price pressures

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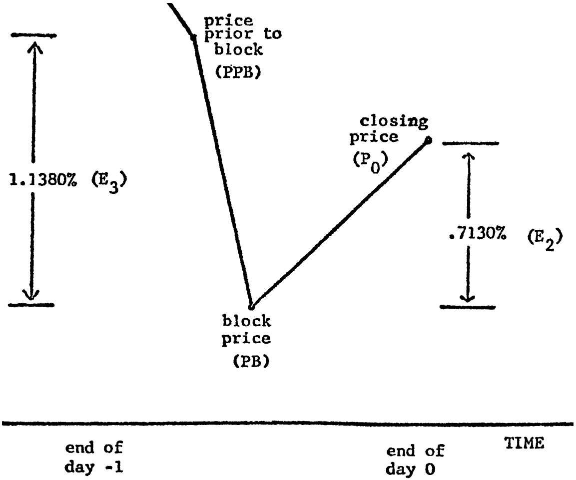
price pressure vs information

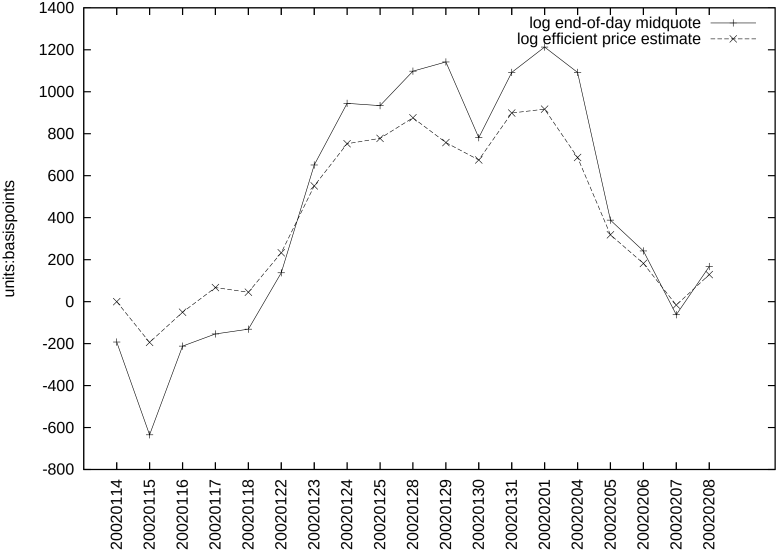


source: Kraus and Stoll (1972), E_2 is price pressure, $E_3 - E_2$ is information
price pressure equilibrates liquidity demand and supply

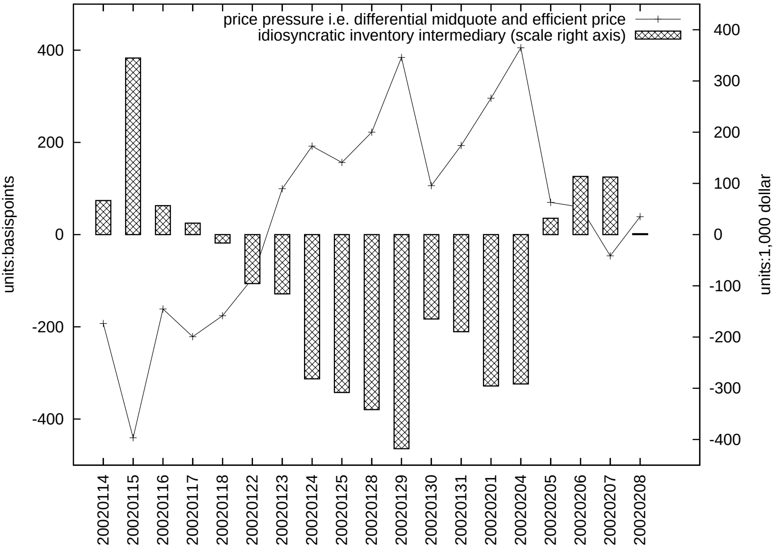
state space model

$$
\begin{aligned}
m_t &= m_{t-1} + w_t \\
p_t &= m_t + s_t \\
s_t &= \varphi s_{t-1} + \varepsilon_t
\end{aligned}
$$

