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

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The Evolving Structure of the US Treasury Market

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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 processsed 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.
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3. Solution: frequent batch auctions
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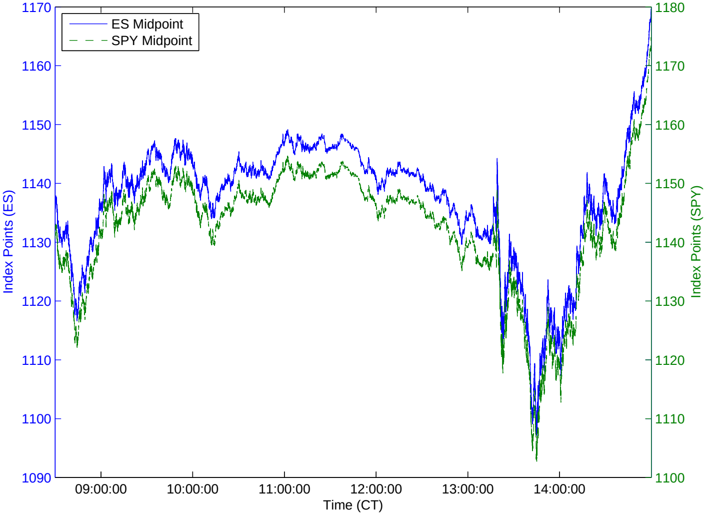
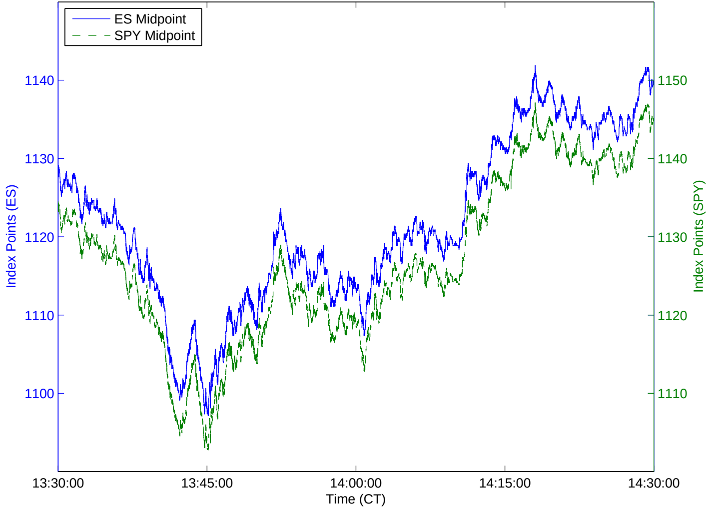
Market Correlations Break Down at High Frequency

ES vs. SPY: 1 Day



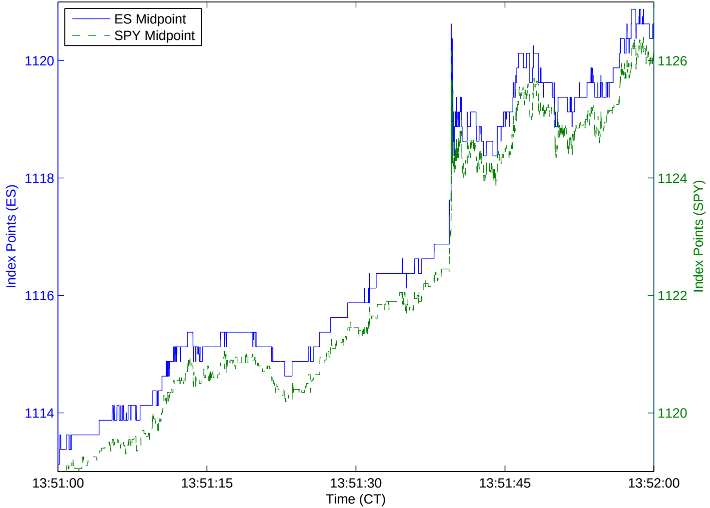
Market Correlations Break Down at High Frequency

ES vs. SPY: 1 hour



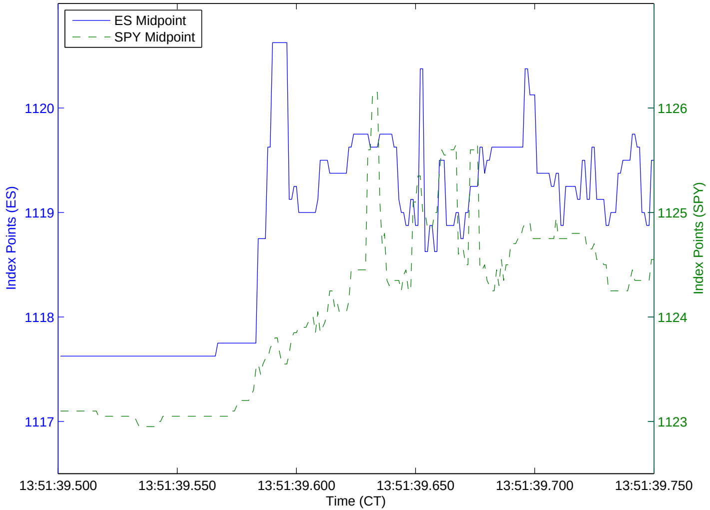
Market Correlations Break Down at High Frequency

