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FOR QUANTITATIVE FINANCIAL RESEARCH

Arbitrage Asymmetry and the Idiosyncratic Volatility Puzzle

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The Idiosyncratic Volatility Puzzle

- IVOL: "Idiosyncratic" volatility not due to systematic risk
- Long-standing question: Is expected return related to IVOL?
- Empirical evidence:
  - No relation

    Fama and MacBeth (1973), Bali and Cakici (2008)
  - Positive relation

    Lintner (1965), Tinic and West (1986), Lehmann (1990), Malkiel and Xu (2002), Fu (2009)
  - Negative relation

    Ang, Hodrick, Xing, and Zhang (2006, 2009), Jiang, Xu, and Yao (2009), Guo and Savickas (2010), Chen, Jiang, Xu, and Yao (2012)
- Evidence of a negative relation, consistent with most recent studies, has been the most puzzling.

Proposed Explanations

- The IVOL puzzle
  - reflects lower disclosure (of negative information) $\Rightarrow$ higher IVOL (Jiang, Xu, and Yao, 2009)
  - is limited to firms with high institutional ownership and shorting (Boehme, Danielson, Kumar, and Sorescu, 2009)
  - reflects negative relation between expected return and idiosyncratic skewness (Boyer, Mitton, and Vorkink, 2010)
  - reflects a preference for lotteries (Bali, Cakici, and Whitelaw, 2011)
  - reflects return reversal (Huang, Liu, Rhee, and Zhang, 2010)
  - reflects systematic risk exposure proxied by IVOL (Barinov, 2011; Chen and Petkova, 2012)
- Possibly at work but challenged to explain our empirical findings.

Our Explanation of the IVOL Puzzle

- We combine two dimensions of arbitrage:
  - Arbitrage risk: higher IVOL $\Rightarrow$ higher risk
  - Arbitrage asymmetry: shorting is different from purchasing
- Source of arbitrage asymmetry:
  - more long-only capital than long-short capital
  - short sellers face different risks
- IVOL versus expected return: depends on mispricing direction
- Among overpriced securities:
  - Greater arbitrage risk $\Rightarrow$ greater overpricing
  - Negative IVOL effect in expected returns
- Among underpriced securities:
  - Greater arbitrage risk $\Rightarrow$ greater underpricing
  - Positive IVOL effect in expected returns
- Arbitrage asymmetry $\Rightarrow$ greater overpricing
- The negative IVOL effect among overpriced securities dominates in the overall cross section.

Empirical Results: Overview

- Relative mispricing measure, based on 11 anomalies
- Stratify stocks, from overpriced to underpriced
- Mispricing and IVOL effects:
  - Among overpriced stocks, negative IVOL effect
  - Among underpriced stocks, positive IVOL effect
  - Stronger IVOL effect among overpriced stocks
  - Negative IVOL effect in overall cross-section
- Investor sentiment - proxy for market-wide mispricing tendency
- Time-Varying IVOL effects:
  - Negative IVOL effect among overpriced stocks is stronger following high sentiment
  - Positive IVOL effect among underpriced stocks is stronger following low sentiment
  - Stronger sentiment-related variation among overpriced stocks

Related Work

- Supporting results of our explanation in other studies
  - Long-short anomaly profits greater among high-IVOL stocks, especially short legs (Jin, 2012)
  - Negative (positive) IVOL effect among the relatively overpriced (underpriced) stocks (Cao and Han, 2010)
  - Negative returns on high-IVOL stocks after relaxing short-sale constraints (Doran, Jiang, and Peterson, 2012)

Asymmetric Capital and Risk-Bearing

- Less capital devoted to short positions than long positions
  $\Rightarrow$ less capital to bear idiosyncratic risk of overpriced assets
  $\Rightarrow$ more overpricing remains
- E.g., assume mean-variance investors with relative risk aversion A
  - L: long-only capital
  - B: long-short capital
  - y_i: noise trader holding of asset i (net of market supply)
- For assets held by the long-only capital:

$$\alpha_i \approx \frac{A}{L+B} y_i \sigma^2_{\epsilon,i}$$

- For assets shorted by the long-short capital:

$$\alpha_i \approx \frac{A}{B} y_i \sigma^2_{\epsilon,i}$$

Asymmetric Risks

- Risks of short sellers and purchasers are not symmetric
- Greater risk of margin call
  - $\Rightarrow$ shorts face greater "noise-trader" risk (Shleifer and Vishny, 1997) - capital constraints necessitate closing an eventually profitable position
- Positive skewness in compounded returns produces greater tail risk for short sellers
- Risk of short squeezes

Asymmetric Risk of Margin Calls

- Maintenance margin requirements apply to

$$m = \text{equity}/(\text{position size})$$

- Consider a short seller and purchaser that begin with
  - identical equity and position sizes
  - $m = 50\%$
- Equal adverse percentage price changes produce
  - equal losses of equity for short seller and purchaser
  - decrease (increase) in position size for purchaser (short seller)
- With maintenance requirement $m = 25\%$ for long and short
  - purchaser receives margin call if price drops 33%
  - short seller receives margin call if price rises 20%
- With short maintenance instead $m = 30\%$ (e.g., FINRA)
  - short seller receives margin call if price rises 15.4%

Asymmetric Tail Risk

- Compounding induces positive skewness in multiperiod returns
- Positive return skewness $\Rightarrow$ tail risk for short sellers
- An adverse move (loss)
  - decreases the exposure of a long position
  - increases the exposure of a short position
- Consider a short seller and purchaser with initially equal positions
- Their underlying monthly portfolio returns:
  - lognormal
  - standard deviation of return is 4%
  - after-cost expected return
    - 0.50% for purchaser
    - -0.50% for short seller
- For a 12-month horizon, the 1% VaR is 22% greater for the short seller

Identifying Mispricing

- Mispricing measure: average rankings for 11 return anomalies
- Anomalies: Relative to Fama-French three-factor model.
  - Failure probability
  - Ohlson's O-score
  - Net stock issues
  - Composite equity issues
  - Total accruals
  - Net operating assets
  - Momentum
  - Gross-profit-to-assets
  - Asset growth
  - Return-on-assets
  - Investment-over-assets
- Average monthly long-short alpha (decile 1 minus decile 10):
  - 1.48% based on the averaged rankings, versus
  - 0.86% for the average long-short anomaly alpha

Idiosyncratic Volatility and Portfolio Formation

- Compute IVOL for each stock using the most recent month's daily benchmark-adjusted returns
- Benchmarks are Fama-French (1993) factors: MKT, HML, SMB
- Form 25 portfolios:
  - Sort first on the mispricing measure, into 5 categories
  - Then sort on IVOL, into 5 categories
- Portfolio IVOL: same pattern as individual-stock IVOL

  $\Rightarrow$ differences in arbitrage risk survive diversification
- Portfolio IVOL versus direction of mispricing
  - U-shape, but asymmetric—steeper for overpricing
  - As expected if
    - arbitrage risk important for degree of mispricing
    - arbitrage asymmetry exists