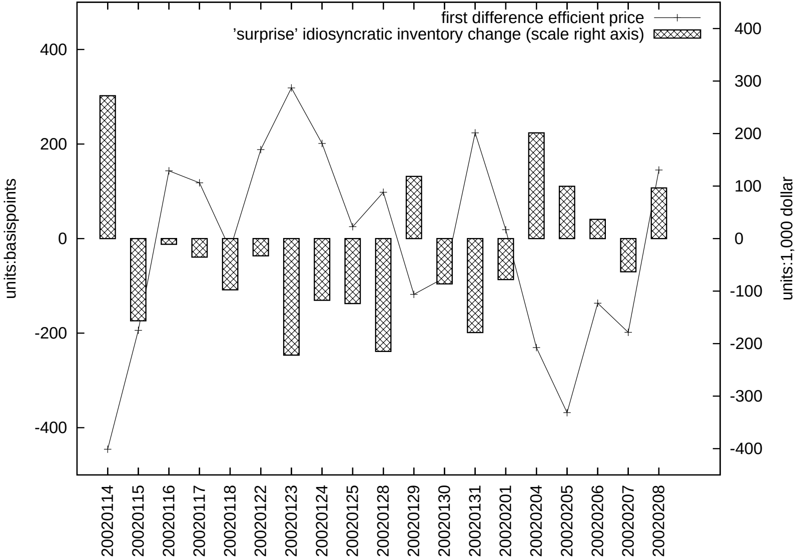
observed price and efficient price



price pressure and inventory



surprise order flow and efficient price change



literature

- prior empirical work finds support for inventory control, but weak support for inventories causing price pressure (e.g. Hasbrouck (1988), Madhavan and Smidt (1991), Madhavan and Smidt (1993), Hasbrouck and Sofianos (1993), Ho and Macris (1984), Hansch, Naik, and Viswanathan (1998), Reiss and Werner (1998), Naik and Yadav (2003), Hendershott and Seasholes (2007))
- theoretical work characterizes price pressure caused by dynamic inventory control (e.g. Ho and Stoll (1981), Madhavan and Smidt (1993), Amihud and Mendelson (1980))

agenda remainder of talk

- present empirical results in detail with focus on time series properties price pressure
- develop simple dynamic inventory model to identify primitive parameters off of these time series properties
- use primitive parameters to analyze constrained pareto efficiency

summary statistics

	mean Q1	mean Q2	mean Q3	mean Q4	mean Q5	st. dev. within[a]
$midquote_{it}$	53.76	44.52	36.65	28.58	19.21	22.20
$invent\_shares_{it}$	8.19	5.55	4.33	3.23	5.39	34.19
$invent\_dollar_{it}$	412.65	168.95	129.48	75.44	77.90	1,383.43
$shares\_outst_{it}$	729.92	157.74	70.08	36.26	18.73	283.75
$market\_cap_{it}$	34.29	5.34	2.06	0.88	0.29	11.57
$espread_{it}$	8.41	12.46	16.50	24.60	46.12	24.20
$dollar\_volume_{it}$	88.21	23.44	10.13	3.63	0.99	42.31

$midquote_{it}$	closing midquote, div/split adjusted[b] ($)
$invent\_shares_{it}$	specialist inventory at the close (1,000 shares)
$invent\_dollar_{it}$	specialist inventory at the close[b] ($1,000)
$shares\_outst_{it}$	shares outstanding (million)
$market\_cap_{it}$	shares outstanding times price ($billion)
$espread_{it}$	share-volume-weighted effective half spread (bps)
$dollar\_volume_{it}$	average daily volume ($million)

