Do Behavioral Biases Affect Prices?

Coval and Shumway (2005)

March 22, 2019

Introduction

Key Points

- Paper documents evidence for behavioral biases among Chicago Board of Trade
- Traders in this market are highly loss-averse, assume above average risk to combat earlier losses
- This behavior has important price impact on afternoon prices
- Prices set by loss-averse traders are reversed significantly more quickly than by unbiased traders

Introduction

Overview

Testing for behavior biases is hard

- Many different behavioral theories rooted in Psychology
- Models cannot be easily tested with aggregate data
  - Detailed data is hard to get
- Hard to measure investor horizon
- Hard to distinguish from noise trading
  - Challenging to link bias impact on prices

Introduction

Setting - Chicago Board of Traders

- Bias should show up:
  - Traders exchange \$200 million worth of contracts per day
  - Traders participate in 95% of all trades
- Trades are done by market makers - with personal accounts
- Trading Horizon is clear - most traders close position every day

Introduction

Roadmap

1. Look for signs of traders taking either greater or lesser risk as profits grow
2. Split trading day and compare trading in morning and evening
3. Examine traders to see if they are more likely to move afternoon prices following morning losses
4. Examine permanence of price moves spurred by morning losses
5. Examine whether prices exhibit greater volatility in afternoons following morning losses

Introduction

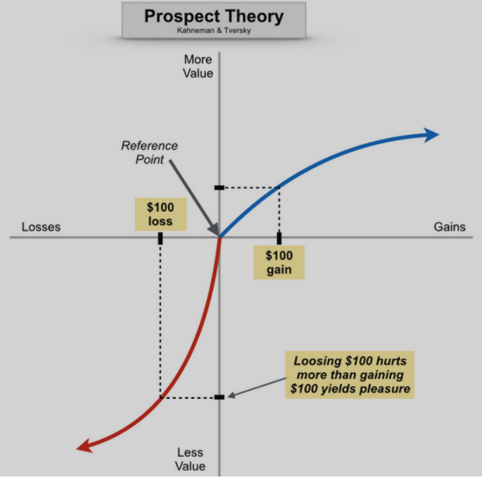
Bias in Beliefs

1. Self-Attribution (overconfidence)
2. Conservativeness and Representativeness

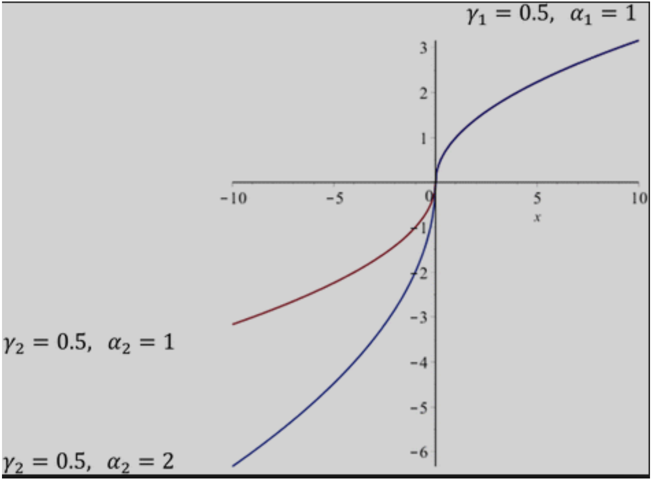
Bias in Preferences

1. Prospect Theory
   - Profits near zero lead to high subsequent risk aversion
   - Risk-seeking behavior present in region of losses
2. House-money Effect

Prospect Theory



Prospect vs VN-M Utility



Hypothesis and Assumptions

Hypothesis: There is no relationship between morning returns and afternoon risk-taking

Assumptions

1. Efficient Markets
2. Rational Traders
3. Traders have Von Neumann-Morgenstern utility functions
4. Negligible Wealth Effects
5. Margin constraints unimportant
6. Traders' compensation and reputation concerns neutral
7. Profit opportunities are uncorrelated across trading day

Hypothesis

Alternative 1

Self-attribution bias, representativeness heuristic, and house money effect predict morning returns will be positively related to afternoon risk-taking

Alternative 2

Risk-seeking in losses predicts the null will be rejected if morning returns are negatively related to afternoon risk-taking

Data

- CBOT T-Bond futures 1998
  - Includes identifiers for buyer and seller, price, time of transaction, and on whose behalf
- 426 Traders using their own personal account.
- To measure profit and inventory, assume each trader closes position at end of day (no beginning inventory)
  - Use inventory controls and winsorize
- Profit computed by looking at market value of inventory times contracts outstanding, added to local's running profit figure