Idiosyncratic Volatility for Double-Sorted Portfolios

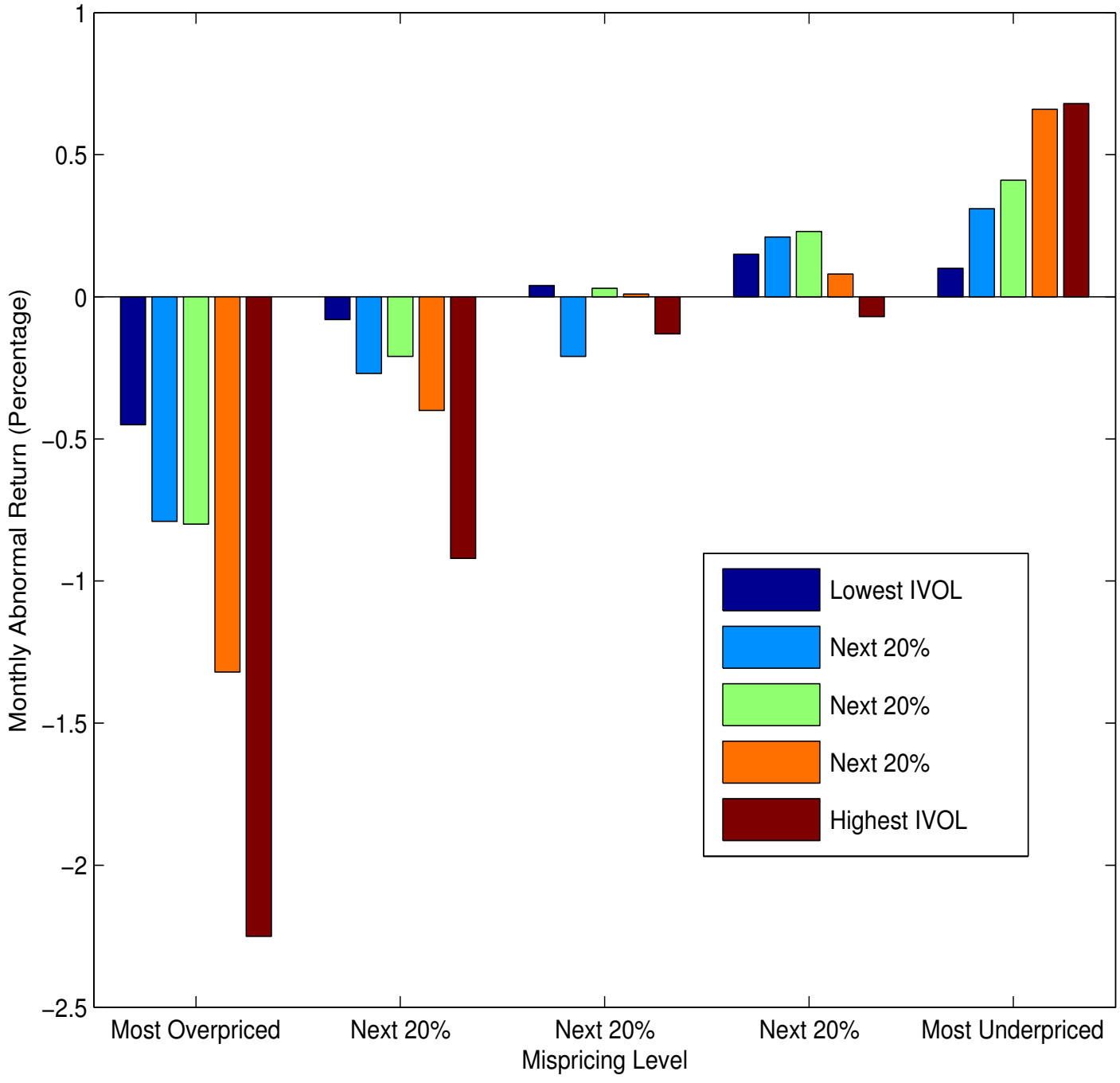
(Percent per month)

	Highest IVOL	Next 20%	Next 20%	Next 20%	Lowest IVOL
Most overpriced	4.43	3.55	3.18	3.06	2.49
Next 20%	3.71	2.92	2.37	2.13	2.12
Next 20%	3.37	2.65	2.22	2.17	2.05
Next 20%	3.74	2.55	2.06	1.77	1.80
Most underpriced	3.39	2.66	2.25	1.93	1.82

Mispricing and IVOL Effects

- "IVOL effect": relation between expected return and IVOL
- If arbitrage risk is important for mispricing, we expect
  - negative IVOL effect among overpriced stocks
  - positive IVOL effect among underpriced stocks
- If arbitrage asymmetry is important for mispricing, we expect the negative effect among overpriced stocks to be stronger.

  $\Rightarrow$ Negative IVOL effect in overall cross section


1
0.5
0
−0.5
−1
−1.5
−2
−2.5
Monthly Abnormal Return (Percentage)
Most Overpriced
Next 20%
Next 20%
Next 20%
Most Underpriced
Mispricing Level
Lowest IVOL
Next 20%
Next 20%
Next 20%
Highest IVOL

IVOL Effects in Underpriced vs. Overpriced Stocks

(Benchmark-Adjusted Returns, Percent per Month)

	Highest IVOL	Next 20%	Next 20%	Next 20%	Lowest IVOL	Highest −Lowest	All Stocks
Most overpriced (top 20%)	-2.25 (-11.91)	-1.32 (-8.72)	-0.80 (-5.79)	-0.79 (-5.31)	-0.45 (-3.92)	-1.80 (-8.28)	-0.81 (-8.14)
Next 20%	-0.92 (-5.76)	-0.40 (-3.00)	-0.21 (-2.08)	-0.27 (-2.83)	-0.08 (-0.82)	-0.84 (-4.33)	-0.23 (-3.88)
Next 20%	-0.13 (-0.88)	0.01 (0.11)	0.03 (0.25)	-0.21 (-2.15)	0.04 (0.48)	-0.18 (-0.95)	-0.07 (-1.47)
Next 20%	-0.07 (-0.42)	0.08 (0.69)	0.23 (2.54)	0.21 (2.69)	0.15 (1.93)	-0.23 (-1.10)	0.18 (4.45)
Most underpriced (bottom 20%)	0.68 (4.63)	0.66 (5.68)	0.41 (4.22)	0.31 (3.90)	0.10 (1.37)	0.57 (3.30)	0.28 (5.67)
Most overpriced − most underpriced	-2.93 (-12.31)	-1.98 (-9.81)	-1.21 (-6.53)	-1.10 (-6.08)	-0.55 (-3.69)	-2.38 (-9.08)	-1.09 (-8.05)
All stocks	-0.69 (-6.09)	-0.12 (-1.56)	-0.00 (-0.01)	0.05 (1.07)	0.08 (1.86)	-0.78 (-5.50)	

