiting inefficiencies

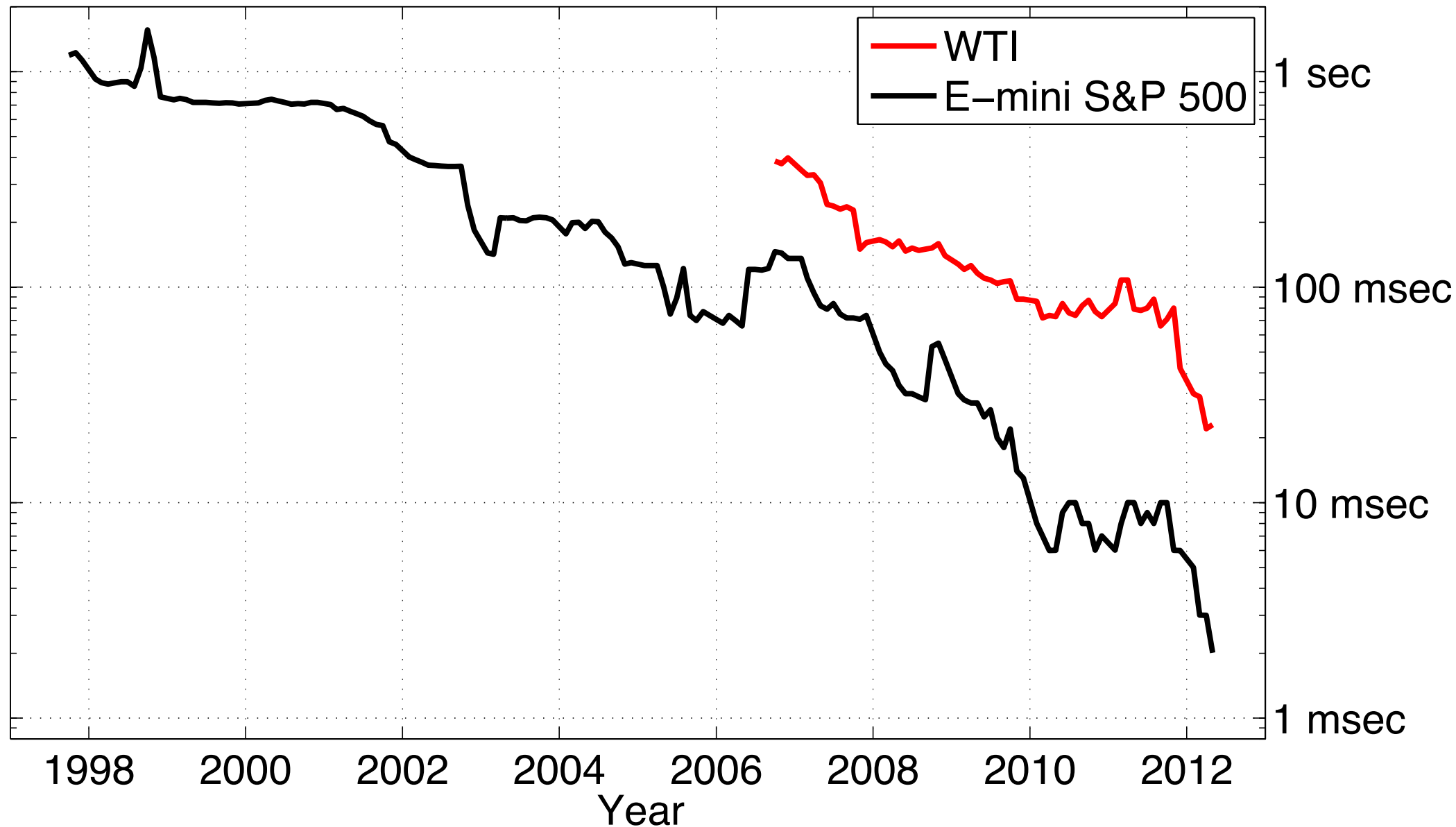
Quote stuffing
Quote smoking
Layering / Spoofing
Momentum ignition
Painting the tape
Order hunting
Human hunting

- By providing simultaneous limit orders to buy and sell, market maker (MM) aims to earn the bid-ask spread. Essentially, spread is the compensation for the risk.
- Speed is an additional advantage that significantly reduces risks
- Moreover many exchanges have “incentive programs” and pay so-called **rebates** (typically <\$0.01 for equities) for every limit order that resulted in transaction.



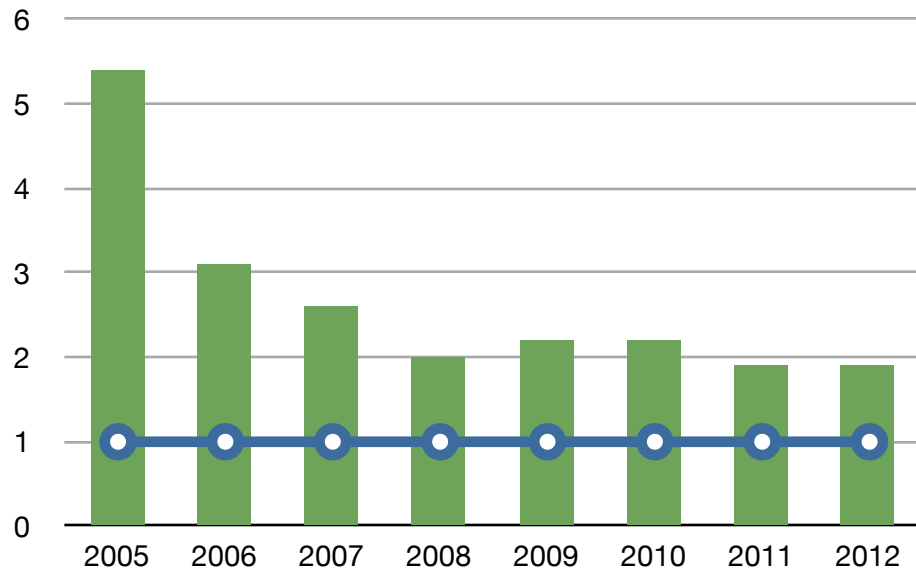
How fast is it?