Data

Measuring Risk

- Use historical price change data, second-by-second time and sales from Future Industry Institute Data Center
- Calculate front-month futures contract prices at the beginning of each minute from 1989 to 1998
- Fit Ordered Logit Regression to get probability of various potential abs price changes over next minute

Data

Measuring Risk

- Use fitted values to construct an expected absolute price change for each minute of each full trading day in 1998.
- Calculate trader's risk by multiplying each minute's risk measure by the trader's position at the beginning of the minute.
- Adjust trader's risk for the minute by any changes in inventory (and therefore risk) in the minute
- Calculate cumulative risk - Total Dollar Risk

Method

- Split trading day into two periods: before 11:00 am and after
- For each trader, calculate morning and evening profits
- Also, calculate total dollar risk, number of trades and average trade size
- Normalize traders profits and risk-taking to account for heterogeneity in margin constraints

Table 1

Panel A: Statistics by Trader-Day

	Morning			Afternoon		
Variable	Mean	Median	St. Dev.	Mean	Median	St. Dev.
All Trader-Days ($N = 82{,}595$) Raw Data						
Profits	1808.33	750.00	171848.13	661.78	187.50	113964.28
Number of trades	116.62	88.00	105.37	73.25	52.00	72.95
Average trade size	10.03	4.84	19.17	9.35	4.53	18.27
Total dollar risk	9641.46	1150.00	57540.27	10876.76	1242.83	75133.82
Price-setting trades	0.202	0.000	0.514	0.327	0.000	0.643
Traders with Profitable Mornings ($N = 55{,}877$) Normalized by Trader						
Profits	0.467	0.276	0.574	0.095	0.067	0.733
Number of trades	−0.035	−0.159	0.986	−0.066	−0.234	0.980
Average trade size	−0.063	−0.222	0.967	−0.046	−0.213	0.989
Total dollar risk	−0.122	−0.317	0.776	−0.100	−0.335	0.801
Price-setting trades	−0.009	−0.188	0.601	−0.017	−0.128	0.467
Traders with Losing Mornings ($N = 26{,}718$) Normalized by Trader						
Profits	−0.563	−0.273	0.727	0.082	0.067	0.915
Number of trades	0.066	−0.065	1.013	0.124	−0.036	1.016
Average trade size	0.119	−0.081	1.040	0.086	−0.114	1.006
Total dollar risk	0.180	−0.146	0.993	0.141	−0.205	0.997
Price-setting trades	0.018	−0.171	0.619	0.036	−0.116	0.526

Panel B: Statistics by Day

Variable	Mean	St. Dev.	Minimum	Maximum
Afternoon price changes	621.8703	215.383	195.00	1582.00
Fraction with morning losses	0.3238	0.049	0.20	0.50
Fraction of loss-averse traders with losses	0.3305	0.055	0.19	0.50
Fraction of price-setting traders with losses	0.3230	0.051	0.19	0.49

Morning Losses Lead to Afternoon Risk-Taking

Regress Afternoon risk-taking on morning profits:

$$\mathrm{RISK}^{\mathrm{A}}_{i,t} = \alpha + \beta_\pi \pi^{\mathrm{M}}_{i,t} + \beta_I |\mathrm{INV}^{\mathrm{M}}_{i,t}| + \beta_{\pi I} \pi^{\mathrm{M}}_{i,t} \cdot |\mathrm{INV}^{\mathrm{M}}_{i,t}| + \beta_R \mathrm{RISK}^{\mathrm{M}}_{i,t} + \varepsilon_{i,t}.$$

where

- $\pi^M_{i,t}$ is trader *i*'s date *t* morning profit
- $|INV^M_{i,t}|$ is abs value of trader *i*'s outstanding position at the end of the morning on date t.
- $RISK^M_{i,t}$ is trader *i*'s morning risk measured on date *t*

They also used Pooled Regression and Fama-MacBeth

Results

- A one standard deviation decrease in morning profits leads the average trader to to place more afternoon trades than normal
- Higher inventory positions midday associated with higher afternoon risk
- Traders who assume significant risk in the morning continue to do so in afternoon
- Consistent results when top N% of traders with morning losses compared to only top N% of traders with greatest morning gains

