Quoting Activity and the Cost of Capital

Ioanid Roșu, Elvira Sojli and Wing Wah Tham

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Motivation

- Information is related to cost of capital (Easley O'Hara 2005)
  $\Longrightarrow$ important to shareholders, market participants
- Information gets into prices via
  - Market makers, who supply liquidity
    - Limit orders/quotes
  - Market takers, who demand liquidity
    - Market orders/trades

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- Information gets into prices via
  - Market makers, who supply liquidity
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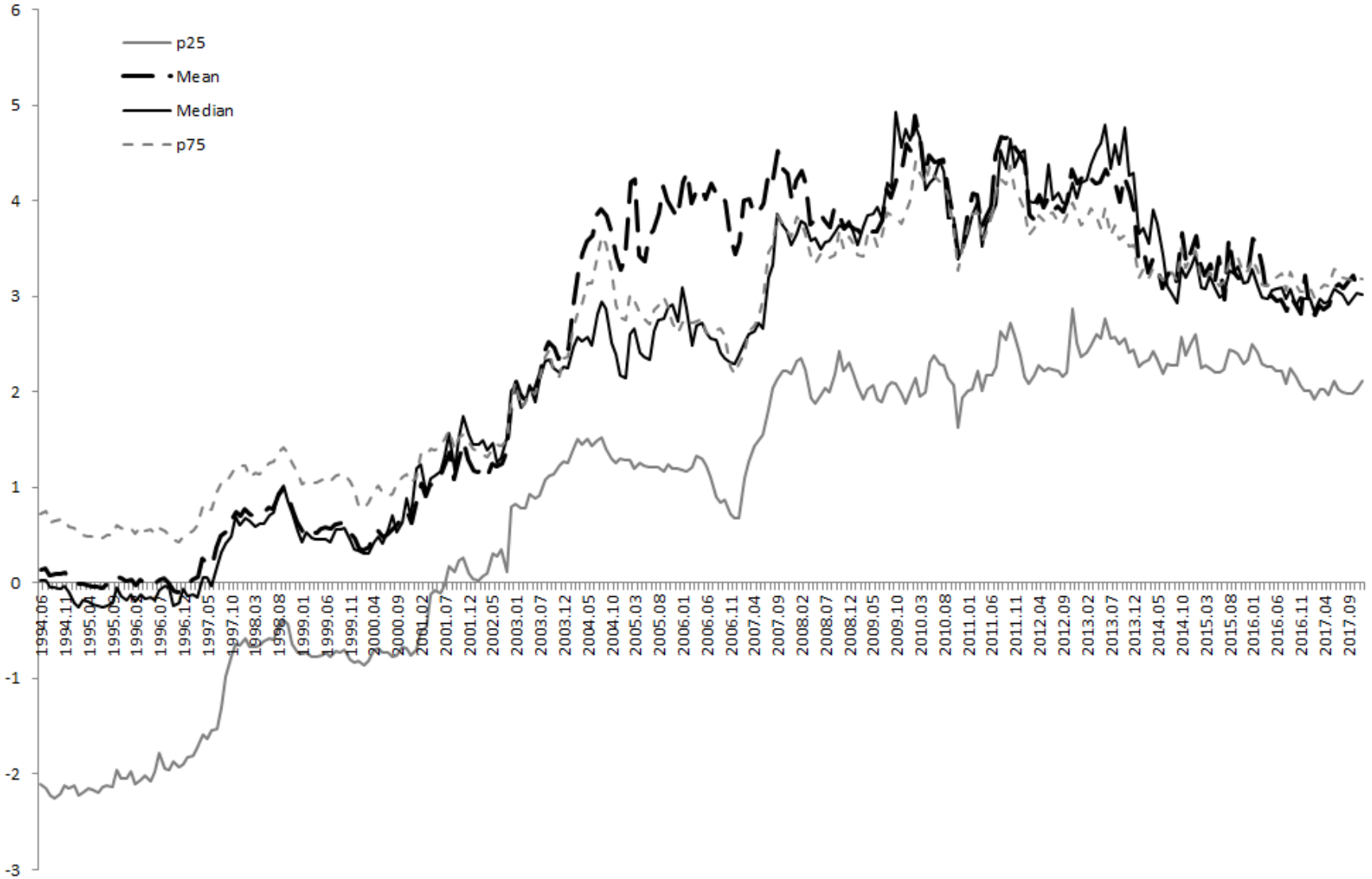
  - Market takers, who demand liquidity
    - Market orders/trades
- Natural to study information and cost of capital via quotes and trades
- Moreover, watching quoting activity is important for regulators and exchanges