autocorrelation midquote return

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	all
Panel A: Autocorrelation 1st lag coef log price change ($x_{it} = y_{i,t-1}$)													
Q1	−0.03	−0.03	−0.05	−0.08	−0.02	−0.00	−0.01	−0.01	−0.05	−0.00	0.00	−0.02	−0.03
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.005)	(0.003)	(0.001)	(0.000)	(0.005)	(0.005)	(0.026)	(0.000)
Q2	−0.02	−0.02	−0.03	−0.07	−0.01	−0.02	−0.04	−0.00	−0.06	−0.02	−0.02	−0.03	−0.03
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q3	−0.00	0.00	−0.02	−0.06	−0.01	−0.04	−0.06	−0.02	−0.06	−0.04	−0.03	−0.03	−0.03
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)
Q4	−0.01	−0.02	−0.03	−0.05	−0.00	−0.03	−0.07	−0.04	−0.08	−0.06	−0.08	−0.04	−0.04
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q5	−0.05	−0.04	−0.02	0.00	0.04	0.01	−0.03	0.00	−0.02	−0.01	−0.04	−0.02	−0.02
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
all	−0.02	−0.02	−0.03	−0.05	−0.00	−0.02	−0.04	−0.01	−0.05	−0.03	−0.03	−0.03	−0.03
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Panel B: Autocorrelation 2nd lag coef log price change ($x_{it} = y_{i,t-2}$)													
Q1	−0.03	−0.05	−0.04	−0.02	−0.03	−0.02	−0.06	−0.05	−0.01	−0.01	−0.02	−0.01	−0.03
	(0.001)	(0.000)	(0.000)	(0.094)	(0.135)	(0.001)	(0.000)	(0.000)	(0.026)	(0.249)	(0.015)	(0.135)	(0.000)
Q2	−0.03	−0.03	−0.03	−0.01	−0.03	−0.01	−0.04	−0.02	−0.01	−0.02	−0.00	−0.02	−0.02
	(0.001)	(0.003)	(0.009)	(0.320)	(0.001)	(0.249)	(0.001)	(0.000)	(0.015)	(0.001)	(0.009)	(0.649)	(0.000)
Q3	−0.02	−0.02	−0.02	−0.01	−0.01	−0.01	−0.04	−0.02	−0.00	−0.00	−0.01	−0.01	−0.02
	(0.584)	(0.070)	(0.045)	(0.664)	(0.584)	(0.029)	(0.000)	(0.017)	(0.010)	(0.029)	(0.029)	(0.001)	(0.000)
Q4	−0.01	−0.02	−0.02	−0.03	−0.02	−0.00	−0.03	−0.02	0.00	−0.01	0.01	−0.00	−0.01
	(0.001)	(0.249)	(0.041)	(0.041)	(0.320)	(0.063)	(0.009)	(0.094)	(0.003)	(0.003)	(0.003)	(0.001)	(0.000)
Q5	−0.01	−0.01	−0.01	−0.00	−0.00	0.00	−0.01	−0.00	−0.01	−0.01	0.00	0.00	−0.01
	(0.029)	(0.000)	(0.017)	(0.017)	(0.000)	(0.010)	(0.500)	(0.000)	(0.017)	(0.009)	(0.087)	(0.070)	(0.000)
all	−0.02	−0.02	−0.02	−0.01	−0.02	−0.01	−0.04	−0.02	−0.00	−0.01	−0.00	−0.01	−0.02
	(0.000)	(0.000)	(0.000)	(0.010)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

n.b. low first order autocorrelation might lead one to underestimate price pressure if true pressure is persistent...

inventory dynamics

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	all
Panel C: Standard deviation of idiosyncratic component specialist inventory I_{it}^{idio}													
Q1	691	968	813	964	1126	1336	1344	1489	1472	1122	1119	1128	1131
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q2	472	510	488	524	530	695	819	647	448	391	441	400	530
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q3	374	429	383	372	430	452	668	437	293	242	266	271	385
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q4	226	254	255	261	291	315	320	333	229	163	145	147	245
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q5	167	159	167	234	204	223	210	186	129	108	95	95	165
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
all	386	464	421	471	516	604	672	619	514	405	413	408	491
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Panel D: AR coef estimates idiosyncratic component specialist inventory I_{it}^{idio} ($x_{it} = y_{i,t-1}$)													
Q1	0.28	0.27	0.26	0.22	0.25	0.27	0.28	0.29	0.28	0.34	0.37	0.25	0.28
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q2	0.47	0.46	0.44	0.38	0.35	0.34	0.36	0.32	0.25	0.28	0.33	0.25	0.35
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q3	0.59	0.59	0.56	0.51	0.49	0.45	0.41	0.41	0.30	0.31	0.34	0.24	0.43
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q4	0.74	0.73	0.71	0.66	0.63	0.63	0.59	0.57	0.40	0.38	0.36	0.29	0.56
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q5	0.82	0.80	0.80	0.77	0.78	0.79	0.77	0.76	0.66	0.61	0.57	0.51	0.72
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
all	0.58	0.57	0.56	0.51	0.50	0.50	0.48	0.47	0.38	0.38	0.39	0.31	0.47
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

