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Bruce Mizrach [a]
[a] Department of Economics, Rutgers University, New Brunswick, NJ, USA

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The next tick on Nasdaq

BRUCE MIZRACH*

Department of Economics, Rutgers University, 303b New Jersey Hall,
New Brunswick, NJ, 08901USA

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The Nasdaq stock market provides information about buying and selling interest in its limit order book. Using a vector autoregressive model of trades and returns, I assess the effect of the entire order book on the next tick. I also determine the influence of individual market makers and electronic networks and find evidence that the identity of market participants can be useful information. Finally, I produce a set of dynamic market price responses to buy and sell orders, and I find that these estimates vary with standard measures of liquidity.

Keywords: Market microstructure; Financial time series; Structure of financial markets; Derivatives securities

1. Introduction

The two major U.S. stock trading centers have gradually increased access and visibility of their limit order books. On the New York Stock Exchange (NYSE), the order book is maintained by a single market maker called the *specialist*. Traders, for many years, pressured the exchange for greater transparency, and in 2002, NYSE created their OpenBook data feed. Orders from floor brokers and rival exchanges are now visible even when they are not in the first position in the book.

The Nasdaq, from its 1971 inception, eschewed a trading floor in favor of a system of multiple market makers. Member dealers communicated through an electronic quote and execution system. In 1997, access to the limit order book was expanded to include alternative trading systems and even individual investors. The SuperMontage initiative, completed at the end of 2002, expanded the book to include multiple levels of liquidity from participants. This enables the public to view the demand and supply curves of all market participants.

The previous literature on the Nasdaq has focused primarily on the so-called *inside spread*, the distance between the best bid and ask prices. This paper asks a surprisingly simple but neglected question: does the *entire* order book help predict the next *inside* quote revision?

*Email: mizrach@econ.rutgers.edu

The econophysics literature has uncovered important statistical regularities in the limit order books of disparate markets. Lillo and Farmer (2004) find that orders on the London Stock Exchange follow a long memory process. Bouchaud *et al*. (2002), while analysing the Paris Bourse, found a power law for the placement of new limit orders and a hump shape for the depth in the order book. Potters and Bouchaud (2003) find similar properties for Nasdaq stocks on the Island ECN. Weber and Rosenow (2005) find a log linear relationship between signed market order flows and returns on Island.

A small number of recent papers have begun to analyse the full Nasdaq order book. Huang (2002) analyses price discovery by electronic communication networks (ECNs) and classes of market makers. His approach focuses more on the long-run cointegration dynamics than on the high frequency tick analysis pursued here. Simaan *et al*. (2002) examine the dealer quotes for continued avoidance of odd ticks by market makers. Chung and Zhao (2004) study both quotes and depth, as I do, but they exclude the ECNs. Several papers have focused on ECNs including Hasbrouck and Saar's (2002) study of the Island ECN, Weston (2002) on overall ECN liquidity provision, and Barclay *et al*. (2003) on execution quality. Boehmer *et al*. (2005) analyse the effect of the NYSE OpenBook.

This paper also draws heavily on the econometric literature in high frequency finance. Contributions here include Biais *et al*. (1995) who provide an empirical analysis of a purely order driven market in Paris. Bollerslev *et al*. (1997) who model the Reuters screen

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based foreign exchange quote system. Mizrach and Neely (2005) look at the U.S. Treasury market.

Our initial approach is most closely related to Hasbrouck's (1991) model of joint trade and quote formation. Engle and Russell (1998) extended this model to include the time duration between trades on the NYSE. Engle and Patton (2004) look at price impact in an error-correction framework. This paper differs not only in looking at a different microstructure, but in looking at dealer specific characteristics including depth.

This paper looks at the order book in its entirety, the full montage of dealer and ECN quotes and depth as well as transactions. For the liquid Nasdaq stocks, there is a vast amount of information. For our sample month, December 2002, The Nasdaq 100 has an average of 75 market participants providing quotes and depth intra-daily. The most active stock, Intel (INTC), has 458,673 quote revisions for the month.

My focus is on the very short-run, the next quote revision or *tick*. The details in the Nasdaq order book allow us to ask very precise questions. Does an increase in quoted depth on the inside bid increase the likelihood of an uptick? Does the number of participants on the bid matter independently of their displayed liquidity? I find, for example, that the number of bids or offers is more important than the quoted depth.

I also examine whether activity away from the inside market is at all relevant. In general, I find that the bids (offers) away from the inside increase the probability of a down (up) tick.

I next explore if individual market makers or ECNs have a larger influence on the next tick. For the liquid Nasdaq 100 stocks, I find strong evidence for this. In my less liquid small cap sample, I find most of the information about identity is not helpful in determining the next tick.

Transactions and quote revisions on the Nasdaq are generally positively autocorrelated. It appears to be a consequence of the Nasdaq microstructure and certainly contributes to the higher volatility relative to the NYSE†. Nonetheless, additional liquidity does reduce volatility. The last result I obtain is that this volatility decreases with larger market capitalization and the presence of more market makers.

The organization of this paper is as follows. In section 2, I outline features of the Nasdaq microstructure. The Nasdaq's latest display and execution systems are described. While the Nasdaq superficially appears like a centralized limit order book, it maintains certain regulations that still fragment the marketplace. I focus more directly on the order book in section 3. Section 4 introduces and extends the Hasbrouck model to include information away from the inside quote. Details of the data set and samples selected are in section 5. Section 6 estimates a VAR at tick frequency with indicators from the entire order book. Section 7 looks at individual market participants, and section 8 models the cross sectional differences in market impact. Section 9 examines the implications of our empirical results with existing market microstructure theories. I conclude in section 10 with a summary of the empirical results and a partial assessment of the recent changes to the Nasdaq microstructure.

2. The Nasdaq trading mechanism

The Nasdaq marketplace is a patchwork system that debuted back in 1971‡. An important early change in Nasdaq came about because of the October 1987 stock market crash. While the Dow Jones Index (then consisting entirely of NYSE stocks) fell −22.6% on October 19th, Nasdaq market makers were essentially unreachable in the afternoon, extending the crash in the Nasdaq composite to a second day: −12.04% on October 19 and −9.43% on October 20. In response to investor complaints, the National Association of Security Dealers, Nasdaq's parent at that time, required mandatory participation in the Small Order Execution System (SOES). In most large capitalization stocks, market makers were required to automatically execute orders of up to 1000 shares. This system led to the first wave of day trading in Nasdaq stocks with so-called *SOES bandits*§ making quick entry and exit as short term trends emerged.

A second wave of reforms followed the Christie and Schultz (1994) debate about Nasdaq price fixing. The SEC instituted new *Order Handling Rules* (OHR)¶ that help to guarantee national market protection to customer orders. A market maker is required to handle a marketable limit order in one of four ways: (1) execute the limit order; (2) change its quote and the size associated with its quote to reflect the limit order; (3) send the limit order to another market maker; (4) deliver a limit order to an electronic communications network (ECN) or unlisted trading privileges market (UTP). In essence, this allowed even small retail customers to become temporary market makers. Nasdaq quoted and effective spreads declined substantially following these reforms. Inside spreads were narrowed further on April 9, 2001 when Nasdaq completed its transition to decimals, with a minimum tick increment of $0.01.

As Nasdaq became a level playing field, dealer's market share began to erode. By 2001, ECNs were handling nearly 40% of volume. Nasdaq made the decision to go public in 2001 and gradually become independent of the National Association of Security Dealers. It has used stock to make acquisitions as well. It acquired two major competing ECNs, Brass Utility in September 2004 and Instinet, originally brought public by Reuters, in December 2005.

†For a recent comparison, see Schwert (2001).
‡For a detailed history of Nasdaq, see Smith *et al.* (1998).
§See Harris and Schultz (1998) for an assessment of the profitability of the SOES bandits.
¶Release No. 34-38156; File No. SR-NASD-96-43 January 10, 1997. http://www.sec.gov/rules/othern/34-38156.txt

Table 1. Limit order book for Fastenal Company (FAS*Notes*:T).

ADFN	35.85	1	BRUT	35.86	2
ARCA	35.85	37	ADFN	35.89	1
BRUT	35.85	1	MLCO	35.94	1
BTRD	35.85	4	GSCO	35.94	1
PIPR	35.83	1	ARCA	35.99	10
CINN	35.81	1	BTRD	35.99	1
SUSQ	35.51	1	BARD	36.00	1
MLCO	35.41	1	PIPR	36.09	1

Nasdaq tried to meet the competitive challenge of the ECNs with a new platform called SuperMontage that allowed market participants to display multiple levels of liquidity. It was introduced in October 2002 and was fully implemented on December 2, 2002. SuperMontage supersedes the earlier SuperSOES and Selectnet systems, unifying the trade and quote generating mechanism†. Nasdaq also introduced an anonymous quote and execution facility‡ which appears in the order book under the identity SIZE. Nasdaq sponsored studies§ report improvements in execution quality.

Even though trading remains fragmented on Nasdaq, the limit order book still provides a centralized view of nearly all the available liquidity. I describe it in detail in the next section.

3. Details on the limit order book

I begin with an example of the quote montage available to traders. I include one partial display for Fastenal Company (FAST: NNM), one of the smaller cap stocks in the Nasdaq 100 Index, at 10:38:37 on December 3, 2002.

Table 1 shows the first five price levels (tiers) of the bid and the first six tiers of the ask. In the complete display, there are 29 distinct non-zero bid and ask prices in the stock. Nasdaq market makers are obliged to offer two-sided quotations; the market maker U.S. Bancorp Piper Jaffray (PIPR) is at 35.83 on the bid and at 36.09 on the offer¶. Depths‖ are in 100s of shares.

The *inside market* consists of the best bid and ask prices and the largest depth. In this case, the quote would be 35.85×35.86 with a depth of 37×2. This would be the quote you would see displayed on most real time quote services. It would not offer you the identity of the liquidity provider, nor would it show you additional depth at the inside quote. A view of the entire order book, in this instance, reveals three ECNs, Archipelago (ARCA), Brut (BRUT), and Bloomberg Trade Book (BTRD), and one UTP, the Instinet ECN (ADFN) on the bid. On the inside ask, there is just the Brut ECN. For all but one large capitalization Nasdaq stock analysed, an ECN was the most frequent inside market participant. In the aggregate, Nasdaq finds that ECNs and UTPs are providing 88.7% of all quotes.

There are five market makers in the display: PIPR, Susquehanna Capital Group (SUSQ) and Merrill Lynch (MLCO) on the bid, and MLCO, Goldman Sachs (GSCO), Robert W. Baird (BARD), and PIPR on the offer.

I wish to determine whether the information in the entire order book is useful for the evolution of the inside quote process. Can the number of bidders and/or the aggregate depth on price tiers beyond the inside quote help predict future returns? Does the identity of specific market makers or ECNs matter? What is the market impact of a buy or sell order? A model for trades and quotes is required to address these questions in a formal way.

4. A tick frequency model of quotes and trades

The standard model of intra-day quote and trade evolution is the vector autoregressive model of Hasbrouck (1991). Let r_t be the percentage change in the midpoint of the bid–ask spread, $\log((p_t^{\mathrm{b}} + p_t^{\mathrm{a}})/2) - \log((p_{t-1}^{\mathrm{b}} + p_{t-1}^{\mathrm{a}})/2)$. Let x_t^0 denote the net sum of the sequence of signed trades since the last tick. A transaction is considered to be a buy (sell) and is signed $+1$ (-1) if it is above (below) the midquote⊤. The quote revision model is specified as

$$r_t = a_{r,0} + \sum_{i=1}^{5} a_{r,i} r_{t-i} + \sum_{i=0}^{15} b_{r,i} x_{t-i}^0 + \varepsilon_{r,t}, \qquad (1)$$

$$x_t^0 = a_{x,0} + \sum_{i=1}^{5} a_{x,i} r_{t-i} + \sum_{i=1}^{15} b_{x,i} x_{t-i}^0 + \varepsilon_{x,t}. \qquad (2)$$

Time t here is measured in terms of quote revisions: any change in the order book represents a tick.

In this section, I extend the specification of the Hasbrouck VAR to include information beyond the inside quote. The quotes and depth in the montage will be interpreted as an empirical excess demand function. This would be literally true if actual depths matched quoted depths. Market maker and ECN identities may be informative about additional depth, so I defer discussion of this issue to the next section. I explore several methods

†During our sample period, the Instinet ECN (INCA) did not participate in SuperMontage and appears in the limit order book as the Alternate Display Facility (ADFN). Instinet handled 18.6% of Nasdaq share volume in 2002.

‡SIZE had only 0.3% of quotes in December 2002, and Mizrach (2006) notes that, by December 2005, this had only grown to 2.1%.

§See 'Results on the Introduction of NASDAQ's SuperMontage', by NASDAQ Economic Research, February 4, 2003.

¶A complete list of Nasdaq market makers and ECNs and their symbols may be found on the Nasdaq website, www.nasdaqtrader.com.