ES vs. SPY: 1 minute



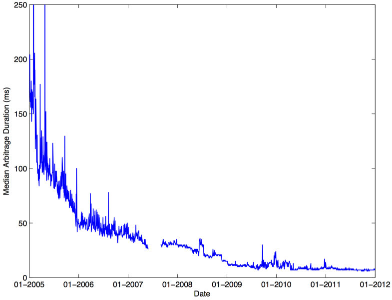
Market Correlations Break Down at High Frequency

ES vs. SPY: 250 milliseconds

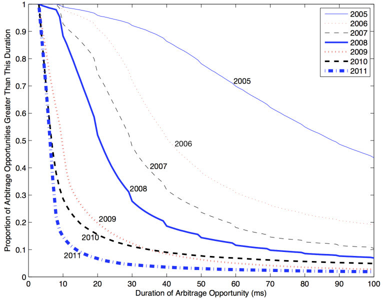


Arb Durations over Time: 2005-2011

Median over time

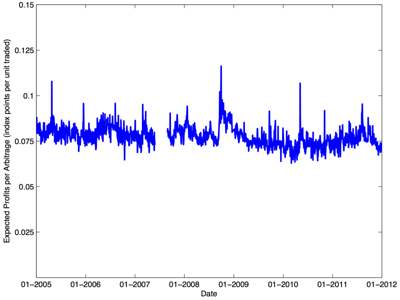


Distribution by year

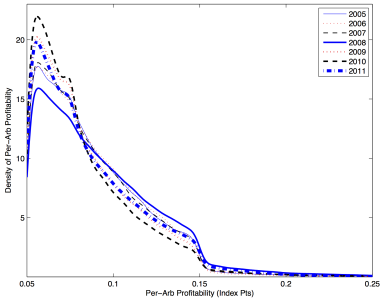


Arb Per-Unit Profits over Time: 2005-2011

Median over time

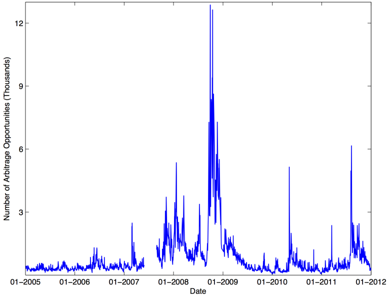


Distribution by year

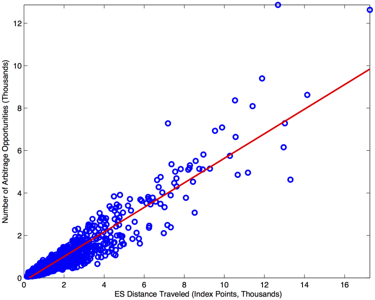


Arb Frequency over Time: 2005-2011

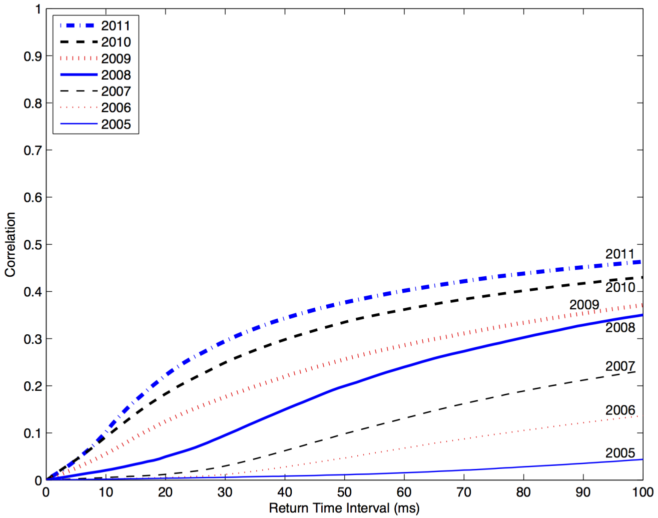
Frequency over time



Frequency vs. Volatility



Correlation Breakdown Over Time: 2005-2011



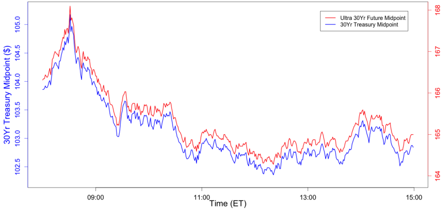
Latency Arb and Arms Race are "Constants" of the Market Design

To summarize:

