The Trading Profits of High Frequency Traders (Risk and Return in High Frequency Trading)

Matthew Baron - Princeton University

Jonathan Brogaard - University of Washington

Andrei Kirilenko – CFTC

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Motivation

- Academic
  - Risk
  - Competition
  - Market Efficiency
- Media
  - April 10, 2012 - "Many retail and institutional investors believe that as much as $2 billion annually in high-frequency trading profits are coming out of their own pockets." ~ Bloomberg
  - August 8, 2012 – "With a high-powered computer and an 'algorithm,' a trader could buy the cheap stock and sell the expensive one almost simultaneously, making an almost risk-free profit for himself." ~Time Magazine
- Regulatory
  - Knight Capital
  - Competition

Overview of Results

(1) HFTs are not a homogenous group

(2) HFTs realize large profits:
- High profitability
  - Persistent
  - High Sharpe ratios
    - Low average risk
    - Tail risk (?)

(3) How do HFTs earn their profits

- From all other trader types
- Short, but not the shortest, time horizons
- Decreasing returns to scale
- Increases with aggressiveness
- Associated with risk

Data

Asset: September 2010 e-mini S&P 500 futures contract

- Quarterly contract
- Expires third Friday of September

Period: Trading for August 2010

Resolution: Trade-by-trade

- **User level buyer and seller id**
- Aggressive and passive party

Time: Focus on regular trading hours 8:30am–3:15pm

Classifying Traders

HFT:

a. high volume (10,000 contracts daily)
b. low inventory (< 15% of positions held at once)
c. end the day with near zero positions (<2% of total trading held at close)

Not all HFTs are the same:

a. Aggressive – HFT + take liquidity > 40% of volume
b. Mixed – HFT + take liquidity > 20%, < 40%
c. Passive – HFT + take liquidity < 20%

