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# The next tick on Nasdaq 

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#### Abstract

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?

[^1]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
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 intradaily. 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 $\dagger$. 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) ब 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.

[^2]Table 1. Limit order book for Fastenal Company (FASNotes: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 | 36.90 | 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 $\dagger$. Nasdaq also introduced an anonymous quote and execution facility $\ddagger$ 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 twosided quotations; the market maker U.S. Bancorp Piper Jaffray (PIPR) is at 35.83 on the bid and at 36.09 on the offer $\boldsymbol{\pi}$. Depths $\|$ are in 100 s of shares.

The inside market consists of the best bid and ask prices and the largest depth. In this case, the quote would be $35.85 \times 35.86$ with a depth of $37 \times 2$. 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, $\log \left(\left(p_{t}^{\mathrm{b}}+p_{t}^{\mathrm{a}}\right) / 2\right)-\log \left(\left(p_{t-1}^{\mathrm{b}}+p_{t-1}^{\mathrm{a}}\right) / 2\right)$. 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 $T$. The quote revision model is specified as

$$
\begin{align*}
& r_{t}=a_{r, 0}+\sum_{i=1}^{5} a_{r, i} r_{t-i}+\sum_{i=0}^{15} b_{r, i} x_{t-i}^{0}+\varepsilon_{r, t}  \tag{1}\\
& x_{t}^{0}=a_{x, 0}+\sum_{i=1}^{5} a_{x, i} r_{t-i}+\sum_{i=1}^{15} b_{x, i} x_{t-i}^{0}+\varepsilon_{x, t} \tag{2}
\end{align*}
$$

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

[^3]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 $p_{k, t}^{\mathrm{b}, i}$ be the bid for market participant $i$ on the tier $k$ of the quote montage at time $t$, and let $p_{k, t}^{\text {a,j }}$ 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, $p_{1, t}^{\mathrm{b}, 1}=p_{1, t}^{\mathrm{b}, 2}=p_{1, t}^{\mathrm{b}, 3}=p_{1, t}^{\mathrm{b}, 4}=35.85$, 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: $p_{2, t}^{\mathrm{a}, 1}=35.89$. For ARCA, $\quad p_{4, t}^{\mathrm{a}, 2}=35.99$. BRUT is the inside offer, $p_{1, t}^{\mathrm{a}, 3}=35.86$, and BTRD is on the fourth tier, $p_{4, t}^{\mathrm{a}, 4}=35.99$. 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 $q_{k, t}^{\mathrm{b}, i}$ and $q_{k, t}^{\mathrm{a}, j}$. 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 $q_{k, t}^{\mathrm{b}}=\sum_{i=1}^{n} q_{k, t}^{\mathrm{b}, i}$ be the aggregate depth on tier $k$ of the bid, and let $q_{k, t}^{\mathrm{a}}=\sum_{j=1}^{n} q_{k, t}^{\mathrm{a}, j}$ be defined symmetrically for the ask, where $n$ is the number of market participants. For the FAST example, $q_{1, t}^{\mathrm{b}}=43, q_{2, t}^{\mathrm{b}}=1$, $q_{3, t}^{\mathrm{b}}=1, q_{4, t}^{\mathrm{b}}=1$, and $q_{5, t}^{\mathrm{b}}=1$. The inside spread is denoted $p_{1, \mathrm{~b}, i}^{\mathrm{b},} \times p_{1, t}^{\mathrm{a}}$. The inside bid and ask depth are $q_{t}^{\mathrm{b}}=\max _{i}\left[q_{1, t}^{\mathrm{b}, i}, \ldots, q_{1, t}^{\mathrm{b}, n}\right]$ and $q_{t}^{\mathrm{a}}=\max _{i}\left[q_{1, t}^{\mathrm{a}, i}, \ldots, q_{1, t}^{\mathrm{a}, n}\right]$. For FAST, $q_{t}^{\mathrm{b}}=37$, and $q_{t}^{\mathrm{a}}=2$. Note that the inside quote display obscures additional depth on the first bid tier, $\sum_{i} q_{1, t}^{\mathrm{b}, i}>q_{t}^{\mathrm{b}}$. 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, $D_{t}^{\mathrm{b}}$. It is a weighted average of the first five tiers of the bid,

$$
\begin{equation*}
D_{t}^{\mathrm{b}}=\left(\sum_{k=1}^{5} \sum_{i=1}^{n} p_{k, t}^{\mathrm{b}, i} \times q_{k, t}^{\mathrm{b}, i}\right) / \sum_{k=1}^{5} q_{k, t}^{\mathrm{b}} . \tag{3}
\end{equation*}
$$

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 $n_{k, t}^{\mathrm{b}}=\sum_{i=1}^{n} I\left(q_{k, t}^{\mathrm{b}, i}>0\right)$, 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, $n_{1, t}^{\mathrm{b}}=4, n_{2, t}^{\mathrm{b}}=1, n_{3, t}^{\mathrm{b}}=1, n_{4, t}^{\mathrm{b}}=1$ and $n_{5, t}^{\mathrm{b}}=1$.

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

$$
\begin{align*}
r_{t}= & a_{r, 0}+\sum_{i=1}^{5} a_{r, i} r_{t-i}+\sum_{i=0}^{15} b_{r, i} x_{t-i}^{0}+\sum_{k=1}^{5} \alpha_{r, k}\left(q_{k, t}^{\mathrm{b}}-q_{k, t}^{\mathrm{a}}\right) \\
& +\sum_{k=1}^{5} \beta_{r, k}\left(n_{k, t}^{\mathrm{b}}-n_{k, t}^{\mathrm{a}}\right)+\sum_{i=1}^{15} \delta_{r, i} \Delta D_{t-i}^{\mathrm{b}} \\
& +\gamma_{r}\left(q_{t}^{\mathrm{b}}-q_{t}^{\mathrm{a}}\right)+\varepsilon_{r, t} . \tag{4}
\end{align*}
$$

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 $\dagger$ 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 $\ddagger$. 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,

[^4]Table 2. Order book estimates for Ross Stores Inc.

