THE JOURNAL OF FINANCE • VOL. LV, NO. 3 • JUNE 2000

Price Discovery without Trading: Evidence from the Nasdaq Preopening

CHARLES CAO, ERIC GHYSELS, and FRANK HATHEWAY*

ABSTRACT

This paper studies Nasdaq market makers' activities during the one and one-half hour preopening period. Price discovery during the preopening is conducted via price signaling as opposed to the auction used to open the NYSE or the continuous market used during trading. In the absence of trades, Nasdaq dealers use crossed and locked inside quotes to signal to other market makers which direction the price should move. Furthermore, we find evidence of price leadership among market makers that bears little resemblance to their IPO/SEO lead underwriter participation.

A FUNDAMENTAL ISSUE IN THE STUDY of market microstructure is the process through which new information is incorporated into security prices. The several mechanisms known to exist include continuous markets, auction markets, price experimentation, and price signaling. The finance literature has studied continuous markets extensively. For example, numerous theoretical papers have developed structural models that provide important insights into the learning process faced by market makers in continuous markets. Copeland and Galai (1983), Glosten and Milgrom (1985), and Easley and O'Hara (1987) are only a few of the many prominent papers on the subject.[1] Empirically, many studies analyze price and trade data and their informational content, with a focus on price discovery during trading periods (see Glosten and Harris (1988), Hasbrouck (1988, 1991), Easley et al. (1996), and Madhavan, Richardson and Roomans (1997), among others).[2] There is also

* Penn State University; Ghysels is also at CIRANO. We thank an anonymous referee, René Stulz (the editor), Gurdip Bakshi, Bruno Biais, Ananth Madhavan, Leslie Marx, Ron Masulis, Harold Mulherin, Ken Nyholm, Paul Schultz, Lemma Senbet, Erik Sirri, George Sofianos, Chester Spatt, Hans Stoll, and seminar participants at Penn State University, the SEC, the University of Maryland, George Washington University, 1998 EFA meetings, the 1998 Market Microstructure Conference in Paris, 1999 AFA meetings, the 1999 Nasdaq–Notre Dame Microstructure Conference, and 1999 WFA meetings for helpful comments. Mike Chernov provided invaluable research assistance. This paper was selected for the NYSE Award for Best Paper on Equity Trading at the 1999 WFA meetings.

[1] For a unified exposition and examination of the major models and theories in market microstructures see O'Hara (1995).

[2] For major U.S. equity markets, the trading period is from 9:30 a.m. to 4:00 p.m. Although off-hours trading is possible (e.g., Crossing Sections I and II on the NYSE, and InstiNet on Nasdaq), its volume is negligible. For example, in 1996 the NYSE average volume was 412 million shares and Crossing Sections I and II averaged 2.5 million shares per day, according to the *1996 NYSE Fact Book*.

an extensive literature on auction markets (see, e.g., Kyle (1985), Amihud and Mendelson (1987), Stoll and Whaley (1990), Madhavan (1992), and Pagano and Röell (1996)) emphasizing the NYSE opening and U.S. Treasury auctions.

The two remaining mechanisms of price experimentation and price signaling have received far less attention. One important contribution to this literature is the work of Leach and Madhavan (1993), who provide a theoretical model of price experimentation where market makers have the ability to expedite price discovery through price experiments. In addition to their theoretical model, the price quotations of an NYSE specialist are used as an empirical example to study price experimentation. There is also an emerging theoretical literature on price signaling. Spatt and Srivastava (1991) show the importance of nonbinding price signals to an issuer in the IPO process. They also point out the potential importance of informal communication via an "indication of interest" on the NYSE.

This paper studies the use of Nasdaq market makers' preopening quotes as signals for price discovery. By focusing on price signaling, our paper continues the tradition of Bagehot (1971) and Garman (1976) in the research of price discovery. As a tool for price discovery, price signaling occurs in the foreign exchange market, the secondary market for bonds, in many goods markets, and in the preopening sessions of the NYSE, the Paris Bourse, and the Nasdaq. In the foreign exchange and the secondary bond markets, indicative price signals are widely disseminated even as transaction prices remain confidential. Some product markets, such as steel, automobiles, and airlines, are often characterized by signaling in advance of expected price changes.