Results - Table 2

$$\text{RISK}^{\text{A}}_{i,t} = \alpha + \beta_\pi \pi^{\text{M}}_{i,t} + \beta_I |\text{INV}^{\text{M}}_{i,t}| + \beta_{\pi I} \pi^{\text{M}}_{i,t} \cdot |\text{INV}^{\text{M}}_{i,t}| + \beta_R \text{RISK}^{\text{M}}_{i,t} + \varepsilon_{i,t}.$$

Method	α	β_π	β_I	$\beta_{\pi I}$	β_R
Panel A: Dependent Variable: Afternoon Number of Trades					
Pooled OLS	0.0187	−0.1349	0.0313	0.056	0.2361
	(4.88)	(−23.38)	(7.26)	(12.99)	(61.66)
FM by trader	0.0315	−0.1173	0.0511	0.058	0.2182
	(2.35)	(−4.62)	(2.35)	(7.49)	(25.7)
FM by date	−0.0143	−0.1874	0.0378	0.0588	0.1499
	(−0.49)	(−27.89)	(7.27)	(10.33)	(23.3)
Fixed effects PCSE	–	−0.1362	0.03395	0.0547	0.2106
	–	(−17.90)	(5.44)	(11.36)	(12.07)
Panel B: Dependent Variable: Afternoon Average Trade Size					
Pooled OLS	0.0098	−0.0691	0.0606	0.0203	0.2159
	(2.53)	(−11.95)	(13.67)	(4.69)	(54.89)
FM by trader	−0.0045	−0.1013	0.0421	0.0227	0.2056
	(−0.27)	(−3.44)	(1.41)	(2.75)	(23.79)
FM by date	0.0095	−0.1076	0.0582	0.0290	0.1726
	(0.65)	(−11.86)	(9.31)	(3.83)	(27.58)
Fixed effects PCSE	–	−0.7061	0.0594	0.0189	0.1964
	–	(−11.16)	(11.70)	(4.18)	(31.28)

Results - Table 2

$$\mathrm{RISK}^{\mathrm{A}}_{i,t} = \alpha + \beta_\pi \pi^{\mathrm{M}}_{i,t} + \beta_I |\mathrm{INV}^{\mathrm{M}}_{i,t}| + \beta_{\pi I} \pi^{\mathrm{M}}_{i,t} \cdot |\mathrm{INV}^{\mathrm{M}}_{i,t}| + \beta_R \mathrm{RISK}^{\mathrm{M}}_{i,t} + \varepsilon_{i,t}$$

Panel C: Dependent Variable: Afternoon Total Dollar Risk					
Pooled OLS	0.0000	−0.0079	0.5802	0.0134	0.3001
	(0.02)	(−3.00)	(195.70)	(6.80)	(98.2)
FM by trader	0.0015	−0.0107	0.6208	0.0170	0.2555
	(1.55)	(−2.41)	(60.93)	(4.27)	(29.81)
FM by date	−0.0007	−0.0161	0.5812	0.0235	0.2868
	(−0.12)	(−3.91)	(63.97)	(4.75)	(39.98)
Fixed effects PCSE	–	−0.0091	0.5794	0.0139	0.2990
	–	(−2.77)	(157.09)	(6.34)	(70.17)
Panel D: Dependent Variable: Afternoon Total Dollar Risk Matched Percentiles of Winners and Losers					
Pooled OLS	−0.0003	−0.0078	0.5925	0.0139	0.2933
	(−0.17)	(−2.83)	(181.63)	(6.75)	(87.31)
FM by trader	−0.0001	−0.0095	0.6342	0.017	0.2501
	(−0.1)	(−2.1)	(61.62)	(4.31)	(28.65)
FM by date	−0.0014	−0.0151	0.593	0.0232	0.2811
	(−0.22)	(−3.57)	(65.03)	(4.64)	(38.8)
Fixed effects PCSE	–	−0.0085	0.5913	0.0143	0.2927
	–	(−2.58)	(147.79)	(6.38)	(63.92)

Results - Linearity? Sort it!

Table III

Table III

Morning Profits and Afternoon Risk-Taking: Double Sorts

This table reports the average afternoon risk-taking by locals at the CBOT when traders are sorted on each day into bins according to morning profits and morning risk-taking, and where morning risk-taking is measured as the number of trades, average trade size, and total dollar risk. Traders are sorted into quintiles according to morning profits and then, within each quintile, are sorted into quintiles according to morning risk-taking. Afternoon risk-taking measures are then averaged across traders in each cell. Standard errors are in parentheses. All variables that depend on measures of inventory are Winsorized at the 1 and 99% levels. The sample contains 82,595 local-days.