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

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 52 nd 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, $\beta_{r}, 1$. 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 $n_{1, t}^{\mathrm{b}}-n_{1, t}^{\mathrm{a}}$ 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 $\gamma$ 's. If you incorporate the aggregate tier 1 volume as $q_{1, t}^{\mathrm{b}}-q_{1, t}^{\mathrm{a}}$, 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 $q_{2, t}^{\mathrm{b}}-q_{2, t}^{\mathrm{a}}, \ldots, q_{5, t}^{\mathrm{b}}-q_{5, t}^{\mathrm{a}}$ 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, $n_{2, t}^{\mathrm{b}}-n_{2, t}^{\mathrm{a}}, \ldots, n_{5, t}^{\mathrm{b}}-n_{5, t}^{\mathrm{a}}$, 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 $D_{t}^{\mathrm{b}}$ are statistically significant and positive. The big four are like the sample as a whole. A complete set of $\alpha_{r}$ 's, $\beta_{r}$ 's and the number of significant $\delta_{r}$ '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 $\alpha_{r}$ 's and 21 significantly negative $\beta_{r}$ 's. The demand curve, as a whole, is also less important. On average, only 0.5 lags of $D_{t}^{\mathrm{b}}$ are statistically significant. A complete set of $\alpha_{r}$ 's, $\beta_{r}$ 's and the number of significant $\delta_{r}$ '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.

|  | $\alpha_{r, 1}$ | $\alpha_{r, 2}$ | $\alpha_{r, 3}$ | $\alpha_{r, 4}$ | $\alpha_{r, 5}$ | $\beta_{r, 1}$ | $\beta_{r, 2}$ | $\beta_{r, 3}$ | $\beta_{r, 4}$ | $\beta_{r, 5}$ | $\gamma_{r}$ | $\# D_{t}^{\text {b }}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 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.

|  | $\alpha_{r, 1}$ | $\alpha_{r, 2}$ | $\alpha_{r, 3}$ | $\alpha_{r, 4}$ | $\alpha_{r, 5}$ | $\beta_{r, 1}$ | $\beta_{r, 2}$ | $\beta_{r, 2}$ | $\beta_{r, 2}$ | $\beta_{r, 2}$ | $\gamma_{r}$ | $\# D_{t}^{\mathrm{b}}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ESRX | -0.005 | 0.048 | 0.033 | 0.009 | 0.012 | 5.461 | 1.013 | 0.673 | 0.298 | 0.154 | 0.071 |  |
| 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 |  |
| 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 |  |
| HSIC | 0.438 | 0.034 | 0.064 | -0.081 | 0.017 | 13.223 | 1.088 | -0.492 | 0.527 | 1.013 | -0.134 |  |
| ICOS | 0.155 | 0.032 | 0.094 | 0.094 | 0.032 | 7.107 | 0.381 | -0.834 | -0.469 | -0.118 | -0.113 |  |
| 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 |  |
| INTU | 0.055 | 0.053 | 0.088 | 0.053 | 0.033 | 6.195 | 0.334 | -0.438 | -0.263 | -0.115 | -0.144 |  |
| IVGN | -0.375 | 0.046 | 0.096 | 0.045 | 0.043 | 9.230 | -0.193 | -0.487 | -0.371 | 0.748 | 0.780 |  |
| 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 |  |
| LLTC | -0.056 | 0.062 | 0.026 | 0.009 | 0.001 | 6.654 | 0.065 | 0.051 | 0.219 | 0.382 | 0.211 |  |
| LNCR | 0.302 | 0.102 | 0.094 | 0.092 | 0.029 | 9.611 | 1.174 | -0.865 | -0.324 | -0.220 | -0.346 |  |
| 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 |  |
| MERQ | -0.025 | 0.031 | 0.033 | 0.045 | 0.044 | 8.377 | 0.081 | -0.535 | -0.257 | 0.176 | 0.285 |  |
| MLNM | -0.126 | -0.003 | 0.021 | 0.006 | 0.027 | 6.635 | -0.609 | -0.336 | 0.009 | -0.209 | 0.297 |  |
| MOLX | -0.181 | 0.034 | 0.029 | 0.016 | 0.008 | 9.485 | 0.102 | -0.519 | -0.601 | 0.108 | 0.397 |  |
| 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 |  |
| 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 |  |
| 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 |  |

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.

|  | $\alpha_{r, 1}$ | $\alpha_{r, 2}$ | $\alpha_{r, 3}$ | $\alpha_{r, 4}$ | $\alpha_{r, 5}$ | $\beta_{r, 1}$ | $\beta_{r, 2}$ | $\beta_{r, 3}$ | $\beta_{r, 4}$ | $\beta_{r, 5}$ | $\gamma_{r}$ | $\# D_{t}^{\mathrm{b}}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 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.

