Competition in Financial Dealership Markets [*]

Ilan Kremer and Valery Polkovnichenko[†]

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[†] Contacts: Ilan Kremer: Stanford University, kremer_ ilan@gsb.stanford.edu. Valery Polkovnichenko: University of Minnesota, polkovni@umn.edu.

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Abstract

In this paper we analyze a model of financial dealership markets in which we incorporate the fact that the position a dealer can take is limited by his capital. This leads to a Cournot equilibrium in which dealers have some market power and earn positive profits. As a result, we are able to endogenize dealers' entry decisions and relate the degree of competition, as measured by the bid-ask spread, to market concentration (i.e. the Herfindahl index) as well as to other factors. We perform an empirical study of stocks traded on the NASDAQ market during 1996. Consistent with predictions of the model, we find that more concentrated markets are less competitive and that markets with larger dealers are more competitive.

1 Introduction

Market makers play a key role in financial dealership markets. They compete for the public order flow by posting quotes at which they will buy and sell securities. Thus, they determine prices as well as actively trade. Since dealers compete over prices, the finance literature tends to describe these markets as perfectly competitive. Still, there are papers that describe equilibria in which identical dealers hold some market power. However, in practice dealers are not identical; they differ both in their characteristics and in their trading activity. Some dealers trade very actively while others take only a small fraction of the order flow. In this paper we attempt to go a step further and develop and test a model in which heterogeneous dealers compete for the order flow. We examine both theoretically and empirically what factors influence competition in a market. We examine whether standard measures that are widely used in the industrial organization literature apply also here and what other factors influence competition. In our model, we account for the fact that dealers cannot take unlimited positions. Dealers who have a finite amount of capital are limited in their ability to trade. Paradoxically, this limitation helps dealers maintain some market power and earn positive profits. Moreover, this leads to a description of financial markets in the framework of a Cournot competition. The model points to two parameters that are sufficient to determine the degree of competition in a dealership market: concentration and dealer size. We present empirical evidence that is consistent with our theoretical model. We find among other things that a more concentrated market has higher spreads, while a market with larger dealers has lower spreads.[1]

In the theoretical part of this paper we describe a model in which risk neutral dealers engage in price competition for order flow. These dealers are subject to capacity constraints that limit their ability to trade. The model is based on Kreps and Scheinkman (1983) that describes a duopoly model where two identical firms who are facing capacity constraints engage in a price competition. Our model consists of a generalization of their model in which $N \geq 2$ heterogeneous dealers compete for a public order flow.[2] These dealers face capacity constraints that result from the fact that when trading, they need to take a temporary position in the stock. A dealer who buys/sells stock during the day must deliver cash/stock at the end of trading. Dealers must, therefore, carry a costly inventory of capital in the form of cash and stock. This inventory determines their ability to trade. As a result of these constraints, dealers have market power and earn positive profit. The intuition behind this result is that dealers have less incentive to cut prices, as they are not able to capture all the order flow. We then endogenize the capital choice and get a Cournot type of equilibrium where the number of dealers and their cost of raising capital determine

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[1] In the empirical part we use dealers' total activity across all stocks as a measure for their size or ability to raise capital

[2] The main difficulty in generalizing KS is in showing that a dealer who quotes the highest price is the one with the highest capacity (lemma 5 in section 2). The proof is much simpler if one assumes that there are two identical dealers. The only other paper that generalizes KS in this direction is by Davidson and Deneckere (1984). They analyze the effect of mergers by examining an oligopoly of N-1 firms with equal capacities and one firm with higher capacity than the rest. They assume a linear market demand function and show the existence of pure strategy equilibrium. We analyze a general capacity configuration without assuming any special form for the demand function. We characterize all equilibria rather than focusing on a specific one

the degree of competition in the market. We also endogenize entry to the market and show how the degree of competition and number of entrants can be related to market size. We show that the larger the market for a stock, as measured by market capitalization, the more dealers will trade that stock, resulting in a more competitive market.

The empirical analysis uses a new dataset from the National Association of Securities Dealers (NASD).[3] On a monthly basis, this dataset reports the trading volume of individual dealers for each stock. We use also CRSP and TAQ data to obtain supplementary information. We relate the factors discussed in our theoretical model to the bid-ask spread. Consistent with the model, we find that (*i*) the spreads decrease as the number and size of dealers increase as measured by their total activity, (*ii*) spreads increase with concentration of trading volume as measured by the Herfindahl index. We also provide evidence that as the size of the market increases, as measured by the market capitalization, more dealers trade the stock, and as a result the market is more competitive.

A simple intuition suggests that dealers who face a convex cost function make a profit; this is due to the fact that average utility is higher than the marginal one. However, this result is not trivial in case when agents strategically set prices and not act as price takers. Still, there are papers that use a framework in which risk averse dealers set prices and extract positive profits. Roell (1999) and Viswanathan and Wang (1999) describe dealers as risk averse who set prices in divisible good auction. In this framework there are equilibria in which dealers extract positive profits. However, this approach does not address the issues considered in our paper. The first reason is that there exists a continuum of pure strategy equilibria. For example, Roell (1999) proves the existence of a certain symmetric pure-strategy linear equilibrium. However, she also notes that there is a continuum of non-linear equilibria, where dealers are charging higher prices. In general any price that is favorable enough for the dealers can be supported in equilibrium. Hence, while this approach can explain how dealers make a profit it cannot support comparative static. This is because any result depends on equilibrium selection. In fact as the set of equilibria is so large almost any result can be shown using an appropriate selection rule. Moreover, these models do not yield the same comparative static as our model. For example, concentration does not show up in these models. These models cannot predict that in a more concentrated market, dealers have more market power.

Other papers that describe models where dealers can extract positive profits include inventory models and models that focus on the tick size. Inventory models such as Ho and Stoll (1983) and Biais (1993) also assume that dealers are risk averse. They describe dealers as having private valuations for the order flow. These differences in valuations are a result of prior inventories. Unlike Roell (1999) and Viswanathan and Wang (1999) they treat the order-flow as indivisible. Hence, the dealer with the highest valuation can extract surplus in cases where there is a difference between the two most extreme valuations. Bernhardt and Hughson (1997) and Kandel and Marx (1997) focus on the tick size. A minimal tick size yields a possibility for profits. Inventory approach can predict under a proper set of assumptions that increasing the number of dealers results in a more competitive market. However, both approaches do not yield the

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[3] We thank Tim McCormick of the NASD academic liaison office for providing this dataset.

comparative static result as in our paper for concentration measures or dealer size.

Dutta and Madhavan (1997) describe a dealership model as a repeated Bertrand competition. The dealers are able to maintain monopoly prices, which follows from the folk theorem for an infinitely repeated game.[4] In our model the number of dealers and their market shares are endogenous; in their model these are exogenous. An empirical implication of their model is that a more concentrated market (as measured by the Herfindahl index) is more competitive. Our model predicts the traditional reverse relation. We find empirical evidence that a more concentrated market is less competitive. Grossman and Miller (1988) concentrate on the liquidity aspect of a market. In their paper, risk-averse dealers act as price takers and need to take temporary positions as a result of unbalanced order-flow. They are also able to characterize the equilibrium number of dealers. This paper is close to our approach as dealers are limited in the position they can take. Our approach is different in that we concentrate on the strategic interaction among dealers. Our model describes explicitly the process of price formation as dealers set prices.

The remainder of the paper is organized as follows. Section 2 describes the model with symmetric dealers. In section 3 we analyze an asymmetric model. In section 4 we describe the data used in this study and the empirical evidence. Section 5 concludes. Proofs appear in the appendix.

2 The model - Symmetric case

Identical risk-neutral dealers trade a single risky asset whose expected payoff is given by $\bar{v}$. It is a four-period model in which strategic decisions take place only in the first three periods. In period 0, dealers decide whether to pay a fixed fee, c, and enter the market. Let N denote the number of dealers who enter the market. In period 1, N becomes common knowledge and the dealers who have entered, simultaneously raise capital which consists of cash and stock. We denote dealer i's choice of cash and stock inventories by w_i, and q_i respectively; w_i is denominated in dollars while q_i represents the number of shares. We assume that the cost of carrying inventory is given by $c(w,q) = r_w w + r_q q$, where r_w and r_q are the marginal costs of cash and stock inventory respectively. It might result from tying capital into the trading process instead of using it in other positive NPV projects. It could also result from over-paying for stock or cash in earlier trading rounds. More generally, its source might be an agency or an adverse selection problem. Still, neither the exact reason for this cost nor its exact functional form are essential for our analysis to hold. Nevertheless, it is important that raising capital bears even minimal costs.

In period 2, after dealers' inventory levels become common knowledge, dealers simultaneously post bid and ask quotes. We denote dealer i's choice of ask and bid by a_i and b_i, respectively. An ask (bid) quote represents a price per share at which a dealer is willing to sell (buy) any amount of stocks.[5]

In period 3, investors arrive at the market. These investors are either potential sellers who are willing to

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[4] Their model describes tacit collusion of dealers in attempt to explain the high spreads found by Christie and Schultz (1994).