Quote-to-Trade Ratio (log-scale)



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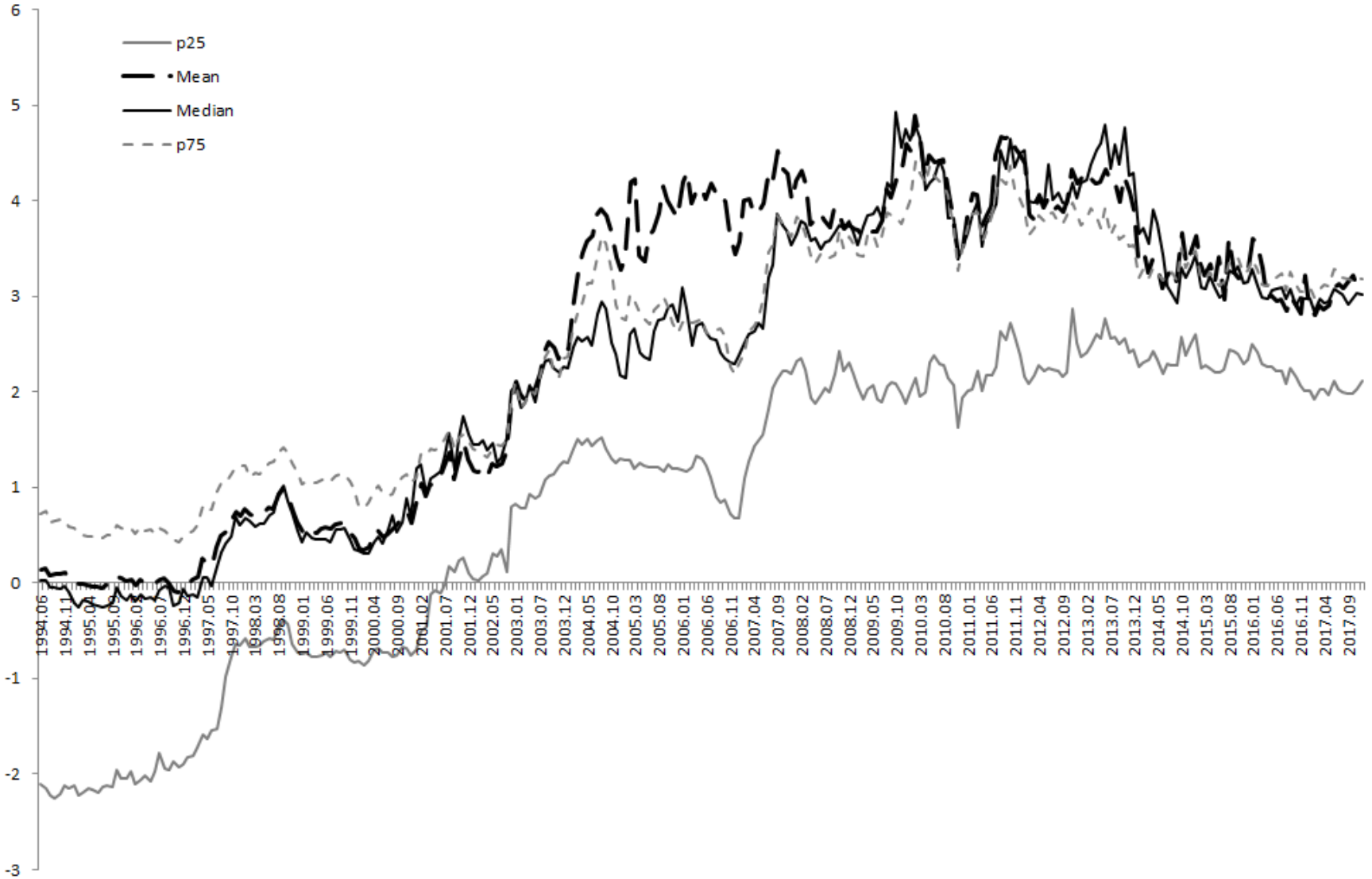