‖Nasdaq allows market participants to place hidden orders where only a portion of the total liquidity is visible in the order book. Unfortunately, the historical database provided by Nasdaq does not include these orders. We may be able to infer something about hidden depth from our analysis of specific market participants. See De Winne and D'Hondt (2005) for a discussion on hidden limit order placement on Euronext.

⊤I also tallied the sum of the signed trading volumes x_t as in Weber and Rosenow (2005), but I found that the binary variable x_t^0 fit the data better.

of aggregating the data in the limit order book to find out which aspects are informative for the next tick.

I begin by introducing notation for the display. It bears repeating here that clock time is determined by any revisions in the order book to prices or quantities. Let $p^{b,i}_{k,t}$ be the bid for market participant i on the tier k of the quote montage at time t, and let $p^{a,j}_{k,t}$ be the corresponding quote on the tier k of the ask by market participant j. Apart from ECNs, you will rarely find $i=j$ at tier $k=1$. For our example order book in table 1, $p^{b,1}_{1,t} = p^{b,2}_{1,t} = p^{b,3}_{1,t} = p^{b,4}_{1,t} = 35.85$, where ADFN is participant 1, ARCA is participant 2, BRUT is participant 3, and BTRD is participant 4. All four of these participants are on the offer. For ADFN's ask quote, participant 1 is now on the second tier of the offer: $p^{a,1}_{2,t} = 35.89$. For ARCA, $p^{a,2}_{4,t} = 35.99$. BRUT is the inside offer, $p^{a,3}_{1,t} = 35.86$, and BTRD is on the fourth tier, $p^{a,4}_{4,t} = 35.99$. I will defer until the next section the individual market participant quote dynamics, and instead focus on aggregate tier quotes and depth.

The posted depths of each participant are denoted by $q^{b,i}_{k,t}$ and $q^{a,j}_{k,t}$. To define our aggregate depth variables, it will be convenient to then assume that if the market maker or ECN is not present on a given tier, their depth is zero. Let $q^{b}_{k,t} = \sum_{i=1}^{n} q^{b,i}_{k,t}$ be the aggregate depth on tier k of the bid, and let $q^{a}_{k,t} = \sum_{j=1}^{n} q^{a,j}_{k,t}$ be defined symmetrically for the ask, where n is the number of market participants. For the FAST example, $q^{b}_{1,t} = 43$, $q^{b}_{2,t} = 1$, $q^{b}_{3,t} = 1$, $q^{b}_{4,t} = 1$, and $q^{b}_{5,t} = 1$. The inside spread is denoted $p^{b}_{1,t} \times p^{a}_{1,t}$. The inside bid and ask depth are $q^{b}_{t} = \max_i[q^{b,i}_{1,t}, \ldots, q^{b,n}_{1,t}]$ and $q^{a}_{t} = \max_i[q^{a,i}_{1,t}, \ldots, q^{a,n}_{1,t}]$. For FAST, $q^{b}_{t} = 37$, and $q^{a}_{t} = 2$. Note that the inside quote display obscures additional depth on the first bid tier, $\sum_i q^{b,i}_{1,t} > q^{b}_{t}$. In the empirical application, I limit the analysis to the first five tiers, $k = 1, 2, 3, 4, 5$. To measure relative buy or sell pressure at each tier, these enter as differences in the final specification.

To take an overall measure of the top tiers of the display, I introduce a variable which I call demand, D^{b}_{t}. It is a weighted average of the first five tiers of the bid,

$$D^{b}_{t} = \left(\sum_{k=1}^{5} \sum_{i=1}^{n} p^{b,i}_{k,t} \times q^{b,i}_{k,t} \right) \Bigg/ \sum_{k=1}^{5} q^{b}_{k,t}. \tag{3}$$

In the example, this sums to 35.8413 because so much depth is at the inside. To avoid problems of collinearity, I have the demand curve variable enter as a first difference.

I next examine whether the number of market participants on a particular tier may provide additional information beyond the aggregate depth. For example, ten market makers each showing a bid of 100 shares might represent more demand pressure than a single market maker with a depth of 1000. Let $n^{b}_{k,t} = \sum_{i=1}^{n} I(q^{b,i}_{k,t} > 0)$, where I is the indicator function. I define a similar measure for the ask and also enter this variable as a difference. In the FAST order book, $n^{b}_{1,t} = 4$, $n^{b}_{2,t} = 1$, $n^{b}_{3,t} = 1$, $n^{b}_{4,t} = 1$ and $n^{b}_{5,t} = 1$.

Now I incorporate the entire book of quotes and depths into an extended specification for the VAR,

$$\begin{aligned} r_t = a_{r,0} &+ \sum_{i=1}^{5} a_{r,i} r_{t-i} + \sum_{i=0}^{15} b_{r,i} x^{0}_{t-i} + \sum_{k=1}^{5} \alpha_{r,k}(q^{b}_{k,t} - q^{a}_{k,t}) \\ &+ \sum_{k=1}^{5} \beta_{r,k}(n^{b}_{k,t} - n^{a}_{k,t}) + \sum_{i=1}^{15} \delta_{r,i} \Delta D^{b}_{t-i} \\ &+ \gamma_r(q^{b}_{t} - q^{a}_{t}) + \varepsilon_{r,t}. \end{aligned} \tag{4}$$

There are 26 new coefficients, each of which also enters the trade equation (2), and 48 parameters overall. These do not present any estimation difficulties except for a few illiquid stocks in the second sample. If the order book is an excess demand function, any variable that reflects increased buying interest should put upward pressure on the next tick. It follows that all of the new variables are expected to enter with a positive sign.

I turn to data and sample selection in the next section before reporting estimates of the extended VAR.

5. Data and sample selection

Since January 1999, Nasdaq has collected a complete record of dealer quotes and trades in a monthly compilation called the Nasdaq Trade and Quote Database (NASTRAQ). The NYSE also collects data for Nasdaq stocks in their Trade and Quote Database (TAQ), but the database is limited to a display of inside quote information. The NASTRAQ database provides complete inside quote depth and all subsequent tiers of the bid and offer curves. The identity of the market participant is also known.

Since SuperMontage debuted in 2002, market participants have been able to display multiple levels of liquidity. Nasdaq's TotalView† provides a real time display of the entire limit order book. Unfortunately, NASTRAQ only records each participant's top quote in their historical database. In December 2002, this was not a very serious issue though, with 71% of market makers and six of eight ECNs entering only a single level of quotes.

I selected two samples of stocks from this database for the month of December 2002. The first group is the Nasdaq 100 stocks‡. This is the primary index of large capitalization Nasdaq stocks. In December of 2002, they had an average market capitalization of $13.38 billion, and an average share price of $26.84. I also examine separately the biggest four stocks of the Nasdaq: Microsoft (MSFT); Intel (INTC); Cisco Systems (CSCO); and Dell Computer (DELL). They have an average market cap of $143.65 billion and an average share price of $21.54. The complete list along with some data characteristics is in appendix A.

I chose a sample of 250 smaller capitalization stocks using three criteria, a price of greater than $5.00 per share, an average daily trading volume of 7500 to 40,000 shares,

†https://www.nasdaqtrader.com/ easp/totalview_form.asp
‡Due to index changes, mergers and delistings, I only have 95 companies in the final sample.

Table 2. Order book estimates for Ross Stores Inc.

$10^4 \times \alpha_{r,1}$	0.092	$\delta_{r,1}$	0.292
	(0.907)		(3.433)
$10^4 \times \alpha_{r,2}$	0.029	$\delta_{r,2}$	0.594
	(1.127)		(6.791)
$10^4 \times \alpha_{r,3}$	0.058	$\delta_{r,3}$	0.640
	(2.206)		(7.254)
$10^4 \times \alpha_{r,4}$	0.006	$\delta_{r,4}$	0.735
	(0.260)		(8.320)
$10^4 \times \alpha_{r,5}$	−0.002	$\delta_{r,5}$	0.504
	(0.915)		(5.704)
		$\delta_{r,6}$	0.391
			(4.488)
$10^4 \times \beta_1$	9.292	$\delta_{r,7}$	0.329
	(27.009)		(3.778)
$10^4 \times \beta_{r,2}$	0.614	$\delta_{r,8}$	0.459
	(1.982)		(5.281)
$10^4 \times \beta_{r,3}$	−0.981	$\delta_{r,9}$	0.302
	(3.176)		(3.472)
$10^4 \times \beta_{r,4}$	−0.009	$\delta_{r,10}$	0.347
	(0.295)		(5.497)
$10^4 \times \beta_{r,5}$	0.452	$\delta_{r,11}$	0.384
	(1.607)		(4.422)
		$\delta_{r,12}$	0.267
			(3.064)
$10^4 \times \gamma_r$	0.321	$\delta_{r,13}$	0.248
	(2.852)		(2.875)
		$\delta_{r,14}$	0.093
			(1.089)
		$\delta_{r,15}$	−0.096
			(1.150)

Notes: The sample period is December 2002. The model is estimated on the full sample of 190,275 ticks.

and 90 day moving average of volume in the 28 to 52nd percentile. From this group of 250, I chose 100 issues using a random number generator. Due to data limitations, delistings, and exclusion of basket stocks, the final sample contained 87 issues which are described in appendix B. This small to midcap group has substantially different characteristics than the Nasdaq 100. The average market capitalization is $333.17 million with an average share price of $14.90.

Quote activity on the Nasdaq 100 is extremely active. For the big four, there are an average of 109.25 market makers and ECNs per stock, generating an average of 443,205 quote revisions. For the Nasdaq 100, there are an average of 75.31 market makers and ECNs per stock, generating 290,279 quote revisions. Among the smaller stocks, 11,378 quote revisions are provided by an average 21.36 market makers and ECNs per stock.

6. Estimation of the VAR

I estimated the model (2) and (4) for both the large cap and small cap samples, using data from the official market hours, 9:30 to 16:00. I discuss a representative estimation of the new model for Ross Stores, Inc. (ROST). Coefficient estimates are in table 2.

There are several typical patterns in table 2 that deserve mention. Notice that inside depth enters significantly positive, $\gamma_r > 0$, but does not subsume all of the information in the demand curve. The most significant explanatory variable is the ratio of the number of bidders to offers on the first tier, β_r,1. The entire demand curve $\delta_{r,i}$ impacts the next tick and is surprisingly persistent. Only after 13 ticks does the order book's impact on the next tick become insignificant. The ratio of bids to offers on the tiers away from the inside are generally insignificant and incorrectly signed at tier 5.

For the Nasdaq 100 sample, the inside bid tier number difference $n^{\mathrm{b}}_{1,t} - n^{\mathrm{a}}_{1,t}$ is significantly positive in all but four of the regressions (CTXS, GENZ, PDCO, and TLAB) with an average t-statistic of 37.58. It is the single best predictor of the next tick. The inside quote volume is significant in 53 regressions, 44 of which are positive as the model would predict. MSFT and DELL are two of the nine negative γ's. If you incorporate the aggregate tier 1 volume as $q^{\mathrm{b}}_{1,t} - q^{\mathrm{a}}_{1,t}$, this ratio is significantly positive in only 14 regressions, with 24 negative. Three of the big four are among the positive 14, DELL, INTC, and MSFT.

Away from the first tier, quoted depths $q^{\mathrm{b}}_{2,t} - q^{\mathrm{a}}_{2,t}, \ldots, q^{\mathrm{b}}_{5,t} - q^{\mathrm{a}}_{5,t}$ are only occasionally significant. There are 47 significant $\alpha_{r,2}$ (45 positive), 48 significant $\alpha_{r,23}$ (47 positive), 42 significant $\alpha_{r,4}$ (40 positive), and 33 significant $\alpha_{r,5}$ (31 positive). The number of bids and offers away from the inside though, $n^{\mathrm{b}}_{2,t} - n^{\mathrm{a}}_{2,t}, \ldots, n^{\mathrm{b}}_{5,t} - n^{\mathrm{a}}_{5,t}$, appears to be a weaker signal. There are 21 significantly negative $\beta_{r,2}$, 22 significantly negative $\beta_{r,3}$, seven significantly negative $\beta_{r,4}$, and one significantly negative $\beta_{r,5}$ against only 24 positive coefficients. For the large caps, a trader interested in the short run should look for real buying interest primarily in the number of inside bids to offers, and the inside quote depth.

Taking the measure of the entire bid side of the market does appear to be worthwhile. On average, 8.8 lags of the demand variable D^{b}_t are statistically significant and positive. The big four are like the sample as a whole. A complete set of α_r's, β_r's and the number of significant δ_r's is in tables 3–5.

Information away from the inside quote is simply less important overall for a small cap stock sample. The ratio of inside bids to offers is the only consistently strong variable. It enters significantly positive in 52 of 88 regressions. The inside quote depth is significantly positive in only 14 cases. Aggregating the tier 1 depth does not help much. This ratio is significantly positive in only 15 cases. I do find several cases in which apparent increases in aggregate demand produce downticks: there are 11 significantly negative α_r's and 21 significantly negative β_r's. The demand curve, as a whole, is also less important. On average, only 0.5 lags of D^{b}_t are statistically significant. A complete set of α_r's, β_r's and the number of significant δ_r's for the small caps is in tables 6–8.