Prior research on price signaling as a mechanism of price discovery has often confounded the informational effect of the nonbinding price signals with that of contemporaneously occurring transactions. This paper differs from previous studies in that it emphasizes the combination of nontrading periods and nonbinding signals in studying the informational content of price quotation signals when there is no trading. On Nasdaq during the preopening, individual market makers' indicative quotes are displayed and widely disseminated in the absence of trading. In particular, we examine all of the market maker quotes and identifications collected during the preopening period for the 50 most active Nasdaq National Market issues in 1994. This set of approximately 800,000 preopening quotes provides insights into the role of signaling for price discovery. We are able to identify different types of signals, establish that there is price leadership among market makers, and explore the linkages between price leadership and IPO/SEO underwriting relationships.

Nasdaq features an *inside quote* mechanism that is a combination of the highest bid and the lowest ask across all market makers. We find that the preopening often involves *crossed* and *locked* inside quotes, where the highest bid price is respectively greater than or equal to the lowest ask. The percentage of all inside quotes that are crossed and locked are 24 and 11 percent respectively. In contrast, such unbalanced inside quotes occur only 0.3 per-

cent of the time during regular trading hours.[3] We find that the direction of crosses and locks is strongly associated with the evolution of the price between the close and the open, consistent with signaling. Further, there is evidence of leadership in creating crossed and locked market conditions. In each stock the top three market makers account for an average of 40 percent of the price contribution during crossed markets but they represent only nine percent of the quote frequency during the preopening.[4] There is also a distinction between crosses and locks: Crosses carry a much stronger signal than locks. We identify a difference in the *types* of market makers who tend to cross the market and those involved in locks. The main protagonists for crossed markets are the full-service brokers who engage in strong price signaling during the preopening. A more modest role is played by large wholesale brokers who engage more actively in locking markets, sending much weaker signals to other Nasdaq dealers. In summary, the results show that nonbinding price quotes contain important information, and there is significant price discovery during the preopening period which is driven by the types of signals used and the identities of the market makers who transmit the signals.

This paper is part of an emerging literature about the role of the preopening. Biais, Hillion, and Spatt (1999) focus on the Paris Bourse and discuss the coordination game and learning mechanism that takes place during the preopening session. They find strong evidence of active learning during the preopening session. Madhavan and Panchapagesan (2000) cover the role of the specialist at the NYSE in determining the opening price. They present convincing evidence that specialists facilitate price discovery at the opening by setting more efficient prices than would prevail in an auction using public orders. There are significant differences in market opening procedures between the NYSE (stabilized auction market), the Paris Bourse (public limit-order book), and the Nasdaq (dealer market with price signaling). An examination of the ability of the Nasdaq preopening session to facilitate price discovery and impound overnight information into the opening price provides more insight into the functioning of preopening sessions.

Extant studies on the subject of price signaling also document leadership patterns. Peiers (1997) identifies price leadership patterns in interbank quotes during trading hours on foreign exchange markets. These quotes are similar to Nasdaq preopening quotes as they are indicative and nonbinding, but they differ in that a substantial volume of trading is occurring contemporaneously. Consequently, it is a noisier test of price signaling than the Nasdaq preopening.

[3] In principle, inside crosses and locks are discouraged during trading hours according to Nasdaq regulations. The market maker who creates a cross or a lock often is contacted by Nasdaq officials to resolve the cross or lock quickly. Under rule 4613, the market makers are also obligated to trade at their unbalanced bid and ask prices and therefore risk monetary losses should they lock or cross a market. Evidence of such risks have been documented in the literature on small order execution system (SOES) bandits; see for instance Battalio, Hatch, and Jennings (1997) and Harris and Schultz (1998).

[4] As explained in Section IV, we define the top three market makers in terms of their price contribution.

There is an additional role for preopening price discovery on Nasdaq besides the daily start of trading. Before trading opens in Nasdaq IPOs, there is a (midday) preopening session during which market makers post nonbinding quotes for the new stocks in a manner similar to the start of the trading day. Aggrawal and Conroy (1999) study the initial price discovery process of IPOs on Nasdaq, including the dominance of the lead underwriter. Ellis, Michaely, and O'Hara (2000), among others, examine the relationship between market making in the IPO aftermarket and the underwriting of IPOs. They find a strong association between market making and underwriting activity over the short term. Yet the question of whether there is a long-term association is unanswered. We find that IPO and SEO underwriters, in aggregate, contribute only a small fraction to price discovery during the daily preopening period. This finding suggests that IPO and SEO underwriters' short-term association with market making activity does not spill over into longer horizons for the actively traded stocks comprising our sample. This is in sharp contrast to the significant short-term association between market making activity and underwriting.