Panel A: Afternoon Number of Trades

	Morning Number of Trades				
Morning Profits	1 (low)	2	3	4	5 (high)
1 (low)	−0.0498	0.0359	0.1385	0.1679	0.4264
	(0.0226)	(0.0199)	(0.0185)	(0.0188)	(0.0197)
2	−0.0639	−0.0218	0.0169	0.145	0.2965
	(0.0157)	(0.0182)	(0.0191)	(0.0214)	(0.024)
3	−0.1539	−0.0899	−0.0088	0.0288	0.2229
	(0.0159)	(0.0172)	(0.019)	(0.0206)	(0.0244)
4	−0.2404	−0.1891	−0.0818	−0.0283	0.0852
	(0.0182)	(0.017)	(0.0181)	(0.0186)	(0.021)
5 (high)	−0.2983	−0.2088	−0.1626	−0.0597	0.0578
	(0.0227)	(0.0189)	(0.0184)	(0.018)	(0.0184)

Results - Linearity? Sort it!

Table III

Panel C: Afternoon Total Dollar Risk

	Morning Total Dollar Risk				
Morning Profits	1 (low)	2	3	4	5 (high)
1 (low)	−0.3069	−0.2571	−0.1572	0.054	1.0201
	(0.0163)	(0.0075)	(0.0065)	(0.0068)	(0.0081)
2	−0.4177	−0.344	−0.2171	−0.0334	0.5934
	(0.0125)	(0.0061)	(0.0059)	(0.0064)	(0.0091)
3	−0.4461	−0.3432	−0.2362	−0.0559	0.4879
	(0.0112)	(0.0066)	(0.0064)	(0.0067)	(0.0091)
4	−0.462	−0.3522	−0.2495	−0.041	0.5967
	(0.0102)	(0.0099)	(0.0099)	(0.0104)	(0.0114)
5 (high)	−0.4879	−0.3701	−0.257	0.0038	1.1277
	(0.0159)	(0.0274)	(0.0276)	(0.0255)	(0.0191)

Results - Logit Model for Robustness

Table IV

Binary Results for Morning Profits and Afternoon Risk-Taking

This table reports the results of a number of different logit models relating morning profits to afternoon risk-taking by locals at the CBOT. All models measure both morning profits and afternoon risk in a binary form, and the logit models have the basic form,

$$\text{Prob}\left(\text{RISK}^{\text{A}}_{i,t} > 0\right) = \frac{\exp X'\beta}{1+\exp X'\beta},$$

where

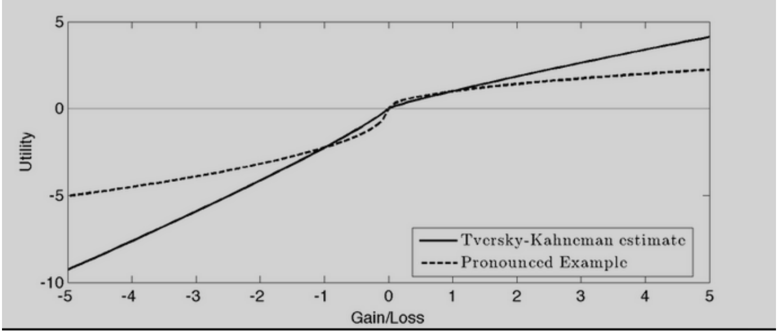
$$X'\beta = \alpha - \beta_\pi I\left(\pi^{\text{M}}_{i,t} < 0\right) + \beta_I \left|\text{INV}^{\text{M}}_{i,t}\right| + \beta_{\pi I} I\left(\pi^{\text{M}}_{i,t} < 0\right) \cdot \left|\text{INV}^{\text{M}}_{i,t}\right| + \beta_R \text{RISK}^{\text{M}}_{i,t}.$$

The t-statistics are in parentheses. All variables that depend on measures of inventory are Winsorized at the 1 and 99% levels. In Panel D, only the top (i.e., most profitable) X% of all traders on a given day is included in the regression, where X is the fraction of traders with losses on that day. In Panels A through C, the sample contains 82,595 local-days. In Panel D the sample contains 65,061 local-days.