[5] As this is a risk-neutral environment with no information asymmetry, allowing dealers to use price schedules instead of a single price would not change our results.

sell the stock for less than $\bar{v}$, or potential buyers who are willing to buy the stock for more than $\bar{v}$. Further, potential buyers differ in the amount they are willing to pay for the shares, while potential sellers differ in the amount of cash they demand for their shares. This setting can be motivated either by assuming that investors are risk averse and differ in their endowment or by assuming that investors differ in their inter-temporal rate of substitution. Rather than modeling individual preferences, we focus on aggregate demand/supply. We model aggregate demand/supply as unbalanced in that there are either only buy orders or only sell orders.[6] This way, dealers who make the market need to take a position (at least temporarily) in the stock and not just cross buy orders with sell orders. We assume that with probability 0.5 it is an ask market represented by a demand function for stocks $D_A(a)$, where a is the ask price. With probability 0.5 it is a bid market represented by a demand function for cash $D_B(b)$ where b is the bid quote. This demand for cash is equivalent to a supply of shares; a demand for $\$w$ at a bid b represents a supply of $\frac{w}{b}$ shares. We assume that $D_A(\cdot)$ is monotone decreasing while $D_B(\cdot)$ is monotone increasing. We denote by $P_A(\cdot)$ and $P_B(\cdot)$, the inverse demand functions, that is $P_A(\cdot) = D_A^{-1}(\cdot), P_B(\cdot) = D_B^{-1}(\cdot)$. Since $P_A(q+x)$ represent the ask at which the market demands $q+x$ shares, if a dealer is selling q shares at a price which implies demand for $q+x$ shares then his expected profit is given by[7]:

$$q\left(P_A(q+x) - \bar{v}\right)$$

If a dealer is buying shares for $\$w$ at a price which implies a demand for $(w+x)$ dollars then his expected profit is given by:

$$\frac{w}{P_B(w+x)}\bar{v} - w$$

We assume that for every $x \geq 0$, both $q\left(P_A(q+x) - \bar{v}\right)$ and $\frac{w}{P_B(w+x)}\bar{v} - w$ are concave in q and w respectively.

When trading, dealers are subject to constraints determined by their capital level. On the bid side a dealer who has cash inventory of $\$w$ cannot buy shares for more than $\$w$, so if he quotes a bid b he can not buy more than $\frac{w}{b}$ shares. On the ask side a dealer who has an inventory of q shares, can sell up to q shares. Demand is allocated according to the efficient rationing rule; demand is allocated first to dealers with the best quotes. A dealer with a high ask price sells shares only if demand is not exhausted by dealers with lower ask quote. That is, dealer i is facing residual demand of: $\max\{0, D^A(a_i) - \sum_{j \text{ s.t.} a_j < a_i} q_j\}$. As sales by dealer i are bounded by his stock inventory, we conclude that if he is the only dealer to quote a_i

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[6] This can be easily generalized. If the order-flow is an unbalanced mixture of buy and sell orders, then dealers can cross orders which can be matched. These trades do not require taking any position in the stock and hence by price competition would be traded in a competitive way. Our model can be viewed as concentrating on buy/sell orders which could not be matched.

[7] This term can be viewed as a Stackelberg follower payoff.

as an ask, he sells[8,9]

$$\min\left\{q_i, \max\left\{0, D^A\left(a_i\right) - \sum_{j \text{ s.t.} a_j < a_i} q_j\right\}\right\}$$

If dealer i is not the only dealer to quote a_i as an ask, dealer i sells:

$$\min\left\{q_i, \max\left\{0, \frac{q_i}{\sum_{l \text{ s.t.} a_l = a_i} q_l}\left(D^A\left(a_i\right) - \sum_{j \text{ s.t.} a_j < a_i} q_j\right)\right\}\right\}$$

Similarly dealers with low bids are able to buy shares only if the supply is not exhausted by dealers with higher bids.

Before solving the model we offer a few remarks. The competitive quotes which yield zero profits (net of entry costs) on both ask and bid are given by $\bar{v} + r_q$ and $\frac{\bar{v}}{1+r_w}$ respectively. Worse quotes indicate non-competitive behavior. Also note that the assumption that dealers post quotes before the shock of demand/supply is realized plays no role in the prevailing equilibrium, since dealers have no incentive to change their quotes after the demand/supply shock is realized. This is due to the fact that the uncertainty dealers are facing regarding the market is only whether it is a demand or supply a shock.

We solve the model using backward induction starting at period 2 (in period 3 no strategic decision takes place), and going back to period 0.

2.1 Period 2 sub-game equilibria: choosing quotes

We focus on the ask side, the analysis for the bid side is similar. Suppose N dealers entered in period 0 and chose stock inventory of $\{q_i\}_{i=1}^N$ in period 1 . Let $Q \equiv \sum_{i=1}^N q_i$ denote aggregate share inventory and $Q_{-i} \equiv Q - q_i$.

In this sub-game dealers choose ask quotes $\{a_i\}_{i=1}^N$As implied by the previous section, if dealer i is the unique dealer to quote a_i as an ask, his expected profit is given by:

$$\left(a_i - \bar{v}\right)\min\left\{q_i, \max\left\{0, D^A\left(a_i\right) - \sum_{j \text{ s.t.} a_j < a_i} q_j\right\}\right\}$$

In the case when dealer i is not the only dealer to quote a_i, his expected profit is given by:

$$\left(a_i - \bar{v}\right)\min\left\{q_i, \max\left\{0, \frac{q_i}{\sum_{l \text{ s.t.} a_l = a_i} q_l}\left(D^A\left(a_i\right) - \sum_{j \text{ s.t.} a_j < a_i} q_j\right)\right\}\right\}$$

We begin by proving that at least one equilibrium exists. We can not use standard arguments as the payoff function is discontinuous in quotes. For example, if there are two dealers with the same quote, then each

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[8] We implicitly assume that dealers choose to sell the maximum number of shares they can sell. This is without loss of generality and is done for expositional purposes. In equilibrium the ask will be higher than $\bar{v}$ and dealers strictly prefer to sell all their shares.

[9] It can be shown that the efficient rationing rule can be derived by maximizing the aggregate utility of the public.

dealer could increase his payoff by a discrete amount by lowering his ask by a small $\varepsilon > 0$. Fortunately, the set of discontinuities has measure zero, and we can use Dasgupta and Maskin (1986a),(1986b) to show that indeed there exists at least one mixed strategy equilibrium.

Lemma 1 *For any* $\{q_i\}_{i=1}^N$*, an equilibrium in mixed strategies exists.*

Proof. See appendix. ■

We can now focus our attention on equilibrium strategies. In a mixed-strategy equilibrium each dealer picks an ask quote from a distribution over the real line. Let $\underline{a}_i$ and $\overline{a}_i$ denote the minimal and maximal mixed strategy ask prices quoted by dealer i respectively. Formally:

$$\underline{a}_i = \sup \{a | pr\,(\text{dealer } i \text{ chooses a price lower than } a) = 0\}$$

$$\overline{a}_i = \inf \{a | pr\,(\text{dealer } i \text{ chooses a price higher than } a) = 0\}$$

Also let $\underline{a} = \min_i \{\underline{a}_i\}$ and $\overline{a} = \max_i \{\overline{a}_i\}$.

We start our analysis by placing a lower bound on the prices quoted in equilibrium. This lower bound is independent of the other dealers' strategies. Since each dealer is guaranteed to sell all his shares if he quotes the market clearing price, $P_A(Q)$, we conclude that no dealer quotes (with positive probability) an ask lower than this price. That is:

Lemma 2 $\underline{a}_i \geq P_A(Q)$, *for all* i.

Next we turn our attention to the highest prices quoted. Let $s_A(x)$ denote the optimal number of shares for a Stackelberg follower when the inverse demand function is given by $P_A(\cdot)$,[10]:

$$s_A(x) = \arg\max_q q\,(P_A(x+q) - \bar{v})$$

and $S_A(x)$ denote his payoff:

$$S_A(x) = s_A(x)\,(P_A(x + s_A(x)) - \bar{v})$$

There are two different categories of possible equilibria. The first category is what we call an equilibrium tie, where two or more dealers quote the highest price $\overline{a}$ with a positive probability. The second is what we call a non-tie which covers all other possibilities.

We start by considering the case of an equilibrium tie. If the highest quoted ask is higher than the market clearing price, that is $\overline{a} > P_A(Q)$, dealers who quote the highest ask are guaranteed not to sell all their inventory. Thus if there were a tie where $\overline{a} > P_A(Q)$, each dealer who quoted $\overline{a}$ with positive probability could increase his payoff by quoting $\overline{a} - \varepsilon$ for some small $\varepsilon > 0$. He would thereby increase the number of shares he sells by a discrete amount while lowering his price by only a small amount. Therefore

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[10] If $q\,(P\,(x+q) - \bar{v})$ is monotone increasing in q we define $s_A(x) = \infty$. In all other cases since $q\,(P\,(x+q) - \bar{v})$ is concave in q, $s_A(x)$ is well defined.

$\overline{a} \leq P_A(Q)$, and since $\underline{a} \geq P_A(Q)$ (Lemma 2) and $\underline{a} \leq \overline{a}$ we conclude that $\overline{a} = \underline{a} = P_A(Q)$. Hence a tie could only occur in a pure-strategy equilibrium where all dealers quote $P_A(Q)$ with probability 1. We continue by observing that if $q_i > s_A(Q_{-i})$ for some dealer i, this dealer would prefer to quote an ask of $P_A(Q_{-i} + s_A(Q_{-i}))$ and sell $s_A(Q_{-i})$ shares rather than selling q_i shares at a price of $P_A(Q)$. Hence we conclude that in the case of an equilibrium tie it must be that $q_i \leq s_A(Q_{-i})$ for all i; each dealer's inventory constraint is binding. Lemma 3 summarizes our analysis for this case.