Typical market makers' reaction time

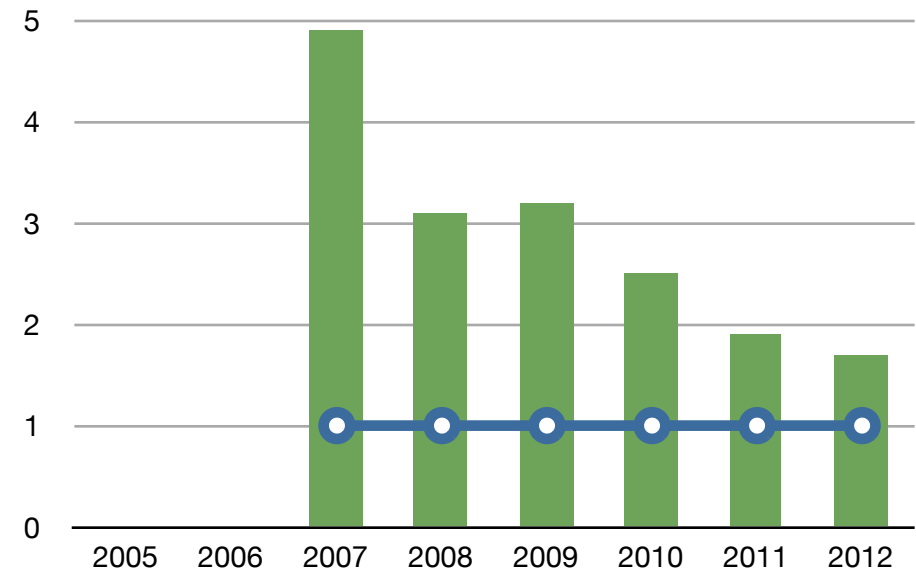


Typical volume

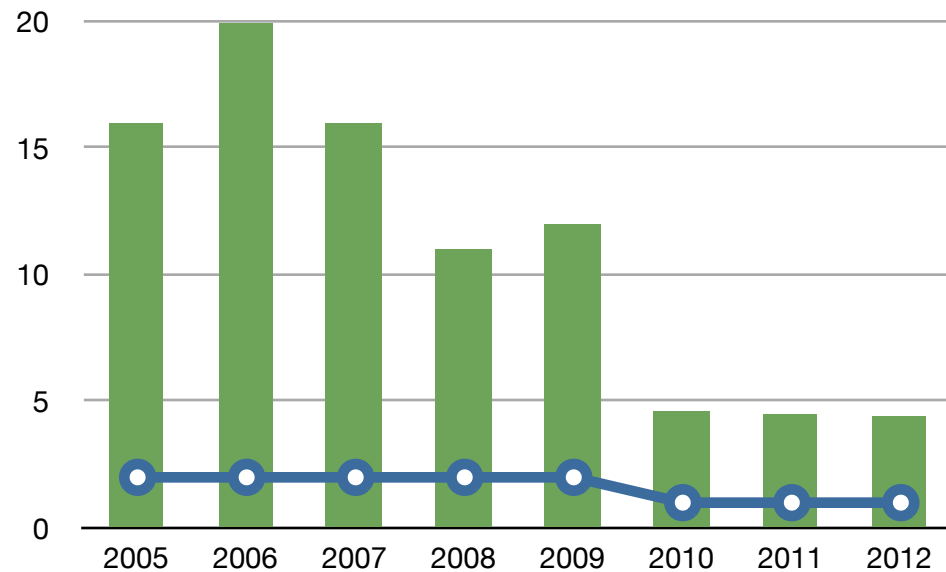
Brent Crude Oil



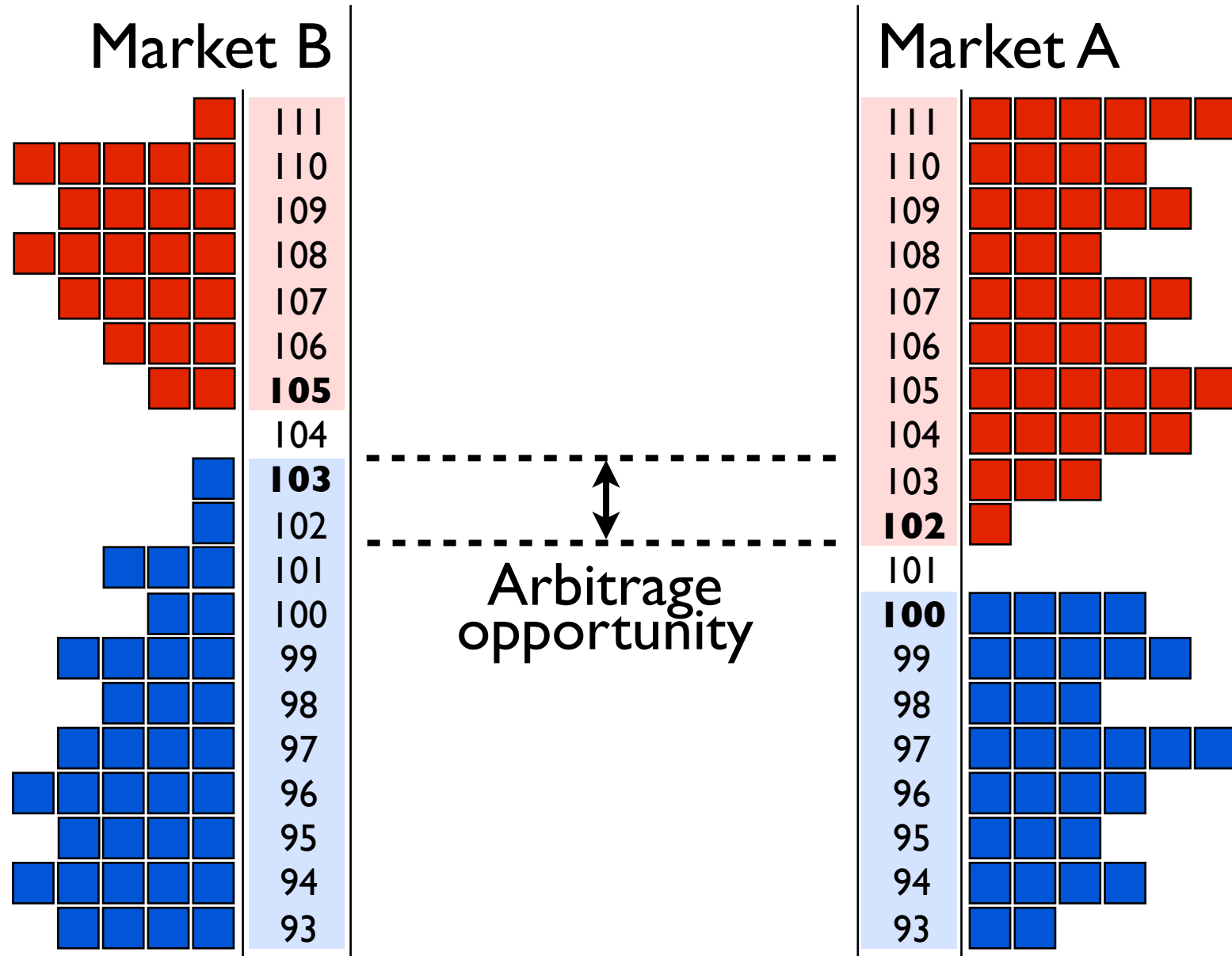
WTI

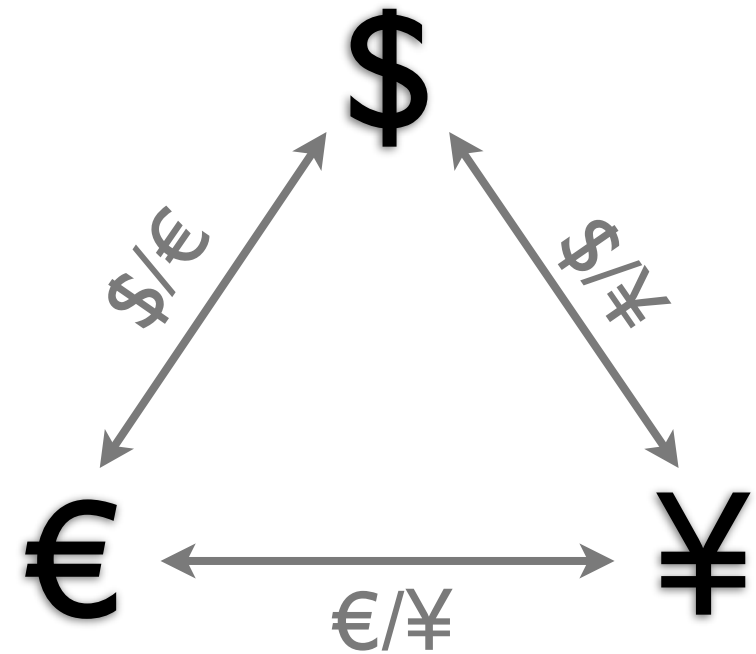
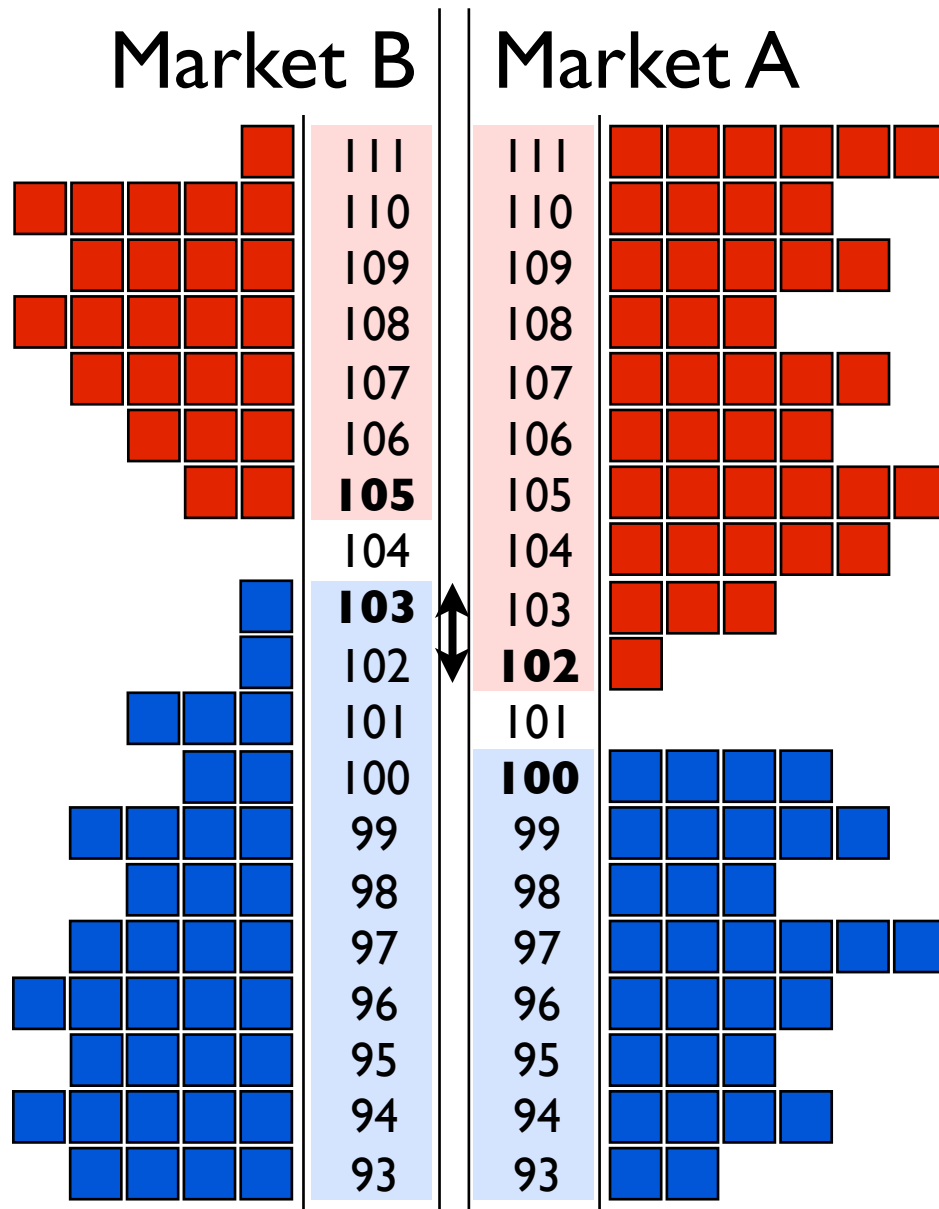