Our paper also yields insights on the differences in close-to-open price reaction to overnight news announcements across markets. Greene and Watts (1996) examine the difference between the NYSE and the Nasdaq reaction to overnight earnings announcements, and find that the Nasdaq opening mechanism impounds more of the nontrading hours' information into the price. Masulis and Shivakumar (1997) compare the speed of price adjustment for stocks on the NYSE/AMEX with the speed on Nasdaq to overnight seasoned equity offering announcements. They find that Nasdaq stocks react much faster to SEO announcements than do NYSE/AMEX stocks. The faster Nasdaq response is surprising given that these stocks are less frequently traded and have smaller equity capitalization than the NYSE/AMEX stocks. Our results reveal that the faster price adjustment for Nasdaq stocks is attributed to the informational role of the preopening session: The Nasdaq preopening is a significant coordination vehicle to absorb the price shock and to facilitate price discovery in such cases.

Finally, the nature of our data set and the institutional settings of Nasdaq provide a unique perspective for exploring a number of issues raised in the broader literature. In particular, game theorists study games of coordination and pre-play without firm commitments. The game theory literature has coined the term "cheap talk" to designate situations analogous to the preopening where Nasdaq market makers communicate without commitment (see Farrell and Rabin (1996) for a recent survey). The phenomenon of preopening activity on the Nasdaq provides an interesting study of the nature of the communication game in the absence of firm commitments.[5] Relatively

[5] The informativeness of preopening quotes enable Nasdaq dealers to identify potential noncooperative strategies, which lead to "proposed" or "suggested" prices, using the terminology of Dutta and Madhavan (1997).

little empirical evidence exists about such phenomena. In fact, the absence of data has recently prompted some researchers to use laboratory experiments to analyze noncredible communication (cheap talk) in the new issues market. In a recent paper, Forsythe, Lundholm, and Rietz (1999) examine communication in laboratory games with asymmetric information and show how cheap talk improves market efficiency but falls short of the perfect information outcome. We examine a similar issue of information revelation but with actual market data.

The paper is organized as follows. Section I describes the institutional environment of the Nasdaq preopening. Section II describes the preopening data. Section III provides evidence of price discovery during the preopening. In Section IV, we examine leadership among market makers and its characteristics. Concluding remarks are offered in Section V.

I. The Preopening Session on the Nasdaq

The Nasdaq Stock Market is an electronic securities market composed of competing market makers whose trading is supported by a communications network that includes quote dissemination, trade reporting, and order execution systems. Trading in individual stocks is characterized by a multiple dealer market in which participants are required to display their individual bid and ask quotes on the system. The reported inside quotes (e.g., the best bid-ask prices) consist of the highest bid and the lowest ask quotes posted by the market makers. The Nasdaq reporting system updates the inside quote whenever a dealer updates his quotes and either exceeds the highest bid or undercuts the lowest ask and therefore affects the existing best bid-ask quotes.[6] Although the trading system opens at 9:30 a.m., the quotation reporting system of the Nasdaq market opens much earlier. The first quotation of the day typically is at around 8:15 a.m. During the preopening period from 8:00 to 9:30 a.m., market makers transmit their bid-ask quotes, observe other dealers' quotes and identity, and, most importantly, revise their own quotes in response to the quotes of others. One important difference between the preopening quotes and those posted during trading hours is that preopening quotes are nonbinding. In contrast, dealers are obligated to honor their quotes for the minimum quantity of up to 1,000 shares during trading hours.[7] Al-

[6] In January 1997, the Securities and Exchange Commission implemented reforms that permit the public to submit limit orders and to compete with Nasdaq market makers. The reform also mandates display of customer limit orders and superior quotes placed in proprietary trading system (see Barclay et al. (1999)). These rules do not apply to our sample period and most do not apply to the preopening.

