ROTTERDAM SCHOOL OF MANAGEMENT
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High-Frequency Trading
and
Market Stability

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and lives in the future

HFT & MARKET STABILITY - MOTIVATION

In recent years, regulatory and technological innovations have induced a new form of electronic market making to arise:

High-Frequency Trading (HFT)

Key features of these new “middlemen”:

- Superior information processing: not necessarily possess private information, but faster to process “hard information” (e.g. patterns in the order book)
- Low latency: speed is key (milliseconds)

HFT & MARKET STABILITY - MOTIVATION

Reducing latency – further background:

- HFTs invest heavily in costly technology to improve computing power (“race to zero”)
- Trading platforms offer “co-location services”, and compete to attract HFTs
- “Low-Frequency Traders” (LFTs) could join the race, move to liquidity-demanding strategies or divert to other trading platforms

➔ HFT emergence induced changes in market structure

➔ HFTs involved in 55% of all daily US equity trading volume, 45% of European (Tabb, 2012)

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What are the effects of HFT on financial markets ?

HFT & MARKET STABILITY - MOTIVATION

Existing empirical results on HFT:

- Improves liquidity
  Hendershott, Jones and Menkveld (2011), Brogaard (2010), Kirilenko et al (2010), Jovanovic and Menkveld (2012)
- Does not increase volatility, may even dampen it
  Chaboud et al (2009), Hasbrouck and Saar (2010)
- Improves price discovery
  Hendershott and Riordan (2010), Brogaard (2010), Kirilenko et al (2010), Brogaard et al (2012), Jovanovic and Menkveld (2012)

➔ HFT makes market more efficient and more liquid

➔ Investors can make better portfolio decisions at lower costs

HFT & MARKET STABILITY - MOTIVATION

Existing theoretical results on HFT:

- Algorithms improve market liquidity by bypassing human limited cognitive abilities to process large-scale info

  Biais, Hombert and Weill (2010)

- Heterogeneity in processing speed generates additional adverse selection, and overinvestment in speed from a welfare perspective

  Biais, Foucault and Moinas (2011)

- HFTs act as “middlemen” and reduce adverse selection related to non-simultaneous trader arrival

  Jovanovic and Menkveld (2012)

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HFT & MARKET STABILITY - MOTIVATION

Open questions (SEC, 2010; CESR, 2010; Foucault, 2012):

- **Liquidity**: is HFT liquidity more likely to evaporate in turbulent times?
- **Distributional issues**: do “fast” HFTs make profits at expense of “slow” LFTs (long-term investors, traditional market makers, ….)? Or does fast trading benefit all investors?
- **Systemic Risk**: does HFT increase the risk of market crashes? Are markets more fragile?

➔ We construct a dynamic limit order book model to address these issues

➔ Guidance for regulators + future empirical work

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Market setting:

- Single asset, traded on a limit order book (LOB)
- Repeated game in continuous time
  - every iteration identical
  - steady state solutions
- Ask side of the book (bid side analogous)
- Pricing grid with discrete tick size
- Undercut quotes are cancelled
- Public fundamentals-based value in given iteration: μ
  - $p(1)$ lowest ask quote on grid larger than μ

Liquidity providers (sell limit orders):

- LFTs:
  - Fixed number N, all identical
  - Arrive to the market with intensity λ
  - Observe full history of LOB, but unable to process this information at high speed
  - Participation cost C_{LFT}

Liquidity providers (sell limit orders):

- HFTs:
  - Fixed number *M*, all identical
  - Arrive to the market with intensity $\gamma\lambda$, with $\gamma \geq 1$ (lower monitoring cost) **= SPEED ADVANTAGE**
  - Observe full history of LOB, and able to process this information at high speed **= SUPERIOR INFORMATION PROCESSING**
  - Participation cost C_{HFT}

Liquidity demanders (buy market orders):

- Liquidity traders (*liq*):
  - Reservation value $p_{liq} > \mu$
  - Arrive to the market with intensity λ_{liq}
  - Unit demand size

- Informed traders (*inf*):
  - Private information that value is $p_{inf} > p_{liq}$
  - Arrive to the market with intensity $\lambda_{inf} > \lambda_{liq}$
  - Unit demand size, replicating liquidity traders

Informational setting:

- State of nature ζ_I in iteration I, with $\zeta_I \in \{inf, liq\}$:
  - Randomly drawn at start of each iteration
  - Markov transition matrix

    $\alpha : liq \rightarrow liq \quad 1-\alpha : liq \rightarrow inf$

    $\beta : inf \rightarrow inf \quad 1-\beta : inf \rightarrow liq$
  - States are persistent
    - Consistent with clustered informed trading (Admati and Pfleiderer, 1988)
    - Allows for learning based on timing of trades in previous iteration(s) and inference on current state by HFTs
- Public information releases between iterations consistent with private information
  - Yet uninformative about future states of nature