E-Mini S&P 500 Futures



○ Median ■ Average



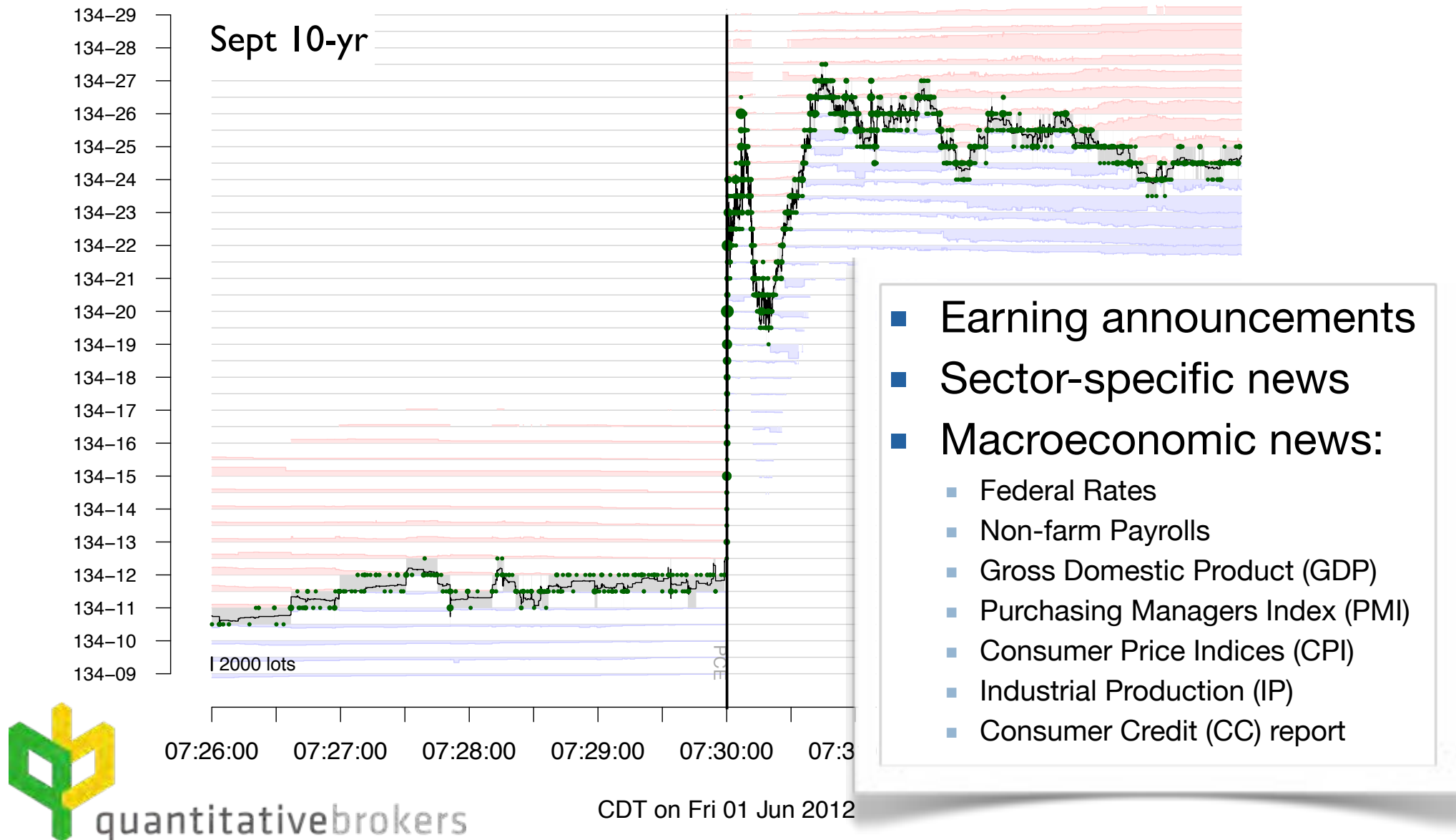


Triangular arbitrage

$$\text{Bid}(¥/\epsilon) * \text{Bid}(\$/¥) > \text{Ask}(\$/\epsilon)$$

$$\text{Ask}(¥/\epsilon) * \text{Ask}(\$/¥) < \text{Bid}(\$/\epsilon)$$

Nonfarm Payrolls -- June 1, 2012



Expired

Expired

Expired

Expired

Front-running and “Flash Orders”

The 500-Millisecond Advantage

Under the “Regulation NMS” rules, exchanges are forced to route participants orders out to other exchanges if the other exchange is briefly offering a better price on a stock the customer wants to buy even if that price would be bad for the customer – and bad for the exchange too, who lose the custom. To avoid this, some exchanges are offering an order option called “flash” that displays for just 500ms, that might help get the customer filled at a better price without breaking the Regulation NMS rules about not holding up orders for longer than a second. Each customer saving might just be pennies, but it can sometimes happen millions of times a day.



Source: Seeking Alpha (2009)

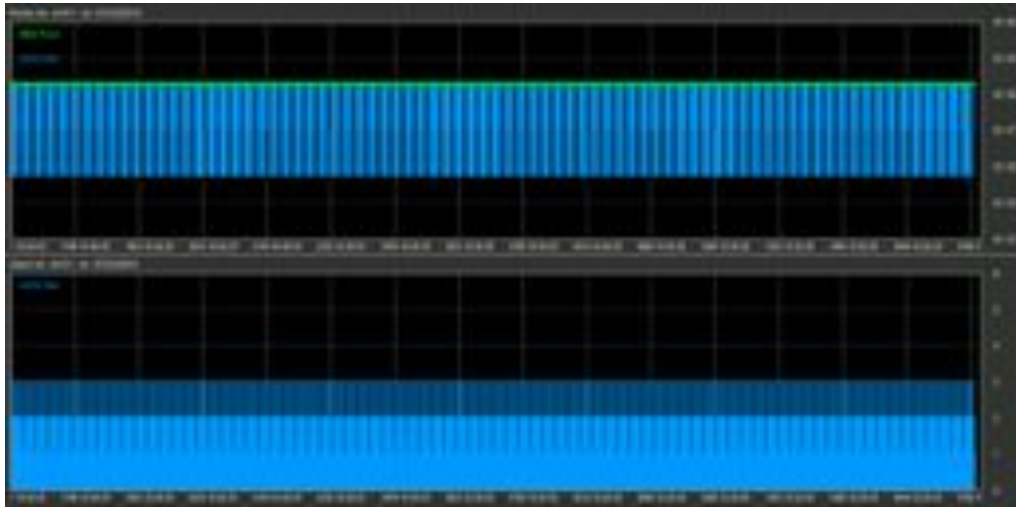
Under an exception to Rule 602 of Regulation NMS flash orders are currently allowed

“I need your clothes, your boots and your motorcycle”

Anonymous cyborg, 1991

“Quote Stuffing”

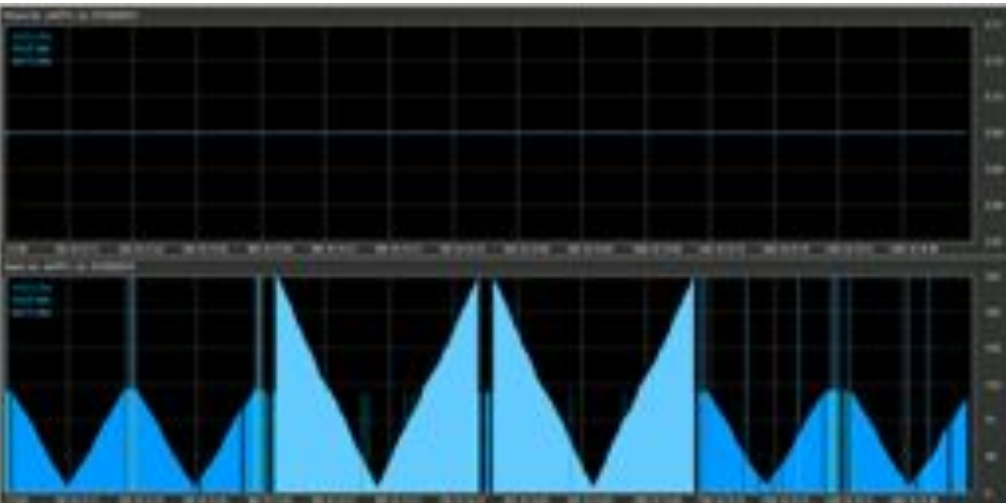
Quote stuffing is an HFT practice of putting in a large number of quotes and then immediately canceling them.