Lemma 3 *In a case of an equilibrium tie, all dealers use pure strategies in which they quote $P_A(Q)$ with probability 1. Moreover, in this case $q_i \leq s_A(Q_{-i})$ for all i.*

We now consider the case of a non-tie equilibrium. This is the case when at most one dealer quotes $\overline{a}$ with positive probability. We start by assuming that exactly one dealer, say i, quotes $\overline{a}$ with a positive probability. When dealer i is quoting the highest price $\overline{a}$, he is guaranteed to be under sold by a total of Q_{-i} shares. Thus, his payoff is at most Stackelberg follower payoff, $S_A(Q_{-i})$. Since $\overline{a} > P_A(Q)$, dealer i is not selling all his shares when quoting $\overline{a}$. Thus inventory is not a binding constraint for dealer i, which implies that $q_i > s_A(Q_{-i})$ and his profit is given by $S_A(Q_{-i})$. For the case when no dealer quotes $\overline{a}$ with a positive probability, let i denote the dealer for whom $\overline{a}_i = \overline{a}$. As dealer i is quoting with positive probability quotes which are arbitrarily close to $\overline{a}$, he could get the same payoff had he quoted $\overline{a}$ with probability 1. Thus our previous argument also holds for these equilibria. The following lemma summarizes our conclusions.

Lemma 4 *In a non-tie equilibrium a dealer i who quotes the highest quote, receives Stackelberg follower payoff, $S_A(Q_{-i})$; moreover $q_i > s_A(Q_{-i})$.*

In the last lemma we show that in a non-tie equilibrium a dealer who quotes the highest ask has the largest amount of shares. As the proof for this lemma is more technical it appears in the appendix.

Lemma 5 *In a non-tie equilibrium, $\overline{a}_i = \overline{a}$ implies that $q_i \geq q_j$ for all j.*

Proof. See appendix. ■

Finally we are able to characterize equilibria payoffs in the period 2 ask side sub-game.

Theorem 1 *(i) If $q_k \leq s_A(Q_{-k})$ for all k, then the period-2 ask side sub-game has a unique equilibrium. This equilibrium is a pure-strategy equilibrium where all dealers quote the same ask, $a_k = P_A(Q)$ for all k. (ii) If $q_k > s_A(Q_{-k})$ for some k, at least one equilibrium exists. All equilibria in this case are equilibria in mixed strategies. Moreover, in any of these equilibria, a dealer who has the highest number of shares could have received at least as high a profit had he owned a smaller amount of shares.*

Proof. We start by assuming that $q_k \leq s_A(Q_{-k})$ for all k, that is capacity constraints are not binding. By lemma 1 we know that an equilibrium exists. In lemma 4 we proved that in a non-tie equilibrium $q_i > s_A(Q_{-i})$ for some i, so we conclude that this equilibrium must have a tie. Lemma 3 implies that a tie implies an equilibrium in pure strategies where each player quotes $P_A(Q)$ with probability 1, so the first part of this theorem follows. We now assume that $q_k > s_A(Q_{-k})$ for some k. From lemma 1 we conclude that there exists at least one equilibrium, and from lemma 3 we conclude that all equilibria in this case must be without a tie. ¿From lemmas 4 and 5 we conclude that one of the dealers with the highest inventory of stocks, dealer i, who also has excess inventory, i.e. $q_i > s_A(Q_{-i})$, gets only Stackelberg follower payoff. Since i could get this payoff by quoting $a_i = P_A(Q_{-i} + s_A(Q_{-i}))$ had it chosen $q_i = s_A(Q_{-i})$, the second part of the theorem follows. ■

The analysis of the bid side is similar to the ask side. We denote aggregate cash inventory by W, where $W \equiv \sum_{i=1}^{N} w_i$, and we let $W_{-i} \equiv W - w_i$. Let $s_B(x)$ be the optimal cash level of a Stackelberg follower when the inverse demand function is given by $P_B(\cdot)$[11]:

$$s_B(x) = \arg\max_{w} \frac{w}{P_B(w+x)}\bar{v} - w$$

Theorem 2 *(i) If $w_k \leq s_B(W_{-k})$ for all k, then the period 2 bid side sub-game has a unique equilibrium. This equilibrium is a pure-strategy equilibrium, where all dealers quote the same bid, $b_k = P_B(W)$ for all k. (ii) If $w_k > s_B(W_{-k})$ for some k, at least one equilibrium exists. All equilibria in this case are equilibria in mixed strategies. Moreover, in any of these equilibria, a dealer who has the highest amount of capital could have received at least as high a profit had he owned a smaller amount of capital.*

Proof of theorem 2 parallels that of theorem 1.

2.2 Period 1 sub-game equilibria: choosing inventory levels

In this section we take the number of dealers N as given, and based on the previous subsection, we endogenize the inventory choice. The main result in this section is that when endogenizing the inventory choice we get a Cournot equilibrium. This implies basic comparative static results which are indicated in corollary 1.

Theorem 3 *The period 1 sub-game has a unique equilibrium in the class of equilibria where dealers choose capital using pure strategies.*[12] *In period 1 all dealers choose inventory levels of w_N^*, q_N^* so that:*

$$w_N^* = \arg\max_{w} \frac{w}{P_B(w + (N-1)\,w_N^*)}\bar{v} - w\,(2r_w + 1) \text{ for all } i$$

$$q_N^* = \arg\max_{q} qP_A\left(q + (N-1)\,q_N^*\right) - q\,(2r_q + \bar{v}) \text{ for all } i$$

As a result, in period 2 all firms choose the same bid and ask using pure strategies:

$$a_i = a_N^* = P_A\left(Nq_N^*\right) \text{ for all } i$$

$$b_i = b_N^* = P_B\left(Nw_N^*\right) \text{ for all } i$$

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[11] If $\frac{w}{P_B(w+x)}\bar{v} - w$ is monotone increasing in w we define $s_B(x) = \infty$. In all other cases since $\frac{w}{P_B(w+x)}\bar{v} - w$ is concave in w, $s_B(x)$ is well defined.

[12] At the present we have not ruled out the possibility of a mixed-strategy equilibrium where dealers use mixed strategies for capital choice. For $N = 2$ it follows from Kreps and Scheinkman (1982) that such an equilibrium does not exist.

Proof. We first show that choosing q_N^*, w_N^* in period 1 and quoting $a = P_A(Nq_N^*), b = P_B(Nw_N^*)$ in period 2 is indeed an equilibrium. Consider possible deviations for player i. Choosing $w > s_B(W_{-i})$ or $q > s_A(Q_{-i})$ is not optimal. This follows from theorems 1 and 2 as dealer i could get in period 2 at least as much had he chosen a lower level of inventory. Since inventory is costly, this is not optimal. Hence, we restrict our attention to deviations where dealer i chooses $w_i \leq s_B(W_{-i})$ and $q_i \leq s_A(Q_{-i})$ which implies that $w_k \leq s_B(W_{-k})$ and $q_k \leq s_A(Q_{-k})$ for all k. In this case $i's$ profit is given by:

$$\frac{1}{2}\left[qP^B\left(q+(N-1)\,q_N^*\right)-q\bar{v}+\frac{w}{P_B(w+(N-1)\,w_N^*)}\bar{v}-w\right]-r_w w-r_q q$$

and choosing w_N^*, q_N^* is optimal. To show that it is the only pure strategy equilibrium we note that by theorems 1 and 2 it must be that $w_i \leq s_B(W_{-i})$ and $q_i \leq s_A(Q_{-i})$ for all i. Thus again, by theorems 1 and 2, period 2 equilibrium quotes would be $P_A(Q)$ and $P_B(W)$. Hence, since the Cournot equilibrium is unique we conclude that there exists only one pure strategy equilibrium ■

Since the equilibrium we get is a Cournot equilibrium we conclude that the "standard" comparative static results in a Cournot model also hold here. That is:

Corollary 1 *As the number of dealers grows the quotes become more competitive:*

$$\frac{db_N^*}{dN} > 0, \frac{da_N^*}{dN} < 0$$

As $N \to \infty$ quotes converge to the competitive outcome and expected profits converge to zero.

$$\lim_{N\to\infty} a_N^* = \bar{v} + r_q$$

$$\lim_{N\to\infty} b_N^* = \frac{\bar{v}}{1+r_w}$$

Quotes become more competitive as the cost of capital decreases:

$$\frac{db_N^*}{dr_w} > 0, \frac{da_N^*}{dr_q} < 0$$

2.3 Equilibria of the full game: Entry choice

We now endogenize the number of dealers who enter the market. Suppose that in period 0 dealers have to pay a fixed fee to participate in the market. We let this fee depend on market size and relate the number of entrants to the size of the market. We then study the effect of market size on the degree of competition in the market. For now we keep the value of a single stock as given, that is we assume $\bar{v}$ is fixed. Doing that we can treat the number of shares and the market capitalization of the firm as equivalents.This yields the following specification:

$$\begin{aligned} D_A(\alpha, a) &= \alpha D_A(1, a) \\ D_B(\alpha, b) &= \alpha D_B(1, b) \end{aligned}$$

where $D_A(\alpha, a)$ and $D_B(\alpha, b)$ denote the demand for stocks and cash respectively in a market of size α. If we denote the inverse demand functions in a market of size α by $P_A(\alpha, q)$ and $P_B(\alpha, w)$, the above equations are equivalent to:

$$\begin{aligned} P_A(\alpha, \alpha q) &= P_A(1, q) \\ P_B(\alpha, \alpha w) &= P_B(1, w) \end{aligned}$$

We start by examining the properties of the period 1 sub-game, that is we take the number of entrants as given. Denote by $a^*_{N,\alpha}, b^*_{N,\alpha}$ the equilibrium ask,bid quotes in a market of size α with N dealers respectively, let $w^*_{N,\alpha}, q^*_{N,\alpha}$ denote equilibrium choice of shares and cash inventory respectively.

