



Centre de Recherche en Gestion

Imperfect Competition in Financial Markets: ISLAND vs NASDAQ

Bruno BIAIS, Christophe BISIÈRE and Chester SPATT

March 2003

Cahier de recherche no. 2003 – 155



IAE de Toulouse
Place Anatole France – 31042 Toulouse Cedex
Tél : 05 62 30 34 21 – Fax : 05 61 23 84 33
E-mail : nicole.cassagne@univ-tlse1.fr

Imperfect competition in financial markets:

ISLAND vs NASDAQ*

Bruno Biais¹, Christophe Bisière² and Chester Spatt³

Revised March 14, 2003

Many thanks to participants at presentations at the Banque de France, the 2003 Economics of the Software and Internet Industries Conference in Toulouse, the 2002 European Finance Association Meetings, the 2002 European Econometric Society Meeting, NASDAQ, the Fall 2002 National Bureau of Economic Research Market Microstructure meetings, the 2002 Rutgers University Market Microstructure Conference in honor of David Whitcomb, and the 6th Toulouse Finance Workshop. We are particularly grateful for insightful comments from Thierry Foucault, Burton Hollifield, Stewart Mayhew, Richard Roll, Gideon Saar, Patrik Sandas and Leonid Waverman. The financial support of the Fondation Banque de France is gratefully acknowledged.

¹Toulouse University (IDEI-CRG-GREMAQ)

²Toulouse University (IDEI-CRG)

³Carnegie Mellon University

Abstract

The Internet technology reduces the cost of transmitting and exchanging information. ECNs exploit this opportunity to enable investors to place quotes at very little cost and compete with incumbent trading systems. Does this quasi-free entry situation lead to competitive liquidity supply? We analyze trades and order book dynamics on Nasdaq and Island. The Nasdaq touch is frequently undercut by Island limit orders, using the finer tick size prevailing on that ECN. Before decimalization, the coarse tick size constrained Nasdaq spreads, and undercutting Island limit order traders earned oligopoly rents. After decimalization, the hypothesis that liquidity suppliers do not earn rents cannot be rejected.

Imperfect competition in financial markets:

ISLAND vs NASDAQ

1 Introduction

Internet technology reduces communication and information processing costs. In turn, this reduces the cost of entry in financial markets. Thus, new market mechanisms can be created and compete with incumbent trading systems, and a larger population of investors and traders can access the market. In conjunction with this technological revolution, the regulatory change brought about by the 1997 SEC order display rule has enhanced the ability of investors to post offers to trade stocks in the market. Electronic Communication Networks (hereafter ECNs) developed to exploit these opportunities. These changes in the structure of the market should foster competition to supply liquidity.

Against this backdrop, the goal of the present paper is to study the following issues: Do competing internet-based trading mechanisms improve market liquidity? What are the liquidity supply strategies followed on these new market venues? How do they affect incumbent trading systems, and how do the latter react? Thus we aim at studying competition among liquidity suppliers within one trading mechanism *and* competition between trading mechanisms.

To study these issues, we focus on Island, one of the largest ECNs, which amounted to nearly 10 % of Nasdaq trading volume in 2002.⁴ Island is operated as a fully transparent electronic limit order market, where all investors can anonymously post quotes. Its book is freely observable to all on the web in real time. Accessing this market is very inexpensive. In fact, Island grants a small compensation to limit orders when they are hit, to reward liquidity supply.

Stigler (1957) lists conditions under which perfect competition obtains according to Adam Smith: “1) The rivals must act independently, not collusively. 2) The number of rivals, potential as well as present, must be sufficient to eliminate extraordinary gains. 3) The economic units possess tolerable knowledge of the market opportunities. 4) There must be freedom to act on this knowledge.” Imperfect competition in financial markets has been documented when these conditions are violated because small groups of financial intermediaries have privileged access to information collection and dissemination (see e.g., Christie and Schultz, 1994, or Chen and Ritter, 2000). Such violations are less likely on Island. First note that condition 1) and 2) should hold on Island since there is open access to the market to many investors via the net. Also, the remarkable transparency of Island should ensure that condition 3) is satisfied. Finally, the 1997 Order Handling Rule emphasized investors’ right to place orders, thus condition 4) should hold also. In this paper, we test if liquidity supply on Island corresponds to the free-entry perfect competition equilibrium characterized theoretically by Glosten (1994).

Another interesting feature of the competition between Nasdaq and Island is related to the pricing grid used in these two market places. Before April 2001, the pricing grid

⁴Island recently merged with Instinet. One of the motivations of the merger was that Instinet wanted to take advantage of Island’s dynamic and efficient market model.

on Nasdaq was relatively coarse, as the tick size was one-sixteenth, and quite thin on Island, where the tick size was $1/256$. Since April 2001, Nasdaq prices are quoted in cents, while the Island tick is one-thousandth of a dollar. Did the rather coarse pricing grid prevailing on Nasdaq prior to decimalization constrain liquidity suppliers on this market? Did Island liquidity suppliers take advantage of the thinner grid prevailing on this ECN? How did the decimalization affect the competition between the two trading systems?

To conduct our analysis, we combine two sources of data for actively traded Nasdaq stocks. On the one hand we have downloaded the sequence of trades and order book dynamics from the Island site, on the other hand we have used the Nasdaq dataset from Nasdaq. To study liquidity supply on Island and Nasdaq, we analyze the distribution of the spread between the best quotes on the Island limit order book and on the Nasdaq market (excluding Island quotes) as well as the placement of limit orders on Island.

In the pre-decimalization sample, we find that the Nasdaq touch is equal to one tick more than 80% of the time. This suggests the tick size was binding on Nasdaq and resulted in excessively large spreads. During this sample period, the most frequent values of the bid-ask spread on Island were one and two Nasdaq ticks. Note however that Island traders were not constrained to place their orders on this relatively coarse grid size. Indeed, we find that the next most frequent values of the Island spread correspond to situations where the Nasdaq tick was undercut by just one (very thin) Island tick.

This suggests that Island limit order traders engaged in competition for order flow with the Nasdaq market makers more than among themselves. If this conjecture is correct, Island limit orders should undercut the current market best quotes more often when these quotes are set by Nasdaq market makers than when they are set by Island limit orders. To investigate this point we study the frequency of undercutting orders on Island. Undercutting orders are defined as (non immediately marketable) limit orders placed within the best quotes (see Biais, Hillion and Spatt, 1995). We find that when the best quote is set by an Island order the probability that the next Island order be undercutting is less than 10%. In stark contrast, when the best quote is set by other Nasdaq participants, the probability that the next Island order be undercutting is greater than 33%.

In the post-decimalization sample, the most frequent values of the Nasdaq touch are one, two, three and four Nasdaq ticks, and the Nasdaq spread is much tighter on average. In that sample also, it is found that Island spreads most often either match the Nasdaq spread or undercut it by just one (very thin) Island tick.

These results suggest that Island limit orders compete quite significantly with Nasdaq quotes. There is much less evidence of competition among Island traders. During the pre-decimalization period, the Nasdaq spread was constrained to be artificially large, due to the coarse tick size. In this context, Island limit orders just undercutting the Nasdaq spread were likely to earn rents. If after decimalization, the Nasdaq tick size is no longer significantly binding, undercutting Island traders should no longer earn rents. To investigate this point further we develop an econometric analysis relying on a standard market microstructure theoretical model, in the line of Glosten (1994), Bernhardt and Hughson (1997), and Biais, Martimort and Rochet (2000). The hypothesis that limit orders placed on Island face no adverse selection cost is rejected. Our estimates are consistent with Island limit orders earning oligopoly rents before decimalization.