inventory subsequent return correlation

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	all
Panel E: Regression coefficient log price change on lagged idiosyncratic component specialist inventory $I_{i,t-1}^{idio}$													
Q1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01
	(0.005)	(0.000)	(0.009)	(0.000)	(0.005)	(0.135)	(0.005)	(0.005)	(0.001)	(0.249)	(0.063)	(0.135)	(0.000)
Q2	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02
	(0.041)	(0.009)	(0.015)	(0.000)	(0.041)	(0.000)	(0.001)	(0.041)	(0.000)	(0.135)	(0.135)	(0.063)	(0.000)
Q3	0.02	0.02	0.02	0.02	0.02	0.03	0.05	0.01	0.05	0.03	0.03	0.03	0.03
	(0.010)	(0.001)	(0.045)	(0.000)	(0.145)	(0.001)	(0.000)	(0.000)	(0.000)	(0.017)	(0.102)	(0.199)	(0.000)
Q4	0.03	0.02	0.04	0.05	0.04	0.06	0.08	0.05	0.11	0.05	0.08	0.06	0.06
	(0.063)	(0.135)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.026)	(0.000)	(0.026)	(0.000)
Q5	0.08	0.08	0.03	0.02	0.06	0.06	0.14	0.10	0.15	0.08	0.12	0.13	0.09
	(0.000)	(0.199)	(0.010)	(0.017)	(0.006)	(0.416)	(0.000)	(0.000)	(0.000)	(0.009)	(0.008)	(0.500)	(0.000)
all	0.03	0.03	0.02	0.02	0.03	0.03	0.06	0.04	0.07	0.04	0.05	0.05	0.04
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.008)	(0.000)

state space model

$$
\begin{aligned}
p_t &= m_t + s_t \\
m_t &= m_{t-1} + \beta\hat{\gamma}_t + w_t \quad w_t = \kappa_i(I_t^{idio} - E_{t-1}[I_t^{idio}]) + u_t \\
s_t &= \alpha I_t^{idio} + \beta^0\hat{\gamma}_t + \cdots + \beta^3\hat{\gamma}_{t-3} + \varepsilon_t
\end{aligned}
$$

α	conditional price pressure per \$100,000 inventory
$\alpha\sigma(I)$	average price pressure or transitory volatility
$(\alpha\sigma(I))^2/\sigma_w^2$	transitory to permanent variance ratio

conditional price pressure α

$$
\begin{aligned}
p_t &= m_t + s_t \\
m_t &= m_{t-1} + \beta\hat{\gamma}_t + w_t \quad w_t = \kappa_i(I_t^{idio} - E_{t-1}[I_t^{idio}]) + u_t \\
s_t &= \alpha I_t^{idio} + \beta^0\hat{\gamma}_t + \cdots + \beta^3\hat{\gamma}_{t-3} + \varepsilon_t
\end{aligned}
$$

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	all
Q1	−0.03	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02	−0.01	−0.01	−0.01	−0.02
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q2	−0.06	−0.05	−0.05	−0.04	−0.03	−0.05	−0.05	−0.05	−0.05	−0.03	−0.03	−0.03	−0.04
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
Q3	−0.11	−0.09	−0.09	−0.07	−0.09	−0.12	−0.11	−0.06	−0.09	−0.06	−0.07	−0.06	−0.09
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q4	−0.33	−0.25	−0.30	−0.27	−0.26	−0.34	−0.27	−0.23	−0.27	−0.14	−0.19	−0.16	−0.25
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q5	−1.07	−1.04	−0.78	−0.74	−1.01	−1.09	−1.19	−1.30	−1.20	−0.86	−0.94	−0.87	−1.01
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
all	−0.32	−0.29	−0.25	−0.23	−0.28	−0.32	−0.33	−0.33	−0.32	−0.22	−0.25	−0.23	−0.28
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