Lemma 6 *(i)Keeping the number of entrants fixed, equilibrium inventory is linear in market size. That is,* $w^*_{N,\alpha} = \alpha w$ *and* $q^*_{N,\alpha} = \alpha q^*_{N,1}$*for all* α *(ii) Keeping the number of entrants fixed, equilibrium quotes do not depend on market size. That size* $a^*_{N,\alpha}$ *and* $b^*_{N,\alpha}$ *do not depend on* α

Proof. We show the proof only for $q^*_{N,\alpha}$. The proof for $w^*_{N,\alpha}$ follows the same arguments. We start with proof of part (i), by definition, $q^*_{N,1}$ is the solution to:

$$q^*_{N,1} = \arg\max_q qP_A\left(1, q + (N-1)\, q^*_{N,1}\right) - q\left(2r_q + \bar{v}\right)$$

while $q^*_{N,\alpha}$ is the solution to:

$$q^*_{N,\alpha} = \arg\max_q qP_A\left(\alpha, q + (N-1)\, q^*_{N,\alpha}\right) - q\left(2r_q + \bar{v}\right)$$

Using the fact that $P_A(\alpha, aq) = P_A(1, q)$ part (i) follows from the first order condition. Part (ii) then follows from part (i) and the fact that $P_A(\alpha, aq) = P_A(1, q)$ ■

Let $\pi_{N,\alpha}$ denote the profit for a single dealer (as we deal with a period 1 sub-game we ignore entry fees it follows from lemma 6 that:

Corollary 2 *(ii)* $\pi_{N,\alpha} = \alpha \pi_{N,1}$ *for all* α.

We now introduce an entry cost to the market, we denote this cost by c.[13] *Denote by* $N(\alpha)$ *the equilibrium number of dealers who enter the market. This number is determined by the following inequalities:*

$$\pi_{N(\alpha),\alpha} \geq c \tag{1}$$

and for all $N' > N(\alpha)$

$$\pi_{N',\alpha} < c \tag{2}$$

An immediate result of the Cournot equilibrium and corollary 2 is that in a larger market we find more dealers, that is:

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[13] We implicitly assume that the entry cost does not depend on the market size. Theorem 4 can be easily generalized to cases in which the entry cost is a function of market size.

Theorem 4 *The number of equilibrium dealers is non-decreasing in market size. That is,* $N(\alpha)$ *is non-decreasing in* α.

This has direct implication on the relation between the market size and the degree of competition. If we let $a(\alpha), b(\alpha)$ denote the equilibrium quotes in a market of size α an immediate implication of the above theorem is that:

Corollary 3 *Larger markets are more competitive, that is,* $a(\alpha)$ *is non-increasing in* α, $b(\alpha)$ *is non-decreasing in* α.

3 Asymmetric case

The analysis in the previous section was for the case where all firms face the same cost of capital and entry costs. In this section we consider a more general setting which is later used in our empirical study. We analyze an asymmetric model in which dealers having different cost functions, where firm i's cost of building inventory is given by $c_i(w,q) = r_{w,i}w + r_{q,i}q$. We also let entry cost depend on the individual dealers as well as the specific market characteristics which include size. Entry cost is given by $g_i(\alpha, x)$ where α represents size and x represent some other market characteristics.[14] We maintain our previous assumption regarding the relation between market size and the inverse demand function. Let $P_A(\alpha, q), P_B(\alpha, w)$ denote the inverse demand function in a market of size α. We again assume that:

$$\begin{aligned} P_A(\alpha, aq) &= P_A(1, q) \\ P_B(\alpha, \alpha w) &= P_B(1, w) \end{aligned}$$

We first focus on the period 1 sub-game, where we take dealers' entry decisions as given. First we establish the existence of a pure strategy equilibrium. For that purpose let $\{q_i\}, \{w_i\}$ be the unique solution to:

$$w_i = \arg\max_w \frac{w}{P_B(\alpha, w + W_{-i})}\bar{v} - w(2r_{i,w} + 1) \text{ for all } i \tag{3}$$

$$q_i = \arg\max_q qP_A(\alpha, q + Q_{-i}) - q(2r_{i,q} + \bar{v}) \text{ for all } i \tag{4}$$

It follows that $w_i \leq s_B(W_{-i})$, and $q_i \leq s_A(Q_{-i})$ for all i. For $\{q_i\}, \{w_i\}$ to be a pure strategy equilibrium we need a stronger restriction:

Assumption 1 $\max\{w_i\} \leq s_B(W), \max\{q_i\} \leq s_A(Q)$.

We can now prove that similar to the symmetric case (see theorem 3) there exists a unique pure-strategy equilibrium. This equilibrium is a Cournot equilibrium, where capital levels are determined by equations (1) and (2).

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[14] Letting size be the only exogenous variable leads to a model where size is the only determinant of spread. By including other characteristics we can examine a richer setting where potentially other factors might affect competition.

Theorem 5 *Choosing* $\{q_i\}, \{w_i\}$ *in period 1 and* $a_i = a = P_A(Q), b_i = b = P_B(W)$ *for all* i *in period 2, is the unique period 1 pure-strategy equilibrium.*

Proof. We first argue that this is indeed an equilibrium. Consider possible deviations for an arbitrary dealer. We argue that if player k chooses $q > s_A(Q_{-k})$ rather than q_k, it must be that $q > \max_{i \neq k}\{q_i\}$. To see this note that $s_A(Q_{-k}) > s_A(Q)$ and hence it follows from $\max\{q_i\} \leq s_A(Q)$. From theorems 1 and 2 we then conclude that this is not optimal and we can restrict ourselves to deviations where $q \leq s_A(Q_{-k})$. A similar argument restricts us to deviations where $w \leq s_B(W_{-k})$. Since $q_i \leq s_A(Q_{-i}), w_i \leq s_B(W_{-i})$ for all i, dealer $k's$ payoff is given by:

$$\arg\max_q qP_A(q + Q_{-k}) - q(2r_{i,q} + \bar{v})$$

$$\arg\max_w \frac{w}{P_B(w + W_{-k})}\bar{v} - w(2r_{i,w} + 1)$$

and q_k, w_k are optimal. The proof that this is only pure strategy equilibrium follows the same line as the proof for Theorem 3 ■

We now consider the full game with endogenous entry. We assume that assumption 1 holds so that a pure-strategy equilibrium exists. In this case, both market concentration and the average cost of building inventory are endogenous. Still, we argue that these two endogenous variables together are the only determinants for the degree of competition in the market. Therefore, two markets might differ on the profile of entrants but as long as they share the same degree of concentration and have the same average dealers' cost of capital, the equilibrium quotes would be the same. As the analysis of the ask side is similar to the bid side we again present the proofs for the ask side only. We first define our measure for market concentration, the Herfindahl index:

$$R_H = \sum_{i=1}^{N} \frac{q_i^2}{Q^2}$$

and denote by $\bar{r}_q$ the weighted average cost of building stock inventory, that is, $\bar{r}_q = \sum_{i=1}^{N} r_{q,i}\frac{q_i}{Q}$

Lemma 7 *The aggregate profit of all dealers on the ask side period 1 sub-game (gross of entry costs) is given by* $\Pi = -\frac{1}{2}Q^2P_A'(\alpha, Q)R_H$.

Proof. See appendix. ■

For the next result we need to assume that the inverse demand function for stocks satisfies the following condition[15]:

Assumption 2 $Q^2P_A'(\alpha, Q)$ *is non-increasing in* Q.

The following theorem summarizes the comparative static results of the asymmetric model:

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[15] Examples of functions that satisfy this condition are: $P_A(Q) = \frac{\gamma}{Q}$ for some $\gamma > 0$ and $P_A(Q) = \gamma - \delta Q$ for some $\delta, \gamma > 0$.

Theorem 6 *(i)In equilibrium the ask price depends only on market concentration R_H and average cost of capital $\bar{r}_q$ (ii) Keeping dealers' average cost of capital $\bar{r}_q$ and market size α fixed, the equilibrium ask is non-decreasing in R_H (iii) Keeping concentration, R_H, and size, α, fixed the equilibrium ask is non-decreasing in $\bar{r}_q$.*

Proof. (i) Assume by contradiction that there are two markets with the same equilibrium concentration R_H and $\bar{r}_q$, but with two different equilibrium asks $a_1 = P_A(\alpha_1, Q_1) > a_2 = P_A(\alpha_2, Q_2)$. We begin by assuming that these two markets are of the same size, that is $\alpha_1 = \alpha_2 = \alpha$. As $P_A(\alpha, Q)$ is non-increasing we conclude that $Q_2 > Q_1$. Since both quantities are above the monopoly quantity[16] we conclude that $\Pi_1 > \Pi_{2.}$. But $Q_2 > Q_1$ and $Q^2 P_A^{'}(\alpha, Q)$ being non-increasing imply by lemma 7 that $\Pi_2 > \Pi_1$. For the case when $\alpha_1 > \alpha_2$, note that when we calculate the equilibrium quotes we can ignore the entry decision. Hence, we can apply the following procedure: keep the entrants in market 1 and resize it to the size of market 2. If we let a_1^* denote the new equilibrium ask in this market, it follows from the homogeneity of the demand and the linearity of the cost functions that this procedure does not change the equilibrium quote, that is, $a_1^* = a_1$. But from the first part we conclude that $a_1^* = a_2$.

(ii) By the same argument as in part (i) we can assume without loss of generality that the two markets are of the same size, that is, $\alpha_1 = \alpha_2 = \alpha$. Assume by contradiction that $\bar{r}_q^1 = \bar{r}_q^2$, and that $R_H^1 < R_H^2$ but $a_1 > a_2$. As before, $a_1 > a_2$ implies that $Q_1 < Q_2$ and $\Pi_1 > \Pi_{2.}$. But by lemma 7 and assumption 2 we conclude that $\Pi_2 > \Pi_1$ and we have a contradiction.