|  | $\alpha_{r, 1}$ | $\alpha_{r, 2}$ | $\alpha_{r, 3}$ | $\alpha_{r, 4}$ | $\alpha_{r, 5}$ | $\beta_{r, 1}$ | $\beta_{r, 2}$ | $\beta_{r, 3}$ | $\beta_{r, 4}$ | $\beta_{r, 5}$ | $\gamma_{r}$ | $\# D_{t}^{\mathrm{b}}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ACGL | -0.731 | -0.405 | -0.054 | 2.372 | 0.236 | 58.565 | 21.932 | -0.698 | -40.450 | 12.320 | 2.466 |  |
| AMIE | -9.257 | 1.386 | 0.582 | 0.701 | 6.217 | 284.339 | -94.871 | 20.228 | -17.218 | 0.830 | 10.416 |  |
| ARLP | 33.372 | $-1.633$ | -0.602 | 2.095 | -2.836 | 46.439 | -54.411 | 8.338 | 32.698 | -15.486 | -31.718 |  |
| ARRO | 14.150 | 2.403 | -2.354 | -0.992 | $-0.261$ | 14.107 | -15.184 | 9.782 | 5.917 | $-6.781$ | -8.715 |  |
| ASPM | -36.960 | $-1.369$ | -0.623 | -6.568 | 6.504 | 206.798 | -8.374 | -176.765 | 51.914 | -51.740 | 41.730 |  |
| ASRV | -13.229 | 1.695 | -3.103 | -1.791 | -13.845 | 421.087 | 103.393 | 129.747 | 20.462 | 227.848 | 18.539 |  |
| 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 |  |
| BASI | 3.100 | 1.012 | -19.178 | -0.123 | -34.671 | 660.090 | -273.092 | 392.890 | 431.969 | -86.772 | 20.295 |  |
| BBDC | 473.965 | 3.402 | 5.414 | 3.839 | -22.171 | -30.655 | -41.875 | -369.764 | -310.535 | $-117.787$ | -457.953 |  |
| BELFB | -30.102 | $-2.482$ | -0.342 | 1.233 | -6.172 | 113.031 | 33.720 | -35.429 | -43.650 | $-103.374$ | 43.093 |  |
| BIOI | -80.331 | 6.441 | -46.009 | -79.824 | 6.298 | 11.760 | -129.263 | 220.981 | 677.800 | 453.003 | 146.581 |  |
| BRKL | -2.699 | 0.044 | -0.434 | 0.127 | $-0.003$ | 40.305 | -0.932 | 7.662 | 0.398 | -3.673 | 4.908 |  |
| BSBN | -12.080 | 1.153 | -2.710 | 1.782 | 1.897 | 65.807 | 16.826 | 48.298 | -19.042 | -32.563 | 19.324 |  |
| CACC | 366.887 | -8.678 | -1.301 | -6.399 | 11.732 | -442.519 | 16.876 | -58.974 | 174.173 | 37.500 | -350.846 |  |
| 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 |  |
| CENT | 10.251 | 0.101 | -0.584 | -0.467 | -0.106 | 58.070 | -0.252 | 14.122 | 2.868 | -7.551 | -7.686 |  |
| CHDN | -12.099 | 1.359 | 0.440 | $-0.394$ | 1.289 | 35.644 | 1.788 | $-1.477$ | 3.579 | 7.538 | 13.471 |  |
| CITZ | 11.875 | -0.722 | $-0.042$ | 1.541 | -1.422 | 42.372 | 14.039 | 3.577 | -16.175 | -27.940 | -9.409 |  |
| CORS | -23.938 | 2.104 | $-2.490$ | 6.452 | -5.375 | 84.905 | -29.682 | 138.083 | -93.843 | -16.289 | 53.603 |  |
| CRZO | -3.135 | 6.086 | 17.167 | 6.877 | -3.989 | 240.698 | 44.684 | -138.614 | -269.422 | -222.676 | 10.871 |  |
| CWTR | -11.628 | 1.806 | -2.471 | 4.402 | -6.285 | 90.281 | -24.761 | -16.275 | 29.427 | 23.618 | 31.543 |  |
| CYBE | 166.205 | -2.490 | 3.550 | 3.498 | -4.535 | 292.999 | -76.077 | 66.567 | 35.056 | 133.736 | -188.732 |  |
| DEBS | -11.911 | 4.847 | -5.317 | -1.154 | -0.131 | 118.640 | 17.532 | 47.238 | -10.279 | -10.205 | 25.651 |  |
| 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 |  |
| ELOY | -0.321 | 0.849 | -3.155 | 9.952 | 0.938 | 215.231 | 10.796 | 85.525 | 65.540 | -249.400 | 12.703 |  |
| 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.

|  | $\alpha_{r, 1}$ | $\alpha_{r, 2}$ | $\alpha_{r, 3}$ | $\alpha_{r, 4}$ | $\alpha_{r, 5}$ | $\beta_{r, 1}$ | $\beta_{r, 2}$ | $\beta_{r, 3}$ | $\beta_{r, 4}$ | $\beta_{r, 5}$ | $\gamma_{r}$ | $\# D_{t}^{\text {b }}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 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 |

[^5]Table 8. Order book regression results for small caps.