Thus our analysis sheds light on the way in which the Internet can enhance competition, and correspondingly, increase liquidity. It enables efficient modern market architectures to be set up. These compete with the incumbent and force them to catch

up. But, perfect competition does not emerge immediately, even on an Internet-based transparent easily accessible limit order book, although Adam Smith's conditions for perfect competition seem to hold. Competition between markets is necessary to make up for imperfect competition among traders.

Our GMM analysis of limit-order schedules and adverse selection builds on the insightful structural econometric analysis of Sandas (2001), though we take a somewhat different viewpoint. While our approach directly stems from the theoretical model (Glosten, 1994, Biais, Martimort and Rochet, 2000) and does not require parametric assumptions, Sandas (2001) relies on some parametric assumptions (to specify the link between the size of trades and their information content) and on some simplifications of the theoretical model (e.g., by postulating an exogenous joint distribution of orders and values). Also, while Sandas (2001) assumes competitive liquidity supply, we investigate market power.

Our empirical analysis is also related to Hasbrouck and Harris (1996), in particular to their "ex-post performance measure," which computes the profitability of different types of orders, e.g., limit orders at the best quotes, when they are executed. Our focus differs from theirs, however. While, they compare the performance of order placement strategies, we focus on the competition to supply liquidity and document undercutting strategies. Furthermore our econometric analysis of the profitability of limit orders relies on a theoretical model, while they take a more descriptive approach. Finally, we take advantage in our identification strategy of the fact that we have two different samples, over which the order-handling cost is likely to remain constant while other parameters, such as the oligopoly mark-up are likely to change.

Interesting empirical analyses of ECNs are offered by Simaan, Weaver and Whitcomb (1998), Huang (2002), Barclay, Hendershott and McCormick (2001) and Hasbrouck and Saar (2001). Our focus on the competition for liquidity supply differs from Huang (2002), who analyzes price discovery, Barclay, Hendershott and McCormick (2001), who focus upon market quality, and Hasbrouck and Saar (2001), who analyze the relationship between volatility and the order flow as well as fleeting orders. We complement this literature in the following dimensions:

- Most papers rely on Nasdaq data, where Island quotes are rounded to match the Island grid. This precludes observing situations when Island quotes are strictly better than Nasdaq quotes by less than one Nasdaq tick. In contrast, by using unrounded Island data, we can shed light on the extent to which Island limit orders undercut Nasdaq quotes.
- We analyze undercutting strategies by Island limit order traders.
- We show that the competition between Nasdaq and Island has been significantly changed by decimalization.
- We develop a new structural econometric approach to analyze quantitatively the trade-offs faced by liquidity suppliers between adverse selection costs and oligopoly rents. A by-product of this analysis is to offer a new method to disentangle components of the spread without relying on parametric assumption on distributions, while building directly from a standard microstructure model.

Our analysis also adds to the debate on centralized vs. fragmented markets (as illustrated by the theoretical studies by Chowdhry and Nanda (1991) and Parlour and Seppi (2003)).

The next section presents the institutional environment. Section 3 presents the data. Section 4 presents our empirical analysis of orders, quotes and spreads on Island and Nasdaq. Section 5 extends this analysis by offering a structural investigation of profits and spreads on Island. Section 6 concludes.

2 Institutional environment

2.1 ECNs

ECNs use web-based platforms, which collect limit and market orders, and match them or display them on internet-based order books. In 2002 they have been estimated to capture 39.3% of the dollar volume of Nasdaq trading (source Market Data).⁵ The largest ECN, Instinet, was estimated to represent 12% of the trading volume on Nasdaq in February 2002, while Island amounted to 9.6%, Redi Book to 6.5%, and Archipelago to 10.5%.

While ECNs compete with the traditional source of liquidity on Nasdaq (i.e., market makers), they are brokers: they do not take proprietary positions, but simply handle and display their customer's orders. Since they are regulated as brokers, they are subject to the best execution rule, which means that they cannot conduct trades away from the current best market prices. This best execution rule implies that ECNs, as all brokers, must allocate orders according to price priority. However, time priority is not enforced between ECNs and Nasdaq market makers.

Interestingly, empirical evidence so far does not suggest that the trading process managed by ECNs is systematically free riding on price discovery achieved by the traditional market participants (the Nasdaq dealers). To the contrary, Huang (2002) shows empirically that ECNs are important contributors to the price discovery process.

2.2 Island

Island is a web-based transparent limit order book.⁶ Trades and the best 15 quotes on each side of the book can freely be viewed in real time through the internet. Island subscribers can freely place orders. Trades can take place from 7:00 a.m. to 8:00 p.m. Immediately executed orders are charged .25 cent per share traded. Non-marketable limit orders posted in the book receive .1 cent per share when executed, as compensation for supplying liquidity. When an order is transmitted to Island, if it is not immediately marketable, it is stored and displayed anonymously in the Island order book.⁷ If the order is marketable it is executed at the best market price. This can be set by an Island quote, or correspond to another quote in the Nasdaq system, in which case the Island order trades with an order outside Island.

Until April 2001, the Nasdaq tick size was 1/16 and the Island tick size was 1/256. Since April 2001, the Nasdaq tick size has been reduced to one cent (\$0.01), while on Island prices are quoted with a three digit precision, i.e., the tick size is one-thousandth of a dollar. The thinner price grid on Island makes it easier for traders placing orders on that ECN to undercut Nasdaq market makers' quotes.

The best Island bid and ask quotes are displayed on the Nasdaq screen, along with the best quotes of ECNs and market makers. Note however that Island quotes displayed

⁵In 2000, this proportion was 26% (McAndrews and Stefanadis, 2000).

⁶Hasbrouck and Saar (2001) offer a good description of the market structure.

⁷Traders also can place hidden orders.

and “advertised” on the Nasdaq screen are not shown at their actual price (quoted on a thin grid) but at rounded prices (from the Nasdaq grid). For example, when the Nasdaq tick was one-sixteenth, if the best ask for stock XYZ on Island was one dollar and $1/24$, it was displayed on Nasdaq at one dollar and $1/16$. Rounding the Island quotes enables NASDAQ to avoid price priority constraints, and reduces the ability of the ECN to advertise good quotes and thus attract orders. This makes it very important for Island to use another vehicle besides NASDAQ screens to disseminate information. This may be one of the reasons for the excellent and easily accessible website Island has developed.

Since the best Island bid and ask quotes are displayed on the Nasdaq screen, if the grid size was the same in the two market segments, the Nasdaq inside quote would, by construction always be at least as good as the Island spread. The grid is thinner on Island than on Nasdaq, however. This raises the possibility that Island quotes, placed on thin ticks inside the relatively coarse grid Nasdaq, could better the Nasdaq quote, at least on one side of the book.

3 Data

We downloaded a continuous record of the Island book from the Island website during 5 trading days in March 2000 (from March 8 to March 14) and 5 trading days in June 2001 (from June 18 to June 22). We collected this data for 7 stocks: COMS, Cisco, Dell, Intel, Microsoft, QCom, and Sun. We also acquired quotes and trades data from Nasdaq (including the Dealer Quotes (DQ) file, the Inside Quote (IQ) file, and the Trades (TR) file).

We consider data starting at the opening of NASDAQ (at 9:30 or a few minutes before) and ending at the NASDAQ close: 4:00 p.m. (because of a data feed problem, for March 10, we have data only between 9:30 and 2:30).