[7] The minimum display size, and hence the minimum quantity that must be honored, varies substantially across time and across stocks. For our sample stocks during the interval of the study, our data reveal that dealers almost invariably display 1,000 shares. In March 1995, Nasdaq switched from a 500-share minimum to 1,000. As of March 1998, the rule is 1,000 shares (200 or 500 for less active stocks).

though dealers can execute trades during the preopening on the interdealer electronic communication network (ECN) markets, trading activity is negligible.[8]

The Nasdaq system contains no formal order-matching procedure for the opening of trading. At 9:30 a.m., Nasdaq market makers may begin entering trades into the system. Individual market makers are expected to report transactions in chronological sequence within 90 seconds of execution.[9] These conditions prevail throughout the trading day. Volume is typically very high during the first few minutes of trading. Chan, Christie, and Schultz (1995) provide a detailed analysis of the price discovery process during Nasdaq trading hours and elaborate on its institutional aspects. They note that early trading is characterized by a large number of small trades, with an average size of 1,300 shares, after which the average trade size increases substantially to 2,400 shares.

All registered market makers in a stock are under an affirmative obligation to quote firm prices after the opening or jeopardize their market maker status in that stock. In contrast, market makers are under no obligation to quote during the preopening period. This raises the question of why they would quote at all. If they do quote, why would the quote be a credible signal to the market? To address this, we need to consider the institutional issues of the best bid-ask price, the practice of displaying only the minimum required size, Nasdaq rules on best execution, the stability of the population of active market makers in a given stock over time, and the role of preferencing.[10]

There are a number of institutional factors that, taken together, limit the ability of market makers to act as informed traders and exploit their private information, as described in Kyle (1985). In principle, any informed market maker with short-lived private information regarding order flow or prospects for the company's stock could choose not to reveal his information prior to the market opening and exploit the value of the information when trading starts. However, under Nasdaq rules the counterparty dealer is only obligated to trade his displayed size or the Nasdaq minimum at that market maker's posted price. In practice, Nasdaq dealers routinely post the mini-

[8] There are a number of ECNs, the most active of which is InstiNet. Using the Trade and Quote (TAQ) database to extract ECN trades before 9:30 a.m., the preopening volume is about 0.5 percent of the volume traded between 9:30 a.m. and 4:00 p.m. during our sample period. To identify such trades we use Rule 6620 trades. Rule 6620 requires that all trades (including InstiNet trades) during the preopening by NASD member firms be reported.

[9] A recent study by Porter and Weaver (1998) finds that out-of-sequence reporting was substantial on the Nasdaq system in 1990. They also find that the frequency of late trade reports fell dramatically after their results were made public.

[10] Preferencing refers to the practice of directing an order to any market maker who has agreed in advance to execute orders at the best quoted price, regardless of the prices actually quoted by the market maker to whom the order is directed. As a result of preferencing, market makers who offer the best price do not necessarily attract more order flow. According to Battalio, Greene, and Jennings (1997) and Godek (1996), virtually all Nasdaq market makers are preference traders. In related work, Christie and Schultz (1994), Huang and Stoll (1996), and Kandel and Marx (1999) discuss the role that preferencing can play in reducing price competition.

mum quote size during our sample period, so an informed dealer may be limited in his ability to purchase (or sell) a large number of shares. On the other hand, the informed dealer also has the obligation to act as a market maker and quote a two-sided market. Furthermore, a market maker receiving an order to trade must execute that order consistent with Nasdaq rules on best execution, typically at the prevailing best bid-ask spread. If the informed dealer receives a customer order on the same side of the market, he must either execute that order against his own account or allow the order to trade ahead of him against the uninformed dealer. The problem of exploiting private information is compounded if the informed market maker has a preferencing contract and is obligated to trade the customer order at the prevailing best bid-ask spread against his own account. A final point is that stability of the registered market maker community in a stock makes the preopening a repeated game in which reputation may limit the ability of informed dealers to take advantage of their information by trading against their fellow market makers. A market maker who exploits his information at the expense of other dealers may find them unwilling to trade with him in the future.