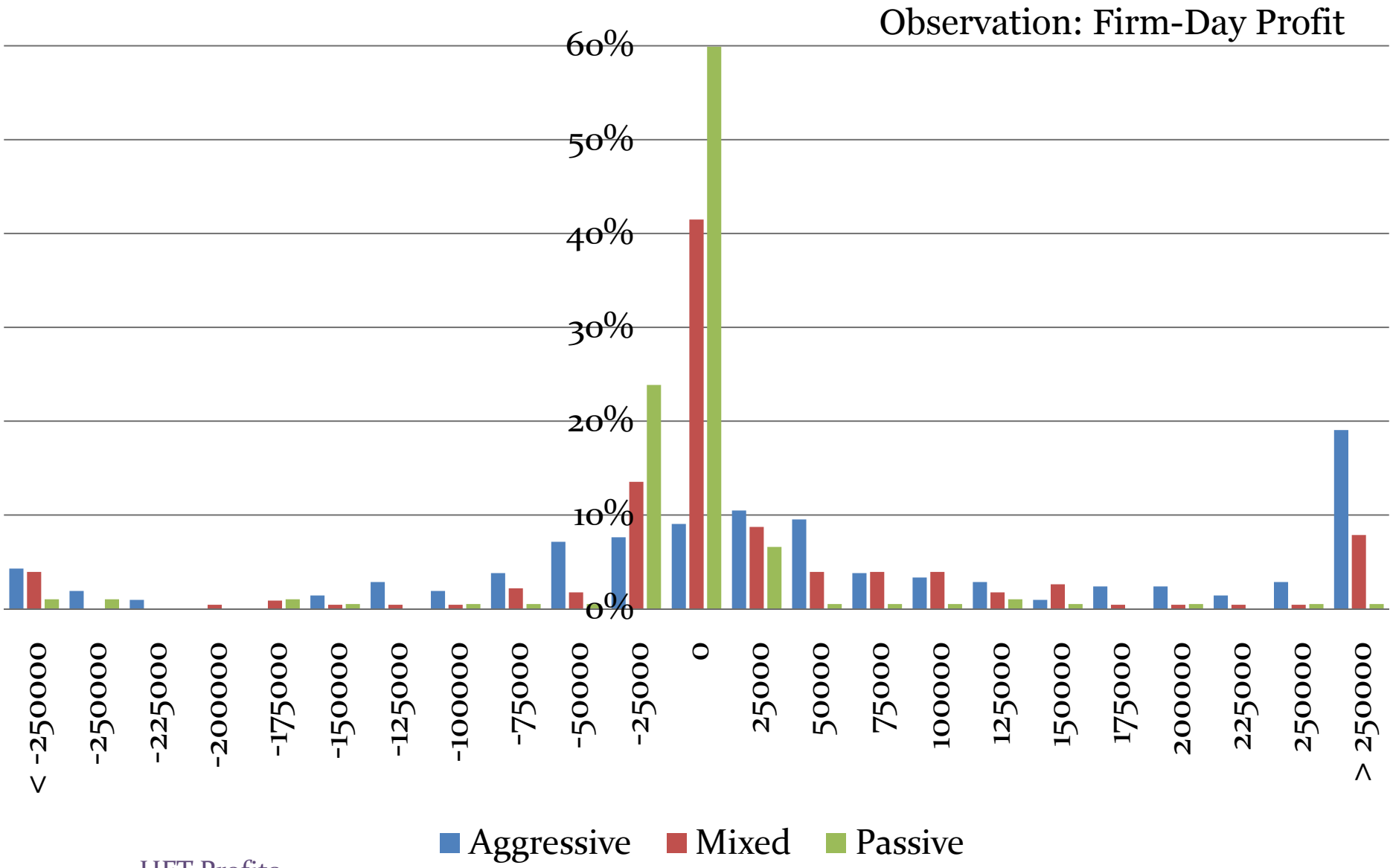
Classifying Traders

- Non-HFT Market Maker:
  - Take liquidity < 20%, trade > 100 contracts
- Fundamental (Institutional):
  - Trade > 5000 contracts, takes a direction position
- Small (Retail):
  - Trade < 10 contracts
- Opportunistic:
  - Trade a medium or large amount and tend to take time-varying directional positions

Descriptive Statistics

Trader	Daily % Market Volume	Daily Aggressive Ratio
HFT□ (n=10)	25.00%	67.70%
HFT□ (n=11)	15.59%	29.00%
HFT□(n=10)	6.18%	12.60%
Fundamental (n=157)	6.95%	51.10%
Small Trader (n=25150)	0.65%	57.90%
Non-HFT M. M. (n=47)	3.05%	9.10%
Other (n=6008)	42.58%	55.60%
Total (n=31403)	**3,187,011**	

Daily Profit Distribution



HFT Profits

Profits test 1:
Daily Profit Distribution

Observation: Firm-Day Profit

Panel A: Daily Profit

	N	Mean	Median	Std. Dev.
HFT	210	$95,508	$46,262	$258,991
HFT	229	$35,562	$13,825	$298,187
HFT	197	$5,484	$6,437	$59,580
HFT	636	$46,039	$12,331	$237,608

Panel B: Daily Profit Per Share

HFT	210	$0.89	$0.98	5.94
HFT	229	$2.08	$0.53	18.8
HFT	197	$0.22	$0.34	1.9
HFT	636	$1.11	$0.53	11.84

Profits test 2:
Profit Consistency

	By firm-obs	By # of firms		
	# of Firms-Obs	**% Firm-Obs Profitable**	**% Firms Profitable ≥ 90%**	**% Firms Profitable ≥ 75%**	**% Firms Profitable ≥ 50%**
HFT	210	68%	20%	40%	80%
HFT	229	76%	9%	54%	100%
HFT	197	71%	10%	70%	80%
HFT	636	74%	13%	55%	87%

Risk – Inventory Control

Panel A: End of Day Inventory Unit of Observation: Firm-Day

	N	Mean	Std. Dev.	Min.	Median	Max.
HFT□	210	-12.2	237	-1015	0	1016
HFT□	229	-12.4	639	-3818	0	4312
HFT□	197	-4.3	141	-799	0	814
HFT	636	-9.8	414	-3818	0	4312

Panel B: Max. Inv. from 0 / Total Shares Traded

HFT□	210	2.20%	3.90%	0.30%	1.20%	50%
HFT□	229	2.60%	7.00%	0.10%	1.20%	100%
HFT□	197	1.10%	1.20%	0.20%	0.70%	7.60%
HFT	636	2.00%	4.80%	0.10%	1.00%	100%

Profits test 3:
Sharpe Ratios

$$SR_{i,t} = \frac{r_{i,t} - r_f}{\sigma_i} * \sqrt{252}$$

Unit of Observation: Firm

Panel A: Daily Profit

	Mean	25%	Median	75%
HFT□	8.46	2.3	8.08	13.89
HFT□	10.46	2.23	13.23	17.11
HFT□	8.56	1.27	9.47	13.22
HFT	9.2	2.23	9.7	13.89

Panel B: Daily Profit per Share

HFT□	8.82	1.02	6.24	18.11
HFT□	11.08	2.21	14.04	20.92
HFT□	6.51	1.16	7.72	9.87
HFT	8.88	1.16	7.49	17.7

Risk – Realized Losses

	Total Monthly Profits	Max Loss	Max Loss Per Average $-Profit
HFT□	$20,056,713	-$876,938	-$6.92
HFT□	$8,143,800	-$2,661,600	-$35.61
HFT□	$1,080,388	-$323,163	-$29.92
HFT	$29,280,900	-$2,661,600	-$35.61