Summary statistics on the Island data and the Nasdaq data are presented in Table 1. The Island data set includes 138432 trades for the March 2000 sample and 139966 trades for the June 2001 sample. The average trade size on Island in the March 2000 sample is 389 shares, while its counterpart for the June 2001 sample is 450 shares. The average trade size on Nasdaq is about twice as large (797 shares per trade in 2000 sample and 898 in 2001). While market activity was comparable in 2000 and 2001, prices fell dramatically; while the average transaction price is 99.14 in the March 2000 sample, it is 31.69 in the June 2001 sample. Volatility tends to be lower in the 2001 sample than in its 2000 counterpart.

One advantage of the Island data (downloaded from the Island website) is that it is not rounded to sixteenths (unlike the ECN quotes reported in the NASDAQ DQ file). Hence we can study the use of fine ticks by Island traders.

4 Orders, quotes and spreads on Island and Nasdaq

In this section we compare liquidity supply by Island limit order traders and by other Nasdaq participants, in particular market makers. To study the consequences of decimalization, we conduct this analysis separately for the March 2000 and June 2001 samples.

4.1 Before decimalization

The inside spread on Nasdaq in March 2000 First consider the best quotes posted on Nasdaq by market makers and other ECNs than Island. The corresponding time-weighted average spread in March 2000 was 1.27 Nasdaq ticks, corresponding to \$.079.⁸ The mode and the median spreads were equal to exactly one Nasdaq tick: one-sixteenth of a dollar (\$.0625). In fact, the spread was exactly equal to one tick 81.5% of the time. The two other most frequent values of the spread were 2 ticks (13.25% of the time) and 3 ticks (3.36% of the time). These observations suggest that before decimalization, the relatively coarse tick size prevailing on Nasdaq was likely to be rather constraining (as illustrated in other contexts by Harris (1991, 1994)). Potentially, this could have resulted in excessively wide Nasdaq spreads. We investigate this point further in the remainder of the paper.

The Island inside spread in March 2000 During this period, the tick size was much finer on Island. Hence, it was possible to offer liquidity much more aggressively on that market. This could be achieved by undercutting the Nasdaq quotes, using the fine grid prevailing on Island. We document this empirically.

On Island the time-weighted average spread for our 7 stocks and our sample period was equal to $50.70/256$, that is \$ 0.198. The mode and the median were $32/256$, i.e., \$.125. Thus, the average Island spread was on average larger than the Nasdaq inside spread resulting from Island's competitors.⁹

Figure 1, Panel A, depicts the frequency of different values of the spread for the seven stocks in our sample, on Island and on Nasdaq in March 2000.¹⁰ As illustrated in the figure there is marked clustering in the data.¹¹ Clustering on one Nasdaq tick is less frequent for the Island spread than for the Nasdaq inside spread. Interestingly, the spread on Island was quite often just one Island tick below these levels, e.g. $15/256$, $31/256$, etc. This is likely to reflect undercutting, by a fine increment, of the Nasdaq spread by Island liquidity providers. By following this strategy, they acquire price priority relatively cheaply.¹²

Undercutting of the best quotes by Island limit orders The discussion above suggests that, while Island limit order traders compete market shares away from Nasdaq by undercutting Nasdaq quotes, competition within Island is less strong. Hence, undercutting of the best quotes by Island orders should be more prevalent when the best quotes are set by Nasdaq than when they are set by the Island book.

To test this conjecture, we analyzed the Island order flow in more detail. In line with Biais, Hillion and Spatt (1995) we differentiated 12 categories of events:

- trades resulting from the placement of market orders to buy or sell;
- new buy or sell limit orders not immediately executed, placed within the best quotes, at the best quotes, or away from the best quotes;

⁸Average spreads for each of the 7 stocks in our sample are presented in Table 1.

⁹Average spreads on Island for the 7 stocks in our sample are presented in Table 1.

¹⁰This graphical representation of the empirical frequency of different values of the spread is similar to Figure 2 in Barclay et al, 1999.

¹¹The pervasiveness of clustering is documented in Harris (1991).

¹²Note however that, since Island prices were rounded before being represented on the Nasdaq system, the Island liquidity suppliers benefitted from this priority advantage only with respect to the Island order flow.

- cancellations of orders, at or away from the best quotes, on the bid or the ask side;

We computed the frequency of each of these 12 events, overall and also conditionally on whether the Island quotes were as good, better than or worse than the quotes of the Nasdaq market makers and other ECNs than Island. To conduct this conditional analysis we merged the Island data file and the Nasdaq IQ data file.¹³ The results for the 2000 sample are reported in Table 2, Panel A. Note that cancellations and order placement away from the best quotes are quite frequent. For example their frequency is much higher than in the Paris Bourse (see Biais, Hillion and Spatt, 1995).

Undercutting corresponds to the placement of limit orders within the quotes. The frequencies reported in Table 2, Panel A, show that undercutting by Island limit orders on the ask side is strikingly more frequent when Nasdaq sets the best ask than when Island sets the best ask. A similar result holds on the bid side. These results are in line with our conjecture.

Comparing the Island and Nasdaq spreads Using the merged data set, we also compared the best Island bid quote and the best bid posted on Nasdaq by its competitors. 35.89% of the time the Island bid was strictly highest, 43.16% of the time it was lower, and 20.94% of the time the two bid quotes were equal. On the ask side, the best Island quote was better than that of its competitors 26.71% of the time, it was higher 43.43% of the time, and the two quotes were equal 29.87% of the time.

These results are consistent with the findings by Simaan, Weaver and Whitcomb (1998), that ECNs often establish the inside market. Our results differ from, and complement theirs because we analyze data on unrounded Island quotes, downloaded from their site, rather than rounded quotes from the Nasdaq DQ file. Hence, we find more frequent occurrences of the situation where Island beats the Nasdaq market makers quotes, and we document undercutting by Island orders on a finer grid than the sixteenth grid.¹⁴

4.2 After decimalization

The inside spread on Nasdaq in June 2001 Again, consider the best quotes posted on Nasdaq by market makers and other ECNs than Island. In June 2001, the Nasdaq tick was one cent, and the time-weighted average spread was 1.48 ticks. The spread was exactly equal to one tick 78.08% of the time. The two other most frequent values of the spread were 2 ticks (12.26% of the time) and 3 ticks (4.23% of the time). Thus, decimalization led to a dramatic decrease in the average spread on Nasdaq, as well as a reduction in clustering. This is consistent with the view that the coarse tick size before decimalization constrained liquidity supply and led to artificially large spreads.

Spreads and undercutting The average spread on Island for our 7 stocks in June 2001 was equal to \$ 0.0648. This is definitely below the corresponding figures for March 2000.

Figure 1, Panel B, presents the histogram of spread sizes on Island and Nasdaq for our June 2001 sample. As in the March 2000 case, there is a lot of clustering on the

¹³This was made difficult by synchronicity problems. The consequences of these non-synchronicity problems and the way we dealt with them are discussed in the appendix.

¹⁴In the appendix we offer some further discussion of the impact of rounding for the data.

Nasdaq price grid. The Island spread and that of its competitors are most frequently equal to .01, .02 and .03, .04 or .05. There also is clustering for the Island spread just one tick below these values, reflecting undercutting of the Nasdaq quotes.

The order flow frequencies presented in Table 2, Panel B, show that, in 2001 as in 2000, cancellations and order placement away from the quotes were very frequent. The relatively large frequency of undercutting by Island limit orders when Nasdaq was setting the best quotes was less pronounced in 2001 than in 2000.

Comparing the distribution of Island spreads in June 2001 to its March 2000 counterpart (see Figure 1) points to the stark reduction in spreads contemporaneous to the reduction in the Nasdaq tick from 1/16 to 1/100 and the more modest reduction in the Island tick during that period from 1/256 to 1/1000.