transitory volatility

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	all
Panel E: transitory volatility[a] (σ_i)													
Q1	14	13	13	16	19	22	25	30	22	15	14	9	17
Q2	26	24	22	19	20	33	36	30	23	14	15	13	23
Q3	39	40	35	31	40	48	45	35	23	16	20	17	32
Q4	65	64	69	58	63	86	77	63	41	21	24	21	54
Q5	116	109	115	107	152	177	184	155	108	92	71	54	120
all	52	50	51	46	58	73	73	62	43	31	29	23	49
Panel F: ratio of transitory and permanent variance[a]													
Q1	0.02	0.02	0.01	0.02	0.01	0.02	0.01	0.03	0.02	0.02	0.03	0.01	0.02
Q2	0.08	0.09	0.04	0.03	0.02	0.04	0.03	0.03	0.02	0.01	0.02	0.02	0.03
Q3	0.28	0.27	0.16	0.09	0.13	0.19	0.05	0.07	0.02	0.01	0.04	0.09	0.12
Q4	0.30	0.47	0.47	0.28	0.23	0.47	0.22	0.16	0.06	0.03	0.04	0.05	0.23
Q5	1.11	1.42	1.14	1.16	1.24	2.55	1.96	1.09	0.79	2.10	0.61	0.62	1.32
all	0.36	0.45	0.36	0.31	0.32	0.65	0.46	0.28	0.18	0.44	0.15	0.16	0.34
Panel G: ratio of transitory and permanent "idiosyncratic" variance[a]													
Q1	0.03	0.03	0.02	0.03	0.02	0.02	0.02	0.04	0.03	0.04	0.04	0.01	0.03
Q2	0.10	0.10	0.05	0.04	0.02	0.05	0.04	0.04	0.03	0.02	0.03	0.02	0.04
Q3	0.35	0.28	0.20	0.11	0.18	0.21	0.06	0.10	0.04	0.02	0.05	0.12	0.14
Q4	0.36	0.48	0.54	0.31	0.29	0.51	0.25	0.23	0.08	0.04	0.05	0.05	0.27
Q5	1.28	1.48	1.26	1.28	1.51	2.64	2.16	1.40	0.98	2.31	0.73	0.67	1.47
all	0.42	0.47	0.41	0.35	0.40	0.68	0.51	0.36	0.23	0.48	0.18	0.18	0.39

inventory explains 42% of the variance of transitory price effects

surprise order flow

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	all
Panel C: κ_i informativeness order imbalance innovation $\widehat{I}$													
Q1	−0.08	−0.08	−0.08	−0.07	−0.08	−0.08	−0.09	−0.07	−0.07	−0.06	−0.06	−0.06	−0.07
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q2	−0.16	−0.13	−0.13	−0.14	−0.17	−0.15	−0.18	−0.15	−0.16	−0.15	−0.13	−0.13	−0.15
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q3	−0.22	−0.19	−0.18	−0.21	−0.25	−0.23	−0.26	−0.24	−0.26	−0.25	−0.26	−0.23	−0.23
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q4	−0.34	−0.28	−0.29	−0.37	−0.44	−0.36	−0.47	−0.43	−0.52	−0.56	−0.52	−0.50	−0.43
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q5	−0.59	−0.43	−0.61	−0.63	−0.72	−0.48	−0.73	−0.87	−1.25	−1.43	−1.29	−1.41	−0.87
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
all	−0.28	−0.22	−0.26	−0.28	−0.34	−0.26	−0.35	−0.35	−0.46	−0.49	−0.45	−0.47	−0.35
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Panel D: $\lvert\kappa_i\rvert\sigma(\widehat{I})_i$ explained permanent volatility													
Q1	39	36	38	44	57	65	80	56	55	37	30	27	47
Q2	42	39	41	45	65	70	85	61	56	44	36	36	52
Q3	44	42	43	54	72	70	86	75	60	48	41	36	56
Q4	47	40	42	52	73	64	83	75	66	60	49	43	58
Q5	43	39	49	56	69	56	78	90	80	75	65	63	64
all	43	39	43	50	67	65	83	72	63	53	44	41	55