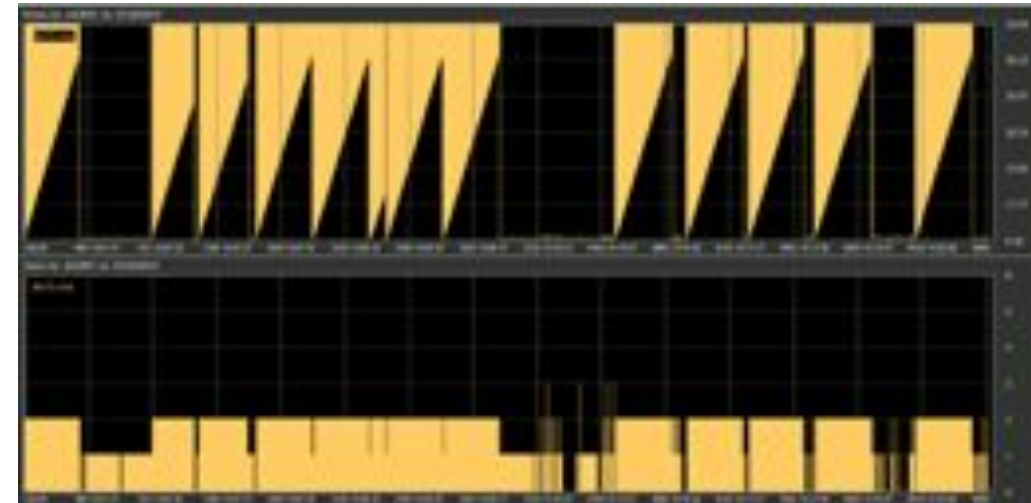
Timespan: 2 sec. 4,000 quotes



Timespan: 11 sec. 15,000 quotes



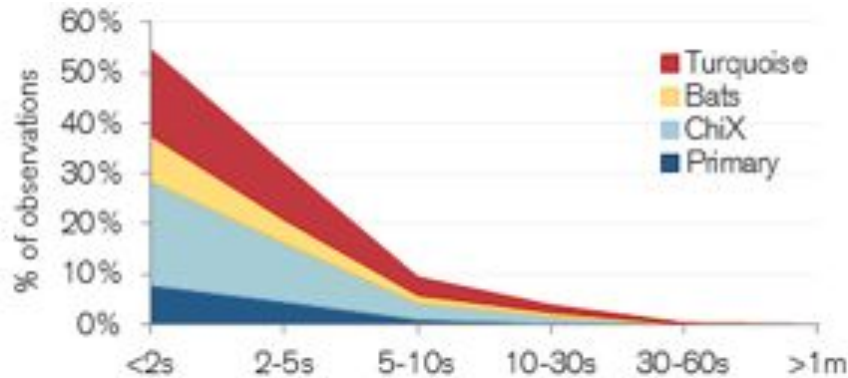
Timespan: ~2 min



Timespan: ~20 min

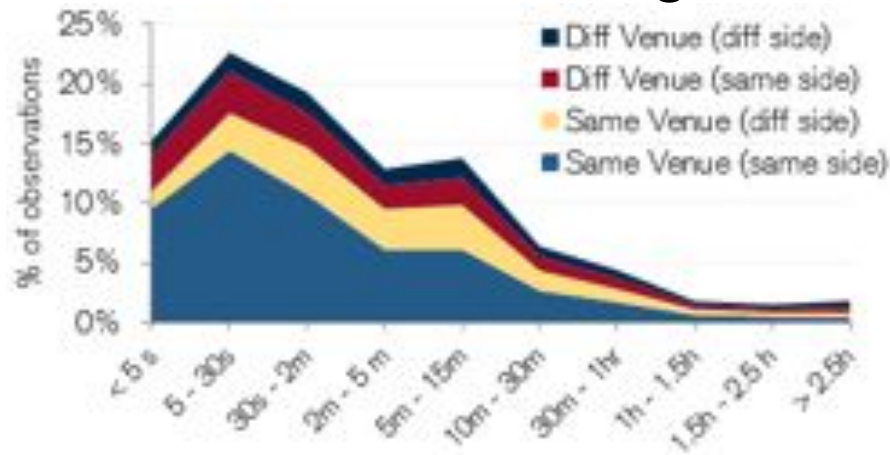
“Quote Stuffing”

Duration of Quote Stuffing Events (EU)



Source: Credit Suisse AES Analysis, STOXX60, Jul – Sep 2012

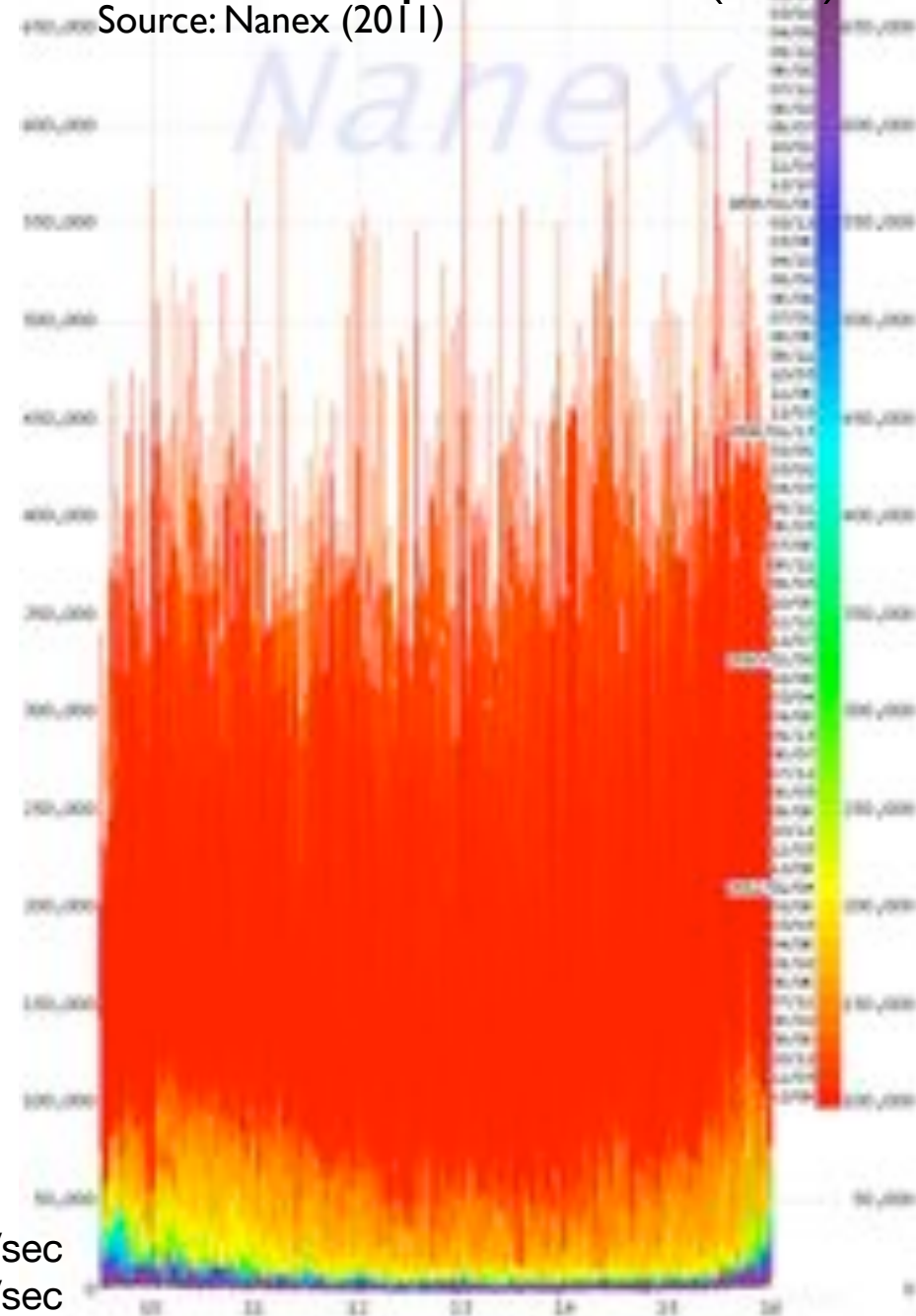
Time between Quote Stuffing Events (EU)