Depth While the spread has decreased after decimalization of Nasdaq, this could be offset by a corresponding decrease in the depth at the quotes. To shed light on this point we have computed the average depth at the best quotes as well as at other levels in the Island book. Our results, presented in Figure 2, show that the depth at the best quotes on Island is not lower in the June 2001 than in March 2000.

In 2000, the average depth in the Island order book was 924.53 shares at the best ask quote, 952.59 at the second best ask quote, and 844.86 at the third best ask quote. The corresponding average depths on the three first best levels in the book on the bid side were 790.09, 757.59, and 692.98.

4.3 Conclusion

Putting together the above results, the following picture of the competition between Nasdaq and Island emerges:

Before decimalization, liquidity supply on Nasdaq was constrained by the coarse tick size, resulting in large spreads. The decrease in spread brought about by decimalization led to a stark decrease in the Nasdaq spread.

Island liquidity suppliers compete for order flow by frequently undercutting the Nasdaq quotes. However, they seem to compete less aggressively within Island, and undercut each other less frequently. The tick size prevailing on Island in 2000 was already extremely thin and very unlikely to constrain liquidity suppliers. Yet, the Island spread was strongly reduced by decimalization. This reduction took place because the Island limit order traders had to react to the decrease of the spread of their Nasdaq competitors. That they were able to engage in this reduction, and yet had not done it before, is suggestive of imperfect competition among Island liquidity suppliers. The next section studies this point further.

5 An econometric analysis of the costs and profits of Island limit order traders

5.1 Theoretical framework

In this section we examine econometrically the costs incurred by Island limit order traders and the profits they earn. Consider a limit order to sell, at time t , at the best quote in the Island limit order book: $A_{1,t}$. If this order is filled its profit is:

$$A_{1,t} - v - (c - f),$$

where v is the fundamental value of the asset, c is the order-handling cost incurred by the limit order trader, and f is the compensation offered by Island to executed limit orders. Note that f is not a parameter to be estimated, but an observable pricing rule set by Island. Similarly, if the sell order was at the i^{th} best quote in the Island book, its profit is:

$$A_{i,t} - v - (c - f).$$

Now consider a standard market microstructure model (as in Glosten, 1994): competitive risk neutral limit order traders face risk-averse investors privately informed about the underlying value of the stock and their own risk-sharing needs. In this case, the marginal limit order just breaks even on average. Denoting the expected profit π_1 , this break-even condition can be written as:

$$\pi_1 = E(A_{1,t} - v - (c - f) | H_t, Q_t \geq Q_{A_{1,t}}) = 0,$$

where H_t is the information set of the liquidity suppliers just before receiving the order, Q_t is the size of the market buy order hitting $A_{1,t}$, and $Q_{A_{1,t}}$ is the depth of the order book at the best quote. As first emphasized by Rock (1990) and Glosten (1994), the conditioning set in this upper tail expectation reflects the workings of the limit order book: the marginal limit order at the best ask in the book is executed if and only if the total size of the market buy order is greater than or equal to the depth at the best ask price in the book.¹⁵ The limit order reflects this informational content of trades. Similarly, in this competitive case, the expected profit of the marginal limit order at the i^{th} best price level in the book is:

$$\pi_i = E(A_{i,t} - v - (c - f) | Q_t \geq Q_{A_{i,t}}) = 0.$$

A symmetric equality holds on the bid side of the book.

On the other hand, if the limit order traders are strategic, as in Bernhardt and Hughson (1997), and Biais, Martimort and Rochet (2000), their expected profits are not equal to zero. In that case, the relevant condition is:

$$E(A_{i,t} - v - (c + \pi_i - f) | Q_t \geq Q_{A_{i,t}}) = 0,$$

where the expected profit (π_i) is not in general equal to 0, as long as the number of liquidity suppliers, N , is finite. As shown in Biais, Martimort and Rochet (2000), when N goes to infinity, the oligopolistic mark-up π_i goes to 0, and quotes go to their competitive level.

5.2 Econometric approach

In this subsection we show how the bid and ask equations above yield empirical restrictions which can be used to test the model and estimate its parameters. Subtracting the bid from the ask, the spread is:

$$A_{i,t} - B_{i,t} = \alpha_i + 2(c - f + \pi_i),$$

¹⁵This differs from the information structure arising in the signaling trading game analyzed in Kyle (1985). In the latter, the transaction price is equal to the expectation of the value of the asset conditional on the exact size of the trade.

where:

$$\alpha_i = [E(v|Q_t \geq Q_{A_{i,t}}, H_t) - E(v|Q_t \leq -|Q_{B_{i,t}}|, H_t)]$$

denotes the informational component of the spread at the i^{th} level in the book.

Some time after (say at time $t + \Delta t$), the liquidity suppliers have updated their expectation of the fundamental value of the asset to form:

$$E(v|H_{t+\Delta t}).$$

This can be proxied, for example, by the mid-quote say half an hour or an hour after the trade:

$$m_{t+\Delta t} = E(v|H_{t+\Delta t}) + \epsilon_{t+\Delta t}.$$

For simplicity, we assume that $\epsilon_{t+\Delta t}$ is white noise. In this context, we obtain that:

$$m_{t+\Delta t} - A_{i,t} = [E(v|H_{t+\Delta t}) + \epsilon_{t+\Delta t}] - [E(v|Q_t \geq Q_{A_{i,t}}, H_t) + c - f + \pi_i].$$

Taking expectations conditional on the occurrence of the purchase at time t :

$$E(m_{t+\Delta t} - A_{i,t}|Q_t \geq Q_{A_{i,t}}, H_t) = E([E(v|H_{t+\Delta t}) + \epsilon_{t+\Delta t}] - [E(v|Q_t \geq Q_{A_{i,t}}, H_t) + c - f + \pi_i]|Q_t \geq Q_{A_{i,t}}, H_t).$$

Applying the law of iterated expectations:

$$E([E(v|H_{t+\Delta t}) + \epsilon_{t+\Delta t}]|Q_t \geq Q_{A_{i,t}}, H_t) = E(v|Q_t \geq Q_{A_{i,t}}, H_t).$$

Hence, the expected difference between the ask price and the subsequent mid-quote simplifies to:

$$E(A_{i,t} - m_{t+\Delta t}|Q_t \geq Q_{A_{i,t}}, H_t) = c - f + \pi_i.$$

A similar equality holds for the bid side:

$$E(m_{t+\Delta t} - B_{i,t}|Q_t \leq -|Q_{B_{i,t}}|, H_t) = c - f + \pi_i.$$

The intuition is that, on average, the informational component of the spread differences out, so that the difference between the transaction price and the subsequent midquote, i.e., the gross trading profit of the liquidity supplier, is equal to his non-informational cost (c net of the compensation offered by Island to liquidity supply, f) plus the oligopoly rent (π_i).

The above analysis yields two moment conditions for each level i of the book, which can be used to estimate the parameters and test the model:

$$E(A_{i,t} - B_{i,t} - [\alpha_i + 2(c - f + \pi_i)]|H_t) = 0, \quad (1)$$

and:

$$E([B_{i,t} - (m_{t+\Delta t} - (c - f + \pi_i))]I(Q_t \leq -|Q_{B_{i,t}}|) + [A_{i,t} - (m_{t+\Delta t} + (c - f + \pi_i))]I(Q_t \geq Q_{A_{i,t}})|H_t) = 0. \quad (2)$$

where $I(\cdot)$ is the indicator function equal to 1 when the condition in the argument holds and 0 otherwise.