Method	α	β_π	β_I	$\beta_{\pi I}$	β_R
	Panel A: Prob(Afternoon Number of Trades > Mean Trades)				
Pooled logit	0.375	−0.2875	−0.0801	0.0537	−0.3865
	(1384.93)	(−286.97)	(−41.82)	(11.71)	(−2107.91)
FM by trader	0.2766	−0.1989	−0.3139	0.3088	−0.4017
	(1.54)	(−1.02)	(−1.11)	(1.11)	(−14.87)
FM by date	0.553	−0.3466	−0.0947	0.0844	−0.331
	(8.58)	(−11.45)	(−4.48)	(1.88)	(−17.94)

Semiparametric Regression

Use semi-parametric model to account for kinks:



Setup

$$
\begin{aligned}
\mathrm{RISK}^{\mathrm{A}}_{i,t} = {} & \alpha + \sum_{j=1}^{20} \beta_{\pi,j} D_{i,j,t} + \beta_I \left|\mathrm{INV}^{\mathrm{M}}_{i,t}\right| + \sum_{j=1}^{20} \beta_{\pi I,j} D_{i,j,t} \cdot \left|\mathrm{INV}^{\mathrm{M}}_{i,t}\right| \\
& + \beta_R \mathrm{RISK}^{\mathrm{M}}_{i,t} + \varepsilon_{i,t},
\end{aligned}
$$

Steps:

- Rank traders each day according to their normalized morning profit and assign them to one of 20 profitability groups
- Conduct daily cross-sectional regressions with model above
- Dummy variable D equals one if trader i's morning profit ranks in group j on the date t.
- Average the cross-sectional regression coefficients across time, compute standard errors

Semiparametric Regression

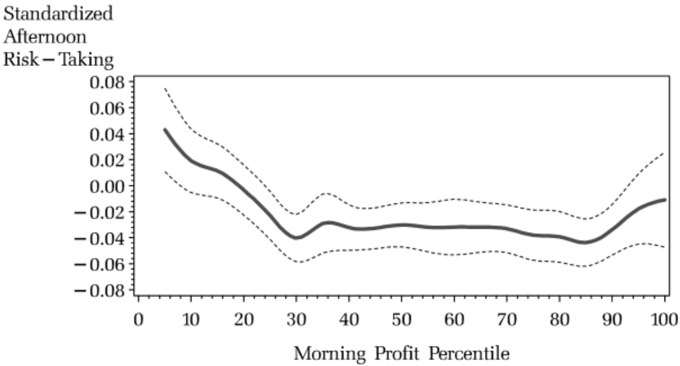


Figure 1. Morning profit percentile and afternoon risk-taking. This figure plots the time-series averages of 236 daily cross-sectional semiparametric regressions of afternoon total dollar risk on morning profit percentile. The regressions are kernel-smoothed and the dashed lines reflect two standard error bands of the time series-averaged regressions.

Losing trader behavior is more sensitive to the level of their losses than winning traders to the level of their gains!

Time until Midday Position Unwound

Traders who lose money in morning assume greater risk in afternoon. Now, want to see the time traders take to unwind their midday inventory using a hazard model.

$$h(\tau, x) = h_0(\tau)\Big[\exp\Big\{\beta_V \mathrm{INV}_{i,t}^{\mathrm{M}}\big(P_t^{\mathrm{M}} - \bar{P}_{i,t}^{I}\big) + \beta_\pi \pi_{i,t}^{\mathrm{M}} + \beta_I \big|\mathrm{INV}_{i,t}^{\mathrm{M}}\big| + \beta_R \mathrm{RISK}_{i,t}^{\mathrm{M}}\Big\}\Big],$$

Where $h_0(\tau)$ is baseline hazard function, τ measures time since 11am, $(P_t^M - \bar{P}_{i,t}^I)$ measures the futures contract price at 11am less the contract weighted average price at which trader i acquired his inventory on day t.

- Interested in coefficient β_V which measures the speed at which positions are unwound.

Time until Midday Position Unwound

$$h(t,x) = h_0(t)\left[\exp\left\{\beta_V \mathrm{INV}_{i,t}^{\mathrm{M}}\left(P_t^{\mathrm{M}} - \bar{P}_{i,t}^{I}\right) + \beta_\pi \pi_{i,t}^{\mathrm{M}} + \beta_I \left|\mathrm{INV}_{i,t}^{\mathrm{M}}\right| + \beta_R \mathrm{RISK}_{i,t}^{\mathrm{M}}\right\}\right],$$

where $h_0(t)$ is a baseline hazard function, P_t^{M} is the futures price at 11 a.m. on day t, and $\bar{P}_{i,t}^{I}$ is the contract-weighted average price at which trader i acquired his inventory on day t. The t-statistics are in parentheses. All variables (except time to unwind) are Winsorized at the 1 and 99% levels. The sample contains 82,595 local-days.