Motivation

- Little attention given to quotes, compared to trades
- Classical models: quotes set mechanically at expected value
  - No expected price appreciation $\Longrightarrow$ cost of capital is zero
  - Quote-to-trade ratio is always equal to 2
- In reality
  - Cost of capital is positive (on average)
  - Cost of capital + QT ratio vary across assets and over time

This paper

- **Model**
  - Extension of Ho Stoll (1981), Hendershott Menkveld (2014)
  - Dealer sets quotes to accommodate random order flow
  - Dealer maximizes expected profit, subject to inventory penalty

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- **Model**
  - Extension of Ho Stoll (1981), Hendershott Menkveld (2014)
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- **New features** in our model:
  - Dealer learns about asset value via costly monitoring
  - Order flow endogenously arises from demand of risk averse investors
- **Empirical predictions**

Results

- **Empirical Predictions:**
  - **P1:** Higher QT among neglected stocks (low market cap, inst. ownership, analyst coverage, volume, volatility)
  - **P2:** Number of MMs inversely related with QT
  - **P3:** QT has increased significantly over time
  - **P4:** Negative relation between QT and cost of capital
    - **P4':** Precisely informed investors $\Longrightarrow$ large QT
    - **P4":** Precisely informed investors $\Longrightarrow$ low cost of capital
  - **P5:** Number of MMs has no effect on cost of capital
- Predictions are consistent with the data

Model

- Risk asset: liquidates at $v \sim \mathcal{N}(v_0, \sigma_v^2)$
- Trading at τ: Poisson intensity normalized to one
- Given quotes a, b, aggregate market orders Q^b and Q^s

$$Q^b = \frac{k}{2}(v-a) + \ell - m + \varepsilon^b, \quad \text{with} \quad \varepsilon^b \overset{IID}{\sim} \mathcal{N}(0, \Sigma_L/2)$$

$$Q^s = \frac{k}{2}(b-v) + \ell + m + \varepsilon^s, \quad \text{with} \quad \varepsilon^s \overset{IID}{\sim} \mathcal{N}(0, \Sigma_L/2)$$

- Dealer maximizes expected profit, penalty on final inventory

$$\mathrm{E}_\tau \left(x_0\, v \;+\; \left((v-b)Q^s + (a-v)Q^b\right) \;-\; \gamma\, x_1^2 \;-\; C(q) \right)$$

Model: Quotes

- Monopolistic dealer, monitors the market with Poisson intensity q, for cost

$$C(q) \;=\; c\,q$$

- Monitoring produces (equivalently)
  - Signals $s_\tau = v + \varepsilon_\tau$ with precision $F(q) = \frac{1}{\mathrm{Var}(\varepsilon_t)} = f\,\ln(q+1)$
  - Forecast w with precision $\tilde{F}(q) = \frac{1}{\mathrm{Var}(v-w)} = f\,q$
- After monitoring, dealer sets quotes

$$\text{ask price} \;=\; a, \quad \text{bid price} \;=\; b$$

Model: Micro-foundations

- **Noise traders** submit random amounts
  - Buy N^b and sell N^s, with $N^b, N^s \sim \mathcal{N}\left(\ell_L, \frac{\Sigma_L}{2}\right)$
- **Investors** are risk-averse with CARA coefficient A
  - Initial endowment $\sim \mathcal{N}(M, \sigma_M^2)$
  - Liquidation value $v + u$, with $u \sim \mathcal{N}(0, \sigma_u^2)$
- **Proposition:** Aggregate market orders Q^b and Q^s are

$$Q^b = \frac{k}{2}(v - a) + \ell - m + \varepsilon^b, \quad \text{with} \quad \varepsilon^b \overset{IID}{\sim} \mathcal{N}\left(0, \frac{\Sigma_L}{2}\right)$$