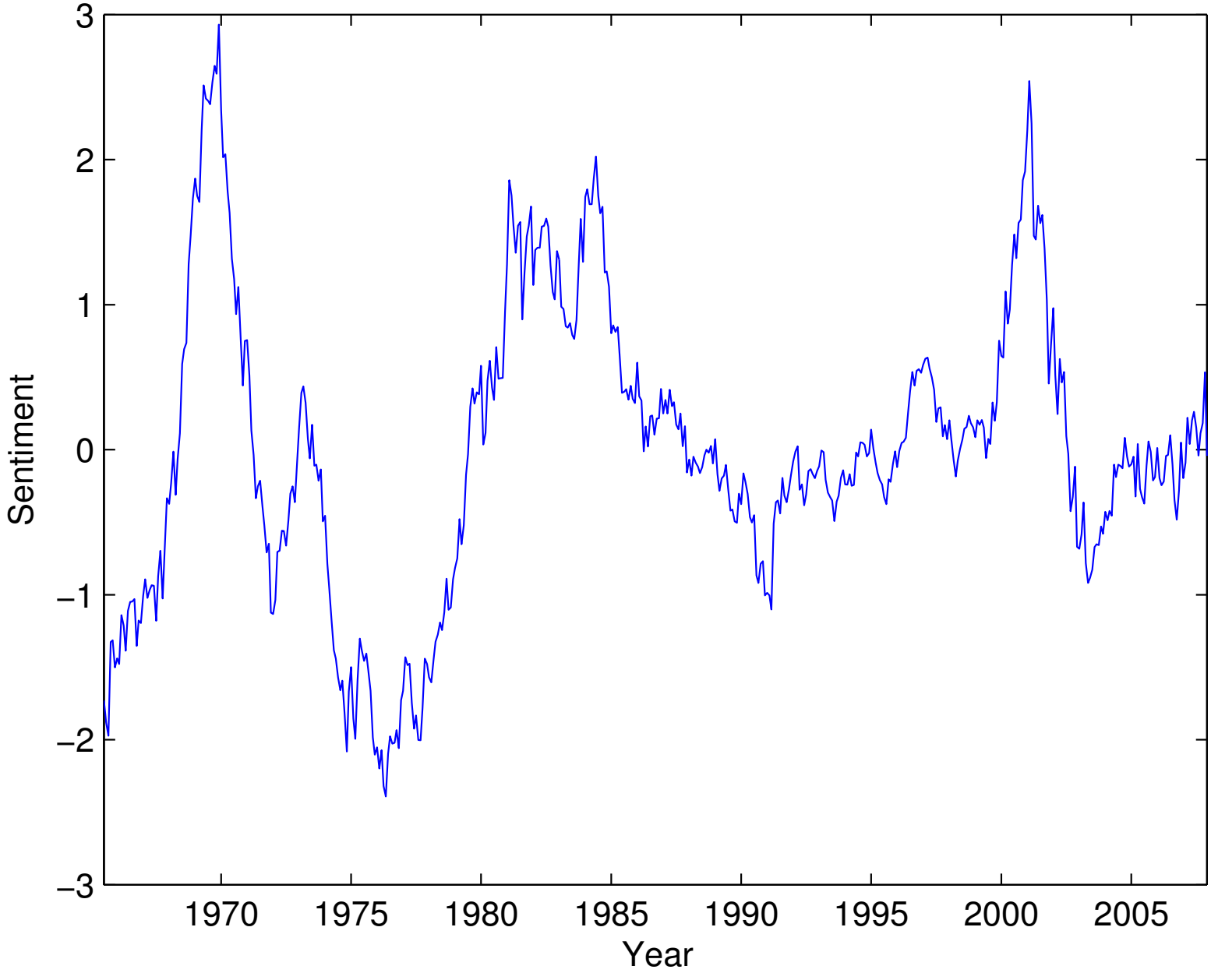
IVOL Effects in Underpriced vs. Overpriced Stocks

(Benchmark-Adjusted Returns, Percent per Month, **Independent Sorts**)

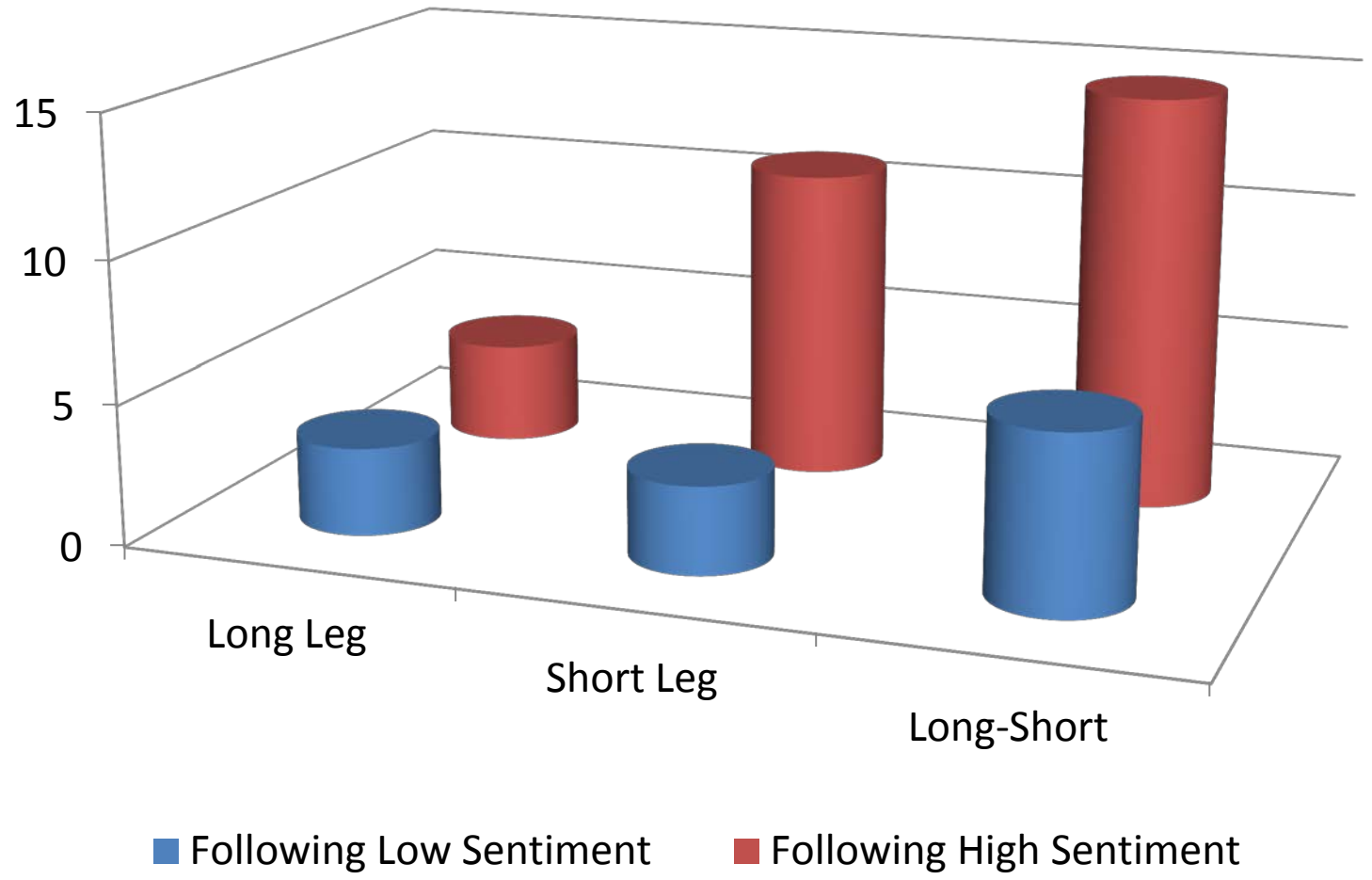
	Highest IVOL	Next 20%	Next 20%	Next 20%	Lowest IVOL	Highest −Lowest	All Stocks
Most overpriced (top 20%)	-1.89 (-12.05)	-0.95 (-7.39)	-0.72 (-4.90)	-0.47 (-3.62)	-0.39 (-3.04)	-1.50 (-7.36)	-0.81 (-8.14)
Next 20%	-0.88 (-5.86)	-0.41 (-3.36)	-0.31 (-3.00)	-0.21 (-2.08)	-0.04 (-0.44)	-0.84 (-4.41)	-0.23 (-3.88)
Next 20%	-0.09 (-0.53)	-0.01 (-0.09)	-0.05 (-0.48)	-0.12 (-1.29)	0.02 (0.18)	-0.10 (-0.53)	-0.07 (-1.47)
Next 20%	-0.15 (-0.80)	0.07 (0.63)	0.17 (1.87)	0.18 (2.33)	0.23 (3.22)	-0.38 (-1.78)	0.18 (4.45)
Most underpriced (bottom 20%)	0.56 (3.27)	0.68 (4.91)	0.51 (5.02)	0.33 (4.10)	0.14 (2.04)	0.41 (2.16)	0.28 (5.67)
Most overpriced − most underpriced	-2.44 (-11.07)	-1.63 (-8.65)	-1.23 (-6.43)	-0.81 (-5.02)	-0.53 (-3.43)	-1.91 (-7.62)	-1.09 (-8.05)

