Exploratory Trading
Theory and Evidence

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The views expressed in this presentation are my own and do not constitute an official position of the U.S. Commodity Futures Trading Commission, its Commissioners or staff.
What do high-frequency traders (HFTs) actually do?

I.e., how/why do their strategies work?
Difficult to analyze HFTs’ effects on markets without first understanding this

Some HFTs basically act like market-makers

What are the other HFTs doing?

If you don’t provide liquidity/immediacy, bear systematic risk, or look at something besides market data, how do you make money?
Concrete Empirical Details

- Empirical context: E-mini S&P 500 futures market
- The E-mini market operates as an order-driven market
  - Order that initiates a transaction called the “aggressive” order
  - “Aggressive” = shorthand for “transaction-initiating”
- How do HFTs manage to profit from their aggressive orders?
- I identify 30 HFTs in the E-mini market (more details shortly)
  - Earn a combined avg of $\approx 1.51$ million per trading day
  - Participate in $\approx 46.7\%$ of total E-mini trading volume
Profits on Aggressive Orders

- As a group, HFTs earn 41% of their profits on aggressive orders.
- Individually, eight HFTs (“A-HFTs”) profit on aggressive orders.
  - A-HFTs: 52.7% of HFT profits, 67.8% of HFT aggressive volume.
- *How do the A-HFTs profit from their aggressive orders?*
- Clue: all eight A-HFTs lose money on their smallest aggressive orders.
Basic strategy:

- Learn about supply elasticity using small “exploratory” orders
- Trade in front of foreseeable demand when supply is inelastic

In the E-mini market, demand is extremely predictable

- *On average*, trading in front of predictable demand is not profitable

Exploratory trading helps to identify when trading in front will be profitable
Why Explore At All?

- Looking at the orderbook isn't enough
  - The (static) levels of resting depth in the orderbook are not very informative
- Need info about the *dynamic* state of the orderbook
  - Specifically, how resting depth responds to the arrival of aggressive orders
Why Explore, Yourself?

- Looking at the response to other traders’ orders isn’t as informative
  - Endogeneity between aggressive orders and orderbook activity
    1. \([\text{AggressiveOrder}] \rightarrow \text{causes} \rightarrow [\text{OrderbookActivity}]\)
    2. \([\text{OtherEvent}] \rightarrow \text{causes} \rightarrow [\text{AggressiveOrder}] \rightarrow \text{causes} \rightarrow [\text{OrderbookActivity}]\)
- My exploratory orders are placed for exogenous reasons
- Anonymity: this exogeneity is private information
Market response to an A-HFT’s small aggr orders provides information that is:

- Valuable
  - Explains significant component of that A-HFT’s performance
  - I.e., incidence, earnings of larger aggr orders placed after

- Private
  - Does not explain other traders’ performance

I’ll call the private part of the market-response signal, “exploratory information”
Description of the Data

- All E-mini “business messages” from 9/17/2010 through 11/1/2010
- Transactions, as well as order entries, cancellations, modifications
  - Price, quantity, order ID, millisecond time-stamp, etc.
  - Account ID (!)
Defining “HFT” in the E-Mini Market

- Minimal accumulation of directional positions
- High turnover in inventory
- High levels of trading activity
  - Rank accounts that meet the first two criteria, using total trading volume
  - “HFTs”: top 30 of these accounts by total volume
  - Results unchanged using (e.g.) top 15, 45, or 60
HFTs’ Aggressive Order Profitability

- Estimate aggressive order profits via subsequent price changes
  - Expected profit equals favorable price change, minus:
    - Half the bid-ask spread ($6.25)
    - Trading/clearing fees ($\approx 0.12$ for HFTs)
  - Eight HFTs clear the $6.25 + fees$ hurdle
    - These 8 are the “A-HFTs”
  - A-HFT aggressive order avg. gross earnings: $7.65/contract$
Empirical Predictions (Recall)

- Market response to an A-HFT’s small aggr orders provides info that is both valuable and private, i.e.,
  - Explains significant component of that A-HFT’s performance
  - Does not explain other traders’ performance
- Make “small” precise by specifying a cutoff, $\bar{q}$, for order-size
- Also need to make precise:
  - “Market response”
  - “Explaining performance”
Market Response Measure

Use change in resting depth, but just its *direction* (for simplicity)

- Define indicator variable $\Omega$ for a given $\bar{q}$ by

$$
\Omega_k = \begin{cases} 
1 & \text{if } DC (k; \text{any}, \bar{q}) > 0 \\
0 & \text{otherwise}
\end{cases}
$$

- $DC (k; \text{any}, \bar{q})$ : depletion after last small aggr order by anyone
- Define $\Omega^A$ likewise, but use depth depletion after last small aggr order *placed by the specified A-HFT*
- $\Omega$ should contain all the public info in $\Omega^A$
Explaining Aggressive Order Performance

