A Market Design Perspective on the HFT Debate:
The Case for Frequent Batch Auctions

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A Simple Idea: Discrete-Time Trading

- My research identifies a simple structural flaw in the design of modern financial exchanges
- HFT has both positive and negative aspects – many of the negative aspects are symptoms of this structural flaw
- The flaw is that trading occurs in “continuous time”
  - Orders processed one-at-a-time in order of receipt (serial)
  - In a race, someone is always first (even if by a nanosecond)
- Solution: trade in “discrete time”
  - Time in units of e.g. 100ms or 10ms. (very fast, but a long time for a computer)
  - Orders processed all-at-once at end of time interval, using an auction (batch processing)
- Benefits of discrete-time trading, aka “frequent batch auctions”
  - Enhances liquidity: competition on speed -> price
  - Eliminates latency arbitrage. Stops the latency arms race
  - Simplifies the market computationally – for exchanges, regulators, algos, investors

(Source: Budish, Cramton and Shim, 2015, Quarterly Journal of Economics)
The Case for Frequent Batch Auctions

A simple idea: discrete-time trading.

1. Empirical facts: continuous markets don’t “work” in continuous time
   - Market correlations completely break down.
   - Frequent mechanical arbitrage opportunities.
   - Mechanical arbs → arms race. Arms race does not compete away the arbs, looks like a “constant”.

2. Root flaw: continuous-time trading
   - Mechanical arbs are “built in” to the market design. Sniping.
   - Harms liquidity.
   - Induces a never-ending, socially wasteful, arms race for speed.

3. Solution: frequent batch auctions
   - Competition on speed → competition on price.
   - Enhances liquidity and stops the arms race.
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Market Correlations Break Down at High Frequency

ES vs. SPY: 1 Day
Market Correlations Break Down at High Frequency

ES vs. SPY: 1 hour

![Chart showing ES and SPY index points over time, with a visible break down in correlations at high frequency.](chart.png)
Market Correlations Break Down at High Frequency

ES vs. SPY: 1 minute

Graph showing the midpoints of ES and SPY over time (CT).
Market Correlations Break Down at High Frequency

ES vs. SPY: 250 milliseconds
Arb Durations over Time: 2005-2011

Median over time

Distribution by year
Arb Per-Unit Profits over Time: 2005-2011

Median over time

Distribution by year
Arb Frequency over Time: 2005-2011

Frequency over time

Frequency vs. Volatility
Correlation Breakdown Over Time: 2005-2011
Latency Arb and Arms Race are “Constants” of the Market Design

To summarize:
- Competition **does** increase the speed requirements for capturing arbs (“raises the bar”)
- Competition **does not** reduce the size or frequency of arb opportunities
- Suggests we should think of latency arbitrage and the resulting arms race as a “constant” of the current market design
Analogy to UK Markets