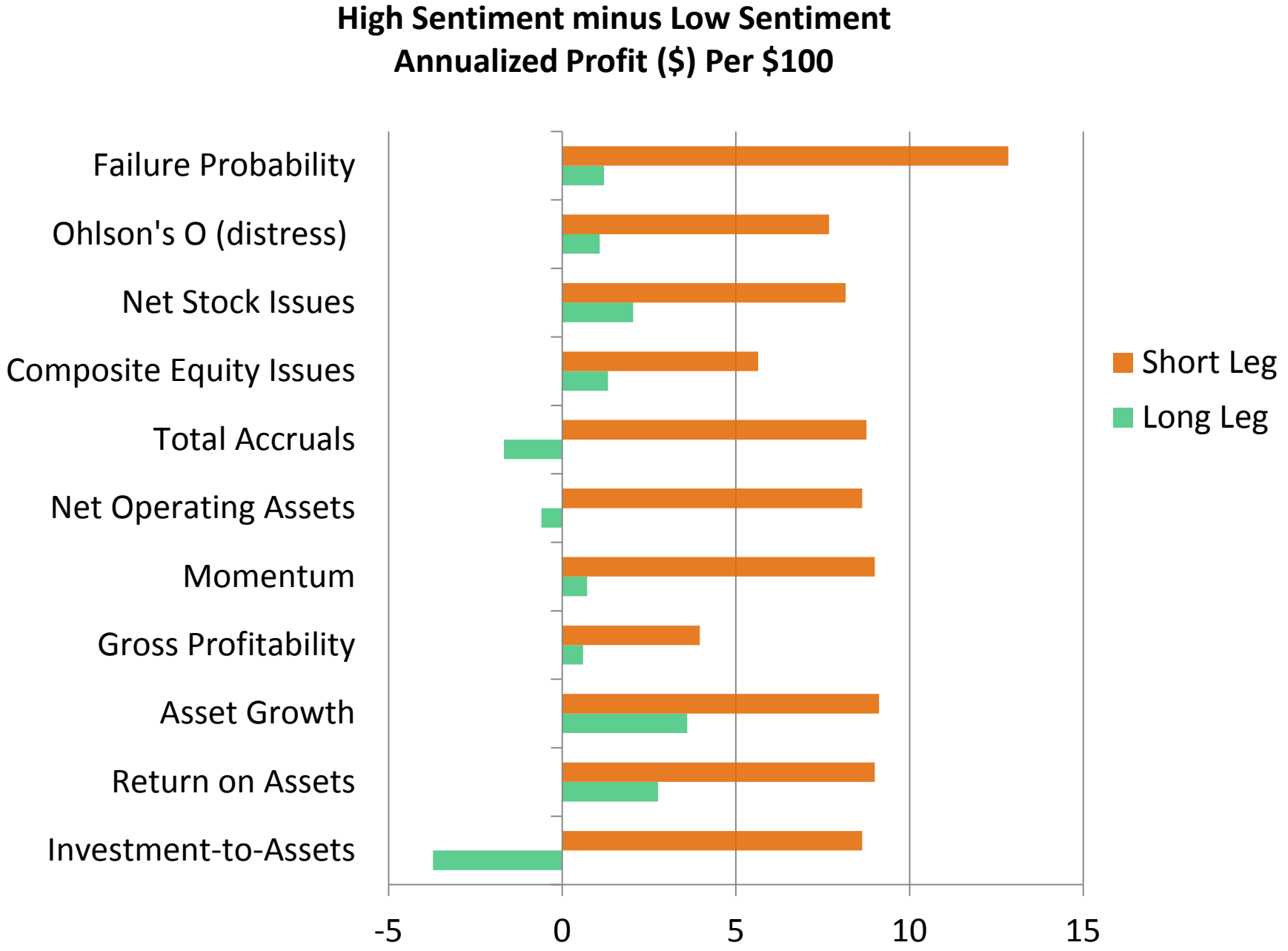
Time-Varying Mispricing

- Evidence of greater overpricing when sentiment is high
  - Stambaugh, Yu, and Yuan (*JFE*, 2012)
- Investor sentiment index (Baker-Wurgler)
  - Indicator of market-wide direction of mispricing
  - Principal component of six underlying measures:
    - closed-end fund discount
    - number of IPO's
    - first-day IPO returns
    - NYSE turnover
    - equity share of new issues
    - dividend premium ($\log B/M$, payers minus nonpayers)


3
2
1
0
−1
−2
−3
Sentiment
1970
1975
1980
1985
1990
1995
2000
2005
Year

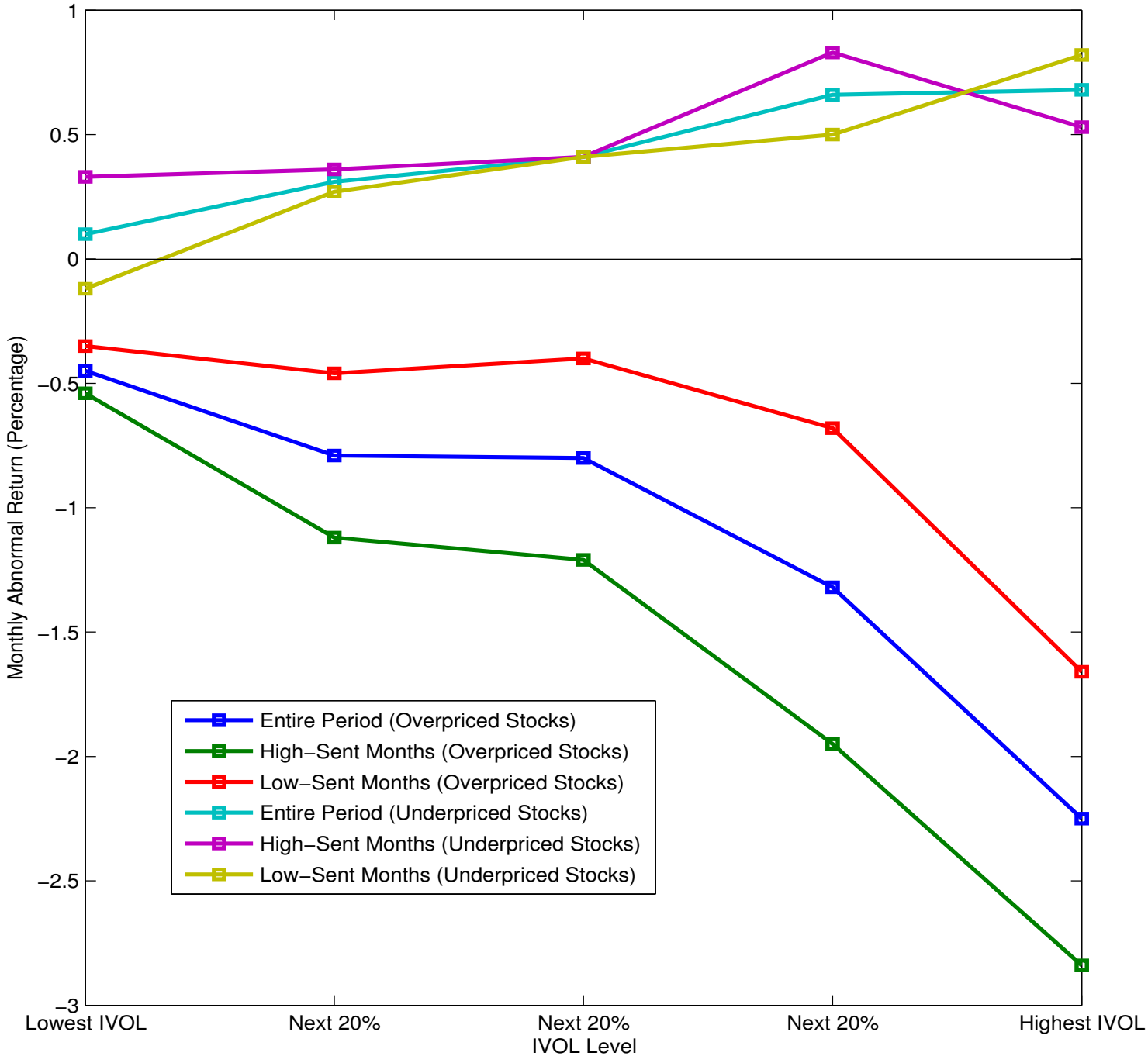
Combined Anomaly Strategy: $100 Long + $100 Short
Annualized Profit ($)