I now return to the information on specific market participants.

Table 3. Order book regression results for large caps.

	$\alpha_{r,1}$	$\alpha_{r,2}$	$\alpha_{r,3}$	$\alpha_{r,4}$	$\alpha_{r,5}$	$\beta_{r,1}$	$\beta_{r,2}$	$\beta_{r,3}$	$\beta_{r,4}$	$\beta_{r,5}$	γ_r	$\#D_t^b$
AAPL	−0.038	0.008	0.012	0.006	**0.026**	**5.730**	**−0.351**	**−0.273**	−0.026	−0.057	**0.103**	8
ADBE	−0.042	−0.008	**0.029**	**0.041**	0.023	**8.023**	**0.378**	−0.193	−0.246	−0.182	0.105	11
ADCT	**−0.049**	−0.013	**0.024**	−0.002	0.013	**5.761**	**−1.185**	−0.267	−0.056	−0.150	**0.136**	7
ALTR	0.003	**0.046**	−0.019	−0.012	0.005	**5.999**	−0.125	−0.086	0.123	−0.009	**0.144**	11
AMAT	**0.059**	**0.008**	**0.010**	**0.008**	**0.015**	**2.716**	**−0.257**	−0.036	−0.023	−0.011	−0.011	10
AMGN	−0.002	−0.001	**0.010**	**0.021**	**0.007**	**3.158**	**0.112**	−0.094	**−0.122**	0.047	**0.030**	8
AMZN	**0.057**	**0.017**	**0.020**	**0.017**	0.011	**3.809**	**−0.290**	**−0.289**	**−0.252**	0.059	−0.055	10
APCC	−0.082	0.044	0.033	−0.014	−0.016	**13.388**	−0.709	−0.699	0.243	0.437	**0.645**	9
APOL	−0.001	**0.050**	**0.048**	**0.032**	**0.046**	**5.287**	**0.440**	−0.142	−0.105	−0.133	−0.034	9
BBBY	**−0.076**	**0.042**	**0.035**	0.011	0.010	**6.185**	0.249	**−0.312**	−0.049	−0.058	**0.283**	14
BEAS	0.019	**0.013**	**0.025**	**0.021**	−0.002	**4.893**	**−0.559**	**−0.337**	−0.217	0.052	**0.082**	9
BGEN	0.046	0.004	**0.036**	**0.053**	**0.038**	**4.741**	**0.395**	−0.163	−0.156	−0.008	−0.040	9
BMET	−0.229	0.003	0.037	0.046	0.021	**7.594**	0.036	0.013	−0.054	0.489	0.314	0
BRCM	−0.005	**0.050**	**0.045**	**0.021**	**0.018**	**6.276**	−0.119	−0.309	−0.006	0.057	0.093	8
CDWC	−0.075	**0.074**	0.024	**0.043**	0.015	**5.463**	**0.909**	0.315	−0.177	0.256	**0.152**	7
CEPH	−0.070	**0.033**	0.013	0.019	**0.045**	**5.119**	**0.264**	0.085	0.128	−0.063	**0.171**	8
CHIR	0.011	0.080	**0.125**	**0.100**	**0.073**	**5.397**	**0.371**	**−0.314**	−0.099	0.063	**0.109**	8
CHRW	0.325	0.018	0.033	0.039	0.009	**12.398**	**−1.659**	0.246	−2.204	−0.241	−0.260	0
CIEN	**−0.022**	0.008	**0.023**	**0.017**	0.002	**5.381**	**−0.619**	**−0.528**	−0.001	0.135	**0.056**	14
CMCSA	−0.039	**0.028**	−0.006	0.004	0.020	**8.662**	−0.198	−0.281	−0.393	−0.196	**0.139**	4
CMVT	0.084	**0.056**	−0.002	−0.014	0.016	**10.579**	−0.509	−0.515	−0.232	−0.269	−0.001	7
COST	**−0.066**	−0.005	**0.018**	**0.027**	**0.027**	**4.427**	0.144	**−0.268**	**−0.249**	−0.182	**0.138**	6
CPWR	**−0.231**	−0.018	−0.016	**−0.073**	−0.021	**7.141**	**−1.327**	−0.064	0.352	0.422	**0.277**	11
CSCO	−0.002	**−0.002**	**0.006**	**0.003**	**0.004**	**0.830**	−0.024	−0.033	−0.003	0.042	0.035	11
CTAS	**−0.113**	**−0.023**	−0.003	0.007	**0.023**	**5.444**	**1.188**	0.001	−0.070	0.282	**0.279**	15
CTXS	−0.098	0.017	0.001	−0.009	0.025	6.583	−0.395	−0.217	−0.129	−0.128	**0.226**	10
DELL	**0.038**	**0.009**	**0.016**	**0.012**	0.003	**2.259**	**−0.109**	**−0.105**	−0.072	0.056	**−0.042**	8
DISH	**−0.160**	−0.001	0.008	−0.002	0.011	**7.012**	−0.036	−0.594	−0.054	−0.106	**0.309**	8
DLTR	**0.284**	**0.080**	**0.209**	**0.108**	**0.096**	**9.981**	0.475	**−1.035**	−0.203	0.065	−0.188	12
EBAY	0.045	0.005	0.033	**0.051**	0.041	**3.210**	0.268	−0.136	−0.424	0.064	−0.045	0
ERICY	**0.128**	**0.049**	−0.009	−0.005	**−0.070**	**17.031**	**−0.872**	−0.100	−0.458	0.519	**−0.143**	3
ERTS	0.003	**0.018**	**0.078**	**0.095**	**0.054**	**5.587**	**0.292**	**−0.421**	**−0.435**	−0.121	0.013	7
ESRX	−0.005	**0.048**	**0.033**	0.009	0.012	**5.461**	**1.013**	**0.673**	0.298	0.154	0.071	9

Notes: All coefficient estimates are $\times 10^4$. Boldface indicates significance at the 1% level. The sample period is December 2002 with the number of observations found in the data appendix.

Table 4. Order book regression results for large caps.

	$\alpha_{r,1}$	$\alpha_{r,2}$	$\alpha_{r,3}$	$\alpha_{r,4}$	$\alpha_{r,5}$	$\beta_{r,1}$	$\beta_{r,2}$	$\beta_{r,2}$	$\beta_{r,2}$	$\beta_{r,2}$	γ_r	$\#D_t^b$
ESRX	−0.005	**0.048**	**0.033**	0.009	0.012	**5.461**	**1.013**	**0.673**	0.298	0.154	0.071	9
EXPD	**−0.406**	**0.108**	**0.089**	**0.091**	0.057	**12.114**	0.111	0.055	−0.571	−0.224	**0.679**	12
FAST	−0.241	−0.002	−0.023	0.022	0.025	**18.944**	0.646	−0.468	−0.179	−0.213	0.404	11
FHCC	**−0.698**	**0.070**	**0.248**	−0.003	**0.299**	**14.740**	−0.252	−2.092	−0.144	−1.001	**1.227**	10
FISV	**0.152**	**0.081**	**0.087**	0.009	0.017	**6.894**	0.124	**−0.431**	−0.296	0.351	**−0.232**	10
FLEX	−0.025	**0.023**	0.015	0.010	0.012	**5.549**	**−0.484**	−0.440	0.077	0.170	**0.218**	11
GENZ	0.052	**0.052**	0.029	0.030	0.007	6.750	0.408	0.055	−0.044	−0.050	**0.166**	12
GILD	0.063	0.011	**0.058**	**0.059**	**0.052**	**6.034**	0.234	**−0.470**	−0.184	−0.201	−0.074	8
GNTX	−0.018	0.021	0.057	**0.072**	0.049	**12.475**	−0.781	−0.940	−0.864	−0.840	0.164	13
HGSI	−0.035	0.030	0.022	0.011	0.024	**10.174**	−0.347	−0.220	**−0.658**	**−0.731**	**0.240**	9
HSIC	0.438	0.034	0.064	−0.081	0.017	**13.223**	1.088	−0.492	0.527	1.013	−0.134	9
ICOS	0.155	**0.032**	**0.094**	**0.094**	0.032	**7.107**	0.381	−0.834	−0.469	−0.118	−0.113	3
IDPH	0.040	0.022	**0.050**	**0.069**	**0.026**	**5.138**	**0.561**	0.077	−0.006	**0.365**	0.070	11
INTC	**0.025**	0.000	**0.007**	**0.008**	**0.009**	**1.331**	−0.032	−0.027	−0.003	0.043	−0.006	6
INTU	0.055	**0.053**	**0.088**	**0.053**	**0.033**	**6.195**	**0.334**	**−0.438**	−0.263	−0.115	**−0.144**	7
IVGN	**−0.375**	0.046	**0.096**	0.045	0.043	**9.230**	−0.193	−0.487	−0.371	**0.748**	**0.780**	8
KLAC	**−0.042**	**0.047**	**0.019**	**0.015**	0.003	**4.154**	0.067	0.096	0.072	**0.186**	**0.174**	13
LAMR	0.133	0.028	**−0.075**	0.045	0.041	**10.416**	−0.142	0.351	−0.507	−0.036	−0.018	7
LLTC	**−0.056**	**0.062**	0.026	0.009	0.001	**6.654**	0.065	0.051	0.219	**0.382**	**0.211**	7
LNCR	**0.302**	**0.102**	**0.094**	**0.092**	0.029	**9.611**	**1.174**	**−0.865**	−0.324	−0.220	**−0.346**	8
MCHP	−0.014	**0.036**	**0.042**	0.015	0.022	**6.845**	0.232	−0.301	0.190	0.276	**0.179**	10
MEDI	0.048	0.004	**0.048**	**0.058**	**0.029**	**4.610**	0.063	−0.472	−0.328	−0.137	0.000	6
MERQ	−0.025	0.031	0.033	**0.045**	**0.044**	**8.377**	0.081	−0.535	−0.257	0.176	0.285	8
MLNM	**−0.126**	−0.003	0.021	0.006	0.027	**6.635**	**−0.609**	−0.336	0.009	−0.209	**0.297**	7
MOLX	**−0.181**	0.034	0.029	0.016	0.008	**9.485**	0.102	−0.519	−0.601	0.108	**0.397**	8
MSFT	**0.048**	**0.016**	**0.014**	**0.014**	**0.015**	**1.853**	0.022	**0.085**	0.067	−0.002	**−0.037**	10
MXIM	0.016	0.015	**0.050**	**0.060**	**0.059**	**6.167**	**0.639**	−0.180	**−0.316**	−0.272	0.014	5
NLVS	**0.030**	**0.051**	**0.059**	**0.042**	0.008	**5.250**	**0.315**	**−0.319**	−0.081	0.165	−0.020	12
NTAP	**0.102**	**0.039**	**0.044**	**0.035**	0.018	**8.499**	−0.276	−0.285	−0.056	0.046	**−0.071**	9
NVDA	**0.061**	**0.047**	**0.043**	**0.019**	0.011	**6.884**	**−0.439**	**−0.443**	−0.076	−0.112	**−0.084**	12
NXTL	**−0.039**	**0.010**	**0.010**	0.003	0.010	**4.219**	**−0.416**	−0.067	0.070	0.026	**0.112**	11
ORCL	0.003	0.001	**0.010**	0.004	**0.011**	**1.701**	**−0.216**	−0.144	−0.037	0.087	**0.021**	8

Notes: All coefficient estimates are $\times 10^4$. Boldface indicates significance at the 1% level. The sample period is December 2002 with the number of observations found in the data appendix.

Table 5. Order book regression results for large caps.