Source: Credit Suisse AES Analysis, STOXX 600 Jul - Sep 2012

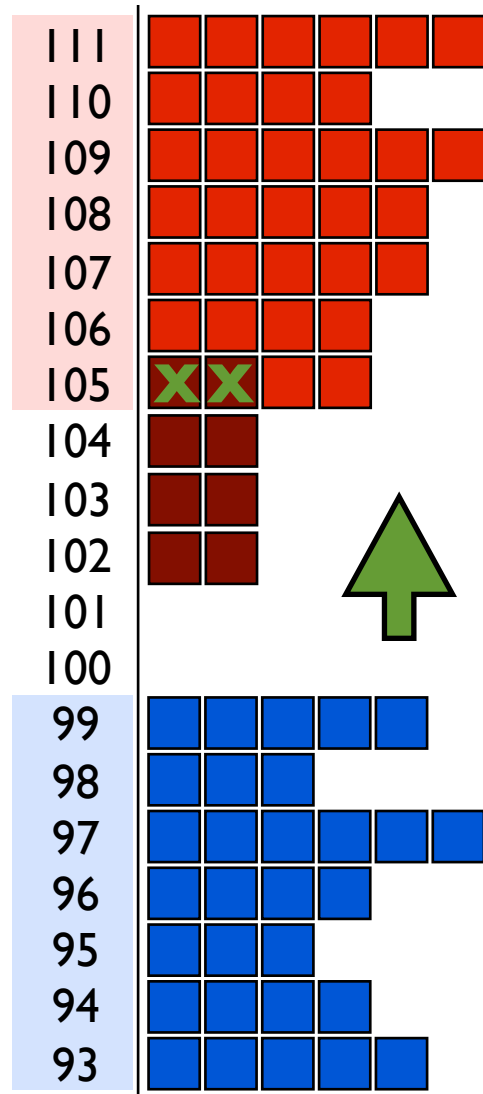
Quote rate per second (U.S.)

Source: Nanex (2011)



2007: ~6,000 quotes/sec
2011: ~600,000 quotes/sec

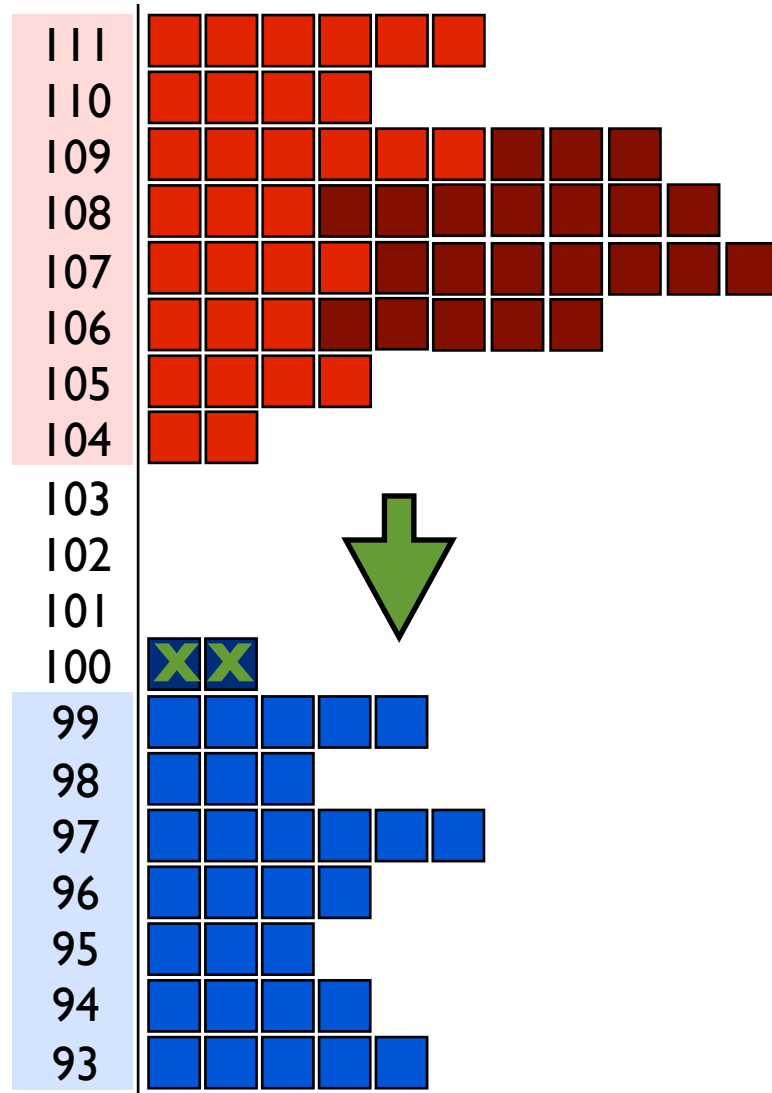
Quote smoking refers to an HFT practice of posting alluring orders to attract low-frequency investors.



- HF trader places alluring quotes to attract limit order
- Observing these quotes slow trader puts market order
- HF trader cancels his quotes
- Market order hits larger ask

By starting the level HF trader is sure that his quotes will be executed first (TOP matching rule)

Layering (spoofing) is a practice of creating selling/buying pressure in order to make naive investor to move the price.

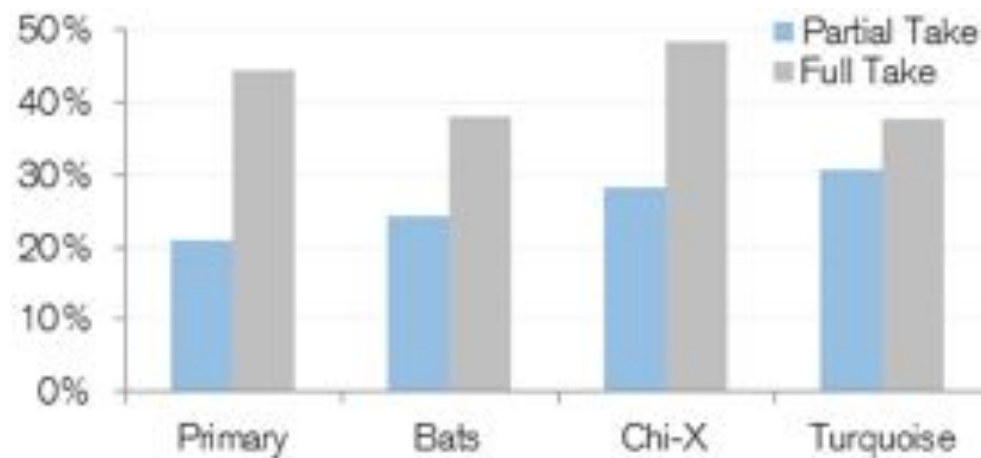


HF trader wants to buy

- HF trader puts large ask limit orders above best ask, creating apparent selling pressure
- Simultaneously he puts limit order to buy in the spread.
- Naive investor is scared and sells against his bid quotes
- HF trader immediately cancels ask orders

Because of latency advantage HF trader is sure that he could cancel his ask orders in case of good news

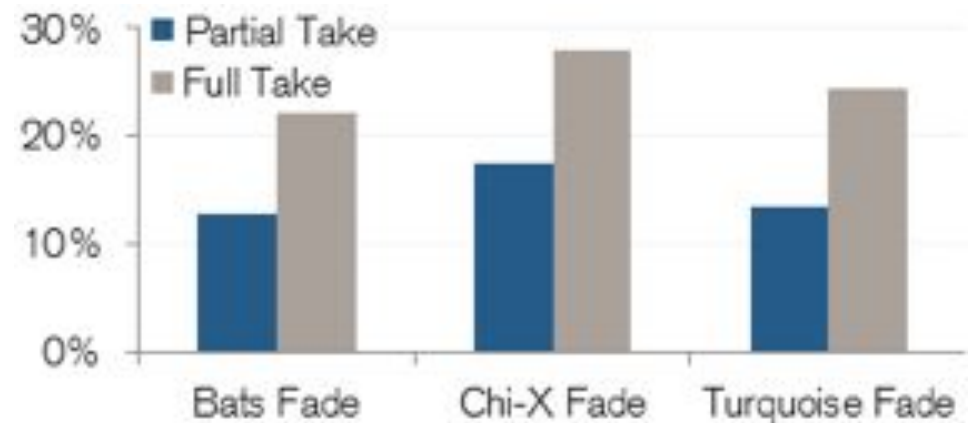
Price Fade refers to volume disappearing immediately after the trade on the same venue