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up to terms of order $O(1/\sigma_M)$

- Coefficients: $k = \frac{2\rho_1}{A\sigma_u^2}$, $\ell = \ell_N + \rho_0 \sigma_M$, $m = \rho_1 M$, with $\rho_0 \approx 0.1995$ and $\rho_1 \approx 0.4092$

Optimal Quotes

- **Proposition:** Equilibrium quotes and prices are

$$a = p + h, \qquad b = p - h$$

$$p = w - \delta$$

where the half-spread h and the discount δ satisfy

$$h = \frac{\ell}{k}, \qquad \delta = \frac{m}{k}\frac{1+2\gamma k}{1+\gamma k} + \frac{\gamma}{1+\gamma k}\, x_0$$

- Price depends on inventory $\Longrightarrow$ price pressure
  - Focus of Hendershott and Menkveld (2014)

Optimal Monitoring and the Quote Rate

- Monitoring rate q is interpreted as **quote rate**
- **Proposition:** Equilibrium quote rate satisfies

$$q^2 = \frac{k(k\gamma + 1)}{fc}$$

- **P1:** Quote rate is large in neglected stocks ($\Leftarrow$ small f)
- **P2:** Quote rate is small when # of MMs is large ($\Leftarrow$ small γ)
- **P3:** Quote rate has increased over time ($\Leftarrow$ decrease in c)

Discussion of Prediction 2

- In practice, there are several market makers in a stock
- $1/\gamma$ is a proxy for aggregate risk tolerance $\Longrightarrow$ proxy for the number of market makers
- **P2:** Quote rate is decreasing in the number of MMs
  - Intuition: q increasing in γ (aggregate risk tolerance)
- Internet Appendix: same result in model with N dealers
  - Intuition: monitoring is public $\Longrightarrow$ positive externalities $\Longrightarrow$ under-monitoring in equilibrium

Pricing Discount and the Cost of Capital

- Expected return is in one-to-one relation with pricing discount δ

$$\frac{\mathrm{E}_t(v) - p_t}{p_t} = \frac{w_t - p_t}{p_t} = \frac{\delta}{w_t - \delta}$$

- Define the **cost of capital** r as

$$r = \delta = \frac{m}{k}\frac{1+2\gamma k}{1+\gamma k} + \frac{\gamma}{1+\gamma k}x_0$$

- **Corollary:** If $x_0 \geq 0$, the cost of capital is increasing in m and decreasing in k.

Quote Effect

- **Corollary:** Holding all parameters constant except for investor elasticity $k \implies$ inverse relation between r and q:
  - q is increasing in k
  - r is decreasing in k
- **P4:** Inverse relation between expected return and QT ratio

Neutral State

- Define **neutral** (or **preferred**) inventory

$$x_{0,\text{neutral}} = \frac{m}{\gamma k}$$

- **Corollary:** In the neutral state $E(Q^b) = E(Q^s)$, and

$$h_{\text{neutral}} = \frac{\ell}{k}, \qquad \delta_{\text{neutral}} = \frac{2m}{k}, \qquad p_{\text{neutral}} = w - \frac{2m}{k}$$

- **Note:** δ_{neutral} no longer depends on γ
  - It only depends on the properties of the order flow
  - Dynamic model: δ_{neutral} = long-term average of δ_t

Prediction 5

- **P5:** Cost of capital is not affected by the number of MMs
  - Recall that $1/\gamma$ is a proxy for the number of MMs
  - But r only depends on the properties of the order flow
  - Internet Appendix: same result in model with N dealers (same intuition)