HFT & MARKET STABILITY - SETUP

Timing of the trading game:

1. HFTs and LFTs decide on participation
2. Iteration 1 starts, state of nature ζ_1 is drawn
3. Liquidity providers randomly arrive to the market and can post sell limit orders
4. Liquidity demander posts buy market order and executes at standing best ask quote
5. Game starts over (iteration 2) from step 2

Equilibrium definition:

- Nash
  - Every player plays optimal strategies
- Two stage strategy
  - Participation and undercutting decision

HFT & MARKET STABILITY – THREE GAME VERSIONS

Three versions of the game:

1. Uninformed case
   - Easy to solve
   - Important building block for “restricted informed case”
2. Restricted informed case
   - Perfect learning by HFTs about previous states
   - Solvable and relatively high tractability
   - Yields main insights paper
3. Fully general model
   - Most realistic
   - Extremely hard to solve and intractable
   - Implicit or numerical solutions at best

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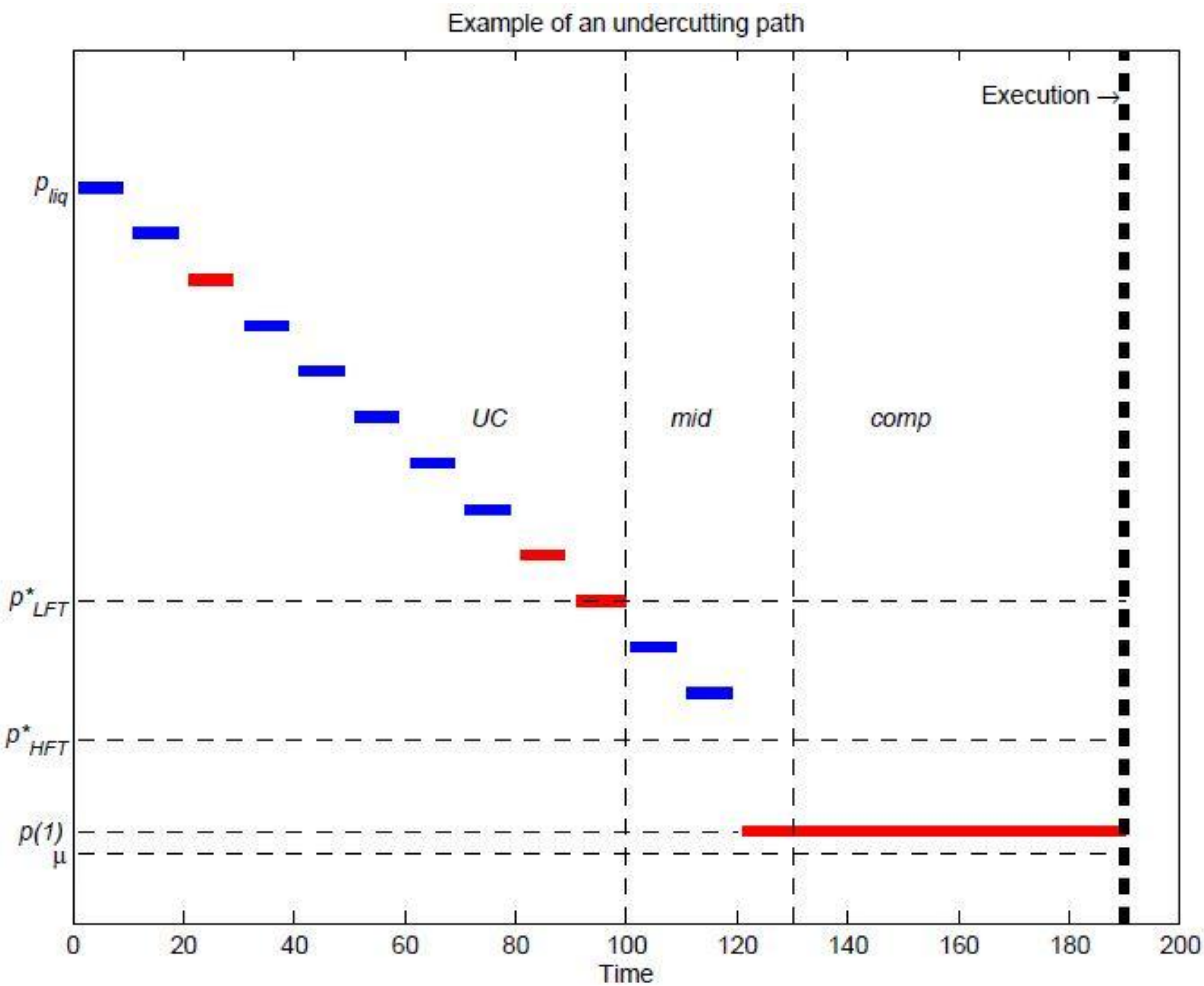
1. Uninformed case