|  | $\alpha_{r, 1}$ | $\alpha_{r, 2}$ | $\alpha_{r, 3}$ | $\alpha_{r, 4}$ | $\alpha_{r, 5}$ | $\beta_{r, 1}$ | $\beta_{r, 2}$ | $\beta_{r, 3}$ | $\beta_{r, 4}$ | $\beta_{r, 5}$ | $\gamma_{r}$ | $\# D_{t}^{\text {b }}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 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 ' $a x$ ', and they claim that taking note of the ax's activity is informative $\dagger$. Let $I\left(q_{1, t}^{\mathrm{b}, \boldsymbol{i}}\right)$ be a dummy variable indicating the presence of market participant $i$ on the inside bid and $I\left(q_{1, t}^{\mathrm{a}, i}\right)$ 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 $\ddagger$ both $I\left(q_{1, t}^{\mathrm{b}, i}\right)$ and $I\left(q_{1, t}^{\mathrm{a}, i}\right)$,

$$
\begin{align*}
r_{t}= & \sum_{i=1}^{5} a_{r, i} r_{t-i}+\sum_{i=1}^{15} b_{r, i} x_{t-i}^{0} \\
& +\sum_{k=1}^{5} \alpha_{r, k}\left(q_{k, t}^{\mathrm{b}}-q_{k, t}^{\mathrm{a}}\right)+\sum_{k=1}^{3} \beta_{r, k}\left(n_{k, t}^{\mathrm{b}}-n_{k, t}^{\mathrm{a}}\right) \\
& +\sum_{i=1}^{15} \delta_{r, i} \Delta D_{t-i}^{\mathrm{b}}+\gamma_{r}\left(q_{t}^{\mathrm{b}}-q_{t}^{\mathrm{a}}\right) \\
& +\sum_{i=1}^{10} \theta_{r, i}^{\mathrm{b}} I\left(q_{1, t}^{\mathrm{b}, i}\right)+\sum_{i=1}^{10} \theta_{r, i}^{\mathrm{a}} I\left(q_{1, t}^{\mathrm{a}, i}\right)+\varepsilon_{r, t} . \tag{5}
\end{align*}
$$

$\theta_{r, i}^{\mathrm{b}}$ and $\theta_{r, i}^{\mathrm{a}}$ 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

[^6]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 $\theta_{r, i}^{\mathrm{b}}$, 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 $\theta_{r, i}^{\mathrm{a}}$ 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 $-4.293 \times 10^{-4}$. The results are positive for the other important ECNs: ADFN $1.948 \times 10^{-4}$; BRUT $2.508 \times 10^{-4} ; \quad$ BTRD $2.050 \times 10^{-4} ; \quad$ CINN $1.414 \times 10^{-4}$. 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 $-5.296 \times 10^{-4}$.

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 $3.858 \times 10^{-4}$. The liquidity of other ECNs instead provides more selling pressure with average tick declines of $-2.964 \times 10^{-4}$ for ADFN, $-2.630 \times 10^{-4}$ for BRUT, $-1.414 \times 10^{-4}$ for BTRD, and $-1.600 \times 10^{-4}$ for CINN. The most prevalent market maker is NITE with an average downtick of $-0.822 \times 10^{-4}$.

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 $\theta_{r, i}^{\mathrm{b}}$, 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 $\theta_{r, i}^{\mathrm{a}}$ 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 $-185.534 \times 10^{-4}$. Unlike the large caps, the other ECNs also have a negative median impact when they take the inside bid: CINN $-105.933 \times 10^{-4}$; ADFN
$-111.817 \times 10^{-4} ;$ BTRD $-120.876 \times 10^{-4}$; and BRUT $-258.082 \times 10^{-4}$; the most influential bid sidemarket maker is GSCO. They have a median uptick of $85.058 \times 10^{-4}$ 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 $225.290 \times 10^{-4}$ for ARCA, $137.475 \times 10^{-4}$ for CINN, $121.829 \times 10^{-4}$ for ADFN, $155.722 \times 10^{-4}$ for BTRD, and $212.732 \times 10^{-4}$ for BRUT. GSCO is again the most significant market maker from the offer. Their median downtick size is $-141.014 \times 10^{-4}$.

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 $\dagger$ from the model without full order book information (1) and from a streamlined $\ddagger$ version of the extended VAR to conserve on degrees of freedom,

$$
\begin{align*}
r_{t}= & a_{r, 0}+\sum_{i=1}^{5} a_{r, i} r_{t-i}+\sum_{i=0}^{15} b_{r, i} x_{t-i}^{0} \\
& +\sum_{i=1}^{5} \beta_{r, i}\left(n_{1, t-i}^{\mathrm{b}}-n_{1, t-i}^{\mathrm{a}}\right)+\sum_{i=1}^{15} \delta_{r, i} \Delta D_{t-i}^{\mathrm{b}}+\varepsilon_{r, t},  \tag{6}\\
x_{t}^{0}= & a_{x, 0}+\sum_{i=1}^{5} a_{x, i} r_{t-i}+\sum_{i=1}^{15} b_{x, i} x_{t-i}^{0} \\
& +\sum_{i=1}^{5} \beta_{x, i}\left(n_{1, t-i}^{\mathrm{b}}-n_{1, t-i}^{\mathrm{a}}\right)+\sum_{i=1}^{15} \delta_{x, i} \Delta D_{t-i}^{\mathrm{b}}+\varepsilon_{x, t} . \tag{7}
\end{align*}
$$

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,

$$
\begin{align*}
n_{1, t}^{\mathrm{b}}-n_{1, t}^{\mathrm{a}}= & a_{n, 0}+\sum_{i=1}^{5} a_{n, i} r_{t-i}+\sum_{i=1}^{15} b_{n, i} x_{t-i}^{0} \\
& +\sum_{i=1}^{5} \beta_{n, i}\left(n_{1, t-i}^{\mathrm{b}}-n_{1, t-i}^{\mathrm{a}}\right) \\
& +\sum_{i=1}^{15} \delta_{n, i} \Delta D_{t-i}^{\mathrm{b}}+\varepsilon_{n, t} \tag{8}
\end{align*}
$$

$\dagger$ 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.