Source: Credit Suisse AES Analysis, Jul - Sep 2012

Likelihood of Price Fade

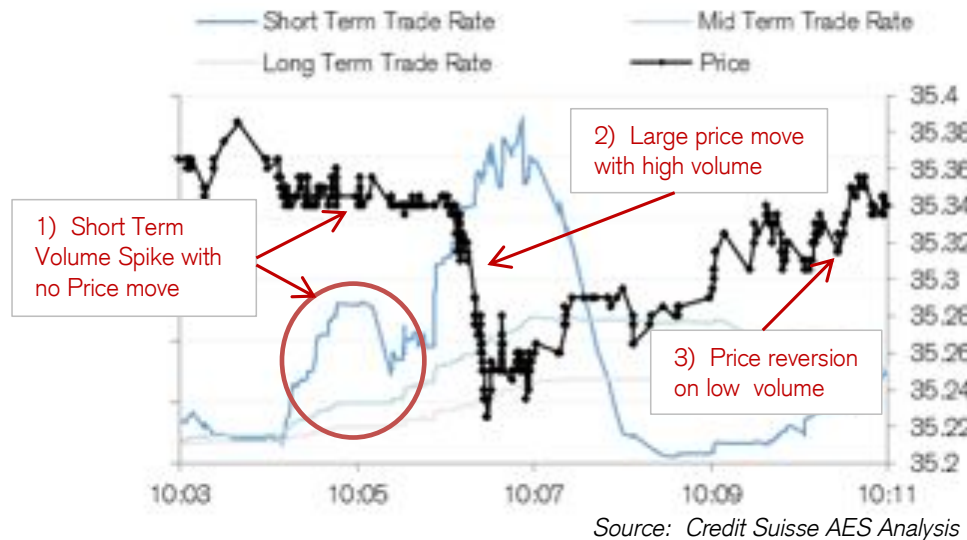
Venue Fade refers to volume disappearing immediately after the trade, but on different venue



Source: Credit Suisse AES Analysis, Jul - Sep 2012

**Likelihood of Venue Fade
following a trade on the Primary**

Momentum ignition refers to a strategy that attempts to trigger a number of other participants to trade quickly and cause a rapid price move. It doesn't occur in the blink of an eye, but its perpetrators benefit from an ultra-fast reaction time.

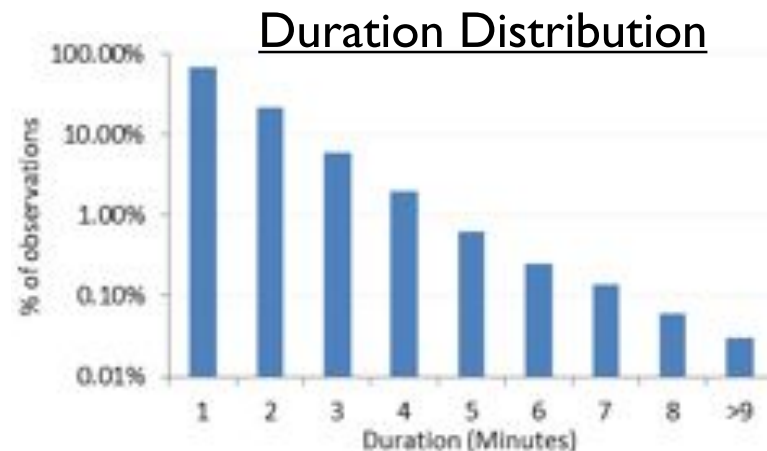


Typically it consists of 3 steps:

- Instigator takes a pre-position and removes liquidity from best side.
- With huge volume instigator triggers the fall of price
- After his orders are executed, he slowly reverts price back to the initial level