(iii) Assume by contradiction that $\bar{r}_q^1 < \bar{r}_q^2$ but that $a_1 > a_2$. We again conclude that $Q_1 < Q_2$. For the monopoly quantities corresponding to two different average cost levels we know from standard comparative analysis that $Q^M(\bar{r}_q^2) < Q^M(\bar{r}_q^1)$. This implies that $Q^M(\bar{r}_q^2) < Q^M(\bar{r}_q^1) < Q_1 < Q_2$. Also, aggregate profit decreases in average cost, i.e. $\frac{\partial \Pi}{\partial \bar{r}_q} = -Q < 0$. These relationships imply the following chain of inequalities:

$$\Pi_1 = \Pi(Q_1, \bar{r}_q^1) > \Pi(Q_1, \bar{r}_q^2) > \Pi(Q_2, \bar{r}_q^2) = \Pi_2$$

so the contradiction is achieved in the same way as before. ■

The comparative static results of theorem 6 provide the basis for our empirical section. In the next section we will investigate some stylized facts to confirm the implications of our model.

4 Empirical evidence: competition among NASDAQ dealers

4.1 Testable implications of the model

There are several testable empirical implications of the model presented in the previous section. In the symmetric case we conclude that:

- As the market size for the stock increases the number of dealers who trade the stock increases.

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[16] By the monopoly quantity we mean $Q^M = \arg\max_Q \frac{1}{2} Q (P_A(\alpha, Q) - \bar{v}) - Q\bar{r}_q$.

In the asymmetric case we conclude that:

1. The Herfindahl index and the average dealers' cost of capital are sufficient statistics to determine spreads.
2. Controlling for the average cost of capital, spreads decline as the market is less concentrated.
3. Controlling for concentration, spreads decline as the dealers trading the stock have a lower cost of capital.

Since our theoretical model does not specify any parametric form for the demand and the supply functions, we test these implications rather than estimate a fully specified model.

There is a considerable empirical literature focusing on bid–ask spread and estimating different components of the spread from the time series of changes in quotes and prices.[17] Our empirical analysis is different and is related to earlier work of Demsetz (1968), Stoll (1978a), Tinic and West (1974), Tinic (1972) who use cross sectional data. These studies find that spreads strongly depend on a number of security characteristics such as market capitalization, volume of trade, stock price, and return volatility. These variables proxy for costs of providing liquidity such as inventory risk, order processing, and adverse selection. According to our model, spreads also contain additional profit. Our results allow us to extend the empirical specifications used in previous studies to show that spreads are not limited to direct and indirect costs of market making. In our cross sectional study of spreads we include the variables that characterize competition among dealers. In the next section we discuss the choice of variables in detail. We then show that these variables are strongly significant in explaining spreads even when traditional controls for costs of market making are included.

Our paper is also related to the inventory models of competitive risk averse dealers such as in Amihud and Mendelson (1980), Garman (1976), Ho and Stoll (1980, 1981, 1983). That inventory level is an important concern of the dealers in financial markets has been recognized by several studies.[18] For example, Hansch, Naik and Viswanathan (1998) use data from the London Stock Exchange to show that dealers act as if there is a bound on the inventory position they can take. This is consistent with limited capacity analyzed in our model. The empirical evidence on risk aversion of market makers from inventory behavior appears to be mixed. Hansch, *et. al.* (1998) find the mean reversion in inventory levels which is consistent with risk aversion of the dealers. Other papers (e.g. Hasbrouck and Sofianos (1993), Madhavan and Smidt (1993)) analyze inventory behavior of the NYSE specialists and do not find the mean reversion.

Our model extends the understanding of dealership market beyond the inventory models. Inventory models rely on the assumption that dealers are risk averse. Bid-ask spread in this setting is a premium for bearing inventory risk and depends on inventory level and on risk aversion. Because risk aversion is not observable, some implications of risk averse dealer behavior for spreads are not testable. For example,

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[17] For time series models estimating the spread component see, for example, Glosten and Harris (1988) and Huang and Stoll (1997). Stoll (2000) provides a survey of this literature.

[18] See also, Stoll (1976), Lyons (1995).

when dealers are risk averse, larger stocks with more market makers may have lower spreads due to better risk sharing. However, the same effect may be due to lower direct costs of market making in larger stocks, or simply due to increased competition.[19] Our model has distinct implications from inventory models featuring competitive risk averse dealers. It points to the concentration as a proxy for market competitiveness distinguishing it from the effects of risk aversion.[20] We find, as predicted by the model, that spreads depend on concentration.

4.2 Data description and variables choice

We use all stocks traded on the NASDAQ market during 1996. This period was chosen for two reasons. First, the data set "Volume by market participants" is available only beginning with 1996. Second, this period precedes the new rules that were introduced by NASDAQ during 1997, and the spreads reported under the old rules are more appropriate for our purpose.[21] We use the following three sources of data:

1. "Volume by market participants" – This is a new dataset which was obtained from the NASD. For every stock traded on the NASDAQ market it reports volume of trade for every dealer on a monthly basis.[22]

2. TAQ – (Trade and Quotes data) We use this dataset to get spreads for each stock.

3. CRSP – (Center for Research in Securities Prices daily files) We use this dataset to extract closing prices, returns and number of shares outstanding.

Since our first data set is monthly, we build 12 monthly samples for 1996. The details of our sample construction are summarized in table 1. In an average month, the NASD data contains 6156 stocks of which 4916 had all TAQ and CRSP information necessary for our study. We then applied a filtering procedure to eliminate "penny stocks" and stocks that are highly illiquid. A stock was removed if any of the following was true: (i) average stock price in a given month was less than 10 cents; (ii) there was no volume on 50% or more of the trading days; (iii) there were no quotes on 20% or more of the trading days; (iv) average spread (as a percentage of midquote) was more than 10%. The motivation for these filters

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[19] Wahal (1997) and Huang and Masulis (1999) find that spreads decrease with more dealers.

[20] The comparative statics with respect to concentration is not valid when spreads are quoted by competitive risk averse dealers. In two markets for two distinct stocks with symmetric dealers the concentration of trading volume on average may be the same. However, if the dealers in one market are more risk averse than in the other, then spreads would be higher in this market too. If dealers were not symmetric then it would still be possible to have similar concentrations in the two markets while having levels of risk aversion in one market higher than in the other which would result in the higher spread.

[21] The new rules *per se* do not change the implications of our analysis. Spreads reported prior to the new rules are economically relevant and related directly to the spreads in our theoretical model. Under the new rules several changes were implemented. In particular, it became mandatory to display limit orders as quotes on the trading system. In our model we do not consider limit orders as they are part of the demand/supply which we do not model explicitly. The TAQ data that we use does not differentiate individual dealers' quotes from limit orders and reports only inside quotes. Thus, if we were to use data after the implementation of the new rules, the measure of spread would be contaminated by the limit orders.

[22] Participants in this data need not be registered market makers (e.g. as in Wahal (1997)). The only requirement is that the dealer traded in the stock, which is a better measure of the number of economically relevant dealers.

was to avoid microstructure effects that are not part of our theoretical model and which may significantly affect spreads. For, example (i) was applied to a avoid problems with price discreteness. Filters (ii),(iii) and (iv) all avoid stocks with extreme information asymmetry. Criteria (ii) and (iii) also remove stocks with little demand/supply, the prices of such stocks are likely to be determined by negotiations between seller/buyer and the executing dealer rather than via dealer's competition. The number of stocks rejected for each reason is indicated in table 1. Note that a stock may be rejected for multiple reasons, but most stocks were omitted based on high spreads. We also applied a filter which requires that at least 80% of the volume was from the dealers that we can identify from the NASD data. After applying these filters we are left with an average of 4187 stocks per month, with maximum of 4450 and minimum of 3774.

We now describe in detail the main variables used in this study and how they are computed. Table 2 reports summary statistics.

$Spread_i$ − We use average spread for stock i during month t. We use all valid TAQ quotes to compute average quoted inside spread as a percentage of a mid quote.[23]

N_i − Number of active dealers who traded in stock i. This was obtained from "Volume by market participants" and includes both registered dealers and non-registered dealers who reported trading in that stock.

$HERF_i$ − As a measure of $i-$th market concentration we use the Herfindahl index:

$$HERF_i = \sum_{k=1}^{N_i} \alpha_{i,k}^2$$

where $\alpha_{i,k}$, computed from "Volume by market participants", is the share of trade in stock i of dealer k . This index ranges from 0 to 1. A higher Herfindahl index corresponds to more concentrated market; a value of 1 indicates a monopolistic market while a value of 0 indicates a perfectly competitive market. Note, from table 2, that while the average stock has about 23 dealers, the average Herfindahl index is 0.2433 which is approximately the Herfindahl index we would get with four symmetric dealers.

$AVCAP_i$− Volume weighted capital of the dealers for the stock i. We use this variable as a proxy for dealers' cost of inventory and capital, which also can be interpreted as a proxy for dealers' size.[24] The motivation for this proxy was that a larger market making firm would have lower costs. It is difficult to obtain direct measures of either capital or costs. Most of the market making firms are privately held, and there is little public information available.[25] Hence, we use a proxy which can be computed from publicly

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[23] We excluded opening quotes and quotes during any kind of trading suspensions. We also used the effective spreads (average difference between quote midpoint and transaction price) in all our tests and found similar results (not reported).

[24] Another interpretation would be a proxy for cost due to risk aversion of a dealer. Larger firm would be able to diversify their inventory better and quote more aggressively, thus displaying a less risk averse behavior on average. As $AVCAP$ may not be a perfect proxy for all costs, later we add more common controls for the costs of market making.