If profits follow an arithmetic brownian motion with constant drift α and constant σ, then:

Probability of Default: $P(\text{Default}) = \exp(-2\alpha V_0/\sigma^2)$

Calibrate Model
V = $10 million
α = $45,000
σ = $250,000

Probability of defaulting within a year = < .01%
Probability of breaking equal in a year is > 99.8%
Probability of doubling capital in a year is 63%

HFT Profits

Conclusion

1. HFTs on average provide more liquidity than they take, but there is wide heterogeneity in their liquidity provision
   - How should we think about the different kinds of HFTs? Do we value some types of HFT and not others?

2. HFTs earn large, persistent profits, not commensurate with the risk they take
   - On a per trade basis these values are small compared to other intermediaries. Should they be smaller? Do costs (labor, technology, data, etc) explain the profits?
   - Is this a competitive market? Are there barriers to entry? Are there positional externalities?
   - Over time is HFT becoming more competitive / less competitive? Are profits increasing / decreasing? Are the same firms maintaining there market position?

From whom do HFTs derive their profits?

Profits/Loss Per Share

	Counterparty								
Profits to:	Fundamental	HFT	HFT□	HFT□	HFT□	Non-HFT Market Maker	Small Trader	Other	Total
Fund.	$0.00	-$1.22	-$1.89	-$0.55	-$0.01	$0.35	$3.08	$0.51	-$0.69
HFT	$1.22	$0.00	-$1.03	$1.08	$1.41	$2.02	$4.42	$2.25	$0.91
HFT□	$1.89	$1.03	$0.00	$1.68	$2.00	$2.57	$4.59	$2.87	$1.76
HFT□	$0.55	-$1.08	-$1.68	$0.00	$0.10	$0.72	$4.11	$1.72	$0.08
HFT□	$0.01	-$1.41	-$2.00	-$0.10	$0.00	$1.01	$4.73	$1.30	-$0.34
Mkt makers	-$0.35	-$2.02	-$2.57	-$0.72	-$1.01	$0.00	$5.12	$1.39	-$0.82
Small	-$3.08	-$4.42	-$4.59	-$4.11	-$4.73	-$5.12	$0.00	-$2.46	-$3.97
Opport.	-$0.51	-$2.25	-$2.87	-$1.72	-$1.30	-$1.39	$2.46	$0.00	-$1.60

Over what horizon do HFTs earn their profits?

	Transaction Interval				
	1-10	**11-100**	**101-1000**	**1001-10000**	**10000+**
HFT^{A}	**$870**	**-$678**	**-$5,348**	**$21,939**	**$22,108**
	[$-2825, $8252]	[$-10887, $5997]	[$-45231, $12597]	[$-9633, $73428]	[$6213, $44481]
HFT^{M}	**$12,145**	**$23,171**	**$8,811**	**-$21,832**	**-$8,483**
	[$7825, $19111]	[$12301, $35883]	[$-5835, $27894]	[$-36494, $-5288]	[$-13018, $2360]
HFT^{P}	**$5,236**	**$12,991**	**$11,408**	**-$7,917**	**-$9,774**
	[$3840, $11170]	[$10174, $20701]	[$7920, $19186]	[$-14282, $-1512]	[$-20778, $-6990]

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	1-10	**11-100**	**101-1000**	**1001-10000**	**10000+**
HFT^{A}	**-$0.32**	**$0.86**	**$0.26**	**-$0.22**	**$0.11**
	[-0.59, -0.06]	[0.6, $1.01]	[-0.41, 0.43]	[-0.4, -0.01]	[-0.29, 0.4]
HFT^{M}	**$0.01**	**-$0.39**	**-$0.72**	**$0.75**	**$1.09**
	[-0.27, 0.07]	[-0.65, -0.21]	[-1.04, 0.11]	[-0.07, 1.21]	[0.74, 1.15]
HFT^{P}	**-$0.48**	**-$0.77**	**-$0.15**	**$0.90**	**$0.82**
	[-0.54, -0.32]	[-1.01, -0.46]	[-0.47, -0.05]	[0.74, 1.2]	[0.73, 0.94]
HFT	**-$0.29**	**-$0.43**	**-$0.15**	**$0.55**	**$0.75**
	[-0.53, -0.01]	[-0.77, 0.86]	[-0.71, 0.4]	[-0.24, 0.94]	[0.37, 1.04]

How do HFTs make their Profits?