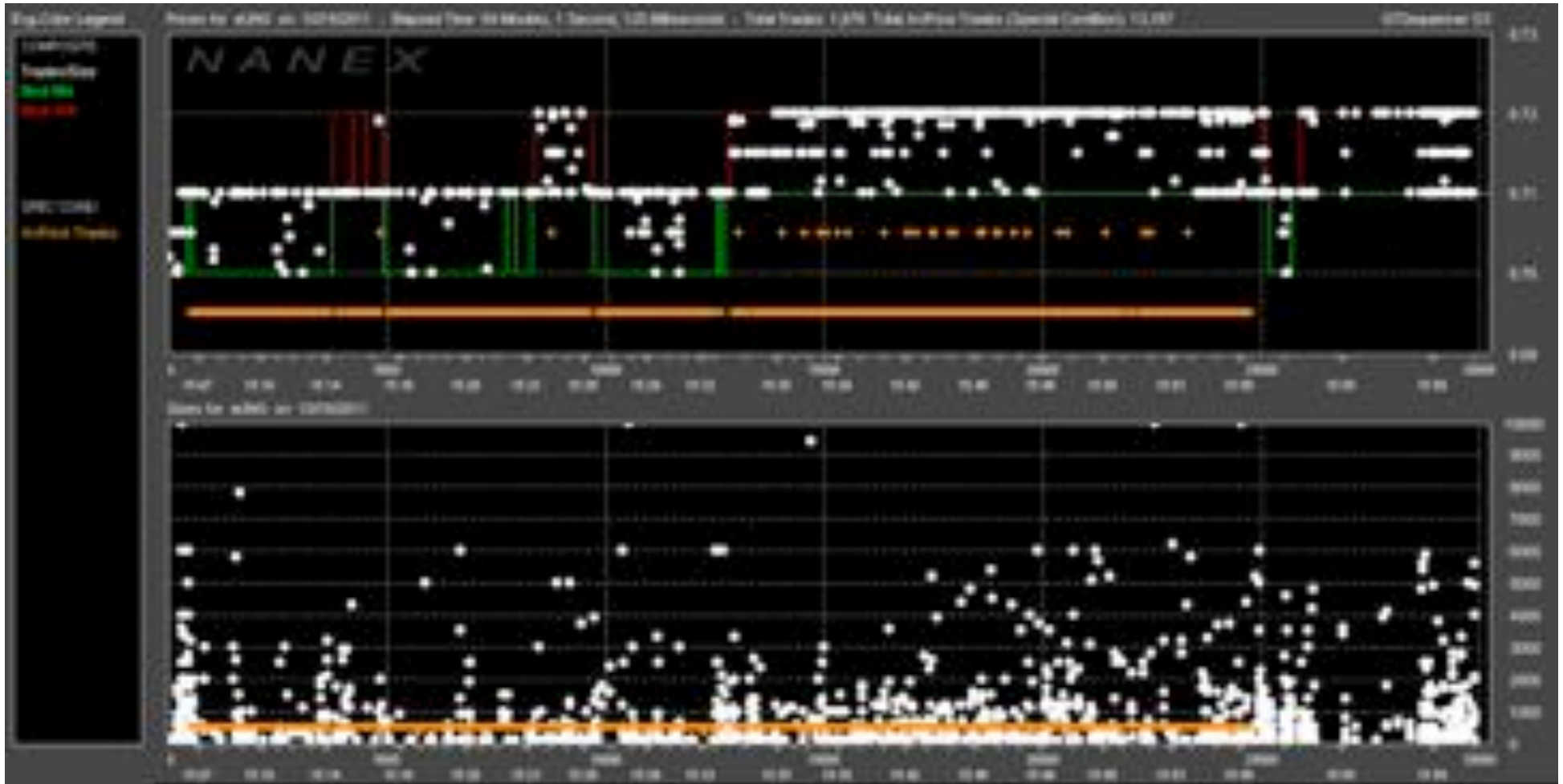


Source: Credit Suisse AES Analysis, STOXX 600 Jul - Sep 2012



Source: Credit Suisse AES Analysis, STOXX 600 Jul - Sep 2012

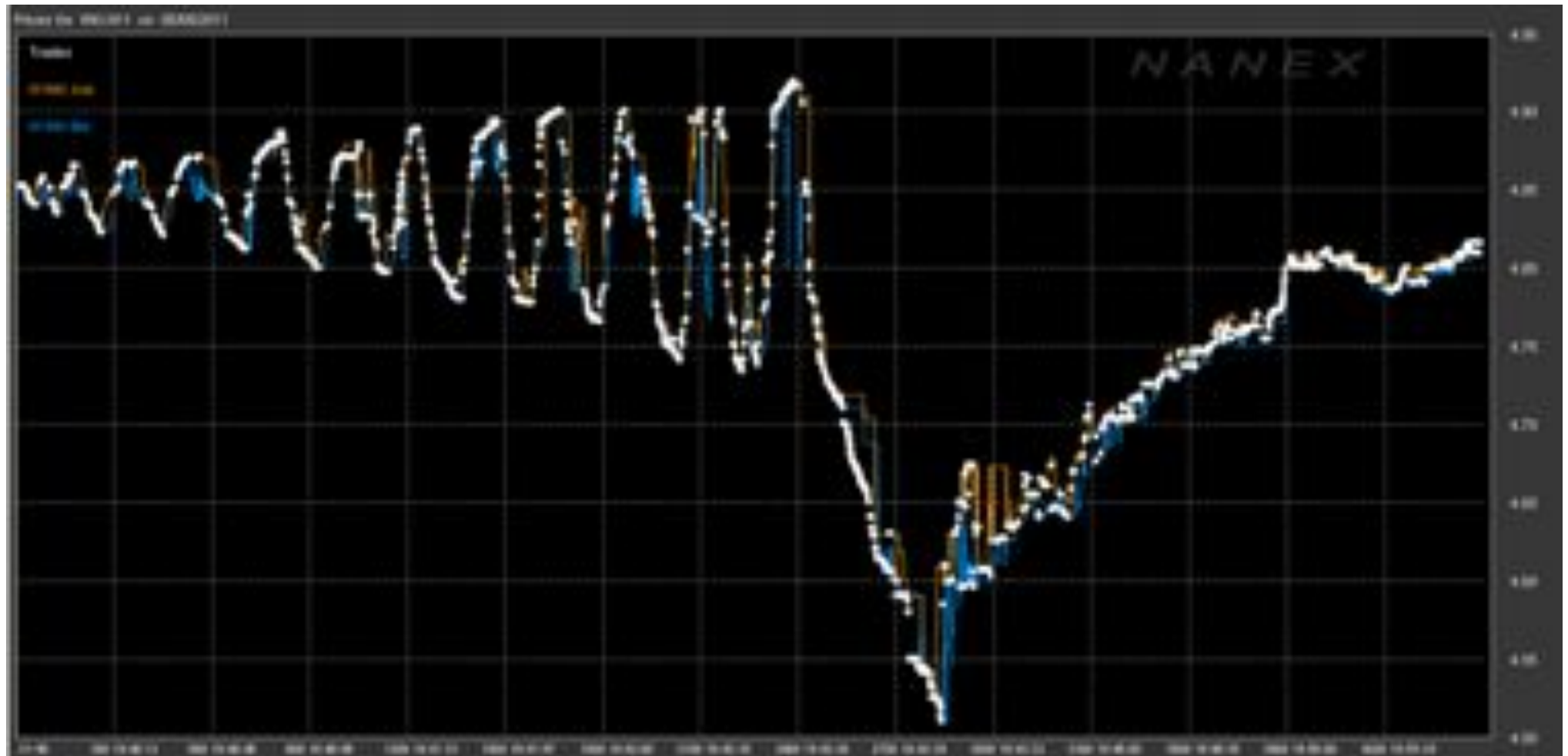
Painting the tape. This practice involves engaging in a transaction or series of transactions which are shown on a public display facility to give the impression of activity or price movement in a financial instrument.



Source: Nanex (2010)

In **50 minutes** there were **13,167 Average-Price trades**, each one immediately followed by an exchange message about cancellation of the. **The trades appeared at a rate of 4 to 5 per second, and each trade was canceled before the next trade appeared.**

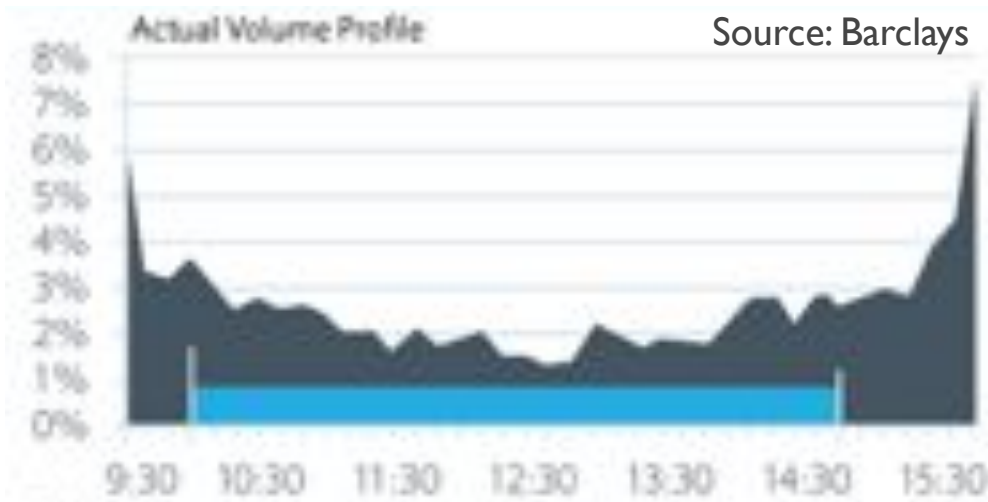
Stop-loss Hunting



Source: Nanex (2011) "Strange Days June 8'th, 2011"

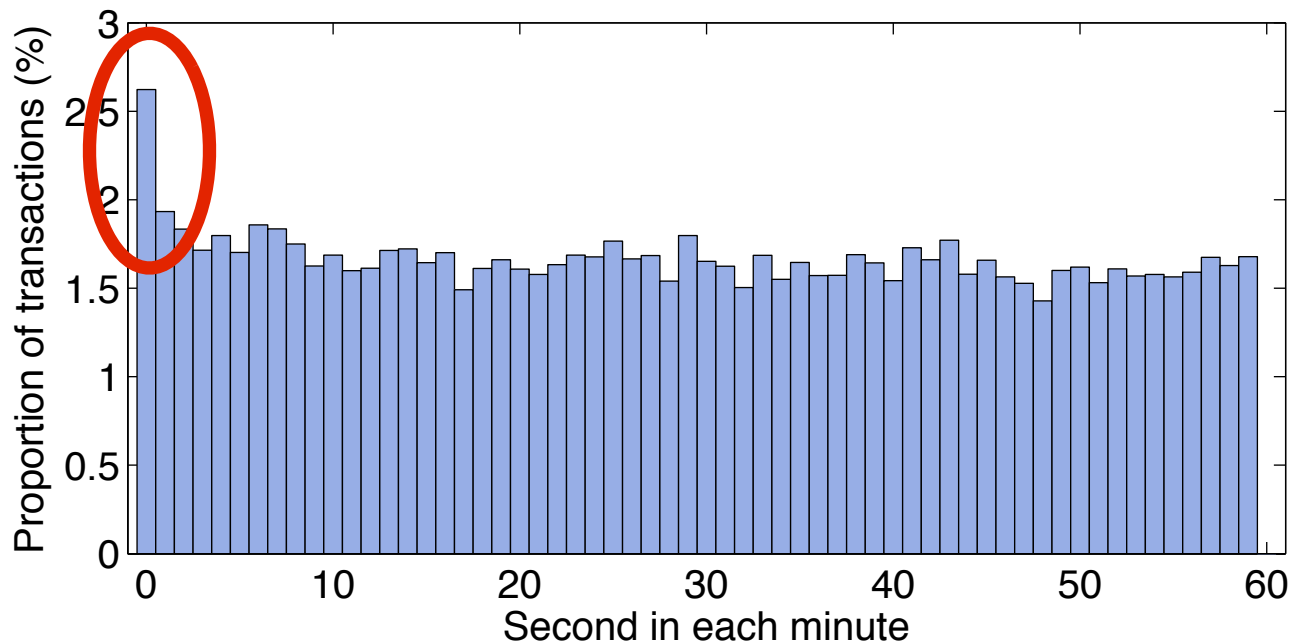
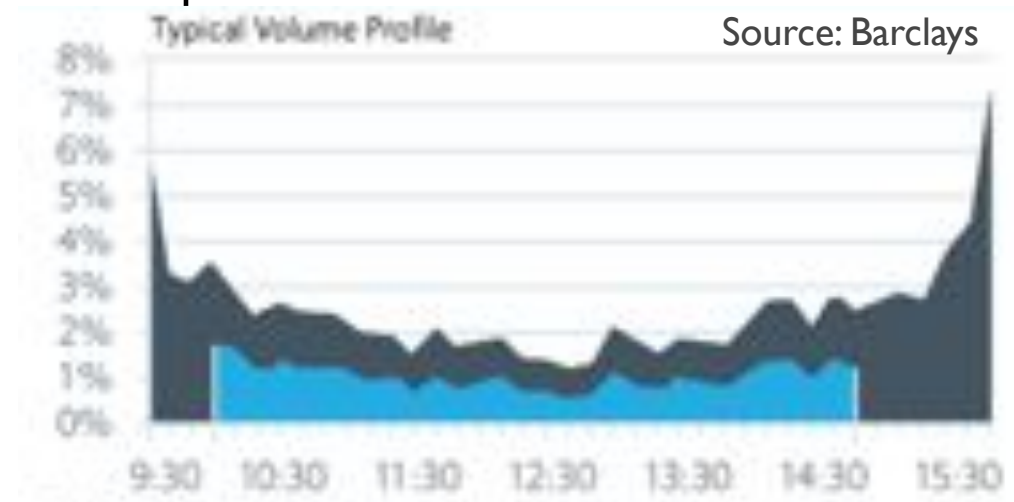
TWAP

Spreads the order out evenly over the user specified time frame.