	$\alpha_{r,1}$	$\alpha_{r,2}$	$\alpha_{r,3}$	$\alpha_{r,4}$	$\alpha_{r,5}$	$\beta_{r,1}$	$\beta_{r,2}$	$\beta_{r,3}$	$\beta_{r,4}$	$\beta_{r,5}$	γ_r	$\#D_t^b$
PAYX	**0.072**	**0.076**	**0.064**	0.009	−0.004	**7.424**	0.007	**−0.661**	−0.008	**0.387**	**−0.096**	11
PCAR	**−0.229**	−0.018	−0.009	**0.022**	**0.039**	**6.479**	**1.080**	0.074	−0.061	−0.074	**0.547**	12
PDCO	0.284	0.033	0.040	−0.064	0.069	11.842	0.828	**−1.403**	0.571	−0.474	−0.100	6
PETM	**−0.327**	0.019	0.018	−0.011	0.049	**17.692**	−0.509	−0.786	−0.755	−0.719	**0.465**	11
PIXR	**−0.787**	0.080	0.003	0.002	0.018	**13.881**	0.303	−0.917	−0.644	−0.083	**1.157**	8
PSFT	0.019	**0.047**	0.010	0.014	**0.026**	**7.294**	−0.171	−0.335	0.004	−0.216	**0.150**	10
PTEN	**−0.322**	0.002	−0.006	−0.010	0.016	**11.402**	−0.025	−0.557	0.372	−0.360	**0.750**	8
QCOM	0.009	**0.040**	**0.014**	0.000	0.003	**3.898**	−0.042	−0.114	−0.008	0.045	**0.083**	11
QLGC	0.015	**0.046**	**0.028**	**0.034**	0.036	**4.678**	**0.207**	0.037	−0.115	0.097	**0.038**	6
RFMD	**−0.087**	**0.019**	−0.001	0.001	0.017	**6.489**	**−0.601**	−0.102	−0.039	−0.193	**0.206**	12
ROST	0.092	0.029	0.058	0.006	−0.024	**9.292**	0.614	**−0.981**	−0.088	0.453	**0.321**	13
RYAAY	−0.166	**0.200**	**0.271**	**0.307**	**0.262**	**25.885**	−0.679	−0.655	−0.965	2.384	0.257	6
SANM	**−0.180**	−0.008	−0.006	0.007	0.012	**7.864**	**−1.009**	−0.032	**0.529**	0.098	**0.308**	10
SBUX	−0.003	0.013	**0.018**	**0.035**	**0.040**	**4.784**	−0.130	−0.208	0.016	−0.142	**0.099**	10
SEBL	**0.035**	**0.012**	**0.021**	**0.024**	**0.021**	**4.178**	**−0.392**	**−0.432**	−0.150	0.059	**−0.035**	11
SIAL	0.098	0.027	−0.017	−0.024	0.011	**6.641**	**0.718**	−0.090	−0.410	−0.558	**0.335**	12
SNPS	−0.081	−0.007	−0.011	0.004	−0.010	**6.810**	0.491	−0.178	−0.415	−0.017	**0.297**	13
SPLS	0.043	**0.023**	0.008	−0.017	0.011	**6.370**	**−0.384**	−0.198	−0.110	−0.095	0.051	9
SPOT	**−0.284**	**0.054**	−0.007	−0.010	0.032	**11.184**	**−0.943**	−0.660	−0.109	−0.425	**0.614**	2
SSCC	**−0.159**	−0.002	0.030	**−0.048**	−0.006	**9.596**	0.480	−0.470	−0.139	0.352	**0.319**	4
SUNW	−0.001	**0.002**	**0.003**	−0.001	**0.002**	**0.757**	**−0.155**	0.031	0.034	0.027	**0.014**	9
SYMC	0.014	**0.128**	**0.126**	**0.072**	**0.055**	**5.841**	0.193	−0.279	−0.398	−0.031	**−0.087**	8
TLAB	−0.126	0.011	−0.025	0.012	0.005	8.854	−0.965	−0.359	0.165	0.357	**0.265**	9
TMPW	−0.025	−0.020	−0.049	−0.025	**−0.100**	**12.084**	−0.805	−0.667	−0.494	0.313	**0.390**	6
USAI	0.130	0.029	−0.017	−0.003	**0.027**	**8.893**	−0.145	−0.300	−0.053	−0.359	0.220	11
VRSN	**−0.295**	0.028	0.032	0.034	0.010	**10.287**	−0.736	−0.859	−0.362	0.288	**0.547**	11
VRTS	**0.008**	0.010	**0.025**	**0.046**	**0.034**	**7.518**	0.258	**−0.464**	**−0.366**	0.008	**0.051**	8
WFMI	0.148	0.005	0.009	−0.015	−0.049	**7.854**	0.269	−0.098	−0.088	−0.275	0.068	12
XLNX	−0.002	**0.051**	0.012	0.008	0.013	**6.696**	0.235	−0.020	−0.068	0.208	**0.137**	8
XRAY	0.167	−0.009	−0.052	−0.023	−0.016	**12.655**	0.332	−0.583	−0.616	0.694	−0.130	11
YHOO	0.012	**0.027**	0.014	0.013	0.011	**4.422**	**−0.419**	**−0.261**	0.015	0.103	**0.088**	9

Notes: All coefficient estimates are $\times 10^4$. Boldface indicates significance at the 1% level. The sample period is December 2002 with the number of observations found in the data appendix.

Table 6. Order book regression results for small caps.

	$\alpha_{r,1}$	$\alpha_{r,2}$	$\alpha_{r,3}$	$\alpha_{r,4}$	$\alpha_{r,5}$	$\beta_{r,1}$	$\beta_{r,2}$	$\beta_{r,3}$	$\beta_{r,4}$	$\beta_{r,5}$	γ_r	$\#D_t^b$
ACGL	−0.731	−0.405	−0.054	2.372	0.236	58.565	21.932	−0.698	−40.450	12.320	2.466	0
AMIE	−9.257	1.386	0.582	0.701	6.217	284.339	−94.871	20.228	−17.218	0.830	10.416	0
ARLP	33.372	−1.633	−0.602	2.095	−2.836	46.439	−54.411	8.338	32.698	−15.486	−31.718	0
ARRO	14.150	2.403	−2.354	−0.992	−0.261	14.107	−15.184	9.782	5.917	−6.781	−8.715	0
ASPM	−36.960	−1.369	−0.623	−6.568	6.504	206.798	−8.374	−176.765	51.914	−51.740	41.730	3
ASRV	−13.229	1.695	−3.103	−1.791	−13.845	421.087	103.393	129.747	20.462	227.848	18.539	0
AUTN	387.234	10.935	−3.840	−9.523	2.192	251.152	−209.712	−71.872	−9.105	117.586	−386.698	0
BANR	−15.284	−0.782	6.008	6.130	−3.275	119.620	−21.873	−22.548	5.231	−15.615	19.720	1
BASI	3.100	1.012	−19.178	−0.123	−34.671	660.090	−273.092	392.890	431.969	−86.772	20.295	0
BBDC	473.965	3.402	5.414	3.839	−22.171	−30.655	−41.875	−369.764	−310.535	−117.787	−457.953	0
BELFB	−30.102	−2.482	−0.342	1.233	−6.172	113.031	33.720	−35.429	−43.650	−103.374	43.093	0
BIOI	−80.331	6.441	−46.009	−79.824	6.298	11.760	−129.263	220.981	677.800	453.003	146.581	0
BRKL	−2.699	0.044	−0.434	0.127	−0.003	40.305	−0.932	7.662	0.398	−3.673	4.908	0
BSBN	−12.080	1.153	−2.710	1.782	1.897	65.807	16.826	48.298	−19.042	−32.563	19.324	3
CACC	366.887	−8.678	−1.301	−6.399	11.732	−442.519	16.876	−58.974	174.173	37.500	−350.846	0
CBSA	−12.029	1.110	−2.909	−0.802	0.180	48.914	−8.683	2.999	30.820	−16.306	16.571	0
CEDC	−5.729	0.942	0.262	−0.612	−0.144	99.238	−15.859	−12.191	−19.995	−11.320	7.521	2
CENT	10.251	0.101	−0.584	−0.467	−0.106	58.070	−0.252	14.122	2.868	−7.551	−7.686	0
CHDN	−12.099	1.359	0.440	−0.394	1.289	35.644	1.788	−1.477	3.579	7.538	13.471	0
CITZ	11.875	−0.722	−0.042	1.541	−1.422	42.372	14.039	3.577	−16.175	−27.940	−9.409	0
CORS	−23.938	2.104	−2.490	6.452	−5.375	84.905	−29.682	138.083	−93.843	−16.289	53.603	0
CRZO	−3.135	6.086	17.167	6.877	−3.989	240.698	44.684	−138.614	−269.422	−222.676	10.871	0
CWTR	−11.628	1.806	−2.471	4.402	−6.285	90.281	−24.761	−16.275	29.427	23.618	31.543	0
CYBE	166.205	−2.490	3.550	3.498	−4.535	292.999	−76.077	66.567	35.056	133.736	−188.732	3
DEBS	−11.911	4.847	−5.317	−1.154	−0.131	118.640	17.532	47.238	−10.279	−10.205	25.651	1
DSWL	−1.242	−6.224	6.196	−12.050	2.581	150.139	67.298	−172.792	8.427	−19.486	2.895	0
DSWT	−21.433	−3.374	−11.621	−0.249	4.548	776.215	639.436	−128.552	264.359	−25.374	26.460	0
ELOY	−0.321	0.849	−3.155	9.952	0.938	215.231	10.796	85.525	65.540	−249.400	12.703	0
EMBX	−11.209	−0.648	−0.357	−1.853	−0.594	94.334	14.726	33.187	−9.383	8.289	19.222	0
EXPO	−1.617	0.807	−2.449	0.582	0.070	158.255	−38.830	92.445	−70.651	119.280	2.992	0
FFIC	2.723	−2.598	2.222	−5.785	−3.095	64.403	25.788	−37.186	−10.129	1.975	4.167	0

Notes: All coefficient estimates are $\times 10^4$. Boldface indicates significance at the 1% level. The sample period is December 2002 with the number of observations found in the data appendix.

Table 7. Order book regression results for small caps.

	$\alpha_{r,1}$	$\alpha_{r,2}$	$\alpha_{r,3}$	$\alpha_{r,4}$	$\alpha_{r,5}$	$\beta_{r,1}$	$\beta_{r,2}$	$\beta_{r,3}$	$\beta_{r,4}$	$\beta_{r,5}$	γ_r	$\#D_t^b$
FNLY	−53.344	−0.781	0.789	10.483	0.644	225.320	22.322	−56.007	−56.647	19.150	66.886	0
FPFC	14.088	1.532	0.285	0.111	0.464	−1.789	−19.810	−14.254	16.200	−39.566	−13.078	2
GMRK	−29.737	−4.979	2.741	1.106	−9.611	152.489	64.514	−20.912	−13.316	55.467	36.205	0
HARB	−15.184	0.438	0.168	−0.658	−1.162	89.099	−3.345	−19.557	4.283	−8.552	17.878	0
HGIC	−37.425	−1.613	0.386	2.224	0.407	115.412	−3.888	−7.982	1.544	18.055	49.566	0
HIBB	−40.222	0.074	0.721	0.153	−0.761	118.177	−12.083	−12.286	−4.730	12.858	49.110	0
HIBNY	−23.676	3.370	3.705	4.149	10.447	1201.04	−260.299	−264.897	−10.772	406.783	34.039	2
HNBC	20.050	−3.451	−2.613	−1.859	16.200	2.072	−2.769	5.527	−5.562	−18.949	−8.698	0
IBKC	8.174	−1.491	−0.175	2.666	−1.317	18.603	−6.758	7.377	−10.073	3.764	−6.679	0
IBNK	9.570	−0.364	−0.507	2.519	1.056	85.874	−12.211	0.303	38.095	33.341	−5.800	0
INDB	47.900	−0.115	−0.159	−1.809	0.444	2.478	−2.520	10.782	−0.729	0.862	−46.355	0
IRETS	−6.274	−0.693	−0.535	−0.416	2.104	109.970	35.598	13.339	0.915	−54.865	13.517	0
LAYN	−13.814	−1.730	0.814	−1.973	1.655	448.290	−38.365	−76.610	91.877	77.471	21.703	0
LBAI	−47.235	8.818	17.363	0.300	1.325	352.508	−145.840	68.251	53.900	−5.522	63.372	0
LSCO	−11.161	1.625	−0.746	1.248	−1.285	138.001	−108.115	122.329	−127.623	80.912	14.818	1
MAFB	−20.744	2.457	3.525	−2.754	6.779	104.917	−29.840	5.609	7.101	−11.365	25.170	0
MDST	−1.613	2.317	−2.656	0.125	0.409	78.049	6.998	38.486	1.172	25.895	9.024	0
MDTL	−63.557	−2.301	4.208	18.023	−14.118	431.680	−45.325	25.998	−264.055	−73.307	64.867	0
MEDM	−8.656	1.186	1.443	17.317	−9.698	137.860	−12.554	26.133	80.873	89.821	11.309	1
MEDW	−14.871	3.549	0.861	−2.326	−3.630	184.457	−35.916	14.772	97.591	−150.661	23.043	0
MERCS	1.967	−2.053	−16.694	11.548	14.270	449.173	485.595	208.081	57.322	−55.823	−20.911	0
MNRTA	−12.753	−0.108	−4.276	3.499	3.066	226.807	−111.119	216.853	−168.013	−239.585	15.778	0
NANX	−20.797	−3.462	2.576	−5.605	−0.404	413.977	−37.886	87.614	109.652	−23.353	27.145	1
NARA	−153.540	−98.985	−22.761	1.279	−15.385	−102.714	204.358	95.565	96.078	−17.882	375.528	0
NEWH	−20.553	6.725	4.739	4.809	−4.958	618.350	−105.333	−69.066	−146.586	−87.459	34.276	0
NHHC	−12.911	−9.092	−21.017	14.879	10.946	366.070	6.968	69.024	−99.884	−103.616	22.070	1
NUCO	−51.596	−3.421	5.787	3.839	5.332	302.700	330.359	373.962	−225.564	296.372	76.002	0
NUTR	−12.037	1.530	−0.671	2.451	−0.708	136.682	5.023	93.458	−16.369	44.252	16.350	3
PEAK	10.882	1.699	−2.912	−17.200	−5.657	286.006	−105.648	37.722	182.422	37.678	−11.320	1
PETD	−19.820	0.194	−8.199	−5.142	−4.826	285.377	153.816	−90.643	−108.980	315.056	25.048	0
PGNX	−59.919	6.558	1.327	−1.698	−0.409	300.074	−53.513	−53.695	−38.020	−52.760	68.482	0
PICO	−51.343	0.643	9.327	−12.395	−6.127	362.385	9.286	17.853	27.214	−36.983	54.218	2

Notes: All coefficient estimates are $\times 10^4$. Boldface indicates significance at the 1% level. The sample period is December 2002 with the number of observations found in the data appendix.