The second moment condition enables one to identify $c + \pi_i$. Denote θ_i the sum of these two parameters. Given the estimate of θ_i (obtained from the second moment condition), α_i can be estimated, using the first moment condition. While in practice we estimate θ_i and α_i jointly, and thus do not follow this two step procedure, this discussion indicates that α_i is identifiable. Our approach to decomposing the spread is robust and avoids relying upon auxiliary parametric assumptions, instead building upon a fundamental microstructure model.

Unfortunately we cannot identify separately the two components of θ_i . Yet, we can rely on two approaches to obtain additional information about these components.

1. The descriptive statistics reported in the previous section suggest that Island liquidity suppliers exert strategic behavior by undercutting the Nasdaq touch by just one tick. Thus, we posit that such undercutting reflects strategic behavior. Under perfect competition, π would be equal to 0, and the fact that Island traders just undercut the Nasdaq grid would be irrelevant for their profits. Under the alternative hypothesis that Island traders are strategic, this undercutting behavior should affect profits. To test the null hypothesis of perfect competition in our GMM framework, we will include in the instruments an indicator variable equal to one when the best quote is set by an undercutting order. Under the null hypothesis, this instrument should be irrelevant. Under the alternative hypothesis of strategic behavior including this instrument should lead to reject the model.
2. We observe data from two subperiods: period 1 before decimalization, and period 2 after. A priori there is no reason to expect α_i or π_i to be constant across the two periods. Indeed, a change in the oligopoly mark-up π_i is to be expected, since the rules of the game are different in the two samples, reflecting the change in the tick size. The information content of trades α_i also might well have changed. Correspondingly, we carry the estimation separately over the two periods, which yields two sets of parameter estimates: $\{\alpha_{i,1}, \theta_{i,1}\}$ and $\{\alpha_{i,2}, \theta_{i,2}\}$. On the other hand, it is plausible that the order handling cost c is constant across our two subsamples. Under this assumption, we disentangle π_i from c_i by comparing the results obtained for the two periods. Since $\theta_{i,1} = c + \pi_{i,1}$ and $\theta_{i,2} = c + \pi_{i,2}$ we have that: $\theta_{i,1} - \theta_{i,2} = \pi_{i,1} - \pi_{i,2}$. Thus, if we find that $\theta_{i,1} - \theta_{i,2} > 0$ and since $\pi_{i,2}$ must be non-negative, we know that $\pi_{i,1} > 0$.

5.3 Empirical results

5.3.1 Observations and instruments

As discussed above, if limit order traders are competitive and risk neutral, the marginal limit orders break even on average (in line with Glosten, 1994, and Sandas, 2001). In contrast, infra-marginal orders can earn profits, even in the competitive case. Hence, to test the hypothesis that liquidity supply is competitive, we impose the moment conditions only on trades involving marginal limit orders in the book. For example, suppose that, at the best ask quote in the book, 500 shares are offered. A market buy order for 250 shares would not hit the marginal limit order. Hence it would not be included in

the data we use to estimate the model and test the competitive hypothesis. In contrast, a market buy order for 500 shares or more would be included.

5.3.2 A first, simple, specification

First we estimate a simple specification, where it is assumed that the parameters are constant across market conditions. The parameter estimates are presented in Table 3:

- As can be seen in the table, the estimates of α are significantly positive in both subperiods, and at both price levels in the book. Negative estimates of α would have contradicted the model. Significantly positive estimates lead to rejection of the hypothesis that there is no adverse selection.
- The estimate of $c + \pi_1$ is significantly positive in 2000 for the pooled data. Hence, we reject the hypothesis that there is no order-handling cost or market power in that period. In contrast, the estimate of $c + \pi_1$ is not significantly different from 0 after decimalization. Under the plausible assumption that c did not vary between the two periods, this suggests that liquidity supply on Island was imperfectly competitive before decimalization, i.e., π_1 was significantly positive during the first period.

5.3.3 A more flexible specification

While the assumption that c is constant through time and market conditions is reasonable, adverse selection and rent earning opportunities are likely to vary. Consequently, we estimate a more flexible specification allowing the parameters to vary with market conditions. In this specification the adverse selection cost parameter for stock k at time t ($\alpha_{1,t}^k$) is specified as:

$$\alpha_{1,t}^k = \beta^{\alpha^k} X_t^k,$$

where β^{α^k} is a vector of parameters and X_t^k is a vector of variables including:

- the constant,
- the depth at the best ask quote for observations corresponding to purchases, and depth at the best bid for observations corresponding to sales,
- the square of the change in the stock price during the last half-hour, to proxy for the volatility.

Similarly,

$$\theta_{1,t}^k = \beta^{\theta^k} X_t^k.$$

The instruments used to carry out the estimation are the variables in X_t^k , to which we add the sign of the last trade.

The p-values for this more flexible specification are presented in Table 4. Both in 2000 and in 2001 the null hypothesis that the model is correct is not rejected at the 5% level for 4 stocks out of 7. This suggests reasonable adequacy of the model to the data.¹⁶

¹⁶This reasonable fit of our structural model with a flexible specification is not unlike that obtained in Sandas (2001).

The parameter estimates are in Table 5. For brevity we only report the estimates obtained when pooling all stocks. For the adverse selection parameter there is no clear effect, apart from the constant. In the 2000 sample, the order handling cost/market power parameter is increasing in volatility.

5.3.4 The role of undercutting

Under perfect competition, Island limit orders' expected profits should be zero, irrespective of whether they undercut Nasdaq or not. Thus, the indicator variable equal to one when the Nasdaq grid is undercut by just one tick should be unrelated to the profit of Island orders. Hence, to test the null hypothesis of perfect competition, we include this indicator variable in the instruments.

The p-level obtained when undercutting is included in the set of instruments are presented in Table 6. The model is now rejected at the 5% level in 4 cases out of 7 in 2000 and 6 cases out of 7 in 2001. This contrasts with the results obtained when undercutting was not included the instruments (in that case the model was rejected in 3 cases out of 7 in 2000 and in 2001). These results point at the relevance of undercutting for the profits of Island limit order traders. While this would be expected to arise with strategic limit order placement, this contradicts the perfect competition hypothesis.

The results presented in Table 6 suggest that undercutting should be included in the variables in the flexible model. Table 7 presents the parameter estimates obtained in this specification. For brevity we only report the estimates obtained when pooling all stocks. Estimates for the constant, volatility and depth are similar to those reported in Table 5 (which speaks in favor of the robustness of the model). The undercutting variable has a positive (but not significant) impact on expected profits, consistent with the imperfect competition hypothesis, according to which Island limit order traders strategically undercut the Nasdaq grid.

6 Conclusion

This paper is a study in the industrial organization of liquidity supply. We examine the competition between limit order traders and market makers as well as on the competition between markets.

We find that, before decimalization, Nasdaq spreads were constrained by the tick size, and were correspondingly excessively wide. Reacting to this situation, limit order traders used Island as a platform to compete for the supply of liquidity. To do so they often undercut the Nasdaq inside quotes, by using the finer Island grid. Undercutting on Island did not lead to competitive liquidity supply however. In contrast with zero-profit free-entry equilibrium, limit orders placed on Island, before the Nasdaq decimalization, earned positive profits (net of transactions costs). After the Nasdaq decimalization, the Island spread became much tighter (without reduction in the depth at the quotes). In this context, the rents earned by Island limit orders virtually disappeared.