$$
\begin{align*}
\Delta D_{t}^{\mathrm{b}}= & a_{D, 0}+\sum_{i=1}^{5} a_{D, i} r_{t-i}+\sum_{i=1}^{15} b_{D, i} x_{t-i}^{0} \\
& +\sum_{i=1}^{5} \beta_{D, i}\left(n_{1, t-i}^{\mathrm{b}}-n_{1, t-i}^{\mathrm{a}}\right) \\
& +\sum_{i=1}^{15} \delta_{D, i} \Delta D_{t-i}^{\mathrm{b}}+\varepsilon_{D, t} . \tag{9}
\end{align*}
$$

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 $12.57 \times 10^{-4}$ 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 $1.439 \times 10^{-4}$ 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 $396.90 \times 10^{-4}$ 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 $\bar{R}^{2}$ is under 0.02 . The model, however, is successful in describing the differential market impacts for the large caps,

$$
\begin{align*}
\text { Market Impact }= & \underset{(4.569)}{54.481}+\underset{(0.660)}{3.546} \times 10^{-5} \times \text { Capitalization } \\
& -\underset{(-1.356)}{0.22} \times \text { Avg. Price } \underset{(-1.052)}{-1.327} \times 10^{-4} \\
& \times \text { Ticks }-\underset{(-1.662)}{0.344} \\
& \times \text { Market Makers, } \quad \bar{R}^{2}=0.201 . \tag{10}
\end{align*}
$$

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

## 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.

[^7]Table 11. Market impact estimates for large caps.

| Symbol | Market impact |  | Symbol | Market impact |  | Symbol | Market impact |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Hasbrouck | Order book |  | Hasbrouck | Order book |  | 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 |  |  |  |

[^8]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 $\dagger$. 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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## References

Barclay, M.J., Christie, W.G., Harris, J.H., Kandel, E. and Schultz, P.H., The effects of market reform on the trading costs and depths of Nasdaq stocks. J. Finan., 1999, 54, 1-34.
Biais, B., Hillion, P. and Spatt, C., An empirical analysis of the limit order book and the order flow in the Paris Bourse. J. Finan., 1995, 50, 1655-1689.

Biais, B., Hillion, P. and Spatt, C., Price discovery and learning during the pre-opening period in the Paris Bourse. J. Polit. Econ., 1999, 107, 1218-1248.
Barclay, M.J., Hendershott, T. and McCormick, D.T., Competition among trading venues: information and trading on electronic communications networks. J. Finan., 2003, 58, 2637-2666.
Boehmer, E., Saar, G. and Yu, L., Lifting the veil: an analysis of pre-trade transparency at the NYSE. J. Finan., 2005, 60, 783-815.
Bollerslev, T., Domowitz, I. and Wang, J., Order flow and the bid-ask spread: an empirical probability model of screenbased trading. J. Econ. Dynam. Contr., 1997, 21, 1471-1491.
Bouchaud, J.P., Mezard, M. and Potters, M., Statistical properties of stock order books: empirical results and models. Quant. Finan., 2002, 2, 251.
Christie, W.G. and Schultz, P.H., Why do NASDAQ market makers avoid odd-eighth quotes?. J. Finan., 1994, 49, 1813-1840.
Calcagno, R. and Lovo, S.M., Bid-ask price competition with asymmetric information between market makers. Rev. Econ. Stud., 2005, forthcoming.
Chung, K.H. and Zhao, X., Price and quantity quotes on Nasdaq: a study of dealer quotation behavior. J. Finan. Res., 2004, 27, 497-519.
De Winne, R. and D'Hondt, C., Market transparency and traders' behavior: an analysis on Euronext with full order book data, Working Paper, 2005 (Catholic University of Mons).
Engle, R.F. and Russell, J., Autoregressive conditional duration: a new model for irregularly spaced transaction data. Econometrica, 1998, 66, 1127-1163.
Engle, R.F. and Patton, A.J., Impacts of trades in an errorcorrection model of quote prices. J. Finan. Mkt., 2004, 7, 1-25.
Foucault, T., Moinas, S. and Theissen, E., Does anonymity matter in electronic limit order markets? HEC Working Paper, 2005.

Handa, P., Schwartz, R. and Tiwari, A., Not held orders: evidence on the value of order timing in an equity market. J. Bus., 2004, 77, 331-355.

Harris, L. and Schultz, P., The trading profits of SOES bandits. J. finan. Econ., 1998, 50, 39-62.

Hasbrouck, J., Measuring the information content of stock trades. J. Finan., 1991, 46, 179-207.
Hasbrouck, J. and Saar, G. Limit orders and volatility in a hybrid market: the Island ECN. Working paper, 2005, NYU Stern.
Huang, R.D., The quality of ECN and Nasdaq market maker quotes. J. Finan., 2002, 57, 1285-1319.
Klock, M. and McCormick, D.T., The impact of market maker competition on Nasdaq spreads. Finan. Rev., 1999, 34, 55-74.
Lillo, F. and Farmer, J.D., The long memory of the efficient market. Stud. Nonlin. Dynam. Economet., 2004, 8, Article 1, http://www.bepress.com/snde/vol8/iss3/art1
Madhavan, A. and Cheng, M., In search of liquidity: block trades in the upstairs and downstairs markets. Rev. Finan. Stud., 1997, 10, 175-204.
Mizrach, B., Does SIZE matter? Liquidity provision by the Nasdaq anonymous trading facility. Competition and Regulation in Network Industries, 2006, forthcoming.
Mizrach, B. and Neely, C., The microstructure of bond market tatonnement. St. Louis Federal Reserve Bank Working Paper, 2005, \#2005-70.