Table 8. Order book regression results for small caps.

	$\alpha_{r,1}$	$\alpha_{r,2}$	$\alpha_{r,3}$	$\alpha_{r,4}$	$\alpha_{r,5}$	$\beta_{r,1}$	$\beta_{r,2}$	$\beta_{r,3}$	$\beta_{r,4}$	$\beta_{r,5}$	γ_r	$\#D_t^{\mathrm{b}}$
PMBC	−19.910	7.641	7.807	−3.027	0.803	159.714	−30.889	−102.216	−26.717	−175.320	13.453	0
PORT	204.430	−3.493	3.447	−3.259	5.163	−215.203	10.153	0.484	−10.447	17.827	−200.868	5
PTSI	−53.740	−0.081	1.349	−0.082	−0.985	293.887	−92.777	53.235	−38.948	13.589	62.411	0
RMIX	−1.092	−8.943	−1.744	−4.005	−2.732	312.539	45.992	−7.422	−0.045	−98.831	23.775	0
SALM	−16.714	0.009	−2.865	−0.695	3.419	104.399	2.681	17.405	−0.394	3.618	25.775	0
SSNC	90.739	25.869	−6.949	−2.369	0.527	65.235	−62.773	−116.653	106.095	−23.956	−84.314	0
SSOL	10.314	−1.844	−0.999	−0.087	−0.751	820.464	276.451	−98.760	−287.143	−304.327	2.516	0
STKR	−90.152	−14.319	−13.773	−34.488	−84.389	1144.89	−1134.637	998.420	−597.432	−614.756	87.008	0
STTS	−11.511	2.555	−6.461	−24.622	−5.068	77.811	108.338	49.026	−79.776	54.613	25.831	0
SYNM	15.327	−6.705	8.113	0.690	−6.624	414.104	56.768	−76.940	−3.432	66.753	−22.535	1
TAYD	123.700	−26.401	29.839	−6.439	33.464	−236.874	1960.524	397.993	210.319	90.313	−116.894	0
TCLP	−1.517	−1.720	3.047	−2.104	0.148	−7.424	52.394	2.301	20.209	−65.239	13.927	0
TDSC	−6.269	−0.305	2.574	1.988	6.190	118.409	−8.040	−42.086	67.053	−70.835	18.762	0
TECUA	−21.363	1.273	0.551	−1.808	1.558	90.135	−41.523	−16.591	36.783	−16.102	26.710	0
TGIC	−16.099	1.121	−2.136	0.419	−0.143	83.351	−5.910	−2.473	−2.811	12.626	22.485	1
THTL	460.750	56.629	−15.028	−14.479	−43.061	−531.341	−336.589	−188.615	−149.780	−26.160	−439.285%	0
VITL	−27.256	0.563	1.265	−0.136	−0.613	123.671	33.133	−58.417	−23.933	6.813	33.962	1
VITX	−13.218	1.514	−0.185	0.084	0.500	827.375	−169.808	41.558	11.016	−69.212	24.069	3
VOLVY	2.124	−0.785	0.619	0.192	0.044	11.039	0.016	5.596	12.866	9.512	1.692	0
WCBO	3.585	−0.012	−0.301	7.598	−6.426	113.799	6.143	79.683%	33.780	5.516	−3.333	1
WDFC	0.387	−0.546	0.333	0.207	0.527	40.136	11.652	−2.486	4.956	−7.090	1.951	1
WFSI	−6.254	1.274	0.417	−0.243	−1.370	116.747	25.170	6.021	−2.109	−9.453	3.413	0
WRLS	−18.842	1.784	−5.131	2.621	4.658	354.738	−190.569	137.631	−165.577	59.287	30.591	0
WTNY	−2.440	0.606	0.085	0.301	0.868	37.882	3.944	−7.504	6.210	3.069	5.415	0

Notes: All coefficient estimates are $\times 10^4$. Boldface indicates significance at the 1% level. The sample period is December 2002 with the number of observations found in the data appendix.

Table 9. Most frequent inside market participants for large caps.

Symbol	Bid	Ask	Symbol	Bid	Ask	Symbol	Bid	Ask
AAPL	ADFN	ADFN	ERTS	ARCA	ARCA	ORCL	ARCA	ARCA
ADBE	ADFN	ADFN	ESRX	AMEX	AMEX	PAYX	ADFN	ADFN
ADCT	ADFN	ADFN	EXPD	ARCA	ARCA	PCAR	ADFN	ADFN
ALTR	ADFN	ADFN	FAST	ARCA	ARCA	PDCO	ARCA	ARCA
AMAT	ADFN	ADFN	FHCC	ARCA	ARCA	PETM	ARCA	ARCA
AMGN	ADFN	ADFN	FISV	ARCA	AMEX	PIXR	ADFN	ADFN
AMZN	ADFN	AMEX	FLEX	ARCA	ARCA	PSFT	ADFN	ADFN
APCC	ADFN	ADFN	GENZ	ARCA	ARCA	PTEN	ADFN	ADFN
APOL	ADFN	ADFN	GILD	JPHQ	JPHQ	QCOM	ADFN	ADFN
BBBY	ARCA	ADFN	GNTX	ARCA	ARCA	QLGC	ADFN	ADFN
BEAS	ARCA	ARCA	HGSI	CINN	CINN	RFMD	ADFN	ADFN
BGEN	ADFN	ARCA	HSIC	ARCA	ARCA	ROST	ADFN	ADFN
BMET	ARCA	ADFN	ICOS	ARCA	ARCA	RYAAY	ADFN	ADFN
BRCM	ADFN	ADFN	IDPH	ARCA	ARCA	SANM	ADFN	ADFN
CDWC	ADFN	ADFN	INTC	ADFN	ADFN	SBUX	ADFN	ADFN
CEPH	ADFN	ADFN	INTU	AMEX	AMEX	SEBL	ADFN	ARCA
CHIR	ADFN	ADFN	IVGN	ARCA	BRUT	SIAL	ADFN	ADFN
CHRW	ARCA	ADFN	KLAC	ADFN	ADFN	SNPS	ADFN	ADFN
CIEN	AMEX	AMEX	LAMR	ADFN	ADFN	SPLS	ADFN	ADFN
CMCSA	ARCA	ARCA	LLTC	ADFN	ADFN	SPOT	ADFN	ADFN
CMVT	AMEX	AMEX	LNCR	AMEX	AMEX	SSCC	ADFN	ADFN
COST	ADFN	ADFN	MCHP	ADFN	ADFN	SUNW	CINN	CINN
CPWR	ARCA	ARCA	MEDI	ARCA	ARCA	SYMC	AMEX	AMEX
CSCO	CINN	ARCA	MERQ	ADFN	ADFN	TLAB	ADFN	ADFN
CTAS	ADFN	ADFN	MLNM	ADFN	ADFN	TMPW	ADFN	ADFN
CTXS	ARCA	ADFN	MOLX	ADFN	ADFN	USAI	ADFN	ADFN
DELL	AMEX	AMEX	MSFT	ADFN	ADFN	VRSN	ADFN	ADFN
DISH	ARCA	ARCA	MXIM	ADFN	ADFN	VRTS	ADFN	ADFN
DLTR	AMEX	AMEX	NTAP	AMEX	AMEX	WFMI	ADFN	ADFN
EBAY	ARCA	ARCA	NVDA	AMEX	AMEX	XLNX	ADFN	ADFN
ERICY	AMEX	AMEX	NVLS	AMEX	AMEX	XRAY	ADFN	ADFN
			NXTL	ARCA	ARCA	YHOO	ADFN	ADFN

Notes: The table shows the market maker or ECN that appears most frequently on the inside bid or ask for the month of November 2002.

7. Effects of individual participants

I first test for the effect that individual market makers or ECNs have on quote revisions. I am particularly interested in the dealer quotes in this setting, to examine if individual market makers have a larger effect on the next tick.

7.1. The ax

Traders call the market makers or ECNs that frequently appear on the inside market the 'ax', and they claim that taking note of the ax's activity is informative†. Let $I(q_{1,t}^{b,i})$ be a dummy variable indicating the presence of market participant i on the inside bid and $I(q_{1,t}^{a,i})$ an indicator of inside ask appearances.

I determine the top inside market participants based on data for the month of November 2002, the month *prior* to my data sample. I call this group 'the axes', and there is a different set of ten for both the bid and the ask. In our bivariate VAR, I add‡ both $I(q_{1,t}^{b,i})$ and $I(q_{1,t}^{a,i})$,

$$
\begin{aligned}
r_t = & \sum_{i=1}^{5} a_{r,i} r_{t-i} + \sum_{i=1}^{15} b_{r,i} x_{t-i}^{0} \\
& + \sum_{k=1}^{5} \alpha_{r,k} (q_{k,t}^{b} - q_{k,t}^{a}) + \sum_{k=1}^{3} \beta_{r,k} (n_{k,t}^{b} - n_{k,t}^{a}) \\
& + \sum_{i=1}^{15} \delta_{r,i} \Delta D_{t-i}^{b} + \gamma_r (q_t^{b} - q_t^{a}) \\
& + \sum_{i=1}^{10} \theta_{r,i}^{b} I(q_{1,t}^{b,i}) + \sum_{i=1}^{10} \theta_{r,i}^{a} I(q_{1,t}^{a,i}) + \varepsilon_{r,t}. \qquad (5)
\end{aligned}
$$

$\theta_{r,i}^{b}$ and $\theta_{r,i}^{a}$ measure the effect of individual participants impacting the next tick from the bid or ask side through their quote behaviour.

As in Huang (2002), I find that ECNs are important providers of liquidity, but primarily for the large caps. A tabulation of the most frequent inside market participants

†See, for example, the advice from the Daytrading University at http://www.daytrading-university.com/ samplesson4ways.htm. "Even with the ECN routing that mm's [market makers] use to hide their order flow, there's still plenty of profitable trading to be had by correctly: (1) Avoiding buying when a major mm/ax is selling (e.g. if you see MSCO and MLCO both sitting on the inside ask you probably shouldn't buy if their bid is three levels outside the market) and (2) 'Shadowing' the ax's buying/selling behavior, if you see that all else looks okay, e.g. no suspiciously strong ECN buying/selling on INCA/ISLD."

‡I also tried adding the depth of the market maker when they took the inside, but I found no additional explanatory power.

Table 10. Most frequent inside market participants for small caps.

Symbol	Bid	Ask	Symbol	Bid	Ask	Symbol	Bid	Ask
ACGL	ARCA	ARCA	EXPO	CINN	CINN	NUTR	CINN	CINN
AMIE	ARCA	BTRD	FFIC	ARCA	ARCA	PEAK	SCHB	NITE
ARLP	CINN	ARCA	FNLY	ARCA	ARCA	PETD	CINN	BRUT
ARRO	ARCA	ARCA	FPFC	STFL	BRUT	PGNX	ARCA	CINN
ASPM	CINN	CINN	GMRK	ARCA	ARCA	PICO	ARCA	ARCA
ASRV	CINN	CINN	HARB	CINN	ARCA	PMBC	CINN	CINN
AUTN	CINN	ARCA	HGIC	ARCA	ARCA	PORT	CINN	ARCA
BANR	ARCA	CINN	HIBB	ARCA	ARCA	PTSI	ARCA	ARCA
BASI	NITE	CINN	HIBNY	CINN	CINN	RMIX	ARCA	CINN
BBDC	NITE	CINN	HNBC	ARCA	CINN	SALM	ARCA	ARCA
BELFB	ARCA	ARCA	IBKC	CINN	ARCA	SSNC	ARCA	ARCA
BIOI	NITE	CINN	IBNK	ARCA	ARCA	SSOL	CINN	CINN
BRKL	ADFN	CINN	INDB	ARCA	ARCA	STKR	NITE	ARCA
BSBN	ARCA	ARCA	IRETS	CINN	ARCA	STTS	CINN	ARCA
CACC	CINN	ARCA	LAYN	CINN	ARCA	SYNM	ARCA	CINN
CBSA	ARCA	ARCA	LBAI	ARCA	ARCA	TAYD	GSCO	CINN
CEDC	CINN	ARCA	LSCO	INCA	CINN	TCLP	ARCA	ARCA
CENT	ARCA	ARCA	MAFB	ARCA	ARCA	TDSC	ARCA	ARCA
CHDN	ARCA	ARCA	MDST	ARCA	ARCA	TECUA	ARCA	ARCA
CITZ	CINN	CINN	MDTL	BRUT	ARCA	TGIC	ARCA	ARCA
CORS	ARCA	ARCA	MEDM	MJSK	GSCO	THTL	ARCA	CINN
CRZO	NITE	CINN	MEDW	FAHN	CINN	VITL	ARCA	ARCA
CWTR	CINN	ARCA	MERCS	NITE	CINN	VITX	NITE	INCA
CYBE	CINN	ARCA	MNRTA	CINN	NITE	VOLVY	TMBR	TMBR
DEBS	CINN	ARCA	NANX	CINN	ARCA	WCBO	ARCA	ARCA
DSWL	NITE	NITE	NARA	ARCA	CINN	WDFC	ARCA	ARCA
DSWT	CINN	GSCO	NEWH	CINN	CINN	WFSI	ARCA	ARCA
ELOY	SBSH	SBSH	NHHC	UBSW	CINN	WRLS	CINN	CINN
EMBX	ARCA	ARCA	NUCO	NITE	ARCA	WTNY	INCA	INCA

Notes: The table shows the market maker or ECN that appears most frequently on the inside bid or ask for the month of November 2002.

is in table 9 for the Nasdaq 100 and table 10 for the small caps.