- No information asymmetry
- Always optimal to undercut standing best ask quote
- Trade-off: margin vs execution probability
  - Execution guaranteed at competitive price *p(1)*

HFT & MARKET STABILITY – UNINFORMED CASE



1. Uninformed case - main results:

- More intense competition and/or faster HFTs (γ)
  - Quicker undercutting (shorter order exposure)
  - More aggressive strategies (higher p^*_k , more so for LFT)
  - Lower average profit margin (more so for LFT)
- HFTs “outrace” LFTs in providing liquidity to uninformed order flow due to their technology advantage (γ)
- Liquidity high + price discovery fast !!!

1. Uninformed case - main results:

- Participation
  - Trade-off participation costs (C_{LFT} and C_{HFT}) against expected profits on three parts of equilibrium path
  - Expected profits are monotonically decreasing in M and N
  - Derive M^* and N^* such that participation for M^*+1 or N^*+1 not optimal

- Main trade-off = "cost of speed" of liquidity provision:

$$\frac{\gamma}{C_{HFT}} > \frac{1}{C_{LFT}} \Rightarrow only\ HFTs$$

$$\frac{\gamma}{C_{HFT}} < \frac{1}{C_{LFT}} \Rightarrow only\ LFTs$$

2. Restricted informed case

- Market not necessarily dominated by HFTs or LFTs:

“cost of speed”

vs

“superior information processing”

2. Restricted informed case

- Extremely aggressive informed trader: $\lambda_{inf} = \infty$
- Remember: *inf* and *liq* states of nature evolve as Markov transition matrix, clustered informed trading

➔ Perfect learning HFT about ζ_{l-1}

- Markov Perfect Equilibrium
- Useful to forecast ζ_l and avoid incoming informed order flow

➔ Perfect learning LFT from standing best quote

- Receive more “toxic” order flow at initial quote

➔ Reduces to problem of posting initial quote

➔ Undercutting is safe, uninformed case then applies

2. Restricted informed case

- Initial quote for HFT
  - Learning not very helpful:
    - Never post if $p_{inf} >> p_{liq}$
    - Always post if p_{inf} close to p_{liq}
  - Learning very helpful:
    - Condition on $\zeta_{l\text{-}1}$ $(\approx PIN)$

- Initial quote for LFT
  - Cannot condition on anything except current state of LOB
  - Adverse selection concerns when arriving to empty LOB:
    - Only when HFTs do condition in equilibrium
    - Not worthwhile to post initial quote if p_{inf} large enough

➔ Potential market freeze !

2. Restricted informed case – properties of freeze

- LFTs get crowded out, but lowering *N* problematic
  - Inference remaining LFTs more accurate
  - Toxic order flow spread among lower *N*
- LFTs are needed to keep the market going, too many HFTs can destroy their own market !

(<u>Note:</u> even incorrectly submitted market orders (e.g. fat-finger error) could trigger freezes in limit order markets featuring HFTs)

2. Restricted informed case – “unfreezing”

- Impatience uninformed liquidity demander
  - Model: after τ periods in freeze reservation price and arrival intensity jump
  - Only HFTs can time right
  - Speculative profits for HFTs in illiquid market restart trading
    - ➔ Costs borne by liquidity demanders

2. Restricted informed case – “unfreezing”

- Increasing costs to liquidity providers
  - HFTs and LFTs incur costs increasing in the duration of the freeze
    - Foregone future rents
    - Costs related to e.g. margin, regulatory scrutiny, …
  - Liquidity suppliers initially shun markets, but over time get incentivized to restore the market
    - Arguably, these costs are higher for HFTs, which are faster inclined to restore markets

3. General case

- More patient informed traders: $\infty > \lambda_{inf} > \lambda_{liq}$
- HFT inference from all historical iterations and survival in current iteration
- HFT strategy depends on expected execution probability
  - Which in turn depends on LFT strategy
- LFT learning problem very hard
  - Need to integrate over all possible histories
  - Tractability goes out the window
  - Implicit or numerical solutions at best
- Intuition and results similar

Conclusion

Our paper addresses a set of open questions on the impact of HFTs, we find that:

- LFTs are crowded out by HFTs, they:
  - Are pre-empted by faster HFTs in good times
  - Receive more toxic informed order flow in bad times
- As a result:
  - With low informed trading: liquidity/price discovery increases with more/faster HFTs, in line with the empirical literature
  - With higher informed trading: low liquidity, slow price discovery, market freezes occur with greater probability in the absence of LFTs
- LFTs are needed to keep the market going!

Future work

- Welfare analysis
- Assess effectiveness of regulatory measures (FTT, latency restrictions, affirmative liquidity provision, …)