High Sentiment minus Low Sentiment
Annualized Profit ($) Per $100
Failure Probability
Ohlson's O (distress)
Net Stock Issues
Composite Equity Issues
Total Accruals
Net Operating Assets
Momentum
Gross Profitability
Asset Growth
Return on Assets
Investment-to-Assets
-5
0
5
10
15
Short Leg
Long Leg

Time-Varying IVOL Effects

- If the degree and direction of mispricing vary over time, so should IVOL effects.
- We expect
  (1) greater negative IVOL effect among overpriced stocks following high sentiment
  (2) greater positive IVOL effect among underpriced stocks following low sentiment
- Arbitrage asymmetry $\Rightarrow$ (1) should be stronger than (2)


1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
Monthly Abnormal Return (Percentage)
Lowest IVOL
Next 20%
Next 20%
Next 20%
Highest IVOL
IVOL Level
Entire Period (Overpriced Stocks)
High−Sent Months (Overpriced Stocks)
Low−Sent Months (Overpriced Stocks)
Entire Period (Underpriced Stocks)
High−Sent Months (Underpriced Stocks)
Low−Sent Months (Underpriced Stocks)

IVOL Effects in High- vs. Low-Sentiment Periods

(Benchmark-Adjusted Returns, Percent per Month)

	High-Sentiment Periods			Low-Sentiment Periods			High-Sentiment Periods − Low-Sentiment Periods		
	Highest IVOL	Lowest IVOL	Highest −Lowest	Highest IVOL	Lowest IVOL	Highest −Lowest	Highest IVOL	Lowest IVOL	Highest −Lowest
Most overpriced (top 20%)	-2.84 (-9.57)	-0.54 (-3.13)	-2.30 (-6.79)	-1.66 (-6.91)	-0.36 (-2.55)	-1.30 (-4.75)	-1.18 (-3.06)	-0.18 (-0.86)	-1.00 (-2.29)
Next 20%	-1.24 (-5.28)	-0.01 (-0.04)	-1.23 (-4.31)	-0.60 (-2.77)	-0.16 (-1.26)	-0.44 (-1.71)	-0.64 (-2.02)	0.15 (0.82)	-0.79 (-2.07)
Next 20%	-0.17 (-0.72)	0.31 (2.34)	-0.48 (-1.75)	-0.10 (-0.54)	-0.22 (-1.92)	0.13 (0.52)	-0.07 (-0.25)	0.53 (3.09)	-0.60 (-1.68)
Next 20%	-0.10 (-0.35)	0.19 (1.44)	-0.29 (-0.84)	-0.04 (-0.23)	0.11 (1.29)	-0.16 (-0.75)	-0.06 (-0.18)	0.08 (0.49)	-0.14 (-0.34)
Most underpriced (bottom 20%)	0.54 (2.43)	0.33 (2.77)	0.21 (0.77)	0.82 (4.05)	-0.12 (-1.21)	0.94 (4.16)	-0.28 (-0.93)	0.45 (2.85)	-0.73 (-2.03)
Most overpriced − most underpriced	-3.38 (-9.36)	-0.87 (-4.02)	-2.51 (-6.48)	-2.48 (-7.82)	-0.24 (-1.22)	-2.24 (-6.60)	-0.90 (-1.85)	-0.63 (-2.23)	-0.27 (-0.53)
All stocks	-1.06 (-5.75)	0.26 (3.81)	-1.32 (-5.88)	-0.33 (-2.45)	-0.10 (-1.87)	-0.23 (-1.35)	-0.72 (-3.16)	0.36 (4.16)	-1.09 (-3.82)

IVOL Effects and Sentiment: Predictive Regressions

$$R_{i,t} = a + bS_{t-1} + cMKT_t + dSMB_t + eHML_t + u_t,$$

	Highest IVOL		Lowest IVOL		Highest−Lowest	
	$\hat{b}$	t-stat.	$\hat{b}$	t-stat.	$\hat{b}$	t-stat.
Most overpriced (top 20%)	-0.78	-3.74	0.01	0.08	-0.79	-3.49
Next 20%	-0.40	-2.50	0.09	0.97	-0.48	-2.50
Next 20%	-0.10	-0.74	0.30	3.20	-0.40	-2.18
Next 20%	-0.13	-0.81	0.05	0.60	-0.18	-0.93
Most underpriced (bottom 20%)	-0.12	-0.92	0.16	1.81	-0.28	-1.80
Most overpriced − most underpriced	-0.66	-2.76	-0.15	-1.12	-0.50	-2.20
All stocks	-0.48	-3.92	0.18	3.77	-0.66	-4.25

Exploring Macroeconomic Effects

- Sentiment may well be related to macro conditions.
- One can nevertheless ask whether macro factors play a role here.
- Baker and Wurgler also construct a version of their index the removes variation related to six macro variables:
  - growth in industrial production
  - growth in durable consumption
  - growth in nondurable consumption
  - growth in services consumption
  - growth in employment
  - NBER recession flag
- If we use that index instead of the original, the results are very similar.

IVOL Effects and Sentiment: Predictive Regressions with Macro-Adjusted Sentiment

$$R_{i,t} = a + b\tilde{S}_{t-1} + cMKT_t + dSMB_t + eHML_t + u_t,$$

	Highest IVOL		Lowest IVOL		Highest − Lowest	
	$\hat{b}$	t-stat.	$\hat{b}$	t-stat.	$\hat{b}$	t-stat.
Most overpriced (top 20%)	-0.74	-3.56	0.03	0.28	-0.76	-3.42
Next 20%	-0.45	-2.89	0.08	0.92	-0.53	-2.81
Next 20%	-0.17	-1.24	0.29	3.10	-0.46	-2.49
Next 20%	-0.17	-1.12	0.04	0.52	-0.22	-1.14
Most underpriced (bottom 20%)	-0.20	-1.54	0.15	1.63	-0.35	-2.22
Most overpriced − most underpriced	-0.54	-2.28	-0.12	-0.87	-0.42	-1.88
All stocks	-0.52	-4.31	0.17	3.53	-0.69	-4.50

Controlling for Additional Macro Variables

- We include five additional variables in the predictive regression:
  - yield spread between BAA and AAA bonds
  - yield spread between 20-year and 1-year Treasuries
  - 30-day T-Bill rate minus inflation rate
  - surplus consumption ratio (Campbell and Cochrane, 1999, Wachter 2006)
  - consumption-wealth variable Cay (Lettau and Ludvigson, 2001)
- Previously identified as being related to expected stock returns
- Results are again very similar.