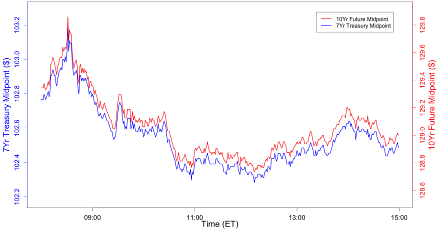
- Competition <u>does</u> increase the speed requirements for capturing arbs ("raises the bar")
- Competition <u>does not</u> reduce the size or frequency of arb opportunities
- Suggests we should think of latency arbitrage and the resulting arms race as a "constant" of the current market design

Analogy to the US Treasury Market

30 year ultra future vs. 30 year cash



10 year future vs. 7 year cash



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 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 (DDM)
E-mini Dow Futures (YM) vs. ProShares UltraPro (3x) 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 (DXD)
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 (NQ) vs. ProShares QQQ Trust ETF (QQQ)
E-mini Nasdaq 100 Futures (NQ) vs. Technology Select Sector SPDR (XLK)
E-mini Nasdaq 100 Futures (NQ) vs. 100 Constituent Stocks
Russell 2000 Index Mini Futures (TF) vs. iShares Russell 2000 ETF (IWM)
Euro Stoxx 50 Futures (FESX) vs. Xetra DAX Futures (FDAX)
Euro Stoxx 50 Futures (FESX) vs. CAC 40 Futures (FCE)
Euro Stoxx 50 Futures (FESX) vs. iShares MSCI EAFE Index Fund (EFA)
Nikkei 225 Futures (NIY) vs. MSCI Japan Index Fund (EWJ)
Financial Sector SPDR (XLF) vs. Constituents
Financial Sector SPDR (XLF) vs. Direxion Daily Financial Bull 3x (FAS)
Energy Sector SPDR (XLE) 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 (6B) vs. Spot AUDUSD
Swiss Franc Futures (6S) vs. Spot USDCHF
Canadian Dollar Futures (6C) vs. Spot USDCAD
Gold Futures (GC) vs. miNY Gold Futures (QO)
Gold Futures (GC) vs. Spot Gold (XAUUSD)
Gold Futures (GC) vs. E-micro Gold Futures (MGC)
Gold Futures (GC) vs. SPDR Gold Trust (GLD)
Gold Futures (GC) vs. iShares Gold Trust (IAU)
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E-micro Gold Futures (MGC) vs. Spot Gold (XAUUSD)
Market Vectors Gold Miners (GDX) vs. Direxion Daily Gold Miners Bull 3x (NUGT)
Silver Futures (SI) vs. miNY Silver Futures (QI)
Silver Futures (SI) vs. iShares Silver Trust (SLV)
Silver Futures (SI) vs. Spot Silver (XAGUSD)
miNY Silver Futures (QI) vs. iShares Silver Trust (SLV)
miNY 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
2 Yr Treasury Note Futures (ZT) vs. iShares Barclays 1-3 Yr Treasury Fund (SHY)
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)
ICE Brent Crude (B) vs. United States Oil Fund (USO)
ICE Brent Crude (B) vs. ProShares Ultra DJ-UBS Crude Oil (UCO)
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Natural Gas (Henry Hub) Futures (NG) vs. United States Nat Gas Fund (UNG)

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Model: Key Idea

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 (ES, 10yr), Fed announcement, company announcement (WMT)
- 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!

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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

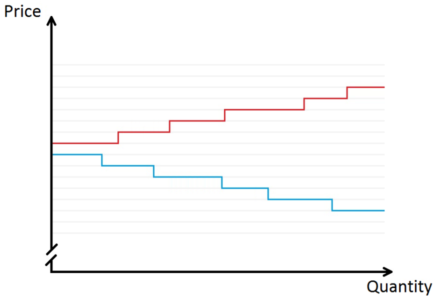
Frequent Batch Auctions: Definition

- During the batch interval (eg 100ms) traders submits 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

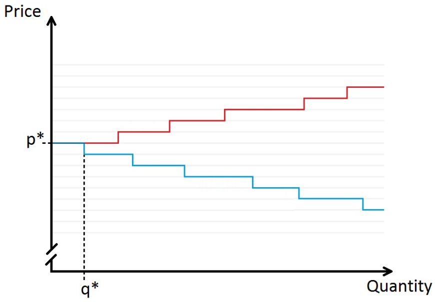


Case 1: No Trade

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



Case 2: Investor Buys q*

Frequent Batch Auctions: 3 Cases

Case 3: Burst of activity in the interval

- Example: there is public news (jump in ES, 10yr, WMT, Fed, etc) 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
  - Unintended consequences (but: remember that the continuous market has itself had numerous unintended consequences which discrete time 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

So, What Next?

- How do we get from continuous-time –> discrete-time?
- Approach 1: private sector innovation.
  - Chicago question: if this is such a good idea, why hasn't an exchange already tried it?
  - Potential frictions:
    - Coordination challenge
    - Regulatory ambiguities
    - 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.
- Two things we can hopefully all agree on
  1. Value of a pilot test (e.g., in a specific cash treasury market)
  2. Data availability for researchers (currently either very expensive or altogether impossible)