Our results suggest that the wide dissemination of information and the reduction in the costs of accessing markets brought about by the internet technology are important but not sufficient to eliminate market power in financial markets, in particular in the supply of liquidity. In addition to the competition between liquidity suppliers within a marketplace, competition between trading mechanisms plays an important role.

Our findings point at the competitive pressure exerted by ECNs such as Island on the Nasdaq system. In light of our results, decimalization on Nasdaq can be interpreted as reflecting (at least in part) a reaction of the market makers to the competitive pressure from Island.¹⁷ Our empirical findings also point at the reduction in Island spreads, brought about by the reduction of the Nasdaq spread, generated by decimalization which took place on Nasdaq.

¹⁷This suggest the Nasdaq market organizers faced the following trade-off. On the one hand, keeping a relatively coarse grid size (one sixteenth) can maintain artificially high spreads, at which Nasdaq dealer earn rents. On the other hand, keeping such a coarse grid makes it easier for Island to compete the order flow away from Nasdaq. This is reminiscent of the classical dilemma faced by oligopolists between the benefits, in terms of profit per unit, of charging large prices, and the costs of this strategy, in terms of market share.

References

- Andresen, M., 2000, Don't CLOBer the ECNs, *Wall Street Journal*, March 27.
- Barclay, M., W. Christie, J. Harris, E. Kandel, and P. Schultz, 1999, The effects of market reform on trading costs and depths of Nasdaq stocks, *Journal of Finance*, 54, 1–34.
- Barclay, M., T. Hendershott and T. McCormick, 2001, Electronic communications networks and market quality, working paper, University of Rochester.
- Bernhardt, D., and E. Hughson, 1997, Splitting orders, *Review of Financial Studies*, 10, 69–102.
- Biais, B., P. Hillion and C. Spatt, 1995, An empirical analysis of the order book and order flow in the Paris Bourse, *Journal of Finance*, 50, 1655-1689.
- Biais, B., D. Martimort and J.C. Rochet, 2000, Competing mechanisms in a common value environment, *Econometrica*, 68, 799–837.
- Chen, H., and J. Ritter, 2000, The seven percent solution, *Journal of Finance*, 55, 1105-1131.
- Chowdhry, B., and V. Nanda, Multimarket trading and market liquidity, *Review of Financial Studies*, 4, 483-511.
- Christie, W., and P. Schultz, 1994, Why do Nasdaq market makers avoid odd-eight quotes?, *Journal of Finance*, 49, 1813–1840.
- Glosten, L., 1994, Is the electronic limit order book inevitable?, *Journal of Finance*, 49, 1127–1161.
- Harris, L., 1994, Minimum price variations, discrete bid-ask spreads, and quotation sizes, *Review of Financial Studies*, 7, 149-178.
- Harris, L., 1991, Stock price clustering and discreteness, *Review of Financial Studies*, 4, 389-415.
- Harris, L., and J. Hasbrouck, 1996, Market versus limit orders: The SuperDOT evidence on order submission strategy, *Journal of Financial and Quantitative Analysis*, 31, 213–231.
- Hasbrouck, J., and G. Saar, 2002, Limit orders and volatility in a hybrid market: The Island ECN, working paper, New York University.
- Huang, R., 2002, The quality of ECN and Nasdaq market maker quotes, *Journal of Finance*, 57, 1285-1319.
- Kyle, P., 1985, Continuous auctions and insider trading, *Econometrica*, 53, 1315-1336.
- Market Data, <http://www.marketdata.nasdaq.com>.
- McAndrews, J., and C. Stefanadis, The emergence of Electronic Communications Networks in the US equity markets, *Federal Reserve Bank of New York Current Issues in Economics and Finance*, Volume 6, Number 12, pages 1 to 6.
- Parlour, C., and D. Seppi, 2003, Liquidity-based competition for order flow, *Review of Financial Studies*, 16, forthcoming.
- Rock, K., 1990, The specialist's order book and price anomalies, working paper, Harvard Business School.
- Sandas, P., 2001, Adverse selection and competitive market making: Empirical evidence from a limit order market, *Review of Financial Studies*, 14, 705–734.
- Stigler, G., 1957, Perfect competition, historically contemplated, *Journal of Political Economy*, 65, 1-17.
- Simaan, Y., D. Weaver, and D. Whitcomb, 1998, The quotation behaviour of ECNs and Nasdaq market makers, working paper, Baruch College.

Table 1: Summary statistics on daily activity

The table reports the average daily number of trades, the average trade size (in terms of number of shares per trade), the average \$ spread, the average difference between the highest and the lowest transaction price of the day, the average transaction price, and the average daily return.

Panel A: 2000 Sample

Stock	# trades		Trade size		Spread		Hi-Low	Price	Return
	Nasdaq	Island	Nasdaq	Island	Nasdaq	Island			
COMS	20 585	2 829	659	393	.08	.218	5.85	64.6	-.045
CSCO	39 831	5 141	655	338	.076	.178	6.15	136.1	-.003
DELL	52 255	5 879	1 185	478	.064	.092	3.33	52.8	0.029
INTC	31 521	3 929	779	392	.075	.211	5.69	119.5	.006
MSFT	41 279	5 157	942	416	.071	.147	3.99	97.6	.010
QCOM	37 713	4 834	463	331	.106	.282	10.5	131	.007
SUNW	21 897	2 611	583	331	.083	.256	5.18	94	-.010
Average across stocks	35 012	4 340	797	389	.079	.198	5.81	99.1	-.001

Panel B: 2001 Sample

Stock	# trades		Trade size		Spread		Hi-Low	Price	Return
	Nasdaq	Island	Nasdaq	Island	Nasdaq	Island			
COMS	2 596	278	1271	326	.015	.072	0.27	4.62	-.0008
CSCO	53 569	6 599	1121	603	.011	.030	1.16	17.16	-.0072
DELL	26 655	3 174	869	447	.012	.060	1.22	23.73	-0.010
INTC	45 518	5 922	848	482	.011	.046	1.46	27.48	-.007
MSFT	39 750	5 472	713	372	.013	.086	2.02	68.55	-.0001
QCOM	25 312	4 157	481	258	.028	.126	3.17	51.06	.0055
SUNW	40 694	5 420	1092	464	.011	.034	1.05	14.61	-.022
Average across stocks	33 442	4 432	898	450	.014	.065	1.48	31.69	-.0059

Table 2: Frequency of different types of orders on Island

The table reports the frequency of the 12 different types of orders on Island.

Panel A: 2000 Sample

	Best bid			Best ask		
	Island	Nasdaq	same	Island	Nasdaq	same
Cancel ask at best quote	15.1	11.79	15.18	10.4	14.04	16.08
Cancel ask away from quotes	17.79	26.84	24.59	30.8	18.75	21.4
New ask at best quotes	13.35	12.57	12.4	5.64	10.1	22.35
New ask away from quotes	20.6	22.9	21.3	32.36	17.3	15
New ask below best quote	17.3	15	14.8	6.1	34	9.6
Buy	15.9	10.9	11.7	14.7	5.8	15.5
Cancel bid at best quote	14.46	14.87	12.66	16.09	12.15	16.48
Cancel bid away from quotes	30.85	17.98	19.53	19.56	26.97	22.55
New bid at best quotes	6.56	8.4	15.28	10.43	8.59	9.22
New bid away from quotes	28.6	16.7	17.1	19.7	24.1	20.7
New bid above best quote	7.5	36.9	16.7	19.5	18.6	18.5
Sell	12	5.15	18.8	14.6	9.6	12.6