Data

- Sample Period: June 1994 to December 2017
- Use complete set of quote updates and trades in TAQ
- Retain stocks for which information is available in CRSP, TAQ, and Compustat
- Remove stocks when $P < \$2$ and $P > \$1,000$
- Use delisting returns of -30% (Shumway 1997)
- Returns are calculated using bid-ask midpoints

Table 1: Characteristics of QT Ratio Portfolios

The table presents the monthly average characteristics for 10 QT portfolios constructed in month t. Portfolio 1 consists of stocks with the lowest QT and portfolio 10 consists of stocks with the highest QT in month t. For each QT decile, we compute the cross-sectional mean characteristic for month $t+1$. The reported characteristics are computed as the time-series mean of the mean cross-sectional characteristic. Column (2) is the QT level, columns (3) and (4) are the number of trades and quote updates in thousands, column (5) shows market capitalization (in million USD), columns (6) and (7) show the share volume (in million shares) and USD volume traded (in million USD), columns (8) and (9) show the quoted spread and relative spread (in % of the mid-quote), column (10) shows the Amihud illiquidity ratio (ILR) in %, column (11) shows volatility (calculated as the absolute monthly return in %), column (12) shows price, column (13) shows the average Book-to-Market value measured at the end of the previous calendar year, and column (14) shows the average monthly portfolio return in excess of the risk free rate (r_{t+1}) for each portfolio.

Average portfolio characteristics at $t+1$													
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
QT		N(trades)	N(quotes)	MCAP	VOLUME (mill.)		SPREAD						
portf (t)	QT	(x 1000)	(x 1000)	(mill.)	Shares	USD	Quoted	Relative (%)	ILR (%)	VOLA (%)	PRC	BM	$r_{p,t+1}$ (%)
1	1.4	131	187	8912	75.1	1725	0.140	1.41	2.75	3.71	15.7	0.63	1.52
2	2.8	47	215	3629	20.0	692	0.160	1.61	3.75	3.58	18.0	0.63	1.30
3	3.9	33	224	2863	13.5	533	0.178	1.71	3.96	3.34	20.3	0.64	1.10
4	5.2	26	229	2497	10.5	444	0.201	1.82	4.41	3.22	22.2	0.64	1.04
5	6.7	20	216	2091	8.1	352	0.233	1.98	5.25	3.13	23.7	0.65	0.95
6	9.0	15	201	2315	7.2	321	0.275	2.14	6.79	2.84	24.6	0.70	0.81
7	13.9	11	166	3302	7.7	335	0.259	1.98	5.69	2.32	24.9	0.76	0.94
8	20.8	7	131	2034	4.7	207	0.278	1.86	4.55	1.98	25.7	0.76	0.84
9	43.6	3	97	1431	2.8	126	0.323	1.95	5.13	1.89	25.9	0.78	0.84
10	154.4	1	85	828	1.2	58	0.441	2.38	7.91	1.73	27.9	1.01	0.65

Table 2: Determinants of QT Ratio

	(1)	(2)
ANF	-0.95***	-0.35***
	(-5.07)	(-3.04)
INST	-41.83***	-55.05***
	(-4.94)	(-7.05)
BM	37.03***	-1.73
	(2.93)	(-0.29)
*R*1	-18.14***	-2.50
	(-4.44)	(-1.19)
MCAP	-2.02	-0.20
	(-0.84)	(-0.09)
PRC	0.42***	0.26***
	(5.83)	(4.69)
USDVOL	-0.19	-1.53***
	(-0.63)	(-3.10)
ILR	12.23**	-0.51
	(2.16)	(-0.21)
SPREAD	-468.18***	-123.72***
	(-8.97)	(-2.67)
IDIOVOL	-394.98***	-106.20***
	(-6.02)	(-3.55)
Stock FE	NO	YES
Time FE	NO	YES
N	805,763	805,763
Adj. R^2	0.044	0.305