FTSE 100 Futures vs. ETF

Euro Stoxx 50 Futures vs. ETF
Other Highly Correlated Pairs
Partial List

- E-mini S&P 500 Futures (ES) vs. SPDR S&P 500 ETF (SPY)
- E-mini S&P 500 Futures (ES) vs. iShares S&P 500 ETF (IVV)
- E-mini S&P 500 Futures (ES) vs. Vanguard S&P 500 ETF (VOO)
- E-mini S&P 500 Futures (ES) vs. ProShares Ultra (2x) S&P 500 ETF (SSO)
- E-mini S&P 500 Futures (ES) vs. ProShares UltraPro (3x) S&P 500 ETF (UPRO)
- E-mini S&P 500 Futures (ES) vs. ProShares Short Short S&P 500 ETF (SH)
- E-mini S&P 500 Futures (ES) vs. ProShares Ultra (2x) Short S&P 500 ETF (SDS)
- E-mini S&P 500 Futures (ES) vs. ProShares UltraPro (3x) Short S&P 500 ETF (SPXU)
- E-mini S&P 500 Futures (ES) vs. 500 Constituent Stocks
- E-mini S&P 500 Futures (ES) vs. 9 Select Sector SPDR ETFs
- E-mini S&P 500 Futures (ES) vs. E-mini Dow Futures (YM)
- E-mini S&P 500 Futures (ES) vs. E-mini Nasdaq 100 Futures (NQ)
- E-mini S&P 500 Futures (ES) vs. E-mini S&P MidCap 400 Futures (EMD)
- E-mini S&P 500 Futures (ES) vs. Russell 2000 Index Mini Futures (TF)
- E-mini Dow Futures (YM) vs. SPDR Dow Jones Industrial Average ETF (DIA)
- E-mini Dow Futures (YM) vs. ProShares Ultra (2x) Dow 30 ETF (UDOW)
- E-mini Dow Futures (YM) vs. ProShares Short Dow 30 ETF (DOG)
- E-mini Dow Futures (YM) vs. ProShares Ultra (2x) Short Dow 30 ETF (OXD)
- E-mini Dow Futures (YM) vs. ProShares UltraPro (3x) Short Dow 30 ETF (SDOW)
- E-mini Dow Futures (YM) vs. 30 Constituent Stocks
- E-mini Nasdaq 100 Futures (QQQ) vs. ProShares QQ Trust ETF (QQQ)
- E-mini Nasdaq 100 Futures (QQQ) vs. Technology Select Sector SPDR (XLK)
- E-mini Nasdaq 100 Futures (QQQ) vs. 100 Constituent Stocks
- Russell 2000 Index Mini Futures (TF) vs. iShares Russell 2000 ETF (IWM)
- Euro Stoxx 50 Futures (FE) vs. Xetra DAX Futures (FDAX)
- Euro Stoxx 50 Futures (FE) vs. CAC 40 Futures (FCE)
- Euro Stoxx 50 Futures (FE) vs. iShares MSCI EAFE Index Fund (EFA)
- Nikkei 225 Futures (NIY) vs. MSCI Japan Index Fund (EWH)
- Financial Sector SPDR (XL) vs. Constituents
- Financial Sector SPDR (XL) vs. Direxion Daily Financial Bull 3x (FAS)
- Energy Sector SPDR (XLF) vs. Constituents
- Industrial Sector SPDR (XLI) vs. Constituents
- Cons. Staples Sector SPDR (XLP) vs. Constituents
- Materials Sector SPDR (XLB) vs. Constituents
- Utilities Sector SPDR (XLU) vs. Constituents
- Technology Sector SPDR (XLK) vs. Constituents
- Health Care Sector SPDR (XLV) vs. Constituents
- Cons. Discretionary Sector SPDR (XLY) vs. Constituents
- SPDR Homebuilders ETF (XHB) vs. Constituents
- SPDR S&P 500 Retail ETF (XRT) vs. Constituents
- Euro FX Futures (6E) vs. Spot EURUSD
- Japanese Yen Futures (6J) vs. Spot USDJPY
- British Pound Futures (6B) vs. Spot GBPUSD
- Australian Dollar Futures (6A) vs. Spot AUDUSD
- Swiss Franc Futures (65) vs. Spot USDCHF
- Canadian Dollar Futures (6C) vs. Spot USD CAD
- Gold Futures (GC) vs. mNY Gold Futures (QO)
- Gold Futures (GC) vs. Spot Gold (XAUUSD)
- Gold Futures (GC) vs. E-mini Gold Futures (MGC)
- Gold Futures (GC) vs. SPDR Gold Trust (GLD)
- Gold Futures (GC) vs. iShares Gold Trust (IAU)
- E-mini Gold Futures (MGC) vs. SPDR Gold Trust (GLD)
- E-mini Gold Futures (MGC) vs. iShares Gold Trust (IAU)
- mNY Gold Futures (QO) vs. E-mini Gold Futures (MGC)
- mNY Gold Futures (QO) vs. Spot Gold (XAUUSD)
- mNY Gold Futures (QO) vs. SPDR Gold Trust (GLD)
- mNY Gold Futures (QO) vs. iShares Gold Trust (IAU)
- Silver Futures (SI) vs. mNY Silver Futures (QI)
- Silver Futures (SI) vs. iShares Silver Trust (SLV)
- Silver Futures (SI) vs. Spot Silver (XAGUSD)
- mNY Silver Futures (QI) vs. iShares Silver Trust (SLV)
- mNY Silver Futures (QI) vs. Spot Silver (XAGUSD)
- Platinum Futures (PL) vs. Spot Platinum (XPTUSD)
- Palladium Futures (PA) vs. Spot Palladium (XPDUSD)
- Eurodollar Futures Front Month (ED) vs. (12 back month contracts)
- 10 Yr Treasury Note Futures (ZN) vs. 5 Yr Treasury Note Futures (ZF)
- 10 Yr Treasury Note Futures (ZN) vs. 30 Yr Treasury Bond Futures (ZB)
- 10 Yr Treasury Note Futures (ZN) vs. 7-10 Yr Treasury Note
- 2 Yr Treasury Note Futures (ZT) vs. 1-2 Yr Treasury Note
- 5 Yr Treasury Note Futures (ZF) vs. 4-5 Yr Treasury Note
- 30 Yr Treasury Bond Futures (ZB) vs. iShares Barclays 20 Yr Treasury Fund (TLT)
- 30 Yr Treasury Bond Futures (ZB) vs. ProShares UltraShort 20 Yr Treasury Fund (TBT)
- 30 Yr Treasury Bond Futures (ZB) vs. ProShares Short 20 Year Treasury Fund (TBF)
- 30 Yr Treasury Bond Futures (ZB) vs. 15+ Yr Treasury Bond
- Crude Oil Futures Front Month (CL) vs. (6 back month contracts)
- Crude Oil Futures (CL) vs. ICE Brent Crude (B)
- Crude Oil Futures (CL) vs. United States Oil Fund (USO)
- Crude Oil Futures (CL) vs. ProShares Ultra DJ-UBS Crude Oil (UCO)
- Crude Oil Futures (CL) vs. iPath S&P Crude Oil Index (OIL)
- ICE Brent Crude Front Month (B) vs. (6 back month contracts)
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- Natural Gas (Henry Hub) Futures (NG) vs. United States Nat Gas Fund (UNG)
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Key idea: think about mechanical arbitrages from a liquidity provider’s perspective