[25] The only source we have found to contain direct capital measures of the dealership firms was the Securities Industry Association (SIA) yearbook. There are two difficulties with using their numbers. First, although SIA claims that 90% of securities firms in the US are the members of the SIA, we have found in the data many dealers who are not members. If we restrict our stock sample so that we can identify a relatively large fraction of the dealers by trading volume, the sample size would drop to only a few hundred stocks. Another difficulty when using the SIA yearbook is that the data is not recorded in a standard way. For example, many firms report the accounting data of their parent company.

available data as follows: for every member firm of the NASD we compute aggregate activity as the sum of all its trade across all NASDAQ stocks. If we denote by CAP_k the aggregate (dollar) volume of dealer k over all NASDAQ stocks then:

$$AVCAP_i = \sum_{k=1}^{N_i} \alpha_{i,k} CAP_k$$

$SIZE_i-$ Stock's average total market value in a current month (market capitalization).

4.3 Results

We start by estimating the dependence of the number of dealers on the size of the market:

$$N_i = a_0 + \sum_{k=1}^{3} a_i DUM_{k,i} SIZE_i + \sum_{k=1}^{2} a_{i+3} DUM_{k,i} + \varepsilon_i$$

We choose a piece-wise linear relation to account for non-linear effects.[26] The results of this regression are presented in table 3 . These results indicate strong evidence of a positive relation between market size and the number of dealers. We continue by examining the relation between spreads and a variety of factors.

First we examine the predictions of our model using only controls that the model suggests. Later we will add other, more traditional variables used in empirical microstructure to investigate the robustness of our original specification. We begin with the following regression:

$$Spread_i = a_0 + a_1 AVCAP_i + a_2 HERF_i + a_3 N_i + \varepsilon_i$$

The results of this regression are shown in table 4. These results indicate a significant relation between the spread and both the market concentration and our proxy for dealers' cost of capital. Note that even after cost is controlled for by $AVCAP$, the concentration enters significantly in this regression. Thus, even if part of the spreads variation was due to risk aversion or some other direct cost, our results indicate strong presence of additional spread component beyond that. Concentration is significant even though number of market makers is included, and unlike the number of market makers it unambiguously suggests that spreads depend on competition among dealers.

Consistent with our model, these results stand in contrast to Dutta and Madhavan (1997) who argue that a more concentrated market is more competitive. Our results are consistent with Laux (1995) who finds that the stocks which have large institutional holders have lower spreads. In our model, more generally, the markets with larger participants (or lower cost of capital) have lower spreads.

Note also that according to our model, when we control for concentration, the number of dealers does not affect spreads. Still, we find a significant negative coefficient on the number of dealers. This may be the result of misspecification in the regression or the result of error in our concentration measurement. If

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[26] We also tried a linear size specification instead of using dummy variables. Apparently the linear dependence is largely misspecified and gives lower R^2 of about 28%, while the specification with dummies results in R^2 of about 50%. For this reason we only report the specification with dummy variables. Also, increasing the number of size dummies does not improve the regression compared to the reported version.

either is the case, the number of dealers contains additional information about the concentration. Also, if dealers are risk averse, the spreads contain premium for bearing inventory risk. Increasing the number of dealers improves the risk sharing and decreases this component of spread. If $AVCAP$ imperfectly controls for costs due inventory risk, then number of dealers would contain additional information.

A potential problem in this regression is of cross sectional simultaneity. That is, there may exist some factor that influences both spreads and concentration. This non specified factor has the potential to create a bias in our estimation. To overcome this potential problem, we need to find an instrumental variable. According to our model, market size affects the spreads only through the entry decision. Hence, it is a valid instrument. We repeat the previous regression but use market size as an instrument for the Herfindahl index. The results, presented in table 5, are similar to the results of the previous regression (table 4).

One could further argue that market size is not a valid instrument. There are two main reasons for this concern. The first reason regards the validity of our assumptions. We have assumed that the demand function is homogenous of degree 1 in market size and that the cost function of capital is linear. These two assumptions imply that size affects spread only through the entry decision. The second reason is that the spread may contain costs of market making which are not described in our model. It is well known from the literature cited earlier that security characteristics (capitalization, return volatility, stock price, etc.) are strongly significant in explaining spreads. These characteristics may be correlated with direct and indirect (adverse selection, risk premium) costs of market making. It is less costly to make market in larger and more liquid stocks, less volatile stocks have lower inventory risk. Also, size and volatility may be correlated with information asymmetry which is an important determinant of spreads. Glosten and Milgrom (1985) have shown that a competitive uninformed dealer who faces a mixture of informed and uninformed traders will quote a positive bid-ask spread. This spread compensates the dealer for trading with informed traders. There are two factors that affect this cost: the fraction of informed investors and the amount of uncertainty regarding the stock's value.[27] Indeed, empirical studies find that spreads contain large adverse selection component. To control for the spread variation due to these additional costs we include in our regression the market capitalization and the standard deviation of daily return in the past six months, $RSTD_i$. Both variables are traditionally used in empirical market microstructure research and have been shown to be strongly significant in the cross-sectional regressions similar to those we consider here. We then estimate the following specification:

$$\begin{aligned} Spread_i &= a_0 + a_1 N_i + a_2 AVCAP_i + a_3 HERF_i \\ &+ \sum_{k=1}^{3} a_i DUM_{k,i} SIZE + \sum_{k=1}^{2} a_{i+3} DUM_{k,i} + RSTD_i + \varepsilon_i \end{aligned}$$

The results of this regression are presented in table 6. In line with earlier studies, this regression shows a very significant positive relation between spreads and volatility. This is consistent with costs due to both adverse selection and inventory risk. Size also comes in significantly negative which is consistent with the

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[27] One can show in the Glosten and Milgrom (1985) model that if noise traders are inelastic to prices, then the spread is linear in the return standard deviation. Thus, including it as a regressor provides an appropriate control for this effect.

hypothesis that it is less costly to make markets in larger and more liquid stocks. Note that the market concentration and our proxy for dealers' cost of capital remain strongly significant. These variables, again, point to the additional spread variation due to dealer competition.

Lastly we consider the temporal shocks, which could be another source of simultaneity. An example of such unanticipated effect is an information release which affects the public order-flow as well as the number of entrants to the market which might bias our estimation.[28] We can overcome this problem, assuming that such shock is uncorrelated with previous information and is not perfectly correlated across firms. We use one month lags of all variables in the previous regression as instruments. The results are presented in table 7. Although for some variables there was a small decrease in t-statistics, all variables remain statistically significant and did not change signs.

5 Conclusions

Our objectives in this paper have been to develop a rich yet simple model of competition in financial dealership markets. We investigate whether we can use "standard" measures of competition when examining those markets. We show that when dealers are limited in their ability to trade they are able to extract profits. This allowed us to endogenize dealers' entry decisions and relate the number of dealers and their size to the degree of competition. We established the existence of a Cournot type of equilibrium. We relate a measure of market concentration (the Herfindahl index) and dealers' characteristics to the degree of competition in the market. Hence, we describe markets which are not perfectly competitive but are not run by a monopolist market maker. We presented empirical evidence consistent with the model. We find strong cross–sectional variation in spreads beyond that captured by the traditional measures of costs of market making. We attribute this part of spreads to rents earned by dealers, as predicted by our model.

A potential extension is to examine how multiple dealers interact with traders who have some information. Many papers focus only on the actions of an informed investor when facing a competitive market maker. We hope to use the model developed here to examine how this behavior differ in the situation when multiple dealers possess market power. Another application would be to extend the existing models of spread components and to estimate the rents earned by the dealers. It would be interesting to see how these rents compare to the adverse selection and other costs commonly associated with spreads.

Appendix

Proof of Lemma 1:

The proof uses theorem 2 in Dasgupta and Maskin (1986a). We first note that the set of discontinuities is the set where there is a tie between quotes. This implies that the set of discontinuities in dealer i's payoff is a subset of a continuous manifold of degree less than N. Firm i's payoff is bounded by the monopoly

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[28] Wahal (1997) studies spreads as number of dealers in the stock changes dynamically.

payoff and is weakly lower semi-continuous in a_i. This follows as cutting prices by a small ε, increase dealer i's payoff by a discrete amount. Finally the total revenues of the N dealers is continuous in the quotes as the discontinuity points involve revenue transfers among dealers. Hence theorem 5 from Dasgupta and Maskin (1986b) can be applied and the existence of equilibrium follows. ■

Proof of lemma 5.

We prove by contradiction. We assume that $q_j = \max_k \{q_k\} > q_i$.

Step 1:$D^A(\ \overline{a}_i) > Q_{-i}$. When dealer i is quoting $\overline{a}_i$ he is guaranteed to quote the highest price. Note that dealer i can always make a strictly positive profit by quoting $D_A^{-1}(Q)$. For i to make a positive profit it must be that $D^A(\overline{a}_i) > Q_{-i}$.

Denote by L the set of agents who quote the lowest price, $\underline{a}$.

Step 2: $D^A(\underline{a}) \leq \sum_{l \in L} q_l$. Assume by contradiction that $D^A(\underline{a}) > \sum_{l \in L} q_l$. Then a dealer $l \in L$ instead of quoting $\underline{a}$ can quote an ask a^* so that $a^* > \underline{a}$, $D^A(a^*) > \sum_{l \in L} q_l$ and $a^* < \underline{a}_k$ for every $k \notin L$. But, $D^A(p^*) > \sum_{l \in L} q_l$ and $a^* < \underline{a}_k$ for all $k \notin L$ guarantees that dealer l would sell q_l shares, and since $a^* > \underline{a}$ dealer l would increase his profit.

Step 3: $j \in L$. Since $D^A(\underline{a}) > D(\ \overline{a})$ we conclude from Steps 1,2 that $\sum_{l \in L} q_l > Q_{-i}$. Since $q_j > q_i$ it must be that $j \in L$.