For 87% of the Nasdaq 100 stocks (82 of 95 on the bid and 83 of 95 on the ask), ECNs are most frequently on the inside. For the large caps, Instinet (ADFN), the largely institutional ECN, is the most frequent participant. It is the 'ax' in 53 stocks on the bid and 54 stocks on the offer. The most active non-ECN is the American Stock Exchange (AMEX) for 11 stocks on the bid and 13 stocks on the ask. Only one Nasdaq market maker is the 'ax' in a stock, J.P. Morgan, Chase, Hambrecht and Quest (JPHQ) for Gilead Science (GILD) on both the bid and offer. The presence of a particular participant does not by itself indicate that they are significant contributors to subsequent quote revisions though. I turn now to the model to address that question.

For the large cap group, there are an average of 3.87 statistically significant axes per stock on both the bid and 3.77 on the ask. The entire group shows at least one ax on the bid and ask (except for BMET). Archipelago ECN (ARCA), which merged with the NYSE in 2005, is significant in 71 bid regressions and 73 ask regressions. Instinet ECN (ADFN) is significant in 58 bid and 52 ask regressions. Brut ECN, now a part of Nasdaq, is in the same range with 50 bid and 52 ask appearances. The American Stock Exchange (AMEX), Island ECN, popular with day traders, and Bloomberg Trade Book ECN (BTRD), form the next echelon, with 37, 29 and 23 on the bid and 30, 29, and 25 significant ask coefficients, respectively. Notice that these are all UTPs and ECNs. The most significant market maker is Schwab Capital Markets (SCHB) with 17 bid appearances, and Knight Trimark (NITE) with 10 on the ask. NITE is the largest Nasdaq market maker by share volume. The remainder of the top ten on the bid are JPHQ, NITE, and Trac ECN (TRAC). Two other market makers, JPHQ and SCHB, and Trac ECN round out the top ten on the ask.

For the Nasdaq 100, there are 368 statistically significant individual bid dummies $\theta^{b}_{r,i}$, but with only 173 signed positively, consistent with the excess demand model. The big four Nasdaq stocks show the influences of the same set of participants generally as the rest of the Nasdaq 100. CINN, ARCA, BRUT, ATTN, and ADFN are the ECNs with significant impact on Cisco, and SCHB is the only market maker. Dell has the following set of significant participants: ADFN and AMEX. Intel's ax group includes the ECNs CINN, ARCA, BRUT, ADFN and two market makers, NITE and Goldman Sachs (GSCO). Finally, Microsoft has these axes: ADFN, ARCA, AMEX, BRUT, CINN, Salomon Smith Barney (SBSH) and SCHB.

On the ask side of the Nasdaq 100, there are 358 statistically significant individual $\theta^{a}_{r,i}$ in the bivariate VAR. Only slightly more than half of these, 188, are signed negatively. CSCO has six ask axes, ARCA, CINN, ADFN, BRUT, BTRD and Attain ECN (ATTN). Dell has only two ask axes, BRUT and ADFN. Intel has

six ask axes, CINN, BRUT, NITE, BTRD, ATTN, and SCHB. MSFT has seven of its 10 axes significant, ADFN, AMEX, ARCA, BRUT, CINN, NITE, and SCHB.

Looking more closely at individual participants, there are some interesting results. When ARCA takes the inside bid, the next tick is more likely to be a downtick than an uptick in 65 of 71 cases. There is a statistically significant average *decline* of -4.293×10^{-4}. The results are positive for the other important ECNs: ADFN 1.948×10^{-4}; BRUT 2.508×10^{-4}; BTRD 2.050×10^{-4}; CINN 1.414×10^{-4}. The most frequently significant dealer on the bid is SCHB, but their impact on the next tick is negative in each of the 17 cases, with an average decline of -5.296×10^{-4}.

On the ask side, I find mirror image results. When ARCA takes the inside ask, there is an uptick in 63 of 73 instances, for an average tick increase of 3.858×10^{-4}. The liquidity of other ECNs instead provides more selling pressure with average tick declines of -2.964×10^{-4} for ADFN, -2.630×10^{-4} for BRUT, -1.414×10^{-4} for BTRD, and -1.600×10^{-4} for CINN. The most prevalent market maker is NITE with an average downtick of -0.822×10^{-4}.

For 74% of the smaller cap stocks (71 of 87 on the bid and 80 of 87 on the ask), ECNs are most frequently on the inside. Archipelago ECN (ARCA) is the most frequent participant on both the bid and offer. The most active non-ECN is the largest Nasdaq market maker, Knight Securities (NITE), for nine stocks on the bid and three stocks on the ask.

For the small cap group, there are 169 statistically significant $\theta^{b}_{r,i}$, indicating instances of individual participants impacting the next tick from the bid side, but only 49 are positive. The most frequent participants impacting the price from the bid are in order: (1) ARCA; (2) CINN; (3) GSCO; (4) ADFN; (5) BTRD; (6) NITE; (7) BRUT; (8) MLCO; (9) SUSQ; and (10) a tie between Salomon Smith Barney (SBSH) and Morgan Stanley (MSCO).

On the ask side, there are 185 statistically significant individual $\theta^{a}_{r,i}$ in the bivariate VAR for the small cap dataset, but only 64 of these are negative. The top ten participants on the ask are: (1) ARCA; (2) CINN; (3) ADFN; (4) GSCO; (5) BTRD; (6) NITE; (7) BRUT; (8) Schwab Capital (SCHB); (9,10) MLCO and SBSH; with the exception of SUSQ or SCHB in place of MSCO (which is 11th on the ask list frequency), this group is the same as on the bid.

The effect of specific participants in the small cap market differs from the large caps. ARCA has a negative impact from the bid in all 41 cases in which it is statistically significant. The median downtick effect is -185.534×10^{-4}. Unlike the large caps, the other ECNs also have a negative median impact when they take the inside bid: CINN -105.933×10^{-4}; ADFN -111.817×10^{-4}; BTRD -120.876×10^{-4}; and BRUT -258.082×10^{-4}; the most influential bid sidemarket maker is GSCO. They have a median uptick of 85.058×10^{-4} in the 16 regressions in which they are significant.

There is a symmetric story on the ask side for the small caps. All five major ECNs are more likely to produce upticks when they take the inside ask. The median upticks are 225.290×10^{-4} for ARCA, 137.475×10^{-4} for CINN, 121.829×10^{-4} for ADFN, 155.722×10^{-4} for BTRD, and 212.732×10^{-4} for BRUT. GSCO is again the most significant market maker from the offer. Their median downtick size is -141.014×10^{-4}.

I now return to using the extended VAR to estimate the resilience of the order book.

8. Estimates of market impact

A vector autogression can be inverted into its moving average representation, and one can then compute impulse responses functions. In our model of trades and quotes, these have the interpretation of market impact functions, or the effect on stock returns of an unexpected buy order arriving into the market.

I compute and compare market impact estimates† from the model without full order book information (1) and from a streamlined‡ version of the extended VAR to conserve on degrees of freedom,

$$r_t = a_{r,0} + \sum_{i=1}^{5} a_{r,i} r_{t-i} + \sum_{i=0}^{15} b_{r,i} x^{0}_{t-i} + \sum_{i=1}^{5} \beta_{r,i}(n^{b}_{1,t-i} - n^{a}_{1,t-i}) + \sum_{i=1}^{15} \delta_{r,i} \Delta D^{b}_{t-i} + \varepsilon_{r,t}, \quad (6)$$

$$x^{0}_{t} = a_{x,0} + \sum_{i=1}^{5} a_{x,i} r_{t-i} + \sum_{i=1}^{15} b_{x,i} x^{0}_{t-i} + \sum_{i=1}^{5} \beta_{x,i}(n^{b}_{1,t-i} - n^{a}_{1,t-i}) + \sum_{i=1}^{15} \delta_{x,i} \Delta D^{b}_{t-i} + \varepsilon_{x,t}. \quad (7)$$

I keep only the consistently significant inside bid number difference for the first tier and the demand curve variable from the quote montage. I specify the latter two variables as 5th and 15th order autoregressive processes,

$$n^{b}_{1,t} - n^{a}_{1,t} = a_{n,0} + \sum_{i=1}^{5} a_{n,i} r_{t-i} + \sum_{i=1}^{15} b_{n,i} x^{0}_{t-i} + \sum_{i=1}^{5} \beta_{n,i}(n^{b}_{1,t-i} - n^{a}_{1,t-i}) + \sum_{i=1}^{15} \delta_{n,i} \Delta D^{b}_{t-i} + \varepsilon_{n,t}, \quad (8)$$

†A more thorough discussion of market impact estimates from the standard VAR can be found in Mizrach (2006).
‡This system is more complete than Engle and Patton's (2004) because it includes the additional depth and number of participants in the limit order book. It also models the autoregressive dynamics of the trades.

$$\Delta D_t^{\mathrm{b}} = a_{D,0} + \sum_{i=1}^{5} a_{D,i} r_{t-i} + \sum_{i=1}^{15} b_{D,i} x_{t-i}^{0} + \sum_{i=1}^{5} \beta_{D,i} (n_{1,t-i}^{\mathrm{b}} - n_{1,t-i}^{\mathrm{a}}) + \sum_{i=1}^{15} \delta_{D,i} \Delta D_{t-i}^{\mathrm{b}} + \varepsilon_{D,t}. \quad (9)$$

The four variable VAR is now given by (6), (7), (8) and (9). While there are 35 parameters in each equation, the large data sample makes the estimation feasible. I then use this system to examine the effects over the next 36 periods of a net one unit buy, $x_t^0 = 1$. Estimates are reported in table 11 for the large caps and table 12 for the small caps.

The results for the large caps indicate that the omission of the full order book generally overstates the market impact. The private information in the quotes may reflect knowledge of order flow that is predictive of the trades. The 36 period market impact averages 12.57×10^{-4} which is about \$0.031 for a \$25 stock. This is about 19% lower than the estimates which omit full order book information. For the big four, the average market impact is 1.439×10^{-4} which is a little bit more than \$0.0036, a reduction of 30.3% compared to the Hasbrouck estimate.

For small caps, the full order book information has the opposite effect on the market impact estimates. 84% of the stocks are estimated to have a positive impact from a buy order, with a median response of 396.90×10^{-4} or \$0.992 for a typically priced stock. This represents an increase of 18% from the original bivariate VAR. It may seem paradoxical that incorporating additional liquidity raises the market impact. If the book is highly autocorrelated though, this can make the trade impact even more persistent.

I now try to explain cross sectional differences in market impact. I use the characteristics from appendices A and B as regressors: capitalization, average price, number of market makers, and number of ticks. Grouping the large caps and small caps together is not successful. None of the explanatory variables is significant and the $\overline{R}^2$ is under 0.02. The model, however, is successful in describing the differential market impacts for the large caps,

$$\begin{aligned}\text{Market Impact} = {} & \underset{(4.569)}{54.481} + \underset{(0.660)}{3.546} \times 10^{-5} \times \text{Capitalization} \\ & - \underset{(-1.356)}{0.222} \times \text{Avg. Price} \underset{(-1.052)}{-1.327} \times 10^{-4} \\ & \times \text{Ticks} - \underset{(-1.662)}{0.344} \\ & \times \text{Market Makers}, \quad \overline{R}^2 = 0.201. \quad (10)\end{aligned}$$

For the large caps, these explain 20% of the data. These estimates suggest that, as firms grow and competition increases, so does liquidity†.

9. Implications for market microstructure theories

The paper has several empirical findings that shed light on existing microstructure theories. Because the Nasdaq is a hybrid order and dealer quote driven market, the facts do not fit neatly into any single model. As a consequence, I examine the implications of my empirical findings for both classes of models.