model sketch

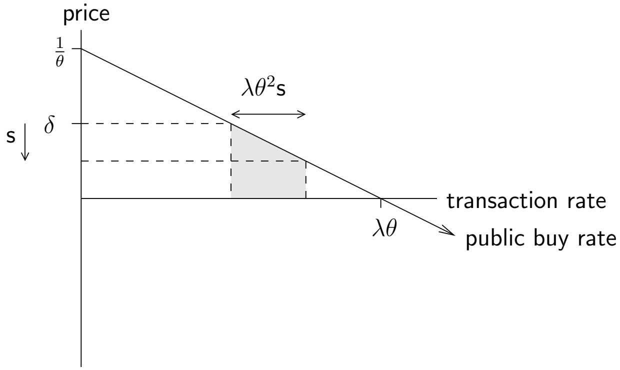
production of immediacy (cf. Ho and Stoll (1981))

- intermediary set prices to maximize time-separable quadratic utility over consumption stream
- price pressure s and half-spread δ, wlog risk is fully captured by stochastic dividend i.e. 'm_t' is fixed at zero

consumption of immediacy (generalization of Ho and Stoll (1981))

- large number of small investors
- private value events with probability $2\lambda\theta$
- conditional on event private value size is unif$[-\frac{1}{\theta}, +\frac{1}{\theta}]$
- arrive and trade if private value is outside of the spread
- motivated by nonzero monitoring cost and impatience (Townsend (1978))

investor supply and demand



s is price pressure ('$p_t - m_t$' in empirical results)
δ is bid-ask spread
net transaction rate change on s price change is $2\lambda\theta^2 s$

intermediary's dynamic program

inventory law of motion is

$$i_{t+1} = i_t - q_s(s_t, \delta_t) + q_b(s_t, \delta_t) = i_t + 2\lambda\theta^2 s_t - \varepsilon_{st} + \varepsilon_{bt}$$

maximize expected utility from infinite horizon dynamic program

$$v_{i_0} = \max_{\{s_t(i^t),\delta_t(i^t)\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \mathrm{E}_{i_0}\Big(\beta^t((c_t - \bar{c}) - \frac{1}{2}\tilde{\gamma}(c_t - \bar{c})^2)\Big)$$

where consumption is nonstorable and equal to

$$\begin{aligned} c_t &= (s_t + \delta_t)q_s(s_t, \delta_t) - (s_t - \delta_t)q_b(s_t, \delta_t) + i_t \Delta m_{t+1}, \\ &= 2\lambda\theta(\delta_t - \theta(s_t^2 + \delta_t^2)) + s(\varepsilon_{st} - \varepsilon_{bt}) + \delta(\varepsilon_{st} + \varepsilon_{bt}) + i_t \Delta m_{t+1} \end{aligned}$$

where $\Delta m_{t+1} \sim \mathrm{N}(0, \sigma^2)$ is stochastic dividend

intermediary's dynamic program

ergo consumption mean and variance are

$$\mathsf{E}(c_t) = 2\lambda\theta(\delta_t - \theta(s_t^2 + \delta_t^2)) \quad \mathrm{var}(c_t) = \sigma_\varepsilon^2(s_t^2 + \delta_t^2) + \sigma^2 i_t^2$$

first-order taylor expansion around average consumption $\bar{c}$ yields

$$v_{i_0} = \max_{\{s_t(i^t), \delta_t(i^t)\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \mathsf{E}_{i_0}\left(2\lambda\theta\delta_t - 2\lambda\theta^2(s_t^2 + \delta_t^2)) - \frac{1}{2}\tilde{\gamma}\sigma^2 i_t^2\right)$$

subject to

$$i_{t+1} = i_t - q_s(s_t, \delta_t) + q_b(s_t, \delta_t) = i_t + 2\lambda\theta^2 s_t - \varepsilon_{st} + \varepsilon_{bt}$$

intermediary's optimal policy

standard solution techniques yield

$$
\begin{aligned}
v_i &= \frac{\lambda}{2(1-\beta)} - P\left(i^2 + \frac{\beta}{1-\beta}\sigma_\varepsilon^2\right) \\
s^* &= \alpha i, \quad \delta^* = \frac{1}{2\theta}
\end{aligned}
$$