- Suppose there is a publicly observable news event that causes his quotes to become “stale”
  - E.g., a change in the price of a highly correlated security, central bank announcement, company announcement
- Liquidity provider will try to adjust his stale quotes
- At same time, many others will try to “snipe” his stale quotes
- In a continuous limit order book, messages are processed one-at-a-time in serial ...
- so the 1 usually loses the race against the Many ...
- Even if he, too, is at the cutting edge of speed
Model: 3 Key Takeaways

1. Mechanical arbs like ES-SPY are “built in” to the market design
   ▶ *Symmetrically observed public information creates arbitrage rents.*
   ▶ This isn’t supposed to happen in an efficient market.
   ▶ OK to make money from asymmetric information, but symmetric information is supposed to get into prices for free. Market failure.

2. Profits from mechanical arbs come at the expense of liquidity provision
   ▶ In a competitive market, sniping costs get passed on to investors.
   ▶ Thinner markets, wider bid-ask spreads.

3. Sniping creates a never-ending race for speed
   ▶ Snipers: win race to pick off stale quotes.
   ▶ Liquidity providers: get out of the way of the snipers!
   ▶ HFT arms race is a *symptom* of flawed market design
Clarifying Remark: Role of HFTs

Role of HFTs

▶ In our model HFTs endogenously perform two functions
  ▶ Useful: liquidity provision / price discovery
  ▶ Rent-seeking: sniping stale quotes

▶ The rent-seeking may seem like zero-sum activity among HFTs
  ▶ But this misses the economics: sniping is like a tax on liquidity provision, which in turn harms non-HFTs

▶ Clarification
  ▶ Our results do not imply that on net HFT has been bad for liquidity or social welfare
  ▶ Our results do say that sniping is bad for liquidity and the speed race is socially wasteful
  ▶ Frequent batch auctions preserve (in a sense, enhance) the useful function that HFTs perform while eliminating sniping and the speed race
Block trade transaction costs have also fallen. The results presented above clearly show that indirect measures of market quality such as total trading volumes, average spreads, and average quoted sizes have improved over time. These measures indicate that transaction costs have dropped for small orders for which execution costs are easily predicted from bid/ask spreads and quotation sizes.