The first regards the autoregressive structure of the quotes. The positive serial correlation in quote revision for the large caps is consistent with quote driven models like Calcagno and Lovo (2005) in which uninformed market makers follow the quotes of informed market makers. It can also be explained in an order driven market by what Biais *et al.* (1995) call the 'diagonal effect' in which they observe that a limit order that improves the inside bid (ask) is more likely to be followed by another limit order which increases (decreases) the inside bid (ask). A similar diagonal effect for trades is present as well. The negative serial correlation in the small caps suggest that the quote revision process for that group can be explained without assuming informed traders, e.g. Roll (1984).

The importance of the entire limit order book in explaining the next tick is supportive of the view that the Nasdaq has an important order driven component. As in many auction designs, additional buy (sell) side interest makes the next price change more likely to be an uptick (downtick). Biais *et al.* (1999) observe this behaviour even in an environment in which quotes are only indicative. Similarly, in the period in which quotes are firm, the authors find that additional depth on one side of the book helps predict the appearance of additional liquidity on the same side of the book.

The significance of participant identity is hard to explain if one assumes that orders and quotes are driven by a noise process or that dealers are symmetrically informed. The market appears to recognize that some dealers and ECNs are more informed than others, and it is more likely to adjust their quotes in line with only some of the most active quote providers. The findings also add some additional subtlety to the importance of anonymity as noted by Foucault *et al.* (2005). While many Nasdaq studies have documented the importance of ECNs in improving the inside market (e.g. Simaan *et al.* 2002) my results show that the market regards anonymous limit orders from Archipelago differently than from Instinet or other ECNs.

Finally, my VAR model produces dynamic estimates of market impact. My analysis indicates that market impact studies need to take into account the entire state of the book, not just the inside quote.

10. Conclusion

This paper has provided some empirical support for the importance of observing the entire limit order book.

†A similar conclusion regarding spreads can be found in Klock and McCormick (1999).

Table 11. Market impact estimates for large caps.

	Market impact			Market impact			Market impact	
Symbol	Hasbrouck	Order book	Symbol	Hasbrouck	Order book	Symbol	Hasbrouck	Order book
AAPL	20.362	0.573	ESRX	−0.795	5.311	PAYX	1.168	1.449
ADBE	0.256	1.651	EXPD	89.492	92.105	PCAR	2.471	7.384
ADCT	56.156	1.124	FAST	19.619	21.681	PDCO	27.452	26.768
ALTR	−2.422	1.593	FHCC	26.934	33.981	PETM	2.660	1.675
AMAT	1.694	1.880	FISV	4.248	3.699	PIXR	34.628	28.142
AMGN	1.185	2.560	FLEX	−2.083	4.741	PSFT	15.060	1.051
AMZN	5.662	2.347	GENZ	1.618	1.314	PTEN	50.090	51.746
APCC	27.240	24.493	GILD	10.450	10.315	QCOM	14.350	16.674
APOL	4.081	5.986	GNTX	8.637	14.357	QLGC	−1.554	−1.170
BBBY	1.489	0.189	HGSI	5.162	0.699	RFMD	2.567	33.798
BEAS	13.972	13.037	HSIC	23.491	26.278	ROST	6.416	4.288
BGEN	1.319	0.385	ICOS	−4.496	−5.190	RYAAY	66.751	43.697
BMET	43.442	43.467	IDPH	7.470	7.818	SANM	0.427	3.345
BRCM	7.539	4.131	INTC	3.338	3.088	SBUX	0.314	−6.138
CDWC	9.531	8.254	INTU	−1.623	2.146	SEBL	7.797	1.628
CEPH	0.621	1.471	IVGN	0.122	0.197	SIAL	41.606	37.014
CHIR	11.479	8.733	KLAC	2.420	0.810	SNPS	9.005	0.102
CHRW	3.158	6.445	LAMR	26.596	31.831	SPLS	19.891	20.496
CIEN	24.544	5.768	LLTC	−5.308	−3.371	SPOT	59.518	50.336
CMCSA	5.235	6.291	LNCR	2.497	5.599	SSCC	−5.697	19.238
CMVT	16.921	1.268	MCHP	−3.468	0.057	SUNW	−4.738	−3.155
COST	0.115	1.735	MEDI	1.199	1.884	SYMC	8.782	4.390
CPWR	117.322	94.838	MERQ	12.414	14.708	TLAB	28.148	26.483
CSCO	−0.747	0.202	MLNM	32.025	15.039	TMPW	−8.184	−3.761
CTAS	2.492	5.020	MOLX	4.088	1.607	USAI	6.919	4.545
CTXS	−6.876	−5.771	MSFT	0.891	1.198	VRSN	6.292	3.883
DELL	1.961	1.267	MXIM	1.680	13.486	VRTS	6.838	9.503
DISH	22.493	23.855	NTAP	22.697	10.199	WFMI	4.980	15.325
DLTR	−5.133	−1.970	NVDA	8.990	3.116	XLNX	−1.674	−0.696
EBAY	29.794	29.790	NVLS	1.226	0.454	XRAY	31.614	29.880
ERICY	7.751	0.004	NXTL	6.648	6.931	YHOO	0.747	0.602
ERTS	−0.610	0.219	ORCL	2.706	4.223			

Notes: The sample period is December 2002 with the number of tick observations found in the data appendix.

Table 12. Market impact estimates for small caps.

Symbol	Market impact		Symbol	Market impact		Symbol	Market impact	
	Hasbrouck	Order book		Hasbrouck	Order book		Hasbrouck	Order book
ACGL	262.714	271.583	EXPO	9.576	27.538	NUTR	471.528	618.413
AMIE	1325.252	1684.312	FFIC	177.087	178.824	PEAK	3052.230	2243.887
ARLP	−323.543	−323.522	FNLY	−401.280	−113.214	PETD	1416.998	890.362
ARRO	34.992	32.248	FPFC	835.372	707.339	PGNX	−190.200	−148.733
ASPM	1844.998	1525.237	GMRK	115.154	123.681	PICO	253.535	272.358
ASRV	−1817.160	−1110.661	HARB	112.467	106.612	PMBC	5103.388	4847.712
AUTN	4041.595	3774.973	HGIC	132.192	174.185	PORT	187.929	157.851
BANR	127.414	143.238	HIBB	108.897	126.075	PTSI	99.653	2.444
BASI	11 305.057	14 136.111	HIBNY	4724.047	4844.756	RMIX	610.227	473.214
BBDC	−944.270	494.413	HNBC	−160.810	−175.960	SALM	213.408	12.841
BELFB	142.737	146.952	IBKC	324.075	305.928	SSNC	88.498	113.629
BIOI	−5010.849	−4062.683	IBNK	174.934	200.057	SSOL	4975.316	5508.736
BRKL	268.647	39.839	INDB	−15.716	−49.685	STKR	485.391	2283.266
BSBN	22.575	270.165	IRETS	798.455	790.929	STTS	941.652	855.887
CACC	1226.008	1063.541	LAYN	1047.584	1732.037	SYNM	1490.935	1900.531
CBSA	269.206	396.896	LBAI	−1107.120	−1059.372	TAYD	336.207	280.895
CEDC	−60.610	−59.208	LSCO	873.352	906.959	TCLP	728.427	710.490
CENT	329.347	343.277	MAFB	−15.982	−37.596	TDSC	1413.736	1531.529
CHDN	−210.917	−204.465	MDST	−46.989	−39.711	TECUA	127.337	113.114
CITZ	249.504	236.008	MDTL	260.519	293.271	TGIC	454.442	426.844
CORS	−60.705	−86.132	MEDM	469.870	902.421	THTL	423.399	547.837
CRZO	1995.768	1929.366	MEDW	196.886	184.515	VITL	92.918	121.870
CWTR	−84.230	−65.560	MERCS	4970.879	7226.071	VITX	1214.895	2432.374
CYBE	655.017	699.614	MNRTA	1642.663	1365.156	VOLVY	44.135	7.888
DEBS	−183.641	32.998	NANX	4819.371	3495.498	WCBO	564.210	568.791
DSWL	−1062.397	−954.186	NARA	136.356	72.426	WDFC	16.658	79.210
DSWT	5583.195	2598.068	NEWH	−1723.901	−1760.483	WFSI	39.427	117.711
ELOY	−1050.077	−1041.161	NHHC	7126.999	7218.077	WRLS	538.865	606.222
EMBX	217.710	161.177	NUCO	292.114	450.204	WTNY	5.192	9.247

Notes: The sample period is December 2002 with the number of tick observations found in the data appendix.

Nasdaq has multiple sources of liquidity, and the quote montage is a noisy road map.

Inside quotes, like those available on free quote services, often provide a less than complete picture of the market. The number of buyers and sellers, I find, is almost always more important than quoted depth. Aggregate depth, either at the inside market, or as a weighted average of the demand curve, is also helpful, and this information is surprisingly persistent. In general, the results are more successful for large cap stocks than small caps.

The institutional ECNs, Instinet and Archipelago, are the most active participants on the inside market. They are also frequently the 'ax' contributing to buying or selling pressure in the stock. Quotes away from the inside are generally not informative. Large numbers of buyers (sellers) at tiers away from the best bid (offer) are more likely to result in a downtick (uptick).

The model of trades and quotes presented also produces dynamic estimates of market impact. The impact of a buy order can be determined beyond its impact on the current spread. The estimates appear to vary sensibly with standard measures of liquidity.

Traders clearly think transparency of the order book matters, and they have successfully pressured the NYSE to provide similar information through OpenBook†. A follow up study to this would examine whether the additional depth visible on the NYSE and the regional exchanges is useful for trade and quote evolution. This paper is supportive of Nasdaq's SuperMontage initiative to provide access to and information about additional liquidity. The recent consolidation of ECNs on Nasdaq may eventually impact the market's quality though.

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†Ron Jordan, the NYSE vice president in charge of the program, was quoted in *Wall Street and Technology Online* of January 24, 2002: "I think that the top three reasons we are launching [OpenBook] are transparency, transparency and transparency," he says. "Since the decimalization of the market ... we've had a lot of demand from the professional trading community to see beyond the best bid ...".

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Appendix A

Table A1. Market characteristics for large caps.

Company	Symbol	Mkt cap	Avg. price	Ticks	MMs
APPLE COMPUTER INC	AAPL	5332.89	14.71	265 865	83
ADOBE SYSTEMS INC	ADBE	6076.50	26.05	298 609	78
ADC TELECOMMUNICATIONS INC	ADCT	1660.72	2.07	285 865	86
ALTERA CORP	ALTR	4787.35	12.52	341 731	82
APPLIED MATERIALS INC	AMAT	23 595.71	14.21	426 341	103
AMGEN INC	AMGN	63 872.19	49.51	416 410	103
AMAZON.COM INC	AMZN	8671.21	21.84	311 190	97
AMERICAN PWR CNVRSION	APCC	3020.71	15.31	151 516	59
APOLLO GROUP INC A	APOL	7483.44	42.58	312 657	62
BED BATH BEYOND INC	BBBY	9773.21	33.93	319 838	71
BEA SYSTEMS	BEAS	3985.06	10.92	324 724	95
BIOGEN INC	BGEN	6255.39	41.85	337 358	84
BIOMET INC	BMET	7206.27	28.11	265 072	66
BROADCOM	BRCM	4888.06	16.48	380 543	89
CDW CORPORATION	CDWC	3786.66	45.77	333 458	63
CEPHALON INC.	CEPH	2846.29	51.25	319 168	66
CHIRON CORP	CHIR	7309.90	39.19	345 781	69
C.H. ROBINSON WORLDWIDE	CHRW	2673.00	31.60	100 937	46
CIENA CORP	CIEN	2639.12	5.63	351 454	92
COMCAST CORP	CMCSA	53 357.15	23.71	313 724	69
COMVERSE TECHNOLOGY INC	CMVT	1259.96	10.65	206 489	78
COSTCO WHOLESALE CORP	COST	13 272.59	29.04	338 420	79
COMPUWARE CORP	CPWR	1864.38	4.87	251 108	61
CISCO SYSTEMS INC	CSCO	95 909.93	13.66	452 317	118
CINTAS CORP	CTAS	8122.78	47.58	336 678	54
CITRIX SYSTEMS INC	CTXS	2085.65	12.67	230 830	74
DELL COMPUTER CORP	DELL	70 957.70	27.61	405 286	107
ECHOSTAR COMMUN CORP	DISH	10 327.67	21.33	256 408	69
DOLLAR TREE STORES INC	DLTR	3017.58	26.39	207 661	66
EBAY INC	EBAY	22 030.38	34.31	403 741	84
ERICSSON (L M) TEL	ERICY	12 916.13	8.17	173 545	78
ELECTRONIC ARTS INC	ERTS	8519.37	58.31	374 488	83

Notes: Market capitalization is in millions of dollars. The average price is the monthly average of the daily closes. The number of market makers is the total for the entire month. All data are for December 2002.

Table A2. Market characteristics for large caps.