where (s^*, δ^*) denote the optimal prices controls and

$$
\begin{aligned}
\alpha &\equiv \frac{-1}{\frac{1}{\beta P} + Q}, \quad Q \equiv 2\lambda\theta^2, \quad R \equiv \frac{1}{2}\tilde{\gamma}\sigma^2 \\
P &\equiv \frac{-(1-\beta) + \beta RQ + \sqrt{(1-\beta)^2 + 2\beta(1+\beta)QR + \beta^2 Q^2 R^2}}{2\beta Q}
\end{aligned}
$$

features of optimal policy

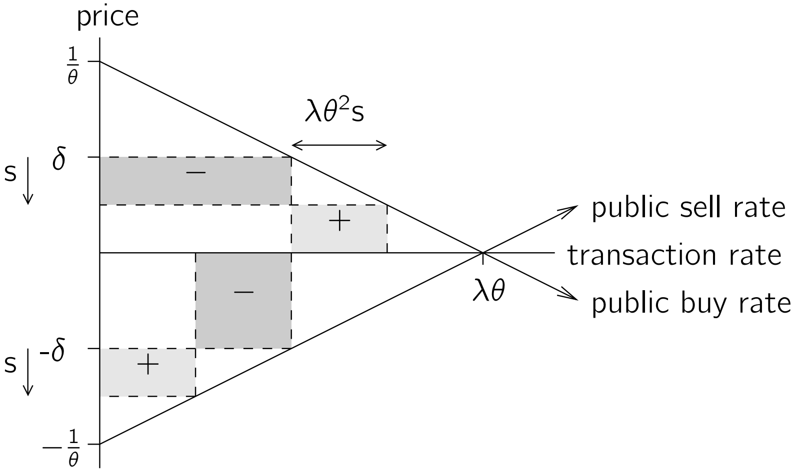
spread and price pressure are orthogonal

- spread is monopolistic and independent of inventory
- price pressure is linear in inventory
- inventory process is AR(1): $i_t = \frac{\beta PQ}{1+\beta PQ} i_{t-1} + \varepsilon_t$

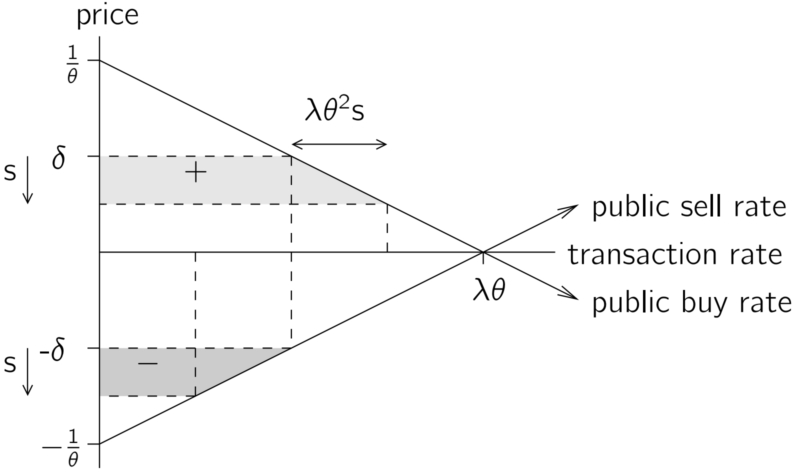
model and observed time series of price pressure identify

- competitive spread to compensate for inventory risk
- primitive parameters for risk aversion and private value process
- social cost of price pressure