[^9]Potters, M. and Bouchaud, J.P., More statistical properties of order books and price impact. Physica A, 2003, 324, 133-140.
Roll, R., A simple implicit measure of the effective bid-ask spread in an efficient market. J. Finan., 1984, 39, 1127-1139.
Schwert, G.W., Stock volatility in the new millennium: how wacky is Nasdaq? NBER Working Paper No. W8436, 2001.
Simaan, Y., Weaver, D.G. and Whitcomb, D.K., Market maker quotation behavior and pretrade transparency. J. Finan., 2002, 58, 1247-1268.

Smith, J.W., Selway, J.P. and McCormick, D.T., The Nasdaq stock market. Historical background and current operation, NASD Working Paper 98-01, 1998
Weber, P. and Rosenow, B., Order book approach to price impact. Quant. Finan., 2005, 5, 357-364.
Weston, J., Competition on the Nasdaq and the impact of recent market reforms. J. Finan., 2000, 55, 2565-2598.
Weston, J., Electronic communication networks and liquidity on the Nasdaq. J. Finan. Serv. Res., 2002, 22, 125-139.

## 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 | 265865 | 83 |
| ADOBE SYSTEMS INC | ADBE | 6076.50 | 26.05 | 298609 | 78 |
| ADC TELECOMMUNICATIONS INC | ADCT | 1660.72 | 2.07 | 285865 | 86 |
| ALTERA CORP | ALTR | 4787.35 | 12.52 | 341731 | 82 |
| APPLIED MATERIALS INC | AMAT | 23595.71 | 14.21 | 426341 | 103 |
| AMGEN INC | AMGN | 63872.19 | 49.51 | 416410 | 103 |
| AMAZON.COM INC | AMZN | 8671.21 | 21.84 | 311190 | 97 |
| AMERICAN PWR CNVRSION | APCC | 3020.71 | 15.31 | 151516 | 59 |
| APOLLO GROUP INC A | APOL | 7483.44 | 42.58 | 312657 | 62 |
| BED BATH BEYOND INC | BBBY | 9773.21 | 33.93 | 319838 | 71 |
| BEA SYSTEMS | BEAS | 3985.06 | 10.92 | 324724 | 95 |
| BIOGEN INC | BGEN | 6255.39 | 41.85 | 337358 | 84 |
| BIOMET INC | BMET | 7206.27 | 28.11 | 265072 | 66 |
| BROADCOM | BRCM | 4888.06 | 16.48 | 380543 | 89 |
| CDW CORPORATION | CDWC | 3786.66 | 45.77 | 333458 | 63 |
| CEPHALON INC. | CEPH | 2846.29 | 51.25 | 319168 | 66 |
| CHIRON CORP | CHIR | 7309.90 | 39.19 | 345781 | 69 |
| C.H. ROBINSON WORLDWIDE | CHRW | 2673.00 | 31.60 | 100937 | 46 |
| CIENA CORP | CIEN | 2639.12 | 5.63 | 351454 | 92 |
| COMCAST CORP | CMCSA | 53357.15 | 23.71 | 313724 | 69 |
| COMVERSE TECHNOLOGY INC | CMVT | 1259.96 | 10.65 | 206489 | 78 |
| COSTCO WHOLESALE CORP | COST | 13272.59 | 29.04 | 338420 | 79 |
| COMPUWARE CORP | CPWR | 1864.38 | 4.87 | 251108 | 61 |
| CISCO SYSTEMS INC | CSCO | 95909.93 | 13.66 | 452317 | 118 |
| CINTAS CORP | CTAS | 8122.78 | 47.58 | 336678 | 54 |
| CITRIX SYSTEMS INC | CTXS | 2085.65 | 12.67 | 230830 | 74 |
| DELL COMPUTER CORP | DELL | 70957.70 | 27.61 | 405286 | 107 |
| ECHOSTAR COMMUN CORP | DISH | 10327.67 | 21.33 | 256408 | 69 |
| DOLLAR TREE STORES INC | DLTR | 3017.58 | 26.39 | 207661 | 66 |
| EBAY INC | EBAY | 22030.38 | 34.31 | 403741 | 84 |
| ERICSSON (L M) TEL | ERICY | 12916.13 | 8.17 | 173545 | 78 |
| ELECTRONIC ARTS INC | ERTS | 8519.37 | 58.31 | 374488 | 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 | 315877 | 59 |
| EXPEDITORS INTL | EXPD | 3373.63 | 33.47 | 132062 | 54 |
| FASTENAL CORP | FAST | 2867.54 | 37.79 | 125931 | 43 |
| FIRST HEALTH GROUP CORP | FHCC | 2330.96 | 24.57 | 124793 | 50 |
| FISERV INC | FISV | 6499.84 | 33.58 | 292052 | 66 |
| FLEXTRONICS INTL LTD | FLEX | 4853.30 | 9.29 | 324176 | 98 |
| GENZYME GENERAL | GENZ | 7282.30 | 32.79 | 313530 | 76 |
| GILEAD SCIENCE | GILD | 7357.41 | 36.54 | 301148 | 71 |
| GENTEX CORP | GNTX | 2407.66 | 31.51 | 118918 | 49 |
| HUMAN GENOME SCIENCE INC | HGSI | 1223.51 | 9.47 | 217752 | 75 |
| HENRY SCHEIN INC | HSIC | 1928.27 | 44.36 | 127002 | 41 |
| ICOS CORP | ICOS | 1750.31 | 27.98 | 270829 | 65 |
| IDEC PHARMACEUTICAL | IDPH | 5254.06 | 33.80 | 362925 | 81 |
| INTEL CORP | INTC | 115992.70 | 17.82 | 458673 | 110 |
| INTUIT INC | INTU | 10104.06 | 49.23 | 348525 | 72 |
| INVITROGEN CORP | IVGN | 1530.94 | 30.46 | 196218 | 56 |
| KLA-TENCOR CORP | KLAC | 7257.70 | 38.14 | 449345 | 90 |
| LAMAR ADVERTISING | LAMR | 2944.45 | 33.91 | 130836 | 45 |
| LINEAR TECHNOLOGY CORP | LLTC | 8887.87 | 28.40 | 416212 | 81 |
| LINCARE HOLDINGS INC | LNCR | 3189.31 | 32.39 | 214494 | 50 |
| MICROCHIP TECHNOLOGY INC | MCHP | 5308.60 | 25.91 | 370730 | 73 |
| MEDIMMUNE INC | MEDI | 6655.98 | 26.64 | 302061 | 79 |
| MERCURY INTERACTIVE CORP | MERQ | 2646.40 | 30.68 | 336734 | 83 |
| MILLENIUM PHARMACEUTICALS | MLNM | 2806.36 | 9.40 | 283255 | 92 |
| MOLEX INC | MOLX | 2444.24 | 24.42 | 266070 | 57 |
| MICROSOFT CORP | MSFT | 291749.01 | 27.09 | 456542 | 102 |
| MAXIM INTEGRATED PRODUCTS | MXIM | 11761.25 | 36.23 | 435510 | 82 |
| NETWORK APPLIANCE INC | NTAP | 3979.11 | 11.64 | 326289 | 90 |
| NVIDIA CORP | NVDA | 2147.78 | 13.46 | 342709 | 92 |
| NOVELLUS SYSTEMS INC | NVLS | 4578.18 | 30.24 | 436736 | 89 |
| NEXTEL COMMUNICATIONS | NXTL | 12547.07 | 12.55 | 386016 | 104 |
| ORACLE CORP | ORCL | 57520.04 | 11.00 | 432974 | 118 |