- Forecast $y_k$, cumulative price change after aggressive order $k$:

$$y_k = \gamma_1 \Delta d_{k-1}^1 + \ldots + \gamma_6 \Delta d_{k-1}^6$$
$$+ \gamma_7 \text{sign}_{k-1} + \ldots + \gamma_{10} \text{sign}_{k-4}$$
$$+ \gamma_{11} q_{k-1} + \ldots + \gamma_{14} q_{k-4} + \epsilon_k$$
$$: = z_{k-1} \Gamma + \epsilon_k$$

- $\Delta d_{k-1}^r$: change in orderbook depth at price level $r$
  - $r = 3$ is best bid, $r = 4$ is best ask

- $\text{sign}_l = \text{sign of aggressive order } l$

- $q_l = \text{signed quantity of aggressive order } l$
Empirical Strategy: Overview

- Augment the baseline regression \( y_k = z_{k-1} \Gamma + \varepsilon_k \) using:
  - 1) Market response info from last small aggr order by anybody
    - i.e., partition just using \( \Omega \)
  - 2) Also using market response info from last small aggr order placed by a specified A-HFT
    - i.e., partition using \( \Omega \) and \( \Omega^A \)

- Find the additional component of performance on larger aggressive orders explained by (2) relative to (1)
  - This is the performance explained by private info in \( \Omega^A \)
  - Compare this between the specified A-HFT and everyone else
Results: Additional Explained Performance
A-HFT and Everyone Else

Average Additional Performance Explained (95% Confidence Intervals)

- A-HFT
- Everyone Else

Cents per Contract

q-Bar

0 5 10 15 20

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9

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Difference in Additional Explained Performance
A-HFT vs. Everyone Else

[A-HFT Addt'l Explained] - [Everyone Else Addt'l Explained] (95% CIs)
Bootstrap [sic] Simulations

Bootstrapping with Trading Robots

- Goal: assess gains from explo info, including avoided bad aggressive orders
- Construct feasible trading strategies based on baseline regression
  - Place aggressive order iff $|\hat{y}_k|$, $DC(k; any)$ large enough, and
    - 1) Nothing else
    - 2) $DC(k; AHFT)$ above 50th percentile
    - 3) $DC(k; AHFT)$ above 99th percentile
- Simulate performance using market data
Broader Opportunities for Exploratory Gains

- A-HFTs’ *small* aggressive orders need not be the sole source of exploratory information
- Repeat the earlier analysis for $\bar{q} = 25, \ldots, 90$
  - Find exploratory effects larger than those for $\bar{q} = 1, 5, \ldots, 20$
  - The A-HFTs’ added orders past $\bar{q} = 20$ are directly profitable
- Natural economies of scale for the A-HFTs
  - Potential barrier to entry
Broader Opportunities for Exploratory Gains

[A-HFT Addt'l Explained] - [Everyone Else Addt'l Explained] (95% Conf. Bands)
Conclusion: Market Quality Implications

- Most important point: A-HFTs engage in costly information acquisition via exploratory trading
  - I.e., not just reacting to public information first
  - Unique contribution to the price-discovery process (?)

- Our exploration continues...
Simplified Model

- Order-driven market, two periods $t = 1, 2$
- Three possible states for future aggressive order flow, $\varphi$:
  - $\varphi \in \{-1, 0, +1\}$
- Two possible liquidity states, $\Lambda$:
  - Accommodating ($\Lambda = A$) or unaccommodating ($\Lambda = U$)
- Liquidity and future aggressive order flow determine price-change after period 2, $y$:
  - Unaccommodating ($\Lambda = U$): $y = \varphi$
  - Accommodating ($\Lambda = A$): $y = 0$, regardless of the value of $\varphi$
Model Timeline

- Consider a single trader ("HFT")
  - Places only aggressive orders, size \( \leq N \)
  - Pays constant trading costs \( \alpha \in (0.5, 1) \) per contract

- \( t = 1 \)
  - HFT can submit an aggressive order (or not)
  - If HFT submits an aggressive order, he learns liquidity state

- \( t = 2 \)
  - HFT observes signal of future aggressive order flow \( \varphi \)
  - HFT can submit an aggressive order (or not)

- HFT’s profits on the aggressive order placed in period \( t \):

\[
\pi_t = yq_t - \alpha |q_t|
\]
Incidence of A-HFTs’ Large Orders

- Additional prediction: exploratory information will help to explain the incidence of A-HFTs’ large orders
  - Expect signed order-size to be an increasing function of forecast price-change
  - Predict stronger response for an A-HFT’s order-size when $\Omega^A = 1$ than when $\Omega^A = 0$

- Regress A-HFTs’ signed order-size on public-info price-change forecast:
  $$ q_k = \beta_0 \left( 1 - \Omega^A_k \right) \hat{y}_k + \beta_1 \Omega^A_k \hat{y}_k + \varepsilon_k $$
Incidence of A-HFTs’ Large Orders

Incidence Coefficient Estimates (95% CIs)

- beta_0 (Elastic)
- beta_1 (Inelastic)

Contracts per Forecast Dollar Change

q-Bar

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