Panel B: 2001 Sample

	Best bid			Best ask		
	Island	Nasd	same	Island	Nasd	same
Cancel ask at best quote	10.5	9.6	11.46	9.65	10	10.83
Cancel ask away from quotes	28.7	30.1	28.1	30.8	29.6	27.6
New ask at best quotes	5.46	8.3	7.45	7.9	4.11	13.4
New ask away from quotes	29.25	26.2	25.6	29.6	26.4	22.8
New ask below best quote	14.8	16.2	15.5	7.6	24.1	12.85
Sell	11.3	9.65	11.8	14.41	5.76	12.51
Cancel bid at best quote	9.7	9.6	10.5	10.55	9.3	11.2
Cancel bid away from quotes	30.5	29.7	27.6	28.05	30.31	28.05
New bid at best quotes	8.1	3.9	10	5.1	7.2	6.2
New bid away from quotes	29.94	28.2	25.02	30.8	27.7	27.75
New bid above best quote	8.35	23.2	13.95	14.1	16.3	15.3
Buy	13.5	5.4	13	11.4	9.3	11.4

Table 3: GMM estimates when the parameters are assumed to be constant across market conditions

The adverse selection cost parameter for stock k : α^k , and the order handling cost/market power parameter: θ^k , are estimated from the 2 moment conditions given in equations (1) and (2). The instruments are the square of the change in the stock price during the last half-hour, to proxy for the volatility, as well as the sign of last trade.

Panel A: 2000 Sample

	α	t-stat	$\theta = c + \pi$	t-stat
COMS	.14	2.84	.01	.28
CSCO	.18	4.95	-.02	-1.38
DELL	.06	4.42	.00	0.08
INTC	.03	.8	.05	2.79
MSFT	.09	2.96	.00	.29
QCOM	.03	.63	.08	2.98
SUNW	.08	1.97	.05	2.14
pooled data	.09	5.54	.02	2.49

Panel B: 2001 Sample

	α	t-stat	$c + \pi$	t-stat
COMS	.04	3.92	.00	.85
CSCO	.02	3.50	.00	.08
DELL	.04	4.63	.00	.12
INTC	.03	3.65	.00	.38
MSFT	.03	2.74	.01	2.56
QCOM	.07	3.80	.01	.58
SUNW	.02	5.87	.00	.30
pooled data	.04	7.88	.00	1.53

Table 4: p-level of the flexible model

The adverse selection cost parameter for stock k at time t ($\alpha_{1,t}^k$) is specified as: $\alpha_{1,t}^k = \beta^{\alpha^k} X_t^k$, where β^{α^k} is a vector of parameters and X_t^k is a vector of variables equal to: the constant, the depth at the best ask quote for observations corresponding to purchases, and the depth at the best bid for observations corresponding to sales, as well as the square of the change in the stock price during the last half-hour, to proxy for the volatility. Similarly, the order-handling-cost/market power parameter is specified as: $\theta_{1,t}^k = \beta^{\theta^k} X_t^k$. The set of instruments includes the variables as well as the sign of last trade.

Panel A: 2000 Sample

	p-value
COMS	.00
CSCO	.16
DELL	.00
INTC	.00
MSFT	.63
QCOM	.05
SUNW	.56

Panel B: 2001 Sample

	p-value
COMS	.12
CSCO	.53
DELL	.00
INTC	.00
MSFT	.25
QCOM	.06
SUNW	.00

Table 5: parameter estimates of the flexible model

The adverse selection cost parameter for stock k at time t ($\alpha_{1,t}^k$) is specified as: $\alpha_{1,t}^k = \beta^{\alpha^k} X_t^k$, where β^{α^k} is a vector of parameters and X_t^k is a vector of variables equal to: the constant, the depth at the best ask quote for observations corresponding to purchases, and the depth at the best bid for observations corresponding to sales, as well as the square of the change in the stock price during the last half-hour, to proxy for the volatility. Similarly, the order-handling-cost/market power parameter is specified as: $\theta_{1,t}^k = \beta^{\theta^k} X_t^k$. The set of instruments includes the variables as well as the sign of last trade. The parameters are estimated using data pooled across stocks.

Panel A: 2000 Sample

Coefficients of the adverse selection parameter (α)

Variable	Coefficient estimate	t-stat
Constant	.12	5.65
Depth	-.00	-1.24
Volatility	-.01	-1.87

Coefficients of the market power/order handling cost parameter ($c + \pi$)

Variable	Coefficient estimate	t-stat
Constant	.00	.27
Depth	.00	1.46
Volatility	.01	3.02

Panel B: 2001 Sample

Coefficients of the adverse selection parameter (α)

Variable	Coefficient estimate	t-stat
Constant	.04	6.95
Depth	-.00	-1.32
Volatility	-.01	-.76

Coefficients of the market power/order handling cost parameter ($c + \pi$)

Variable	Coefficient estimate	t-stat
Constant	.00	1.01
Depth	-.00	-.17
Volatility	.01	1.36

Table 6: p-level of the flexible model when undercutting is included in the instruments

The adverse selection cost parameter for stock k at time t ($\alpha_{1,t}^k$) is specified as: $\alpha_{1,t}^k = \beta^{\alpha^k} X_t^k$, where β^{α^k} is a vector of parameters and X_t^k is a vector of variables equal to: the constant, the depth at the best ask quote for observations corresponding to purchases, and the depth at the best bid for observations corresponding to sales, as well as the square of the change in the stock price during the last half-hour, to proxy for the volatility. Similarly, the order-handling-cost/market power parameter is specified as: $\theta_{1,t}^k = \beta^{\theta^k} X_t^k$. The set of instruments includes the variables as well as the sign of last trade, and the indicator variable equal to one if the Island limit order which has been hit bettered the Nasdaq grid by just one Island tick.

Panel A: 2000 Sample

	p-value
COMS	.00
CSCO	.02
DELL	.00
INTC	.00
MSFT	.90
QCOM	.00
SUNW	.09

Panel B: 2001 Sample

	p-value
COMS	.13
CSCO	.00
DELL	.00
INTC	.00
MSFT	.00
QCOM	.00
SUNW	.00

Table 7: parameter estimates of the flexible model when undercutting is included in the variables and the instruments

The adverse selection cost parameter for stock k at time t ($\alpha_{1,t}^k$) is specified as: $\alpha_{1,t}^k = \beta^{\alpha^k} X_t^k$, where β^{α^k} is a vector of parameters and X_t^k is a vector of variables equal to: the constant, the depth at the best ask quote for observations corresponding to purchases, and the depth at the best bid for observations corresponding to sales, the square of the change in the stock price during the last half-hour, to proxy for the volatility, and the indicator variable equal to one if the Island limit order which has been hit bettered the Nasdaq grid by just one Island tick. Similarly, the order-handling-cost/market power parameter is specified as: $\theta_{1,t}^k = \beta^{\theta^k} X_t^k$. The set of instruments includes the variables as well as the sign of last trade. The parameters are estimated using data pooled across stocks.

Panel A: 2000 Sample

Coefficients of the adverse selection parameter (α)

Variable	Coefficient estimate	t-stat
Constant	.13	5.63
Depth	-.00	-1.19
Volatility	-.01	-1.91
Undercutting	-.05	-1.28

Coefficients of the market power/order handling cost parameter ($c + \pi$)

Variable	Coefficient estimate	t-stat
Constant	-.00	-.01
Depth	.00	1.41
Volatility	.01	3.06
undercutting	.02	1.37

Panel B: 2001 Sample

Coefficients of the adverse selection parameter (α)

Variable	Coefficient estimate	t-stat
Constant	.04	6.80
Depth	-.00	-1.35
Volatility	-.01	-0.77
Undercutting	-.01	-1.11

Coefficients of the market power/order handling cost parameter ($c + \pi$)

Variable	Coefficient estimate	t-stat
Constant	.00	.5
Depth	-.00	-.13
Volatility	.01	1.37
undercutting	.01	1.39

Appendix

The consequences of rounding To better document the impact of the rounding procedure on the quotes observed on the Nasdaq system, we conducted the following experiment. Using the Island data for March 2000 (from the NASTRAQ DQ file), we computed the mean spread on Island. It was equal to \$59.26/256, which is greater than its Island data counterpart, \$50.70/256. This shows that the rounding procedure made the Island quotes much less attractive than they were actually. This confirms our remark above that Island traders relied on other ticks than sixteenths to quote to a large extent.