Step 4: $j's$ profit is $q_j\left(\underline{a} - \bar{v}\right)$ and is at least $R(Q_{-j})$. From Step 3 we conclude that $j's$ profit is at most $q_j\left(\underline{a} - \bar{v}\right)$. Since $D_A(\underline{a}) > D_A(\ \overline{a}_i) > Q_{-i}$, we conclude that $D_A(\underline{a}) > q_j$. Firm j can get at least $q_j(\underline{a}\text{-}\epsilon - \bar{v})$ by quoting $(\underline{a}\text{-}\epsilon)$. Since ϵ is arbitrary small the first part of the claim follows. The second part follows since $q_j > q_i$ and $q_i > s_A(Q_{-i})$ imply that $x_j > s_A(Q_{-j})$, (by differentiating the first order condition it can be shown that $\left|\frac{d}{dx}s_A(x)\right| < 1$).[29]

Step 5: dealer $i's$ profit, which by Lemma 4 equals $R(Q_{-i}$, is at least $q_i\left(\underline{a} - \bar{v}\right)$. Since $D(\underline{a}) \geq q_j > q_i$, dealer i could get at least $q_i(\underline{a}\text{-}\epsilon - \bar{v})$ by quoting $(\underline{a}\text{-}\epsilon)$. Since ϵ is arbitrarily small the claim follows.

We now introduce new notation, let $Q_{-i,j} = Q - q_i - q_j$ and

$$\Theta(q) = q s_A(Q_{-i,j} + q)\left(P\left(Q_{-i,j} + q + s_A(Q_{-i,j} + q)\right) - \bar{v}\right)$$

Step 6: $\Theta(q_j) \geq \Theta(q_i)$. From Steps 4,5 we have: $q_j\left(\underline{a} - \bar{v}\right) \geq R(Q_{-j})$ and $R(Q_{-i}) \geq q_i\left(\underline{a} - \bar{v}\right)$. These two inequalities imply that $q_j R(Q_{-j}) \geq q_i R(Q_{-i})$.

Step 7: $P_A(Q_{-i,j} + q + s_A(Q_{-i,j} + q)) + s_A(Q_{-i,j} + q)P'(Q_{-i,j} + q + s_A(Q_{-i,j} + q)) = \overline{v}$. This follows from first order conditions of:

$$s_A(Q_{-i,j} + q) = \arg\max_x x\left(P_A(Q_{-i,j} + q + x) - \bar{v}\right).$$

Step 8: $\Theta'(q) = \left(s_A(Q_{-i,j} + q) - q\right)\left(P_A(Q_{-i,j} + q + s_A(Q_{-i,j} + q)) - \bar{v}\right)$. Differentiating $\Theta(x)$ using Step 7, yields:

$$\Theta'(q) \quad = \quad \left[q \cdot s_A(Q_{-i,j} + q)\left(P(Q_{-i,j} + q + s_A(Q_{-i,j} + q)) - \bar{v}\right)\right]'$$

---

[29] See for example Tirole (1988) p. 231.

$$
\begin{aligned}
&= s_A(Q_{-i,j}+q)\left(P(Q_{-i,j}+q+s_A(Q_{-i,j}+q))-\bar{v}\right)+\\
&\quad q\cdot s_A(Q_{-i,j}+q)\left(P(Q_{-i,j}+q+s_A(Q_{-i,j}+q))-\bar{v}\right)+\\
&\quad (1+s'_A(Q_{-i,j}+q))\, q\cdot s_A(Q_{-i,j}+q)P'(Q_{-i,j}+q+s_A(Q_{-i,j}+q))\\
&= (s_A(Q_{-i,j}+q)-q)\left(P(Q_{-i,j}+q+s_A(Q_{-i,j}+q))-\bar{v}\right)+\\
&\quad q\,(1+s'_A(Q_{-i,j}+q))\times\\
&\quad [P(Q_{-i,j}+q+s_A(Q_{-i,j}+q))-\bar{v}+s_A(Q_{-i,j}+q)P'(Q_{-i,j}+q+s_A(Q_{-i,j}+q))]
\end{aligned}
$$

By Step 7

$$P(Q_{-i,j}+q+s_A(Q_{-i,j}+q))-\bar{v}+s_A(Q_{-i,j}+q)P'(Q_{-i,j}+q+s_A(Q_{-i,j}+q))=0,$$

and the claim follows.

Step 9 (contradiction): Since $s_A(Q_{-i,j})>0$, and $r(\cdot)$ is decreasing we know that there exists a unique q^* which satisfies $q^*=s_A(Q_{-i,j}+q^*)$, moreover, $q<s_A(Q_{-i,j}+q)$ for $q<q^*$ and $q>s_A(Q_{-i,j}+q)$ for $q>q^*$. By Step 8 we then conclude that $\Theta'(q)$ is positive for $q<q^*$ and negative for $q>q^*$. ¿From Step 6 we know $\Theta(q_j)-\Theta(q_i)=\int_{q_i}^{q_j}\Theta'(q)>0$, which implies that $q_i<q^*$. Define $\hat{q}$ by $q_i=s_A(Q_{-i,j}+\hat{q})$, since $q_i<q^*$, and $q_i>s_A(Q_{-i,j}+q_j)$ (Lemma 4) we have, $\hat{q}\in(q_i,q_j)$. Using the fact that $\Theta(\cdot)$ is increasing for $q<q^*$ and decreasing for $q>q^*$ together with $\hat{q}\in(q_i,q_j)$ and $\Theta(q_j)-\Theta(q_i)>0$ we conclude that $\Theta(\hat{q})-\Theta(q_i)>0$. But,

$$
\begin{aligned}
\Theta(\hat{q})-\Theta(q_i) &= \hat{q}s_A(Q_{-i,j}+\hat{q})\left(P_A(Q_{-i,j}+\hat{q}+s_A(Q_{-i,j}+\hat{q}))-\bar{v}\right)-\\
&\quad q_i s_A(Q_{-i,j}+q_i)\left(P_A(Q_{-i,j}+q_i+s_A(Q_{-i,j}+q_i))-\bar{v}\right)\\
&= q_i\left(\hat{q}P_A(Q_{-i,j}+\hat{q}+q_i)-s_A(Q_{-i,j}+q_i)P_A(Q_{-i,j}+q_i+s_A(Q_{-i,j}+q_i))\right)
\end{aligned}
$$

and by the definition of $s_A(Q_{-i,j}+q_i)$ we conclude that:

$$s_A(Q_{-i,j}+q_i)P(Q_{-i,j}+q_i+r(Q_{-i,j}+q_i))\geq\hat{q}P(Q_{-i,j}+q_i+\hat{q})$$

and therefore $\Theta(\hat{q})-\Theta(q_i)\leq 0$ ■

Proof of lemma 7:

Proof. The period 1 sub game ask side aggregate profits are given by:

$$\Pi=\frac{1}{2}\sum_i q_i\left(a-\bar{v}-2r_{q,i}\right)=\frac{1}{2}Q\left(a-\bar{v}-2\bar{r}_q\right)$$

From the first order condition of

$$q_i=\max_q\frac{1}{2}\left[qP_A\left(q+Q_{-i}\right)-q\bar{v}\right]-r_{q,i}q$$

it follows that: $a-\bar{v}-2\bar{r}_q=-q_iP'_A(Q)$, which implies that aggregate profit is also given by:

$$\Pi=-\frac{1}{2}\sum_i q_i^2P'_A(Q)=-\frac{1}{2}Q^2P'_A(Q)\,R_H$$

■

References

Amihud, Yakov, and Haim Mendelson, 1980, Market making with inventory, *Journal of Financial Economics* 8, 31–54.

Bernhardt, Dan, and Eric Hughson, 1997, Splitting orders, *The Review of Financial Studies* 10, 69–101.

Biais, Bruno, 1993, Price formation and liquidity in fragmented and centralized markets, *Journal of Finance* 48, 157–185.

Christie, William G., and Paul H. Schultz, 1994, Why do NASDAQ market makers avoid odd eights quotes?, *Journal of Finance* 49, 1841–1860.

Copeland, T. E., and D. Galai, 1983, Information effects on the bid-ask spread, *Journal of Finance* 31, 1457–1469.

Dasgupta, Partha, and Eric Maskin, 1986a, The existence of equilibrium in discontinous economic games, i: Theory, *The Review of Economic Studies* pp. 1–26.

———, 1986b, The existence of equilibrium in discontinous economic games, ii: Applications, *The Review of Economic Studies* pp. 27–42.

Davidson, Carl, and Raymond Deneckere, 1984, Horizontal mergers and collusive behavior, *International Journal of Industrial Organization* 2, 117–132.

Demsetz, Harold, 1968, The cost of transacting, *The Quarterly Journal of Economics* 82, 33–53.

Dennert, Jürgen, 1993, Price competition between market makers, *Review of Economic Studies* 60, 735–751.

Garman, Mark, 1976, Market microstructure, *Journal of Financial Economics* 3, 257–275.

Glosten, Lawrence R., and Lawrence E. Harris, 1988, Estimating the components of the bid–ask spread, *Journal of Financial Economics* 21, 123–142.

Glosten, Lawrence R., and Paul R. Milgrom, 1985, Bid, ask and transaction prices in a specialist market with heterogeneously informed traders, *Journal of Financial Economics* 14, 71–100.

Grossman, Sanford J., and Merton H. Miler, 1988, Liquidity and market structure, *Journal of Finance* 43, 617–37.

Hagerty, Kathleen M., 1991, Equilibrium bid-ask spreads in markets with multiple assets, *The Review of Economic Studies* 58, 237–57.

Hansch, Oliver, Narayan Y. Naik, and S. Viswanathan, 1998, Do inventories matter in dealership markets? evidence from the london stock exchange, *Journal of Finance* 53, 1623–56.

Hasbrouck, Joel, and George Sofianos, 1993, The trades of market makers: An analysis of NYSE specialists, *Journal of Finance* 48, 1565–1594.