| PAYCHEX INC | PAYX | 10432.30 | 27.68 | 292304 | 71 |
| PACCAR INC | PCAR | 5451.42 | 46.77 | 320970 | 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 | 123660 | 42 |
| PETSMART INC | PETM | 2598.66 | 18.36 | 136054 | 62 |
| PIXAR | PIXR | 3162.71 | 57.97 | 119386 | 47 |
| PEOPLESOFT INC | PSFT | 6735.46 | 18.50 | 340449 | 93 |
| PATTERSON-UTI ENERGY INC | PTEN | 2546.23 | 31.47 | 168841 | 59 |
| QUALCOMM INC | QCOM | 30901.02 | 38.93 | 428014 | 95 |
| QLOGIC CORP | QLGC | 3569.99 | 37.88 | 432684 | 90 |
| RF MICRO DEVICES INC | RFMD | 1656.60 | 8.99 | 345514 | 88 |
| ROSS STORES INC | ROST | 3344.29 | 43.68 | 190275 | 61 |
| RYANAIR HOLDINGS PLC | RYAAY | 6264.57 | 41.53 | 75725 | 46 |
| SANMINA CORP | SANM | 2160.08 | 4.23 | 332567 | 79 |
| STARBUCKS CORP | SBUX | 8146.41 | 20.83 | 275955 | 78 |
| SIEBEL SYSTEMS INC | SEBL | 3865.36 | 7.83 | 349654 | 106 |
| SIGMA-ALDRICH | SIAL | 3478.90 | 49.15 | 222853 | 52 |
| SYNOPSYS INC | SNPS | 3543.79 | 45.87 | 260232 | 66 |
| STAPLES INC | SPLS | 9085.64 | 18.66 | 265158 | 72 |
| PANAMSAT CORP | SPOT | 2407.28 | 16.04 | 183636 | 55 |
| SMURFIT-STONE CNTR CORP | SSCC | 3643.81 | 14.85 | 177190 | 52 |
| SUN MICROSYSTEMS INC | SUNW | 10897.20 | 3.36 | 430567 | 117 |
| SYMANTEC CORP | SYMC | 6400.92 | 42.17 | 338770 | 83 |
| TELLABS INC | TLAB | 3094.78 | 7.50 | 232375 | 83 |
| MONSTER WORLDWIDE INC | TMPW/MNST | 1259.57 | 11.74 | 206294 | 68 |
| INTERACTIVE CORP | USAI/IACI | 16107.06 | 24.36 | 273760 | 68 |
| VERISIGN INC | VRSN | 2114.37 | 8.79 | 209987 | 79 |
| VERITAS SOFTWARE CO | VRTS | 7312.48 | 17.18 | 344946 | 101 |
| WHOLE FOODS MARKET INC | WFMI | 3182.23 | 53.13 | 165241 | 53 |
| XILINX INC | XLNX | 7337.85 | 21.53 | 412569 | 89 |
| DENTSPLY INTERNATIONAL INC | XRAY | 2855.83 | 36.15 | 125264 | 43 |
| YAHOO INC | YHOO | 10337.47 | 16.94 | 339463 | 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 | 40199 | 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 | 22216 | 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 | 15894 | 22 |
| BIOSOURCE INTL INC | BIOI | 52.00 | 5.67 | 928 | 18 |
| BROOKLINE BANCORP INC | BRKL | 682.46 | 11.84 | 22555 | 35 |
| BSB BANCORP | BSBN | 200.50 | 21.87 | 6961 | 27 |
| CREDIT ACCEP CORP MICH | CACC | 292.31 | 6.90 | 16029 | 18 |
| COASTAL BANCORP INC | CBSA | 161.55 | 31.31 | 4706 | 26 |
| CENTRAL EURO. DIST CORP | CEDC | 123.70 | 11.63 | 13190 | 18 |
| CENTRAL GARDEN PET CO | CENT | 368.79 | 18.81 | 32581 | 25 |
| CHURCHILL DOWNS INC | CHDN | 504.29 | 38.20 | 11547 | 26 |
| CFS BANCORP INC | CITZ | 175.17 | 14.41 | 6178 | 26 |
| CORUS BANKSHARES INC | CORS | 621.05 | 44.23 | 25611 | 21 |
| CARRIZO OIL GAS INC | CRZO | 73.83 | 5.18 | 2698 | 15 |
| COLDWATER CREEK INC | CWTR | 183.00 | 11.45 | 17855 | 20 |
| CYBEROPTICS CORP | CYBE | 47.45 | 5.75 | 3469 | 17 |
| DEB SHOPS INC | DEBS | 300.35 | 21.94 | 18884 | 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 | 12233 | 20 |
| EXPONENT INC | EXPO | 103.16 | 14.37 | 6031 | 17 |
| FLUSHING FINANCIAL CORP | FFIC | 214.03 | 16.68 | 12216 | 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 | 13079 | 17 |
| FIRST PL FINL CORP/DE | FPFC | 225.15 | 16.93 | 3993 | 26 |
| GULFMARK OFFSHORE INC | GMRK | 295.54 | 14.80 | 23465 | 23 |
| HARBOR FLORIDA BANCSHARES | HARB | 510.72 | 21.49 | 18192 | 32 |
| HARLEYSVILLE GROUP INC | HGIC | 778.58 | 25.90 | 33136 | 28 |
| HIBBETT SPORTING GOODS INC | HIBB | 255.87 | 16.71 | 18729 | 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 | 13515 | 23 |
| INDEPENDENT BANK CORP/MA | INDB | 344.53 | 23.63 | 17659 | 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 | 28085 | 27 |
| MID-STATE BANCSHARES | MDST | 392.38 | 16.72 | 14463 | 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 | 14699 | 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 | 12434 | 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 | 17079 | 23 |
| P.A.M. TRANSPORTATION SVCS | PTSI | 258.52 | 22.90 | 17149 | 20 |
| U S CONCRETE INC | RMIX | 153.21 | 5.42 | 10503 | 24 |
| SALEM COMMUNICATIONS CORP | SALM | 458.07 | 25.55 | 22220 | 25 |
| SSC TECHNOLOGIES INC | SSNC | 129.20 | 10.49 | 21193 | 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 | 45350 | 22 |
| TRIAD GUARANTY INC | TGIC | 549.19 | 38.32 | 33267 | 23 |
| THISTLE GROUP HOLDINGS | THTL | 58.21 | 11.15 | 2247 | 25 |
| VITAL SIGNS INC | VITL | 377.21 | 29.22 | 17604 | 21 |
| VI TECHNOLOGIES INC | VITX | 36.85 | 0.90 | 6897 | 24 |
| VOLVO AB SWE | VOLVY | 7245.13 | 17.27 | 15895 | 35 |
| WEST COAST BANCORP/OR | WCBO | 240.01 | 15.80 | 13784 | 24 |
| WD-40 CO | WDFC | 477.43 | 28.69 | 28961 | 20 |
| WFS FINANCIAL INC | WFSI | 843.35 | 20.56 | 28902 | 26 |
| TELULAR CORP | WRLS | 48.66 | 3.76 | 7174 | 19 |
| WHITNEY HOLDING CORP | WTNY | 1330.55 | 32.98 | 39957 | 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.