IVOL Effects and Sentiment: Predictive Regressions with Additional Macro Variables

$$R_{i,t} = a + b\tilde{S}_{t-1} + cMKT_t + dSMB_t + eHML_t + \sum_{j=1}^{6} m_j X_{j,t-1} + u_t,$$

	Highest IVOL		Lowest IVOL		Highest − Lowest	
	$\hat{b}$	t-stat.	$\hat{b}$	t-stat.	$\hat{b}$	t-stat.
Most overpriced (top 20%)	-0.64	-2.68	-0.08	-0.67	-0.56	-2.15
Next 20%	-0.46	-2.52	0.04	0.41	-0.50	-2.29
Next 20%	-0.10	-0.65	0.25	2.56	-0.35	-1.73
Next 20%	-0.09	-0.49	0.09	0.97	-0.17	-0.83
Most underpriced (bottom 20%)	-0.18	-1.21	0.07	0.70	-0.24	-1.42
Most overpriced − most underpriced	-0.46	-1.75	-0.14	-0.94	-0.32	-1.25
All stocks	-0.50	-3.58	0.15	2.84	-0.65	-3.69

Estimating the Role of Mispricing

- In each month t, estimate a cross-sectional regression containing a piecewise-linear function:

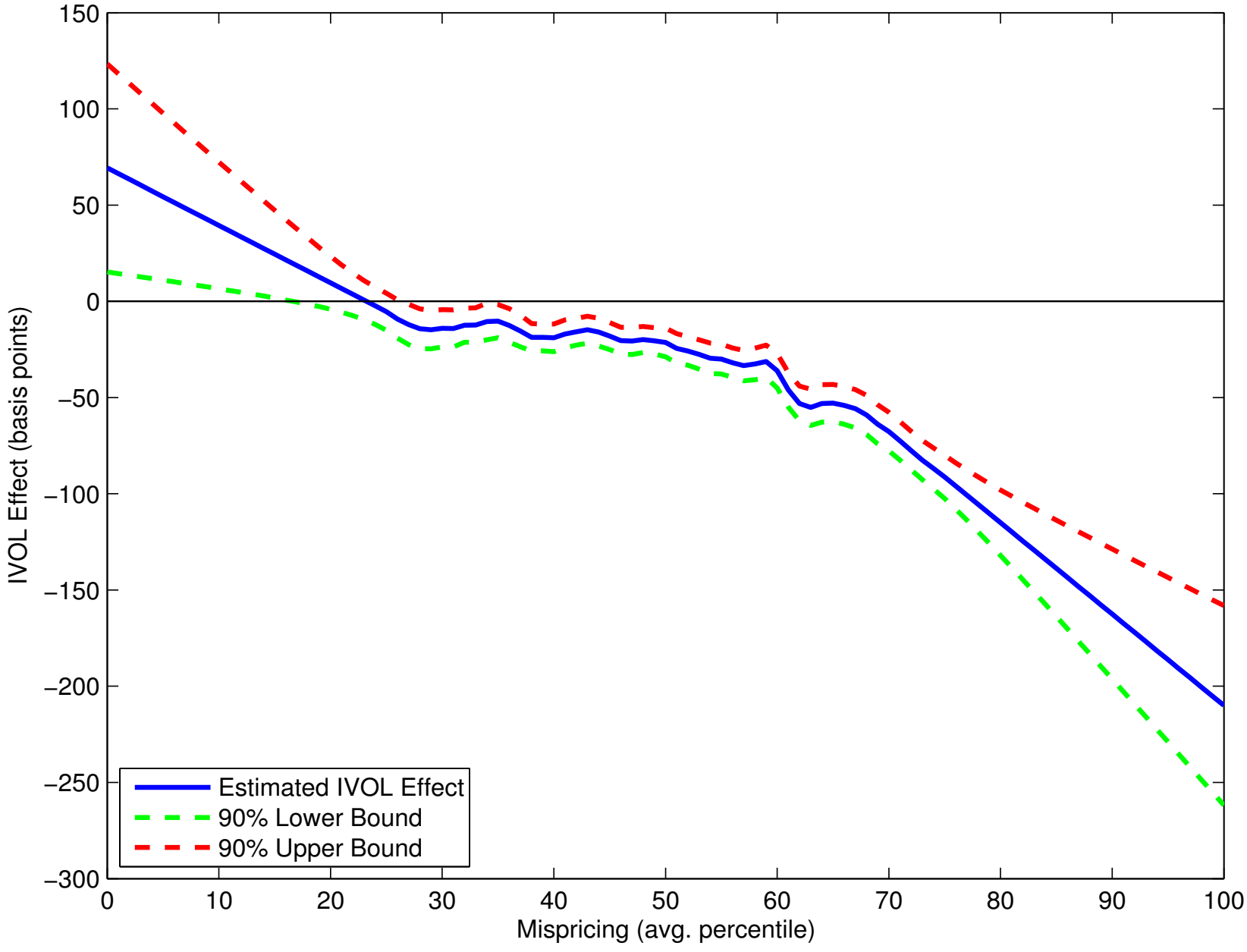
$$r^e_{t+1,i} = \beta_0 + f_t(M_{t,i})\sigma_{t,i} + \epsilon_{t+1,i},$$

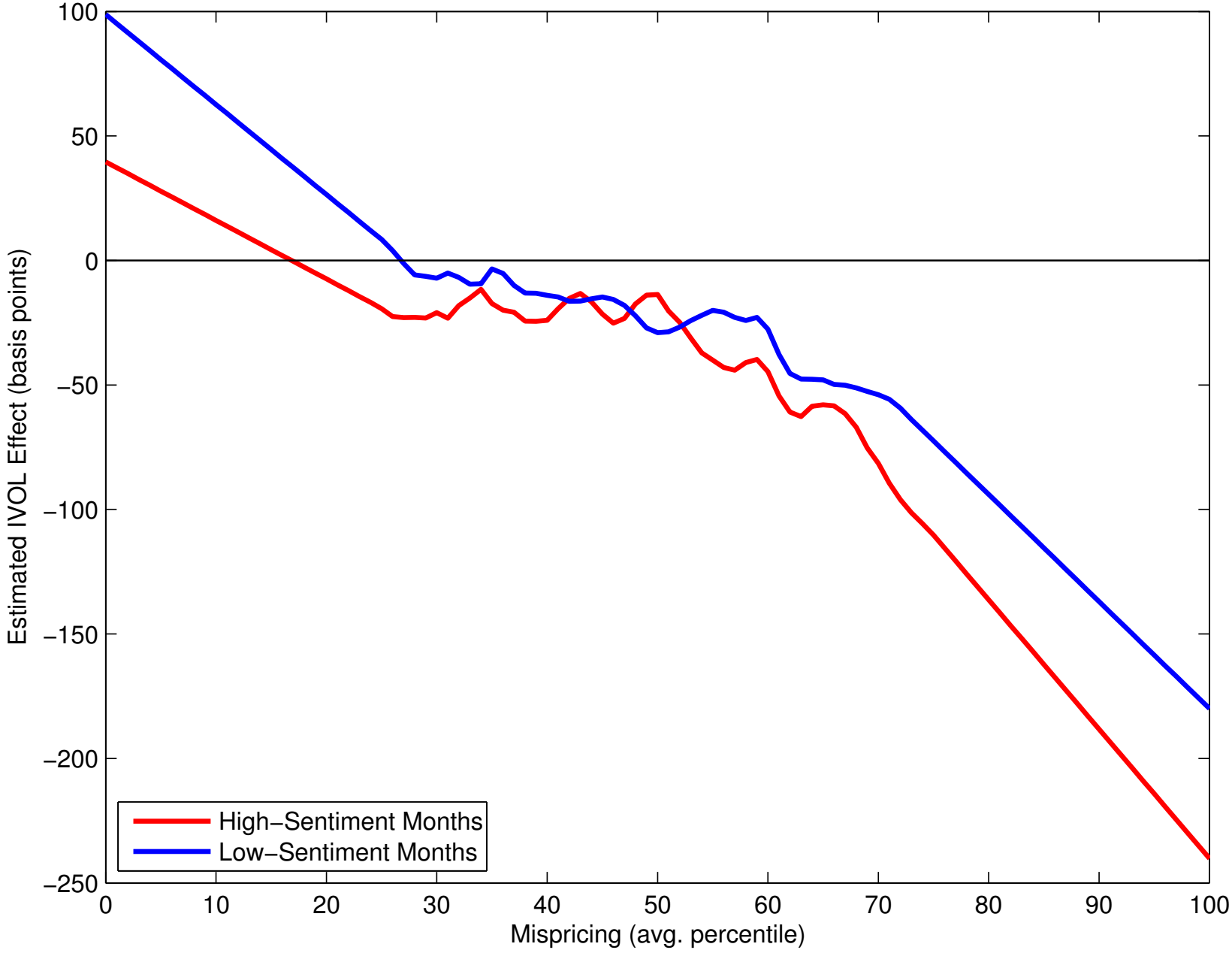
where

$$f_t(M) = \sum_{k=1}^{n} I(\theta_{k-1,t} \leq M < \theta_{k,t}) \times (a_{k,t} + b_{k,t}M),$$

$$a_{k,t} + b_{k,t}\theta_{k,t} = a_{k+1,t} + b_{k+1,t}\theta_{k,t}, \quad [\theta_0 \ \theta_n] = [0 \ 100\%]$$