Synchronicity problems Since the Island quotes are incorporated in the Nasdaq IQ quotes, the former can be better than the latter only when they are on a finer price grid than the Nasdaq grid. This offers an opportunity to assess the magnitude of the problems induced by synchronicity. When the best Island bid (resp. ask) is better than the best Nasdaq bid (resp. ask), it should be on a finer tick than the Nasdaq grid. In our data this is the case for DELL 84.60% (resp. 84.63%) of the time. This suggests that in 15% of the cases synchronicity problems induce mistakes in our best quotes comparisons.

Figure 1, Panel A: Frequency of different values of the spread on Island and Nasdaq (excluding Island) in March 2000 for the 7 stocks in our sample

Note: graph zooms on 0 to 2 Nasdaq ticks. 46% of the time Island spread was greater than 32/256.

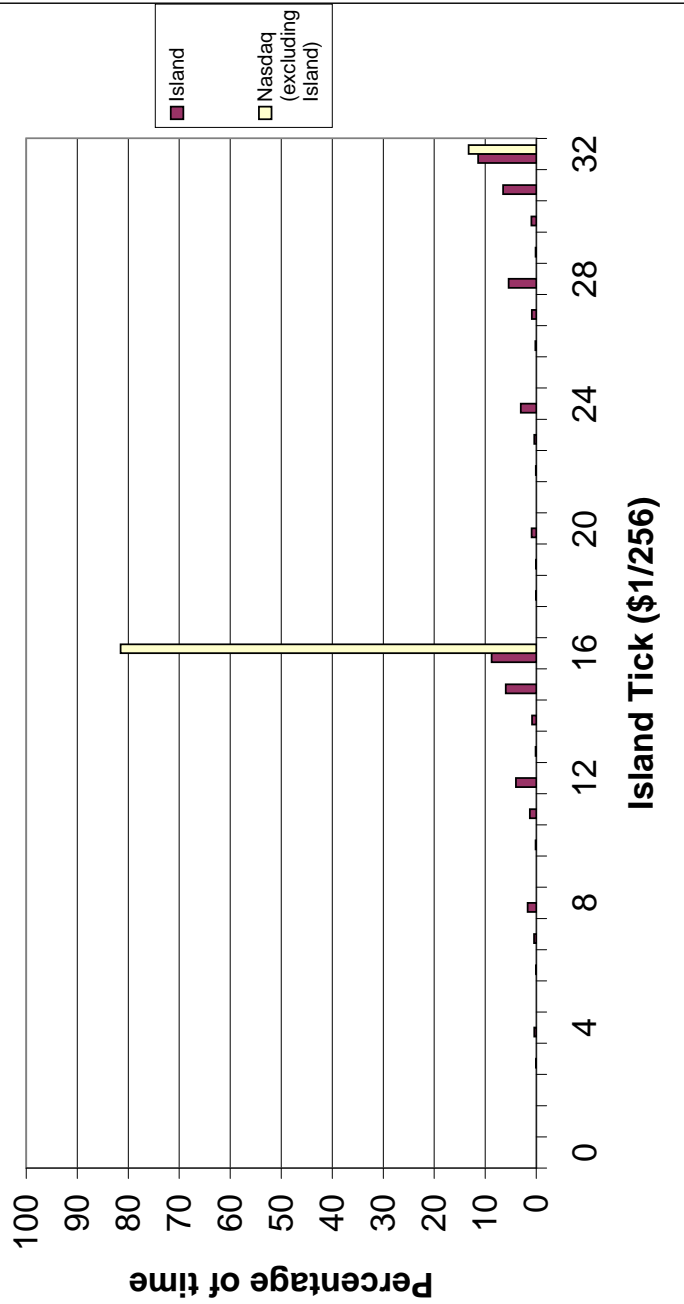


Figure 1, Panel B: Frequency of different values of the spread on Island and Nasdaq (excluding Island) in June 2001 for the 7 stocks in our sample

Note: graph zooms on 0 to 5 Nasdaq ticks. 39% of the time Island spread was greater than 50/1000.

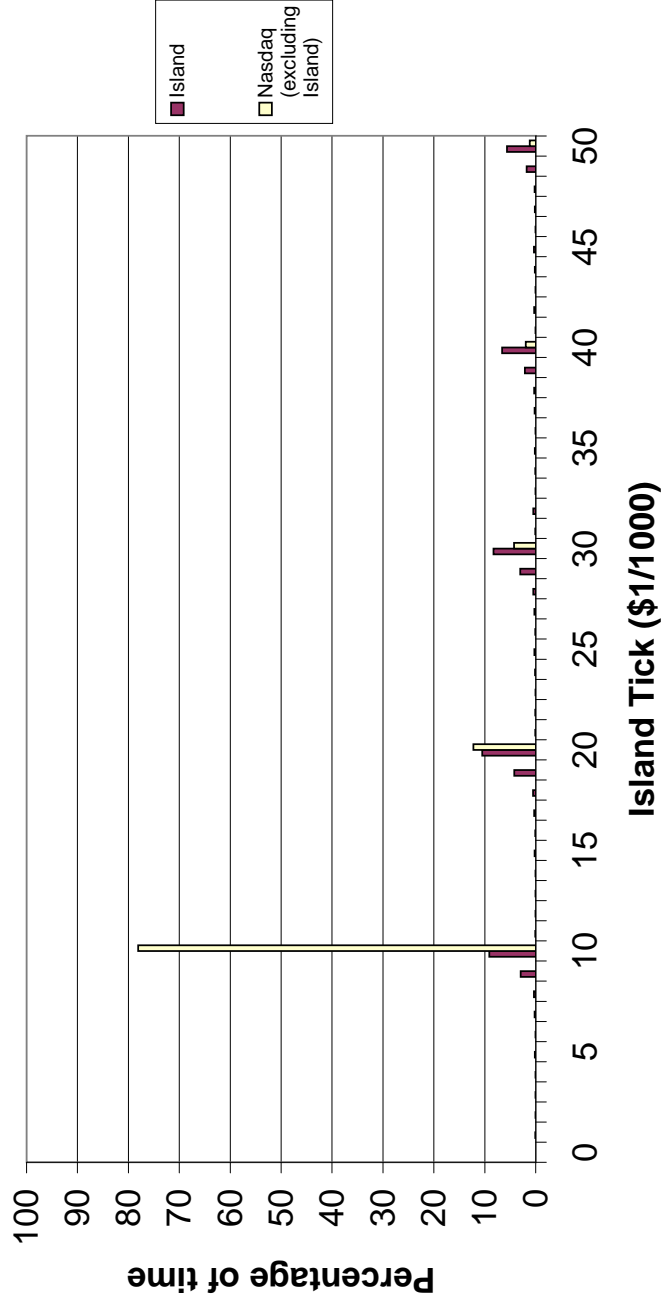


Figure 2: Average depth (in number of shares) in the Island book in March 2000 and June 2001