Although these results also suggest that transaction costs could have decreased for large institutional orders, this conclusion does not necessarily follow from the above evidence. The costs of trading large orders may have increased if traders can more easily front-run large orders in electronic markets than in floor-based markets. This issue lately has become a focus of attention for buy-side traders and regulators who are concerned about the effect of electronic markets on large institutional order transaction costs.

To address their concerns, we analyzed institutional traders from the Ancerno database of institutional trades. Ancerno provides transaction cost analysis services to various investment sponsors, managers, and brokers. The Ancerno database contains institutional trades that Ancerno’s clients have sent to Ancerno for analysis. The trades identify whether they are part of a larger block order. We thus can estimate the transaction costs associated with executing large orders that have been split into small parts for execution.
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Frequent Batch Auctions: Overview

- High level: analogous to the current market design but for two key differences
  - Time is treated as discrete, not continuous
  - Orders are processed in batch, not serial
Frequent Batch Auctions: Definition

- During the batch interval (e.g., 100 ms) traders submit bids and asks:
  - Can be freely modified, withdrawn, etc.
  - If an order is not executed in the batch at time $t$, it automatically carries over for $t + 1, t + 2, \ldots$.
  - Just like standard limit orders.

- At the end of each interval, the exchange “batches” all of the outstanding orders, and computes market-level supply and demand curves.

- If supply and demand intersect, then all transactions occur at the same market-clearing price (“uniform price”).

- Priority: still price-time, but treat time as discrete. Orders submitted in the same batch interval have the same priority. Pro-rata to break ties.

- Information policy: info is disseminated in discrete time. After each auction, all orders active for the auction displayed publicly:
  - Activity during the interval is not displayed publicly (gaming)
  - Discrete time analogue of current practice in a CLOB market.
Frequent Batch Auctions: 3 Cases

Case 1: Nothing happens during the batch interval

- Very common case: most instruments, most 100ms periods (or shorter), there is zero trade
- All outstanding orders carry forward to next interval
- Analogous to displayed liquidity in a LOB market

![Case 1: No Trade](image)
Frequent Batch Auctions: 3 Cases

Case 2: Small amount of trade

- Example: an investor arrives wanting to buy a small amount at market
- Demand will cross supply at the bottom of the supply curve
- Analogous to trading at the ask in a LOB market

![Graph showing price vs. quantity for Case 2: Investor Buys q*]
Frequent Batch Auctions: 3 Cases

Case 3: Burst of activity in the interval

- Example: there is public news and many algos respond
- In this case, FBA and CLOB are importantly different
- CLOB: process burst of activity based on order of receipt: competition on speed
- FBA: process burst of activity using an auction: competition on price
- Helps liquidity in 2 ways
  1. Liquidity providers have until end of interval to adjust their quotes to reflect new info
     - Being tiny bit slower than competition almost never matters
  2. Liquidity providers are protected by the auction: get a market consensus price based on new info
     - No more sniping. Public information induces price competition, not speed competition
Computational Benefits of Discrete Time

- **Overall**
  - Continuous-time markets implicitly assume that computers and communications technology are infinitely fast.
  - Discrete time respects the limits of computers and communications. Computers are fast but not infinitely so.