Ho, Thomas, and Hans R. Stoll, 1980, On dealer markets under competition, *Journal of Finance* 35, 259–267.

———, 1981, Optimal dealer pricing under transaction and return uncertainty, *Journal of Financial Economics* 9, 47–73.

Ho, Thomas S. Y., and Hans R. Stoll, 1983, The dynamics of dealer markets under competition, *Journal of Finance* 38, 1053–74.

Huang, Roger D., and Ronald W. Masulis, 1999, FX spreads and dealer competition across the 24-hour trading day, *The Review of Financial Studies* 12, 61–93.

Huang, Roger D., and Hans R. Stoll, 1997, The components of the bid–ask spread: A general approach, *The Review of Financial Studies* 10, 995–1034.

Kandel, Eugene, and Leslie Marx, 1997, NASDAQ market structure and spreads patterns, *Journal of Financial Economics* 45, 61–90.

Kreps, David, and Jose Scheinkman, 1983, Quantity precommitment and bertrand competition yield cournot outcomes, *Bell Journal of Economics* 14, 326–337.

Kyle, Albert S., 1985, Continous auctions and insider trading, *Econometrica* 53, 1315–35.

Laux, Paul, 1995, Dealer market structure, outside competition, and the bid–ask spread, *Journal of Economic Dynamics and Control* 19, 683–710.

Lyons, Richard, 1995, Tests of microstructure hypotheses in the foreign exchange market, *Journal of Financial Economics* 39, 321–351.

Madhavan, Ananth, and Seymour Smidt, 1993, An analysis of daily changes in specialist inventories and quotations, *Journal of Finance* 48, 1595–1628.

Roell, Ailsa, 1999, Liquidity in limit order book markets and single price auctions with imperfect competition, *working paper.*

Stoll, Hans R., 1976, Dealer inventory behavior: An empirical investigation of NASDAQ stock, *Journal of Financial and Quantitative Analysis* 11, 359–380.

——— , 1978a, The pricing of security dealer services: An empirical study of NASDAQ stocks, *Journal of Finance* 33, 1153–72.

——— , 1978b, The supply of dealer services in securities markets, *Journal of Finance* 33, 1133–51.

——— , 2000, Friction, *forthcoming Journal of Finance.*

Tinic, Seha M., 1972, The economics of liquidity services, *The Quarterly Journal of Economics* 86, 79–93.

——— , and Richard R. West, 1974, Marketability of common stocks in Canada and the USA: A comparison of agent vs. dealer dominated markets, *Journal of Finance* 29, 729–746.

Tirole, Jean, 1988, *The Theory of Industrial Organization* (MIT Press).

Viswanathan, S., and Wang, 1999, Market architecture: Limit-order books versus dealership markets, *working paper.*

Wahal, Sunil, 1997, Entry, exit, market makers and the bid-ask spread., *Review of Financial Studies* 10, 871–901.

Table 1: Sample construction. Stock may have multiple reasons for omission. Low volume stocks had no volume on 50% or more of the trading days. Missing quotes stocks had no quotes on 20% or more of the trading days. High spread stocks had average quoted spread exceeding 10%. Small price stocks had average price less than 10 cents. Finally, we dropped the stocks with more than 80% of the volume traded by dealers who were not on the NASD dealers master file.

	Average	Maximum	Minimum
Traded stocks	6156	6428	5810
TAQ and CRSP data available	4916	5217	4568
Used for analysis	4187	4450	3774

Reasons for omission:			
Low volume	12	14	8
Missing quotes	3	5	0
High spread	684	755	591
Small price	48	69	36
Dealers unidentified	15	17	11

Table 2: Summary statistics

	Averages across all months in 1996				
Variable	25%	Median	75%	Mean	Standard deviation
Spread (%)	2.1611	3.5360	5.5060	4.0036	2.3068
N	10.8333	17.4167	28.0000	23.0766	21.9509
$AVCAP$ (in \$10M)	0.2334	0.3017	0.3814	0.3162	0.1289
$HERF$	0.1273	0.1967	0.3123	0.2433	0.1615
$SIZE$ (in \$100M)	0.3326	0.8165	2.1168	3.0683	18.2072

Table 3: Cross-sectional regressions. For each month in 1996 we run the following regression:

$$N_i \quad = \quad a_0 + \sum_{k=1}^{3} a_i DUM_{k,i} SIZE_i + \sum_{k=1}^{2} a_{i+3} DUM_{k,i} + \varepsilon_i$$

where for each stock i:
N_i- Number of active dealers.
$SIZE_i-$ market capitalization.
$DUM_{1,i}-$ Size dummy for the lowest 33 percentile.
$DUM_{2,i}-$ Size dummy for the middle 33 percentile.
$DUM_{3,i}-$ Size dummy for the highest 33 percentile.

	Averages across all months in 1996	
Variable	Coefficient	t-statistic
const	32.3842	66.9519
DUM_1SIZE	14.0967	3.2900
DUM_2SIZE	6.4042	3.8689
DUM_3SIZE	0.4963	31.4135
DUM_4	-22.6639	-18.4329
DUM_5	-18.4217	-11.7331
R^2 (%)	35.7883	-

Table 4: Cross-sectional regressions. For each month in 1996 we run the following regression:

$$Spread_i = a_0 + a_1 AVCAP_i + a_2 HERF_i + a_3 N_i + \varepsilon_i$$

where for each stock i:
$Spread_i -$ average quoted inside spread (percentage of mid-quote).
$AVCAP_i -$ proxy for average cost of capital.
$HERF_i -$ Herfindahl index.
$N_i -$ number of dealers.

	Averages across all months in 1996	
Variable	Coefficient	t-statistic
Constant	5.1370	41.6081
$AVCAP$	-1.9461	-7.6616
$HERF$	2.0492	9.4260
N	-0.0446	-26.8532
R^2 (%)	24.2269	-

Table 5: Same regression as in table 4, except using size as an instrument for the Herfindahl index.

$$Spread_i = a_0 + a_1 AVCAP_i + a_2 HERF_i + a_3 N_i + \varepsilon_i$$

where for each stock i:
$Spread_i -$ average quoted inside spread (percentage of mid-quote).
$AVCAP_i -$ volume weighted capital proxies of all participants.
$HERF_i -$ Herfindahl index.
$N_i -$ number of dealers.

	Averages across all months in 1996	
Variable	Coefficient	t-statistic
Constant	4.1149	7.7164
$AVCAP$	-1.8301	-6.7645
$HERF$	5.1014	3.3384
N	-0.0341	-6.0396

Table 6: Cross-sectional regressions results when fitting a piece-wise linear relation for size. For each month in 1996 we run the following regression:

$$\begin{aligned} Spread_i &= a_0 + a_1 N_i + a_2 AVCAP_i + a_3 HERF_i \\ &+ \sum_{k=1}^{3} a_{i+3} DUM_{k,i} SIZE_i + \sum_{k=1}^{2} a_{i+6} DUM_{k,i} + a_9 RSTD_i + \varepsilon_i \end{aligned}$$

where for each stock i:

$Spread_i-$ average quoted inside spread (percentage of mid-quote).

N_i- number of dealers.

$AVCAP_i-$ volume weighted capital proxies of all participants.

$HERF_i-$ Herfindahl index.

$SIZE_i-$ market capitalization.

$DUM_{1,i}-$ Size dummy for the lowest 33 percentile.

$DUM_{2,i}-$ Size dummy for the middle 33 percentile.

$DUM_{3,i}-$ Size dummy for the highest 33 percentile.

$RSTD_i-$ Standard deviation of daily returns.

	Averages across all months in 1996	
Variable	Coefficient	t-statistic
Constant	2.4159	19.0833
N	-0.3953	-2.0905
$AVCAP$	-0.0339	-13.6627
$HERF$	2.0751	12.1059
$DUM_1 SIZE$	-0.0002	-7.1066
$DUM_2 SIZE$	-0.0001	-3.8906
$DUM_3 SIZE$	0.0000	7.1274
DUM_1	2.6926	37.2746
DUM_2	1.3189	19.1043
$RSTD$	3.6590	28.7175
R^2 (%)	58.7541	-

Table 7: The same as table 6, except that we add instruments for concentration, number of market makers, standard deviation and dealers' cost of capital using lagged data of the same variables:

$$\begin{aligned} Spread_i &= a_0 + a_1 N_i + a_2 AVCAP_i + a_3 HERF_i \\ &+ \sum_{k=1}^{3} a_{i+3} DUM_{k,i} SIZE_i + \sum_{k=1}^{2} a_{i+6} DUM_{k,i} + a_9 RSTD_i + \varepsilon_i \end{aligned}$$

where for each stock i:
$Spread_i-$ average quoted inside spread (percentage of mid-quote).
N_i- number of dealers.
$AVCAP_i-$ volume weighted capital proxies of all participants.
$HERF_i-$ Herfindahl index.
$SIZE_i-$ market capitalization.
$DUM_{1,i}-$ Size dummy for the lowest 33 percentile.
$DUM_{2,i}-$ Size dummy for the middle 33 percentile.
$DUM_{3,i}-$ Size dummy for the highest 33 percentile.
$RSTD_i-$ Standard deviation of daily returns.

	Averages across all months in 1996	
Variable	Coefficient	t-statistic
Constant	2.1608	10.8477
N	-0.2632	-0.9724
$AVCAP$	-0.0349	-9.1231
$HERF$	2.8469	9.2523
DUM_1SIZE	-0.0002	-4.9631
DUM_2SIZE	-0.0001	-2.5999
DUM_3SIZE	0.0000	6.0271
DUM_1	2.4310	31.1067
DUM_2	1.2029	16.3687
$RSTD$	3.8892	27.0354