Regression analysis:
Observations over 10-second bins

Dependent variable:

Log profits

Regressors:

Scale:
Log Firm Volume
Log Mkt Volume

Risk:
Volatility
Firm Inventory Range
Log Firm Net Position at start of 10s interval

Aggressiveness:
Permanent aggressiveness
Transient aggressiveness

How do HFTs make their Profits?

Panel A: Intraday Strategies

	HFT	HFT□	HFT□	HFT□
α	-1.13***	-.24*	-.671***	-1.29***
	(0.0598)	(0.1170)	(0.1170)	(0.0816)
Log(Firm Volume $_{i,s}$)	**.0875*** **	**.0975*** **	**.086*** **	**.115*** **
	(0.0039)	(0.0059)	(0.0072)	(0.0085)
Log(Market volume $_{s}$)	**.115*** **	**.0859*** **	**.121*** **	**.11*** **
	(0.0068)	(0.0121)	(0.0127)	(0.0099)
Adj-R^2	0.569	0.429	0.53	0.547
N	82283	25241	32036	25006

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	(0.0598)	(0.1170)	(0.1170)	(0.0816)
Log(Firm Volume $_{i,s}$)	.0875***	.0975***	.0863***	.115***
	(0.0039)	(0.0059)	(0.0072)	(0.0085)
Volatility $_{s}$	**.224*** **	**.255*** **	**.251*** **	**.153*** **
	(0.0078)	(0.0142)	(0.0142)	(0.0105)
Firm Inventory Range	**.488*** **	**.745*** **	**.264*** **	**2.3*** **
	(0.0301)	(0.0428)	(0.0441)	(0.1150)
Log(Firm Net Position $_{i,s}$)	**.672*** **	**.621*** **	**.689*** **	**.62*** **
	(0.0041)	(0.0077)	(0.0067)	(0.0068)
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Volatility $_{s}$	.224***	.255***	.251***	.153***
	(0.0078)	(0.0142)	(0.0142)	(0.0105)
Firm Aggressiveness $_{i,s}$	**.297*** **	**.396*** **	**.121*** **	**.238*** **
	(0.0157)	(0.0235)	(0.0294)	(0.0296)
Firm Avg Aggressiveness	**.634*** **	**-0.0048**	**-1.14*** **	**.747*** **
	(0.0233)	(0.0510)	(0.1480)	(0.1030)
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Trading Partners

	Passive							
Aggressive	HFT□	HFT□	HFT□	Fundamental	Non-HFT Market Maker	Other	Small Trader	Total
HFT□	4.16% (5.35%)	6.67% (7.41%)	3.33% (3.64%)	2.71% (2.41%)	1.83% (1.84%)	14.53% (12.60%)	0.21% (0.17%)	33.43%
HFT□	1.25% (1.47%)	1.52% (2.04%)	0.90% (1.00%)	0.79% (0.66%)	0.54% (0.51%)	4.12% (3.47%)	0.07% (0.05%)	9.20%
HFT□	0.26% (0.25%)	0.35% (0.34%)	0.17% (0.17%)	0.12% (0.11%)	0.07% (0.09%)	0.58% (0.58%)	0.01% (0.01%)	1.55%
Fundamental	1.41% (1.15%)	1.66% (1.59%)	0.81% (0.78%)	0.53% (0.52%)	0.37% (0.40%)	2.39% (2.71%)	0.03% (0.04%)	7.20%
Non-HFT M.M	0.12% (0.09%)	0.16% (0.12%)	0.07% (0.06%)	0.03% (0.04%)	0.02% (0.03%)	0.16% (0.21%)	0.00% (0.00%)	0.56%
Other	8.68% (7.57%)	11.56% (10.49%)	5.51% (5.16%)	3.00% (3.41%)	2.65% (2.61%)	15.73% (17.85%)	0.21% (0.25%)	47.35%
Small Trader	0.12% (0.11%)	0.22% (0.16%)	0.10% (0.08%)	0.03% (0.05%)	0.04% (0.04%)	0.20% (0.27%)	0.00% (0.00%)	0.71%
Total	16.00%	22.16%	10.90%	7.21%	5.52%	37.70%	0.52%	35,057,121

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Motivation

"A market is efficient with respect to information set θ_t if it is impossible to make economic profits by trading on the basis of information set θ_t"

~Jensen, 1978

"Prices reflect the information of informed individuals (arbitrageurs) but only partially, so that those who expend resources to obtain information do receive compensation."

~Grossman and Stiglitz, 1980

Discussion

The results lend themselves to multiple directions: Which way should I go?

- Market Efficiency (Grossman-Stiglitz)
- Equilibrium model
- Tail Risk
- Heterogeneity
- Competition
  - -- barriers to entry
  - -- arms race: positional externalities
- Incentives / Organization structure