[^0]:    Suggested Citation: Mizrach, Bruce (2002) : The next tick on Nasdaq: Does level II information matter?, Working Paper, No. 2002-02, Rutgers University, Department of Economics, New Brunswick, NJ

[^1]:    *Email: mizrach@econ.rutgers.edu

[^2]:    $\dagger$ For a recent comparison, see Schwert (2001).
    \$For a detailed history of Nasdaq, see Smith et al. (1998).
    $\S$ See Harris and Schultz (1998) for an assessment of the profitability of the SOES bandits.
    ${ }^{\uparrow}$ TRelease No. 34-38156; File No. SR-NASD-96-43 January 10, 1997. http://www.sec.gov/rules/othern/34-38156.txt

[^3]:    $\dagger$ 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.
    $\ddagger$ SIZE had only $0.3 \%$ of quotes in December 2002, and Mizrach (2006) notes that, by December 2005, this had only grown to $2.1 \%$. $\S$ See 'Results on the Introduction of NASDAQ's SuperMontage', by NASDAQ Economic Research, February 4, 2003.
    $\llbracket$ 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.
    TI 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.

[^4]:    $\dagger$ https://www.nasdaqtrader.com/ easp/totalview_form.asp
    $\ddagger$ Due to index changes, mergers and delistings, I only have 95 companies in the final sample.

[^5]:    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.

[^6]:    $\dagger$ 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."
    $\$ \mathrm{I}$ also tried adding the depth of the market maker when they took the inside, but I found no additional explanatory power.

[^7]:    $\dagger$ A similar conclusion regarding spreads can be found in Klock and McCormick (1999).

[^8]:    Notes: The sample period is December 2002 with the number of tick observations found in the data appendix.

[^9]:    $\dagger$ 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 ...".