Prediction 1

- Neglected stocks have higher QT ratios
- *Neglected* means
  - Low institutional ownership
  - Low analyst coverage
  - Low trading volume
  - Low volatility

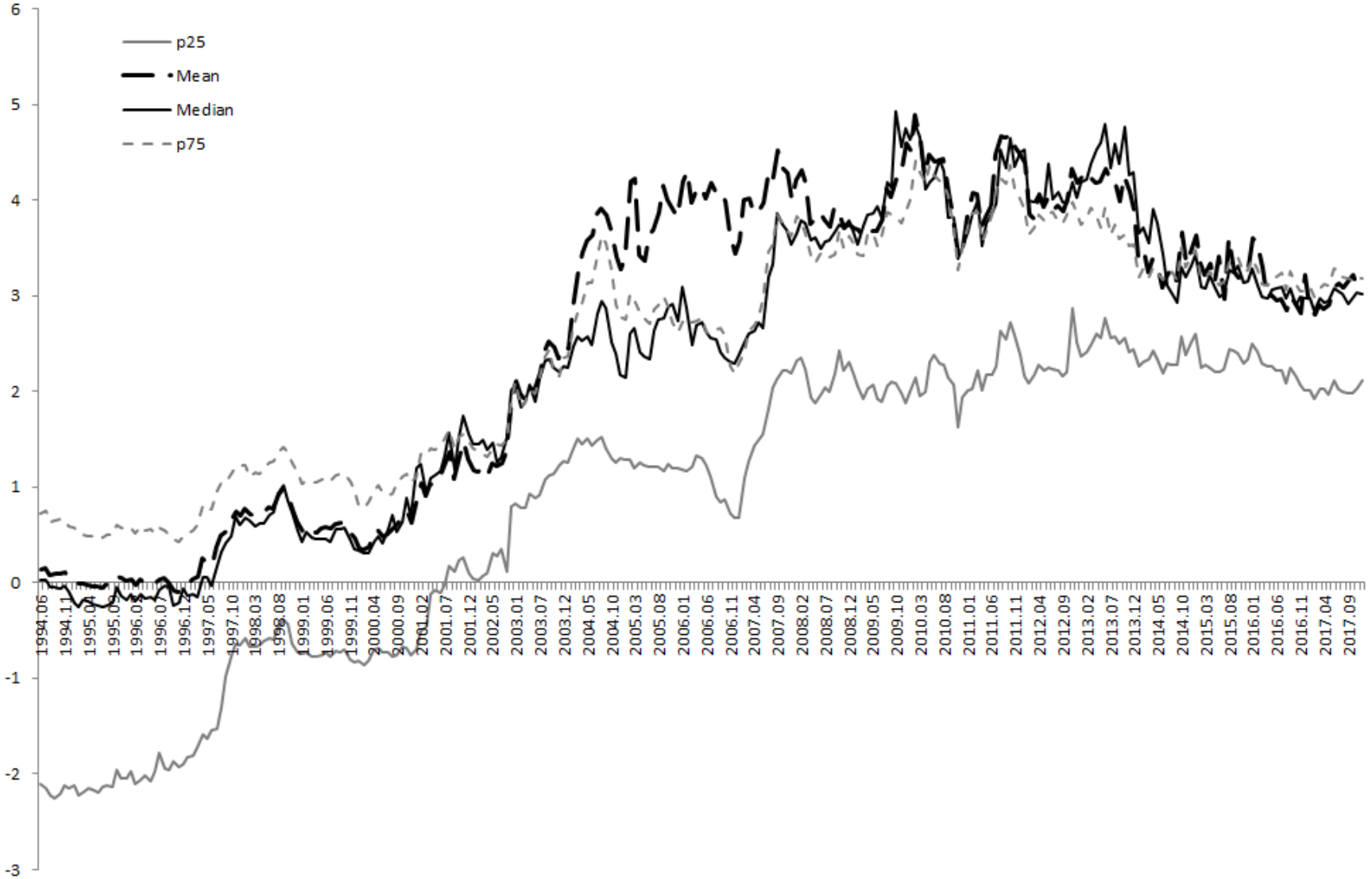
Table 3: Additional Determinants of QT Ratio