- **Exchanges**
  - Eliminates backlog problem (65ms on 10/15/2014, even for state-of-art matching engine)
  - Simplifies message processing (CME trade vs. book update issue)
  - Clock sync becomes simple

- **Algos**
  - Reduce incentive to trade off robustness for speed

- **Regulators**
  - Simplifies audit trail: no need to adjust for latency, relativity
  - “Level playing field” in access to public info – impossible in continuous time

- **Investors**
  - Easier to assess best execution.
Costs and Benefits of Frequent Batch Auctions

- **Benefits**
  - Enhanced liquidity
  - Eliminate socially wasteful arms race
  - Computational benefits of discrete time

- **Costs**
  - Investors must wait until the end of the batch interval to transact

- **We should also be wary of unintended consequences**
  - But remember that the continuous market has itself had numerous unintended consequences which discrete time directly addresses
Alternative Responses to the HFT Arms Race

- Numerous alternative responses: mostly address symptoms, not root cause
- "Bans" on HFT
  - Message ratios, minimum resting times
  - Misunderstand cause and effect
  - Resting times likely to exacerbate sniping
- Taxes on HFT
  - Transaction tax directionally addresses sniping but is a blunt instrument
    - tax would need to be large to effect the arms race
    - cost gets passed on to investors
  - Cancellation tax would increase cost of liquidity provision, which naturally requires cancellations as prices move
  - Tax avoidance + increased complexity
- IEX speed bump + price sliding to NBBO midpoint
  - Eliminates sniping ...
  - But only for non-displayed "pegged" orders that free-ride off of prices discovered elsewhere (see SEC comment letter)
Chicago Question

If discrete time is such a good idea, why isn’t somebody already doing it?
Why Aren’t Exchanges Already Doing This?

1. Relatively new idea
   - Auctions of course are an old idea, but this specific market design is new (and is importantly different from traditional call auctions, beyond just the frequency)
   - New ideas take time to be adopted
2. Regulatory ambiguities

- Reg NMS in US implicitly assumes continuous time (see my IEX comment letter)

- SEC Chair White, in her June 2014 speech “Enhancing our Equity Market Structure”:

  *I am personally wary of prescriptive regulation that attempts to identify an optimal trading speed, but I am receptive to more flexible, competitive solutions that could be adopted by trading venues. These could include frequent batch auctions or other mechanisms designed to minimize speed advantages.*

  *... A key question is whether trading venues have sufficient opportunity and flexibility to innovate successfully with initiatives that seek to deemphasize speed as a key to trading success in order to further serve the interests of investors. If not, we must reconsider the SEC rules and market practices that stand in the way.*
Why Aren’t Exchanges Already Doing This?

3. Coordination Challenge
   - Need to coordinate algorithmic liquidity providers, broker-dealers, investors, etc.
   - This is a standard issue in starting a new marketplace

4. Vested Interests in the Status Quo
   - Exchanges provide arms for the arms race
     - Colocation
     - Latency-sensitive data feeds
     - Substantial proportion of exchange revenues (>60% for BATS in 2011 per S-1 filing)
   - The fact that frequent batch auctions improve market quality does not imply that they improve exchange profitability
So, What Next?

- How do we get from continuous-time $\rightarrow$ discrete-time?
- Approach 1: private sector innovation.
  - Potential frictions:
    - Regulatory ambiguities
    - Coordination challenge
    - Vested interests in the current market structure
- Approach 2: regulatory intervention
  - Potential friction: chicken-and-egg problem
    - Regulatory authorities want a high level of proof (rightly so).
    - But, to fully prove the case, someone has to try it first.
- Three things we can hopefully all agree on
  1. Eliminate regulatory ambiguities
  2. Value of a pilot test
  3. Data availability for researchers (currently either very expensive or altogether impossible)
Summary

- We take a market design perspective to the HFT debate.
- Root problem isn’t “evil HFTs”, it’s continuous-time trading.
- Alternative: discrete-time trading

1. Direct-feed data: continuous-time markets don’t actually work in continuous time: correlations completely break down; frequent mechanical arbs; never-ending arms race
2. Theory: root cause is the current market design
3. Solution: frequent batch auctions
   - Enhances liquidity
   - Eliminates sniping
   - Stops the latency arms race
   - Simplifies the market