Company	Symbol	Mkt cap	Avg. price	Ticks	MMs
EXPRESS SCRIPTS INC	ESRX	3844.92	48.92	315 877	59
EXPEDITORS INTL	EXPD	3373.63	33.47	132 062	54
FASTENAL CORP	FAST	2867.54	37.79	125 931	43
FIRST HEALTH GROUP CORP	FHCC	2330.96	24.57	124 793	50
FISERV INC	FISV	6499.84	33.58	292 052	66
FLEXTRONICS INTL LTD	FLEX	4853.30	9.29	324 176	98
GENZYME GENERAL	GENZ	7282.30	32.79	313 530	76
GILEAD SCIENCE	GILD	7357.41	36.54	301 148	71
GENTEX CORP	GNTX	2407.66	31.51	118 918	49
HUMAN GENOME SCIENCE INC	HGSI	1223.51	9.47	217 752	75
HENRY SCHEIN INC	HSIC	1928.27	44.36	127 002	41
ICOS CORP	ICOS	1750.31	27.98	270 829	65
IDEC PHARMACEUTICAL	IDPH	5254.06	33.80	362 925	81
INTEL CORP	INTC	115 992.70	17.82	458 673	110
INTUIT INC	INTU	10 104.06	49.23	348 525	72
INVITROGEN CORP	IVGN	1530.94	30.46	196 218	56
KLA-TENCOR CORP	KLAC	7257.70	38.14	449 345	90
LAMAR ADVERTISING	LAMR	2944.45	33.91	130 836	45
LINEAR TECHNOLOGY CORP	LLTC	8887.87	28.40	416 212	81
LINCARE HOLDINGS INC	LNCR	3189.31	32.39	214 494	50
MICROCHIP TECHNOLOGY INC	MCHP	5308.60	25.91	370 730	73
MEDIMMUNE INC	MEDI	6655.98	26.64	302 061	79
MERCURY INTERACTIVE CORP	MERQ	2646.40	30.68	336 734	83
MILLENIUM PHARMACEUTICALS	MLNM	2806.36	9.40	283 255	92
MOLEX INC	MOLX	2444.24	24.42	266 070	57
MICROSOFT CORP	MSFT	291 749.01	27.09	456 542	102
MAXIM INTEGRATED PRODUCTS	MXIM	11 761.25	36.23	435 510	82
NETWORK APPLIANCE INC	NTAP	3979.11	11.64	326 289	90
NVIDIA CORP	NVDA	2147.78	13.46	342 709	92
NOVELLUS SYSTEMS INC	NVLS	4578.18	30.24	436 736	89
NEXTEL COMMUNICATIONS	NXTL	12 547.07	12.55	386 016	104
ORACLE CORP	ORCL	57 520.04	11.00	432 974	118
PAYCHEX INC	PAYX	10 432.30	27.68	292 304	71
PACCAR INC	PCAR	5451.42	46.77	320 970	50

Notes: Market capitalization is in millions of dollars. The average price is the monthly average of the daily closes. The number of market makers is the total for the entire month. All data are for December 2002.

Table A3. Market characteristics for large caps.

Company	Symbol	Mkt cap	Avg. price	Ticks	MMs
PATTERSON DENTAL CO	PDCO	2900.57	42.55	123 660	42
PETSMART INC	PETM	2598.66	18.36	136 054	62
PIXAR	PIXR	3162.71	57.97	119 386	47
PEOPLESOFT INC	PSFT	6735.46	18.50	340 449	93
PATTERSON-UTI ENERGY INC	PTEN	2546.23	31.47	168 841	59
QUALCOMM INC	QCOM	30 901.02	38.93	428 014	95
QLOGIC CORP	QLGC	3569.99	37.88	432 684	90
RF MICRO DEVICES INC	RFMD	1656.60	8.99	345 514	88
ROSS STORES INC	ROST	3344.29	43.68	190 275	61
RYANAIR HOLDINGS PLC	RYAAY	6264.57	41.53	75 725	46
SANMINA CORP	SANM	2160.08	4.23	332 567	79
STARBUCKS CORP	SBUX	8146.41	20.83	275 955	78
SIEBEL SYSTEMS INC	SEBL	3865.36	7.83	349 654	106
SIGMA-ALDRICH	SIAL	3478.90	49.15	222 853	52
SYNOPSYS INC	SNPS	3543.79	45.87	260 232	66
STAPLES INC	SPLS	9085.64	18.66	265 158	72
PANAMSAT CORP	SPOT	2407.28	16.04	183 636	55
SMURFIT-STONE CNTR CORP	SSCC	3643.81	14.85	177 190	52
SUN MICROSYSTEMS INC	SUNW	10 897.20	3.36	430 567	117
SYMANTEC CORP	SYMC	6400.92	42.17	338 770	83
TELLABS INC	TLAB	3094.78	7.50	232 375	83
MONSTER WORLDWIDE INC	TMPW/MNST	1259.57	11.74	206 294	68
INTERACTIVE CORP	USAI/IACI	16 107.06	24.36	273 760	68
VERISIGN INC	VRSN	2114.37	8.79	209 987	79
VERITAS SOFTWARE CO	VRTS	7312.48	17.18	344 946	101
WHOLE FOODS MARKET INC	WFMI	3182.23	53.13	165 241	53
XILINX INC	XLNX	7337.85	21.53	412 569	89
DENTSPLY INTERNATIONAL INC	XRAY	2855.83	36.15	125 264	43
YAHOO INC	YHOO	10 337.47	16.94	339 463	99

Notes: Market capitalization is in millions of dollars. The average price is the monthly average of the daily closes. The number of market makers is the total for the entire month. All data are for December 2002.

Appendix B

Table B1. Market characteristics for small caps.

Company	Symbol	Mkt. cap	Avg. price	Ticks	MMs
ARCH CAPITAL GROUP LTD	ACGL	880.84	31.36	40 199	25
AMBASSADORS INTL INC	AMIE	88.10	8.89	1539	23
ALLIANCE RSRC PTNRS	ARLP	273.47	23.82	4254	16
ARROW INTERNATIONAL	ARRO	852.35	19.70	22 216	20
ASPECT MED SYS INC	ASPM	80.30	4.13	6133	20
AMERISERV FINANCIAL INC	ASRV	39.66	2.84	2623	19
AUTONOMY CORP PLC	AUTN	317.52	14.19	3029	20
BANNER CORP	BANR	214.84	18.88	9381	28
BIOANALYTICAL SYS. INC	BASI	13.77	2.97	808	14
BRANTLEY CAPITAL CORP	BBDC	29.90	7.85	2112	16
BEL FUSE INC	BELFB	186.70	18.86	15 894	22
BIOSOURCE INTL INC	BIOI	52.00	5.67	928	18
BROOKLINE BANCORP INC	BRKL	682.46	11.84	22 555	35
BSB BANCORP	BSBN	200.50	21.87	6961	27
CREDIT ACCEP CORP MICH	CACC	292.31	6.90	16 029	18
COASTAL BANCORP INC	CBSA	161.55	31.31	4706	26
CENTRAL EURO. DIST CORP	CEDC	123.70	11.63	13 190	18
CENTRAL GARDEN PET CO	CENT	368.79	18.81	32 581	25
CHURCHILL DOWNS INC	CHDN	504.29	38.20	11 547	26
CFS BANCORP INC	CITZ	175.17	14.41	6178	26
CORUS BANKSHARES INC	CORS	621.05	44.23	25 611	21
CARRIZO OIL GAS INC	CRZO	73.83	5.18	2698	15
COLDWATER CREEK INC	CWTR	183.00	11.45	17 855	20
CYBEROPTICS CORP	CYBE	47.45	5.75	3469	17
DEB SHOPS INC	DEBS	300.35	21.94	18 884	22
DESWELL INDUSTRIES INC	DSWL	132.06	14.51	1821	13
DURASWITCH INDS INC	DSWT	10.58	1.11	1956	17
ELOYALTY CORP	ELOY	26.91	3.84	2858	15
EMBREX INC	EMBX	99.18	12.15	12 233	20
EXPONENT INC	EXPO	103.16	14.37	6031	17
FLUSHING FINANCIAL CORP	FFIC	214.03	16.68	12 216	24

Notes: Market capitalization is in millions of dollars. The average price is the monthly average of the daily closes. The number of market makers is the total for the entire month. All data are for December 2002.

Table B2. Market characteristics for small caps.

Company	Symbol	Mkt. cap	Avg. price	Ticks	MMs
FINLAY ENTERPRISES INC	FNLY	110.01	12.08	13 079	17
FIRST PL FINL CORP/DE	FPFC	225.15	16.93	3993	26
GULFMARK OFFSHORE INC	GMRK	295.54	14.80	23 465	23
HARBOR FLORIDA BANCSHARES	HARB	510.72	21.49	18 192	32
HARLEYSVILLE GROUP INC	HGIC	778.58	25.90	33 136	28
HIBBETT SPORTING GOODS INC	HIBB	255.87	16.71	18 729	29
HIBERNIA FOODS ADR	HIBNY	36.81	1.52	4586	16
HARLEYSVILLE NATL CORP/PA	HNBC	476.89	25.05	8838	24
IBERIABANK CORP	IBKC	259.94	38.68	9097	25
INTEGRA BANK CORP	IBNK	304.04	17.56	13 515	23
INDEPENDENT BANK CORP/MA	INDB	344.53	23.63	17 659	25
INVESTORS REAL ESTATE TRUST	IRETS	381.03	10.52	6621	15
LAYNE CHRISTENSEN CO	LAYN	102.08	8.39	5331	19
LAKELAND BANCORP INC	LBAI	268.24	18.89	6023	26
LESCO INC	LSCO	117.44	13.77	5417	15
MAF BANCORP INC	MAFB	888.60	34.48	28 085	27
MID-STATE BANCSHARES	MDST	392.38	16.72	14 463	23
MEDIS TECHNOLOGIES LTD	MDTL	123.37	5.23	5481	22
MEDAMICUS INC	MEDM	38.53	8.13	3883	19
MEDIWARE INFO SYSTEMS	MEDW	62.48	8.49	3787	18
MERCER INTL INC	MERCS	86.13	5.13	989	15
MONMOUTH RE INVEST CP	MNRTA	102.51	6.92	1318	16
NANOPHASE TECHNOLOGIES CORP	NANX	47.00	3.08	3950	19
NARA BANCROP INC	NARA	116.38	10.65	14 699	22
NEW HORIZONS WORLDWIDE INC	NEWH	49.12	4.65	3150	18
NATIONAL HOME HEALTH CARE	NHHC	54.05	9.83	2543	19
NUCOR INC	NUCO	85.15	8.01	2654	19
NUTRACEUTICAL INTL CP	NUTR	113.56	10.15	7603	16
PEAK INTERNATIONAL LTD	PEAK	45.90	3.83	1641	16
PETROLEUM DVLPMNT CORP	PETD	82.21	5.26	1917	18
PROGENICS PHARMA INC	PGNX	88.11	6.81	7571	23
PICO HOLDINGS INC	PICO	155.49	12.56	12 434	24

Notes: Market capitalization is in millions of dollars. The average price is the monthly average of the daily closes. The number of market makers is the total for the entire month. All data are for December 2002.

Table B3. Market characteristics for small caps.

Company	Symbol	Mkt. cap	Avg.	Ticks	MMs
PACIFIC MERCANTILE BANCORP	PMBC	45.72	7.14	906	17
PORT FINANCIAL CORP	PORT	230.85	43.64	17 079	23
P.A.M. TRANSPORTATION SVCS	PTSI	258.52	22.90	17 149	20
U S CONCRETE INC	RMIX	153.21	5.42	10 503	24
SALEM COMMUNICATIONS CORP	SALM	458.07	25.55	22 220	25
SSC TECHNOLOGIES INC	SSNC	129.20	10.49	21 193	19
SMARTSERV ONLINE INC	SSOL	0.00	0.00	2359	23
STOCKERYALE INC	STKR	21.81	1.52	1409	16
ST ASSEMBLY TEST	STTS	724.06	7.29	3711	24
SYNTROLEUM CORP	SYNM	52.99	1.57	6736	22
TAYLOR DEVICES INC	TAYD	7.15	2.44	1057	13
TC PIPELINES LP	TCLP	428.21	25.86	8872	19
3D SYS CORP/DE	TDSC	100.19	7.85	4324	23
TECUMSEH PRODUCTS CO	TECUA	821.33	44.44	45 350	22
TRIAD GUARANTY INC	TGIC	549.19	38.32	33 267	23
THISTLE GROUP HOLDINGS	THTL	58.21	11.15	2247	25
VITAL SIGNS INC	VITL	377.21	29.22	17 604	21
VI TECHNOLOGIES INC	VITX	36.85	0.90	6897	24
VOLVO AB SWE	VOLVY	7245.13	17.27	15 895	35
WEST COAST BANCORP/OR	WCBO	240.01	15.80	13 784	24
WD-40 CO	WDFC	477.43	28.69	28 961	20
WFS FINANCIAL INC	WFSI	843.35	20.56	28 902	26
TELULAR CORP	WRLS	48.66	3.76	7174	19
WHITNEY HOLDING CORP	WTNY	1330.55	32.98	39 957	31

Notes: Market capitalization is in millions of dollars. The average price is the monthly average of the daily closes. The number of market makers is the total for the entire month. All data are for December 2002.