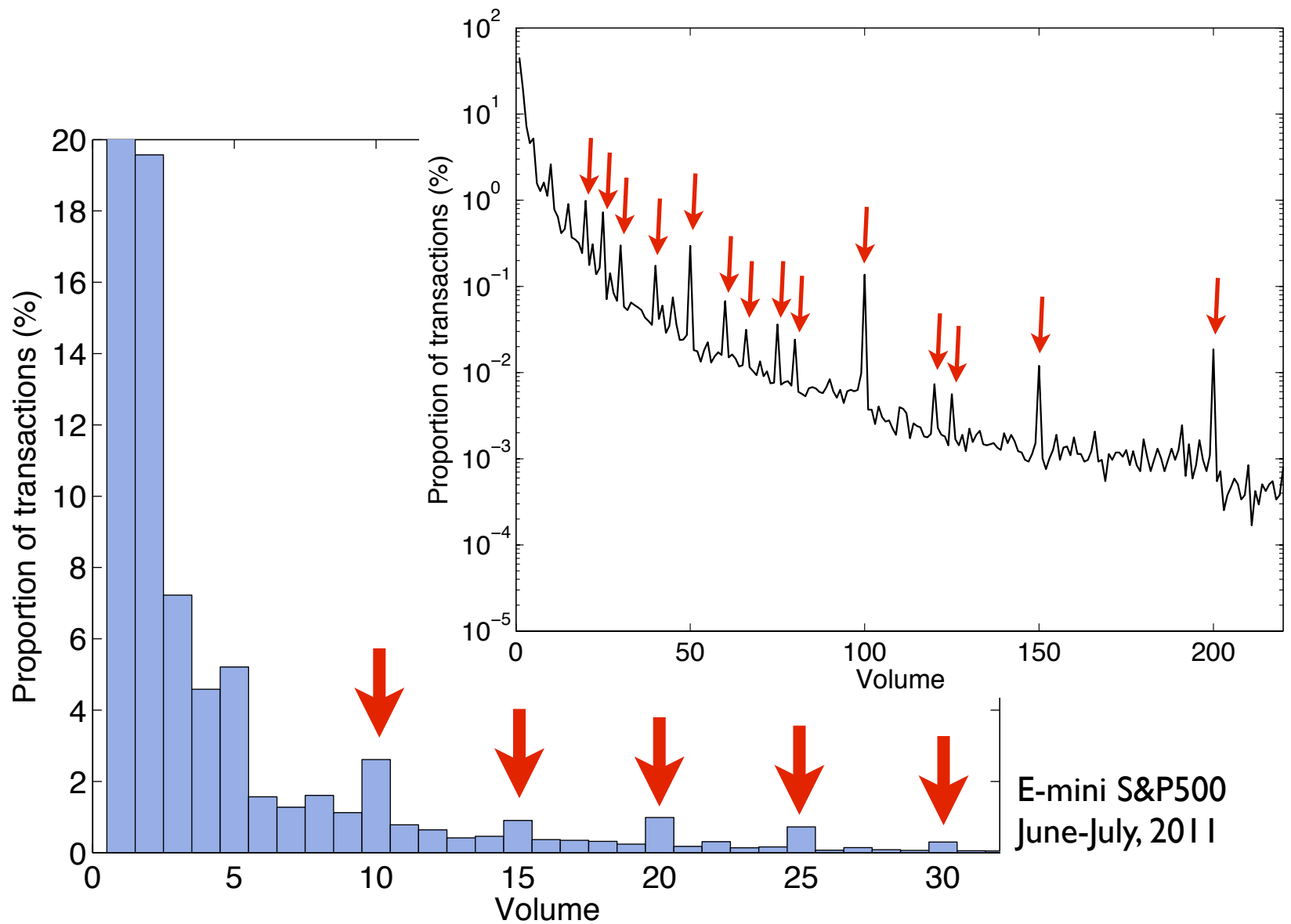


VWAP

Minimizes slippage against VWAP by targeting the stock's expected volume profile within the user specified time frame.



E-mini S&P500
June 13-25, 2011



Human hunting / “Quote Dangling”



Quote dangling: Sending quotes that force a squeezed trader to chase a price against her interests. As soon as the trader gives up, the dangler quotes back at the original level, and waits for the next victim.

Good or Evil?



HFT brings liquidity to markets
HFT reduces cost of trading
HFT corrects market inefficiencies

Speculative behavior
Market stability
Market fairness
Growth of dark and OTC trading
Market integrity
Technological stability

I believe high frequency trading is a clear and present danger to the stability and safety of our markets, and that its use should be curtailed immediately.

As a result, I wanted to remind the Commission that the Congress has already given the Securities and Exchange Commission broad powers to limit or ban this practice.

Member of Congress Edward J. Markey in his letter to SEC
January 18, 2013

High frequency traders (HFT) seem to be the evil red-headed step child of today's markets. [...]

The lawmakers proposing these regulations hope to increase market robustness and to pressure high-frequency firms (HFT) to provide either greater liquidity or to leave the markets entirely. The macro goal of these rules seems to be to slow down the markets, decrease speculation and intermediation, reduce gaming, and curtail short-term equity trading profitability. **If these rules are enacted, I'm not sure that we will experience the perfect market that regulators are hoping for.**

Larry Tabb, founder of TABB Group
October 01, 2012



Many predatory strategies could be already targeted under the existing laws against **market abuse**. Namely, it **is prohibited**:

- to perform transactions or place orders that send a misleading message concerning the offer, demand and price of a financial instrument; in particular - *to place orders without intention of performing transaction*;
- to perform transactions or place orders that maintain the price of a financial instrument at an artificial level;
- to perform transactions or place orders which deceive or mislead others when doing so.

Order-to-Trade (OTR) Fees

Country	Exchange	OTR	Fee
 Norway	Oslo Stock Exchange	70:1	NOK 0.05 (~EUR 0.007)
 Italy	Milan Stock Exchange	40:1 (AIM) 100:1 (MTA)	0.01; 0.02; 0.025
 Denmark	Nasdaq OMX	250:1	0.01
 Finland	Nasdaq OMX	250:1	0.01
 Sweden	Nasdaq OMX	250:1	0.01
 Germany	Xetra Frankfurt	2500:1 (DAX)	0.01-0.03

Order-to-Trade (or Order-to-Execution) Ratio Fee is a financial penalty for individual trading firms that is applied if the number of limit orders to buy or sell they enter do not lead to a “sufficient” number of trades.

Fees are charged on a monthly basis per every limit order above OTR limit.

Germany

Draft of the Law that have passed approval of the German Federal Cabinet (still in the discussion in the Parliament) includes a requirement that *HFT firms are obliged to be licensed*. The law also introduces fines for exceeding OTR.



France

French *Financial Transaction Tax (FTT)* has an HFT component which affects all companies that use algorithmic trading and execution. Taxes are applied based on the median time between order instructions and cancelation ratio threshold.



Italy

Similarly to France, FTT in Italy is linked to cancelled orders relating to trades on Italian markets. The law have passed legislation procedure and will be implemented starting March-July 2013.



1. Forbid Direct Electronic Access (DEA).
2. Establish circuit breakers within and between markets.
3. As part of a proper information collection framework to improve market surveillance:
 - a. Develop a unique identifier required for any HFT and automated transactions.
 - b. Request HFT firms to provide to regulators their algorithms' code on a regular basis.
 - c. Request HFT firms to provide their daily quotation and trading activity audit-trail.
4. Introduce a harmonized definition of market making.
5. Impose liquidity-providing obligations on HFT firms benefiting from a rebate for more than 30% of their trades.
6. Forbid privileged access to venues' order book, including flash orders.
7. Impose a minimum resting time of 1/2 second for orders in the order book.
8. Impose fees on orders cancelled above a 4:1 order-to-trade ratio.