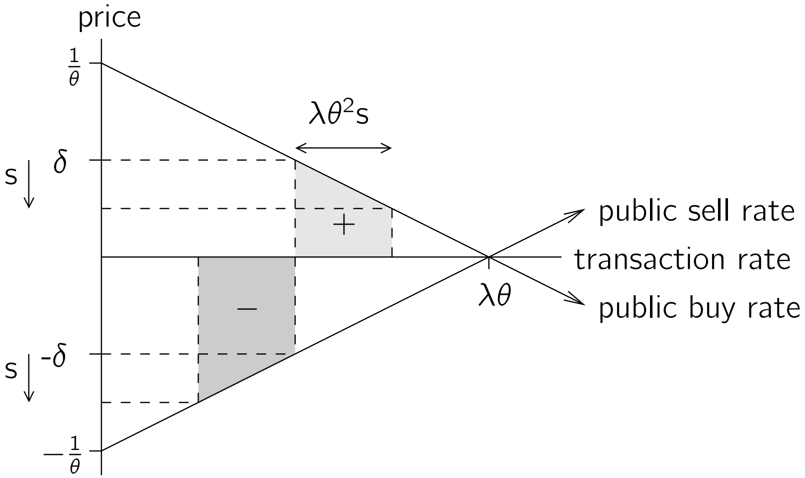
price pressure is cost to intermediary



price pressure is benefit to liquidity demander



social cost price pressure



primitive parameters and transaction cost analysis

	Q1	Q2	Q3	Q4	Q5	all
Panel A: Measured variables that identify model's primitive parameters (cf. Table 1 and 3)						
conditional price pressure α_i (bps per \$1000)	-0.02	-0.04	-0.09	-0.25	-1.01	-0.28
stdev daily inventory $\sigma(I)$ (\$1000)	1131	530	385	245	165	491
1st order autocorrelation inventory	0.28	0.35	0.43	0.56	0.72	0.47
price risk inventory $\sigma(w)_i$ (bps)	153	170	176	179	208	177
daily dollar volume[a] (\$million)	10.86	2.98	1.43	0.60	0.21	3.22
effective half spread	8.41	12.46	16.50	24.60	46.12	21.62
daily discount factor[b]	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998
Panel B: Identification of model's primitive parameters						
daily private value rate λ (\$1000)	59.69	14.12	6.21	2.77	1.46	5.86
	(241.59)	(37.71)	(13.39)	(4.63)	(2.31)	(21.73)
dispersion private value $\frac{1}{\theta}$ (bps)	171	135	148	187	307	186
	(312)	(201)	(166)	(206)	(370)	(260)
intermediary's relative risk aversion γ	0.24	0.15	0.11	0.09	0.05	0.10
	(1.06)	(0.55)	(0.35)	(0.26)	(0.13)	(0.35)
Panel C: Decomposition of the spread paid by liquidity demander						
(1) model-implied competitive spread (bps)	8.05	14.44	22.29	43.63	88.79	25.86
	(17.34)	(28.79)	(45.69)	(83.12)	(182.90)	(67.87)
(2) price pressure subsidy to liq demander (bps)	0.58	1.40	2.63	6.00	15.52	2.88
	(1.21)	(3.13)	(5.64)	(13.49)	(33.26)	(9.56)
(3) net spread to liq demander[c] (1)-(2) (bps)	7.32	12.86	19.43	37.35	73.16	22.60
	(15.81)	(25.31)	(40.04)	(68.62)	(149.27)	(57.68)
(4) constrained Pareto efficient spread (bps)	6.45	10.74	16.05	29.54	54.77	18.67
	(14.07)	(21.59)	(31.87)	(53.53)	(110.32)	(45.48)
(5) deadweight loss[c] (3)-(4) (bps)	0.64	1.54	2.96	6.87	18.18	3.23
	(1.32)	(3.49)	(6.39)	(15.64)	(39.02)	(10.99)

[a]: $dollar\_volume_{it} * specialist\_particip_{it}$ as a proxy for volume intermediated by the specialist

[b]: discount factor equals the reciprocal of the gross riskfree rate from Kenneth French' website

[c]: the reported difference is the median of differences, not the difference of (reported) medians

generalizing from NYSE intermediaries

if N competitive liquidity suppliers: $I_n = I_{tot}/N$:

- α overestimated by $1/N$
- average price pressure and variance ratios unchanged
- cross-sectional variation in competition may affect identification of primitive parameters

price continuity rules causes underestimation of price pressure

conclusion

1. average price pressure ranges from 17 basis points to 120 basis points for large- and small-cap stocks, respectively
2. conditional price pressure ranges from 0.02% to 1.01% on a $100,000 inventory shock for large and small stocks, respectively
3. daily average price pressure is large for smaller stocks: 1.20%, larger than permanent volatility
4. price pressure dynamics suggests low risk aversion in intermediation sector
5. transitory volatility becomes a more significant consideration in market regulation

price pressures

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