- Compute $f(M) = (1/T)\sum_{t=1}^{T} f_t(M)$
- Also average separately over high- and low-sentiment months


150
100
50
0
−50
−100
−150
−200
−250
−300
IVOL Effect (basis points)
0
10
20
30
40
50
60
70
80
90
100
Mispricing (avg. percentile)
Estimated IVOL Effect
90% Lower Bound
90% Upper Bound


100
50
0
−50
−100
−150
−200
−250
0
10
20
30
40
50
60
70
80
90
100
Estimated IVOL Effect (basis points)
Mispricing (avg. percentile)
High−Sentiment Months
Low−Sentiment Months

Excluding Smaller Firms

- Smaller firm size
  - higher IVOL
  - greater overpricing
- Explore sensitivity to excluding smaller firms
- Continue to observe
  - Direction and strength of IVOL effect depend on mispricing
  - IVOL effect among overpriced stocks is significantly negatively related to investor sentiment
- IVOL effect among underpriced stocks also remains negatively related to sentiment, but significance drops

IVOL Effects Under Thresholds for Market Capitalization

	Highest IVOL	Next 20%	Next 20%	Next 20%	Lowest IVOL	Highest −Lowest	All Stocks
			Panel A: 20% Smallest Stocks Deleted				
Most overpriced (top 20%)	-2.15 (-11.08)	-1.29 (-8.59)	-0.84 (-6.04)	-0.75 (-5.02)	-0.46 (-3.91)	-1.69 (-7.69)	-0.80 (-7.98)
Next 20%	-0.89 (-5.72)	-0.40 (-2.92)	-0.25 (-2.51)	-0.30 (-3.12)	-0.10 (-1.03)	-0.79 (-4.16)	-0.26 (-4.33)
Next 20%	-0.13 (-0.89)	0.07 (0.67)	0.05 (0.49)	-0.15 (-1.55)	0.04 (0.46)	-0.17 (-0.93)	-0.05 (-1.15)
Next 20%	-0.04 (-0.22)	0.11 (1.06)	0.21 (2.25)	0.22 (2.72)	0.13 (1.68)	-0.17 (-0.87)	0.16 (4.06)
Most underpriced (bottom 20%)	0.68 (4.40)	0.67 (5.92)	0.40 (4.12)	0.30 (3.67)	0.11 (1.39)	0.58 (3.14)	0.29 (5.77)
Most overpriced − Most underpriced	-2.83 (-11.46)	-1.96 (-9.80)	-1.23 (-6.67)	-1.05 (-5.72)	-0.56 (-3.70)	-2.27 (-8.43)	-1.09 (-7.98)
All stocks	-0.69 (-6.13)	-0.05 (-0.69)	0.03 (0.46)	0.02 (0.51)	0.09 (2.02)	-0.78 (-5.56)	

IVOL Effects Under Thresholds for Market Capitalization

	Highest IVOL	Next 20%	Next 20%	Next 20%	Lowest IVOL	Highest −Lowest	All Stocks
			Panel B: 40% Smallest Stocks Deleted				
Most overpriced (top 20%)	-2.02 (-10.59)	-1.23 (-7.92)	-0.77 (-4.91)	-0.69 (-4.82)	-0.44 (-3.80)	-1.58 (-7.11)	-0.78 (-7.71)
Next 20%	-0.85 (-5.61)	-0.33 (-2.57)	-0.36 (-3.38)	-0.27 (-2.86)	-0.05 (-0.46)	-0.81 (-4.21)	-0.25 (-4.17)
Next 20%	-0.01 (-0.10)	0.07 (0.67)	0.06 (0.56)	-0.15 (-1.61)	0.04 (0.45)	-0.05 (-0.31)	-0.03 (-0.74)
Next 20%	0.01 (0.09)	0.13 (1.22)	0.17 (1.83)	0.25 (3.14)	0.14 (1.74)	-0.12 (-0.65)	0.17 (4.02)
Most underpriced (bottom 20%)	0.74 (5.05)	0.58 (5.38)	0.33 (3.51)	0.33 (4.11)	0.11 (1.35)	0.63 (3.57)	0.28 (5.66)
Most overpriced − Most underpriced	-2.76 (-11.93)	-1.80 (-9.00)	-1.11 (-5.56)	-1.02 (-5.66)	-0.55 (-3.58)	-2.21 (-8.59)	-1.06 (-7.75)
All stocks	-0.63 (-5.63)	-0.03 (-0.39)	0.08 (1.46)	0.01 (0.25)	0.10 (2.19)	-0.73 (-5.20)	

IVOL Effects Under Thresholds for Market Capitalization

	Highest IVOL	Next 20%	Next 20%	Next 20%	Lowest IVOL	Highest −Lowest	All Stocks
			Panel C: 60% Smallest Stocks Deleted				
Most overpriced (top 20%)	-1.67 (-9.02)	-1.05 (-6.69)	-0.66 (-4.11)	-0.58 (-4.58)	-0.41 (-3.64)	-1.25 (-5.96)	-0.71 (-7.37)
Next 20%	-0.62 (-4.03)	-0.26 (-2.29)	-0.30 (-2.84)	-0.16 (-1.59)	-0.04 (-0.41)	-0.58 (-2.94)	-0.21 (-3.65)
Next 20%	0.08 (0.62)	0.12 (1.15)	0.02 (0.21)	-0.14 (-1.45)	0.06 (0.63)	0.02 (0.14)	-0.01 (-0.31)
Next 20%	0.11 (0.83)	0.19 (1.88)	0.06 (0.61)	0.35 (4.03)	0.19 (2.15)	-0.07 (-0.46)	0.17 (3.69)
Most underpriced (bottom 20%)	0.71 (4.91)	0.59 (5.42)	0.31 (3.02)	0.31 (3.70)	0.10 (1.28)	0.60 (3.43)	0.28 (5.39)
Most overpriced − Most underpriced	-2.37 (-10.89)	-1.64 (-7.94)	-0.97 (-4.72)	-0.89 (-5.17)	-0.52 (-3.44)	-1.86 (-7.89)	-1.00 (-7.41)
All stocks	-0.44 (-3.94)	0.00 (0.06)	0.01 (0.26)	0.06 (1.29)	0.09 (1.98)	-0.53 (-3.79)	