	(1)	(2)
ANF	0.14	-0.62***
	(1.09)	(-5.39)
Controls		
MM	-1.40***	-0.33**
	(-10.16)	(-2.14)
AQ		-30.88***
		(-6.22)
SSBAN		-13.84**
		(-2.00)
*TICK*1		-0.37
		(-0.27)
*TICK*2		33.23***
		(7.29)
REG-NMS		29.19***
		(4.33)
Stock FE	YES	YES
Time FE	YES	NO
N	470,082	547,255
Adj. R^2	0.411	0.319

Prediction 2

- Stocks with a more MMs have lower QT ratios

Quotes and Trades (log-scale)



Prediction 3

- QT ratios have increased significantly over time

Table 4: Alphas for QT Portfolios

The table shows risk-adjusted monthly returns for various portfolios sorted on the QT ratio. The α's reported in the table are time series averages of intercepts (risk-adjusted returns) obtained from 24-month rolling window regressions. We show the alpha for the lowest and highest QT portfolios and the alpha for the difference in returns between the low and high portfolios. Stocks are assigned to ten portfolios based on their QT level in month t. Then returns are calculated for each portfolio for month $t+1$.

		Risk-adjusted returns (%)					
	r^e_{t+1}	CAPM	FF3	FF3+PS	FF3+PS +MOM	FF5	FF3+PS +MOM+PIN
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
α_1	1.59***	0.90*	1.05***	1.01***	1.64***	0.95***	1.66***
α_2	1.34***	0.91**	0.86***	0.85***	1.17***	0.59***	1.17***
α_3	1.21***	0.76*	0.67***	0.63***	0.97***	0.52***	0.98***
α_4	1.08***	0.62*	0.49***	0.50***	0.76***	0.34***	0.76***
α_5	1.02***	0.63*	0.47**	0.47**	0.67***	0.25***	0.67***
α_6	0.95***	0.30	0.08	0.10	0.32*	0.19**	0.31*
α_7	1.03***	0.58**	0.24	0.22	0.59***	0.21**	0.60***
α_8	0.93***	0.48***	0.06	0.04	0.32**	0.08	0.32**
α_9	0.95***	0.44	-0.01	-0.02	0.20	0.18**	0.18
α_{10}	0.77***	0.40***	-0.08	-0.10	0.08	0.01	0.06
α(QT1-QT10)	0.83***	0.50	1.13***	1.11***	1.56***	0.94***	1.60***

Table 5: Stock Returns and QT Ratio

The table reports the Fama-MacBeth coefficients from regressions of risk-adjusted monthly returns on firm characteristics. The dependent variable is the risk-adjusted return $r^a_{i,t} = r_{i,t} - \sum_{j=1}^{J} \beta_{i,j,t-1} F_{j,t}$, where the risk factors $F_{j,t}$ come from the FF4+PS model. The characteristics included are: quote-to-trade ratio (QT), relative bid/ask spread ($SPREAD$), Amihud illiquidity ratio (ILR), log-market capitalization ($MCAP$), log-book-to-market ratio (BM), previous month return ($R1$), cumulative return from month $t-2$ to $t-12$ ($R212$), idiosyncratic volatility ($IDIOVOL$) measured as the standard deviation of the residuals from a FF3 regression of daily raw returns within each month, log-dollar-volume ($USDVOL$), and log-price (PRC). The firm characteristics are measured in month $t-1$. All coefficients are multiplied by 100.

