

# Exploratory Trading Theory and Evidence

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## Disclaimer

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.

# Introduction

- 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

# Exploratory Trading

- 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  $[AggressiveOrder] \cdots \overrightarrow{\text{causes}} \cdots [OrderbookActivity]$
    - ②  $[OtherEvent] \cdots \begin{cases} \overrightarrow{\text{causes}} \cdots [AggressiveOrder] \\ \overrightarrow{\text{causes}} \cdots [OrderbookActivity] \end{cases}$
  - My exploratory orders are placed for exogenous reasons
  - Anonymity: this exogeneity is private information



## Empirical Predictions

- 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

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

- $DC(k; any, \bar{q})$  : 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  $k$ :

$$\begin{aligned}y_k &= \gamma_1 \Delta d_{k-1}^1 + \dots + \gamma_6 \Delta d_{k-1}^6 \\ &\quad + \gamma_7 \text{sign}_{k-1} + \dots + \gamma_{10} \text{sign}_{k-4} \\ &\quad + \gamma_{11} q_{k-1} + \dots + \gamma_{14} q_{k-4} + \varepsilon_k \\ &:= z_{k-1} \Gamma + \varepsilon_k\end{aligned}$$

- $\Delta d_{k-1}^r$ : change in orderbook depth at price level  $r$ 
  - $r = 3$  is best bid,  $r = 4$  is best ask
- $\text{sign}_l$  = sign of aggressive order  $l$
- $q_l$  = signed quantity of aggressive order  $l$

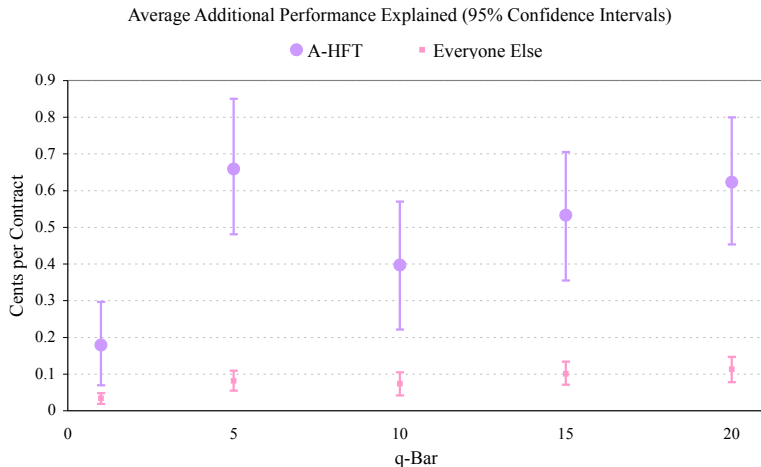
## Empirical Strategy: Overview

- 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



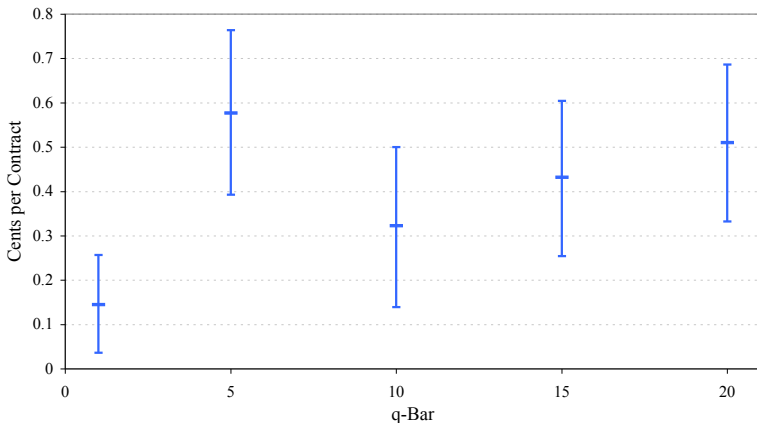
# Results: Additional Explained Performance

## A-HFT and Everyone Else



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

[A-HFT Add'l Explained] - [Everyone Else Add'l Explained] (95% CIs)

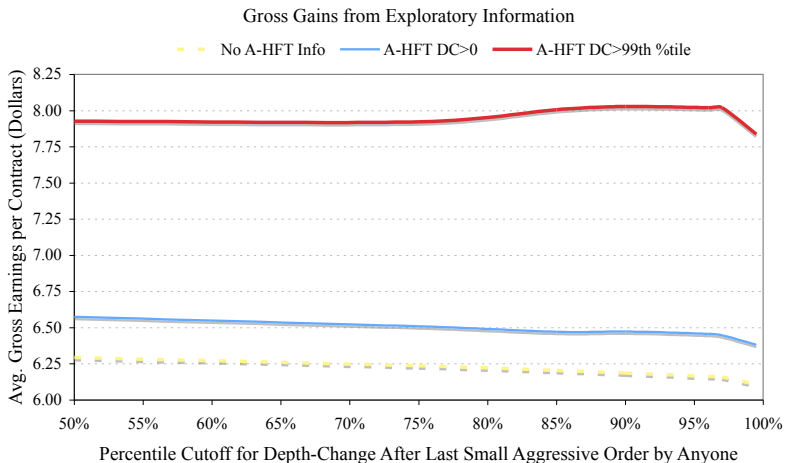


## Botstrap [*sic*] Simulations

### 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

## Botstrap Results

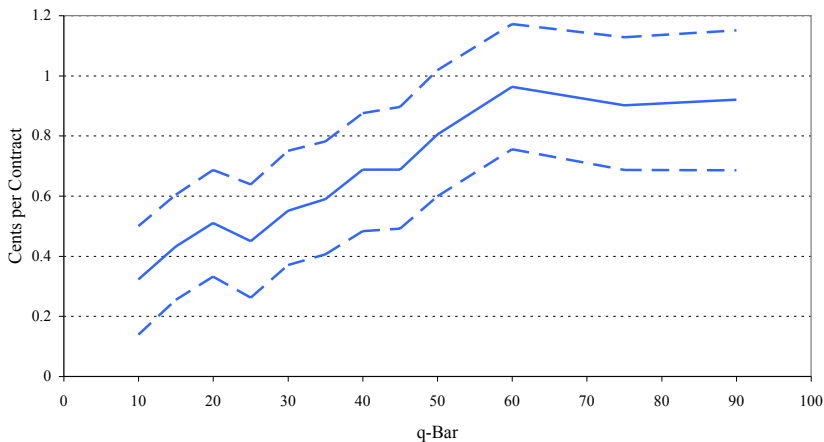


## Broader Opportunities for Exploratory Gains

- A-HFTs' *small* aggressive orders need not be the sole source of exploratory information
- Repeat the earlier analysis for  $\bar{q} = 25, \dots, 90$ 
  - Find exploratory effects larger than those for  $\bar{q} = 1, 5, \dots, 20$
  - 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:

$$q_k = \beta_0 \left(1 - \Omega_k^A\right) \hat{y}_k + \beta_1 \Omega_k^A \hat{y}_k + \varepsilon_k$$

# Incidence of A-HFTs' Large Orders