IVOL Effects Under Market-Capitalization Thresholds

	Highest IVOL	Next 20%	Next 20%	Next 20%	Lowest IVOL	Highest −Lowest	All Stocks
			Panel D: 80% Smallest Stocks Deleted				
Most overpriced (top 20%)	-1.18 (-6.28)	-0.83 (-4.90)	-0.56 (-3.76)	-0.45 (-3.34)	-0.30 (-2.57)	-0.88 (-4.09)	-0.59 (-6.02)
Next 20%	-0.44 (-3.00)	-0.21 (-1.98)	-0.21 (-1.99)	-0.16 (-1.49)	0.06 (0.59)	-0.50 (-2.57)	-0.17 (-3.15)
Next 20%	0.06 (0.45)	0.12 (1.15)	0.08 (0.73)	-0.01 (-0.08)	0.09 (0.95)	-0.03 (-0.17)	0.05 (0.97)
Next 20%	0.16 (1.26)	-0.02 (-0.16)	0.18 (1.77)	0.26 (2.86)	0.13 (1.38)	0.03 (0.18)	0.15 (2.89)
Most underpriced (bottom 20%)	0.54 (3.75)	0.56 (5.20)	0.34 (3.22)	0.32 (3.56)	0.06 (0.71)	0.48 (2.62)	0.28 (4.96)
Most overpriced − Most underpriced	-1.72 (-7.47)	-1.39 (-6.33)	-0.90 (-4.64)	-0.77 (-4.16)	-0.36 (-2.33)	-1.35 (-5.32)	-0.87 (-6.28)
All stocks	-0.28 (-2.58)	0.05 (0.86)	0.02 (0.33)	0.09 (1.84)	0.09 (1.73)	-0.37 (-2.59)	

IVOL Effects and Sentiment Under Market-Capitalization Thresholds

	Highest IVOL		Lowest IVOL		Highest − Lowest	
	$\hat{b}$	t-stat.	$\hat{b}$	t-stat.	$\hat{b}$	t-stat.
Panel A: 20% Smallest Stocks Deleted						
Most overpriced (top 20%)	-0.79	-3.82	0.00	0.04	-0.79	-3.54
Next 20%	-0.44	-2.83	0.10	1.10	-0.53	-2.80
Next 20%	-0.11	-0.84	0.31	3.38	-0.42	-2.41
Next 20%	-0.10	-0.65	0.08	0.95	-0.18	-0.97
Most underpriced (bottom 20%)	-0.07	-0.52	0.14	1.50	-0.20	-1.29
Most overpriced−most underpriced	-0.72	-3.07	-0.13	-0.95	-0.59	-2.62
All stocks	-0.46	-3.80	0.18	3.76	-0.64	-4.15
Panel B: 40% Smallest Stocks Deleted						
Most overpriced (top 20%)	-0.83	-4.03	-0.02	-0.24	-0.80	-3.56
Next 20%	-0.38	-2.31	0.15	1.60	-0.53	-2.58
Next 20%	-0.19	-1.48	0.31	3.13	-0.50	-2.80
Next 20%	0.01	0.11	0.12	1.53	-0.11	-0.61
Most underpriced (bottom 20%)	-0.03	-0.24	0.14	1.45	-0.17	-1.02
Most overpriced−most underpriced	-0.79	-3.45	-0.16	-1.12	-0.63	-2.79
All stocks	-0.43	-3.48	0.19	3.93	-0.62	-3.93

IVOL Effects and Sentiment Under Market-Capitalization Thresholds

	Highest IVOL		Lowest IVOL		Highest − Lowest	
	$\hat{b}$	t-stat.	$\hat{b}$	t-stat.	$\hat{b}$	t-stat.
Panel C: 60% Smallest Stocks Deleted						
Most overpriced (top 20%)	-0.78	-3.86	0.04	0.39	-0.81	-3.77
Next 20%	-0.33	-2.14	0.11	1.23	-0.44	-2.25
Next 20%	-0.01	-0.09	0.27	2.64	-0.29	-1.51
Next 20%	0.03	0.21	0.14	1.73	-0.11	-0.70
Most underpriced (bottom 20%)	0.03	0.20	0.14	1.44	-0.11	-0.64
Most overpriced−most underpriced	-0.80	-3.46	-0.10	-0.70	-0.70	-3.23
All stocks	-0.35	-2.82	0.17	3.49	-0.52	-3.27
Panel D: 80% Smallest Stocks Deleted						
Most overpriced (top 20%)	-0.80	-3.87	0.11	0.94	-0.91	-3.93
Next 20%	-0.34	-2.29	0.18	1.75	-0.52	-2.63
Next 20%	0.00	0.01	0.29	2.82	-0.29	-1.52
Next 20%	0.02	0.16	0.16	1.76	-0.14	-0.85
Most underpriced (bottom 20%)	0.04	0.25	0.11	1.11	-0.07	-0.41
Most overpriced−most underpriced	-0.84	-3.37	0.00	0.01	-0.84	-3.28
All stocks	-0.31	-2.62	0.16	2.97	-0.47	-2.99

IVOL Effects and Institutional Ownership

- Short-sale impediments are likely to be more important among stocks with lower institutional ownership (IO)
- IO data from Thomson Financial Institutional Holdings (1980–2011)
- Compute the residuals in regression of logit IO on log size and $(\text{log size})^2$ (following Nagel, 2005)
- Identify the top 30% and bottom 30% of firms based on residual IO
- Double sort on mispricing and IVOL within high-IO and low-IO groups

IVOL Effects for High and Low Institutional Ownership

	High-IO Sample			Low-IO Sample			Low-IO Sample		
	Highest IVOL	Lowest IVOL	Highest −Lowest	Highest IVOL	Lowest IVOL	Highest −Lowest	Highest IVOL	Lowest IVOL	Highest −Lowest
Most overpriced (top 20%)	-1.84 (-5.39)	-0.75 (-3.59)	-1.09 (-2.55)	-3.09 (-8.39)	-0.22 (-1.10)	-2.87 (-6.81)	1.25 (2.64)	-0.53 (-2.14)	1.78 (3.26)
Next 20%	-0.80 (-2.88)	-0.01 (-0.04)	-0.79 (-2.46)	-1.51 (-4.90)	0.22 (1.30)	-1.73 (-4.74)	0.71 (1.70)	-0.23 (-0.96)	0.94 (2.03)
Next 20%	0.04 (0.14)	0.13 (0.82)	-0.09 (-0.27)	-0.34 (-1.02)	0.10 (0.61)	-0.44 (-1.11)	0.38 (0.88)	0.03 (0.12)	0.35 (0.72)
Next 20%	0.13 (0.53)	0.42 (2.91)	-0.29 (-1.02)	-0.17 (-0.56)	0.30 (1.91)	-0.47 (-1.34)	0.30 (0.79)	0.12 (0.56)	0.18 (0.40)
Most underpriced (bottom 20%)	0.70 (2.76)	0.16 (1.17)	0.54 (1.87)	0.41 (1.53)	0.15 (1.08)	0.25 (0.78)	0.29 (0.86)	0.01 (0.04)	0.28 (0.75)
Most overpriced − most underpriced	-2.53 (-6.01)	-0.91 (-3.43)	-1.62 (-3.04)	-3.49 (-8.25)	-0.37 (-1.44)	-3.12 (-6.34)	0.96 (1.73)	-0.54 (-1.72)	1.50 (2.28)
All stocks	-0.56 (-3.10)	0.18 (1.99)	-0.73 (-3.50)	-1.14 (-5.12)	0.15 (1.56)	-1.28 (-5.14)	0.58 (2.34)	0.03 (0.23)	0.55 (2.10)

Conclusions

- Explain negative relation between expected return and idioscycratic volatility—the IVOL puzzle.
- Combine
  - Arbitrage risk
  - Arbitrage asymmetry
- IVOL effect depends on mispricing
  - negative among overpriced stocks
  - positive among underpriced stocks
  - the first of these is stronger
- IVOL effect varies over time
  - negative effect is greater following high sentiment
  - positive effect is greater following low sentiment
  - the first of these is stronger