	(1)	(2)	(3)	(4)	(5)
Const.	0.005***	0.004***	0.014***	0.012***	0.035***
$QT_{i,t-1}$	-0.172**	-0.199***	-0.251***	-0.261***	-0.156***
	(-2.23)	(-2.91)	(-3.61)	(-3.59)	(-3.85)
$SPREAD_{i,t-1}$		0.166***		0.074*	0.021
$ILR_{i,t-1}$			0.102***	0.081***	-0.008
$MCAP_{i,t-1}$					-0.136*
$BM_{i,t-1}$					0.032
$R1_{i,t-1}$					-3.350***
$R212_{i,t-1}$					0.084
$IDIOVOL_{i,t-1}$					-9.525***
$USDVOL_{i,t-1}$					0.052
$PRC_{i,t-1}$					-0.345***
R^2	0.00	0.01	0.01	0.01	0.03
Time series (months)	278	278	278	278	278

Prediction 4

- QT Effect: Higher QT ratios predict lower expected returns (in the cross-section)

Table 6: Quotes vs. Trades

The table reports the Fama-MacBeth coefficients from regressions of risk-adjusted monthly returns on firm characteristics including the number of quotes and trades. The dependent variable is the risk-adjusted return $r^a_{i,t} = r_{i,t} - \sum_{j=1}^{J} \beta_{i,j,t-1} F_{j,t}$, where the risk factors $F_{j,t}$ come from the FF4+PS model. The characteristics included are: number of quotes ($QUOTE$), number of trades ($TRADE$), relative bid/ask spread ($SPREAD$), Amihud illiquidity ratio (ILR), log-market capitalization ($MCAP$), log-book-to-market ratio (BM), previous month return ($R1$), cumulative return from month $t-2$ to $t-12$ ($R212$), idiosyncratic volatility ($IDIOVOL$) measured as the standard deviation of the residuals from a FF3 regression of daily raw returns within each month, log-dollar-volume ($USDVOL$), and log-price (PRC). All coefficients are multiplied by 100.

	(1)	(2)	(3)	(4)	(5)	(6)
Const.	0.022***	0.021***	0.019***	0.020***	0.020***	0.021***
$QUOTE_{i,t-1}$	-0.320***	-0.337***	-0.290***	-0.313***	-0.130***	-0.154***
$TRADE_{i,t-1}$	0.175*	0.204**	0.235**	0.244**	-0.160	-0.134
$SPREAD_{i,t-1}$		0.023		0.011		-0.006
$ILR_{i,t-1}$			0.081**	0.064*		-0.003
$MCAP_{i,t-1}$					-0.159**	-0.143**
$BM_{i,t-1}$					0.023	0.026
$R1_{i,t-1}$					-3.496***	-3.418***
$R212_{i,t-1}$					0.069	0.073
$IDIOVOL_{i,t-1}$					-7.348**	-8.466***
$USDVOL_{i,t-1}$					0.346***	0.322***
$PRC_{i,t-1}$					-0.573***	-0.534***
R^2	0.01	0.01	0.01	0.01	0.03	0.03
Time series (months)	278	278	278	278	278	278

Prediction 4

- QT effect is driven by the number of quotes rather than the number of trades

Table 7: Stock Returns, QT Ratio and MMs

	(1)	(2)
Const.	0.033***	0.030***
$QT_{i,t-1}$	-0.128*	
$SPREAD_{i,t-1}$	0.048	0.068
$ILR_{i,t-1}$	0.038	0.030
$MCAP_{i,t-1}$	-0.226**	-0.218**
$BM_{i,t-1}$	0.053	0.054
$R1_{i,t-1}$	-3.763***	-3.724***
$R212_{i,t-1}$	0.102	0.109
$IDIOVOL_{i,t-1}$	-10.283**	-10.648**
$USDVOL_{i,t-1}$	0.212*	0.213*
$PRC_{i,t-1}$	-0.496***	-0.556***
$MM_{i,t-1}$	-0.004	-0.001
R^2	0.04	0.04
Time series (months)	278	278

Prediction 5

- Number of MMs has no effect on expected returns

Conclusion: Results

- Patterns in the quoting activity of MMs
  - **P1:** Higher QT among neglected stocks (low market cap, inst. ownership, analyst coverage, volume, volatility)
  - **P2:** Number of MMs inversely related with QT
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