Method	β_V	β_π	β_I	β_R
Dependent Variable: Time until Midday Position Unwound				
Pooled Cox model	0.0283	0.0321	−0.0094	−0.0158
	(5.11)	(5.49)	(−1.82)	(−1.13)
FM by trader	0.0187	0.0178	−0.1067	−0.4013
	(0.90)	(1.11)	(−1.50)	(−1.44)
FM by date	0.0312	0.0577	−0.0042	−0.0155
	(6.54)	(4.83)	(−0.37)	(−1.36)

Price Impact

- Identify local trades that cause the posted price to change from bid to ask because of purchase or sale of local trader for own account
- If local purchases at a price higher than previous price, identify the trade as responsible for having raised the price. Similar with selling.
- With price moving trades, can see if more occur following winning vs losing mornings
- Use following Regression:

$$\Delta_{i,t}^{A} - \bar{\Delta}_{i}^{A} = \alpha + \beta_{\pi}\pi_{i,t}^{M} + \beta_{I}|\mathrm{INV}_{i,t}^{M}| + \beta_{\pi I}\pi_{i,t}^{M} \cdot |\mathrm{INV}_{i,t}^{M}| + \varepsilon_{t}^{i},$$

where $\Delta_{i,t}^{A}$ is the number of price-setting trades placed in the afternoon of day t by trader i, $\bar{\Delta}_{i}^{A}$ is trader i's average number of price-setting trades per afternoon, and other variables are as defined earlier.

Price Impact

- Traders with losses in the morning are much more dramatically reversed than those set by traders with gains in the morning.
- On average the trader with morning losses places 25% more price-setting trades than an equivalent trader with morning gains.
- Reversals are 27% larger for traders with morning losses than that of other trader
- Suggests loss aversion is important factor
- Tick by tick testing shows reversals happen quickly

Price Volatility

Question:

Do price-setting trades executed by locals with morning losses cause afternoon prices to be more volatile?

Claim

- Loss aversion may lead to greater afternoon risk seeking and increased placement of price-moving trades
  - afternoon volatility increases following mornings with widespread losses
- Or could lead to increased reversal in prices set by traders attempting to make up morning losses
  - Should see only little increase in afternoon volatility

Price Volatility

Measurement

standard deviation of price changes measured at 1-second, 1-minute, 5-minutes, 10-minute and half-day frequency.

Regression

Normalize normalize afternoon volatility on the volatility in the corresponding morning

$$\sigma_{h,t}^{A} = \alpha + \beta_{\sigma}\sigma_{h,t}^{M} + \beta_{\lambda}\lambda_{t}^{M} + \varepsilon_{t}$$

- σ^A measures abnormal volatility of afternoon price changes for frequency h.
- λ^M measures aggregate morning losses on day t.

Price Volatility

Results - Volatility

- Afternoon price volatility is related to morning market maker profitability
- Traders with morning losses place additional price-setting afternoon trades to assume additional risk
- Lose results after 10 minute interval
- Traders with morning losses create only short-term afternoon deviations from fundamentals

Price Volatility

Results - Volatility

	λ_t^M = Fraction of Loss-Averse Traders w/Losses			λ_t^M = Fraction of Loss-Averse Price Leaders w/Losses		
Frequency	α	β_σ	β_λ	α	β_σ	β_λ
	Dependent Variable: Abnormal Afternoon Volatility ($\sigma_{h,t}^A$)					
One second	−0.7	0.4	2.09	−0.77	0.39	2.37
	(−1.99)	(6.73)	(2.01)	(−2.07)	(6.67)	(2.09)
One minute	−0.62	0.2	1.87	−0.86	0.19	2.65
	(−1.69)	(3.18)	(1.72)	(−2.2)	(3.13)	(2.24)
Five minutes	−0.62	0.31	1.90	−0.75	0.3	2.34
	(−1.75)	(5.09)	(1.8)	(−1.98)	(4.96)	(2.03)
Ten minutes	−0.39	0.23	1.17	−0.45	0.23	1.39
	(−1.06)	(3.72)	(1.08)	(−1.15)	(3.64)	(1.17)
Half day	0.61	0.12	0.81	0.44	0.1	1.40
	(1.7)	(1.7)	(0.7)	(1.16)	(1.48)	(1.12)

Conclusion

- Paper claims to offer unique setting to test behavioral theory
- Traders appear loss averse
- Assume more risk following morning losses
- Price impact is not long lasting for these traders

Other Thoughts

- One year of data - Could this be learned by traders and corrected?
- Do we see cyclical ebbs and flows of biases?