On the other hand, non–market makers can exploit private information against the market maker since each market maker tends to take the other side from his clients' orders.[11] Therefore, there are incentives for market makers to communicate with each other so that the opening bid and ask quotes reflect all available information. As described by Farrell (1995), a central insight from the theory of communication games is that a receiver of a signal changes his actions in a way that is both beneficial to him and to the sender. Since dealers mutually benefit by an opening that reflects all available information, one would expect the market to open at or near the equilibrium price if a communication game takes place during the preopening and functions properly.[12]

The remaining issue is why market makers communicate using Nasdaq quotes, as opposed to other means of communication. Nasdaq quotes are widely disseminated and a market maker can reach all the other market makers in a stock via the Nasdaq quote montage. Unlike other widely used systems such as InstiNet, the Nasdaq quote displays a market maker's identification code. By sending a price signal via Nasdaq, the market maker can both signal a price and reveal his or her identify.

To better understand the role played by price signals during the preopening we need to further elaborate on one last attribute of the Nasdaq national market. Nasdaq Rule 4613 prohibits market makers from entering or maintaining quotes during normal business hours that cause a locked or crossed

[11] Such orders could be internalized or preferenced depending on whether they originate with the market making firm or with an order-entry firm. Smith (1999) reports that such trades are the majority of Nasdaq trades.

[12] Recent studies by Christie and Schultz (1994) show that Nasdaq market makers communicate effectively and coordinate their quotes to maintain supracompetitive inside markets.

market without first making a reasonable effort to avoid locking or crossing the market. Crossed and locked markets, though formally prohibited during regular trading hours, occur frequently during the preopening since Rule 4613 does not apply. In fact, these market conditions often prevail for more than a short duration. We therefore define crossed and locked *sequences* as follows:

- Crossed sequence is defined as a continuous series of crossed inside quotes. A crossed sequence begins with the last uncrossed inside quote prior to the sequence. It ends with the first inside quote that is neither crossed nor locked.
- Locked sequence is defined as a continuous series of locked inside quotes. A locked sequence begins with the last unlocked inside quote prior to the sequence and ends with the first unlocked inside quote. Also, whenever a crossed inside quote occurs after the start of a locked sequence, the locked sequence is considered ended and a crossed sequence begins.

II. Data

Two intraday data sets are used to conduct our empirical analysis. The first is the Nasdaq preopening data obtained from Bridge Information Services.[13] The data were downloaded by saving screens of real-time quotes for the preopening period from 8:00 to 9:30 a.m. The sample period extends from October 1, 1995 through September 30, 1996.[14] The preopening data set contains (1) individual market maker quotes including the identifying market maker code, and (2) the inside quotes (i.e., the best bid-ask prices), which are updated when the best individual market maker quotes (the bid, the ask, or both) change. Both quotes are time stamped to the nearest minute and are recorded in chronological sequence within each minute.

The second data set consists of all trades and quotes for our sample recorded in the Trade and Quote (TAQ) database compiled by the New York Stock Exchange. Several standard filters are used to screen the data. First, trades and quotes flagged as errors, nonstandard delivery trades, and nonfirm quotations are excluded. Second, quotes with obvious recording errors are discarded (e.g., negative bid or ask quote, depth, share price, and volume). In the TAQ database, the inside quotes are time-stamped to the nearest second and are updated when the best individual market maker quotes change. The inside quotes are available for both preopening and trading periods from the TAQ database, the individual market maker quotes are not.

[13] We thank Bridge Information Services for providing access to the Nasdaq data.

[14] During the sample period there is much less evidence of odd-eighths avoidance than is described by Christie and Schultz (1994). There are nine sample firms with each odd-eighth frequency below 10 percent, but these firms have otherwise similar preopening and trading characteristics as the rest of the sample.

Our sample consists of the 50 most active stocks among the 3,772 Nasdaq National Market (NNM) issues, as measured by 1994 share volume. The list is obtained from the *1995 Nasdaq Fact Book and Company Directory*. Among our sample firms, the highest and lowest share volumes are respectively 1.2 billion and 151 million shares. These stocks are also among the largest on Nasdaq as there is a high correlation between trading activity and market capitalization. Hence, our analysis includes major Nasdaq stocks such as Microsoft, Intel, Cisco Systems, and Biogen. Five stocks switched to other markets or were otherwise delisted from Nasdaq during the sample period; so, to maintain a total sample size of 50, other stocks were added in order of their 1994 share volume. Three stocks are excluded because fewer than 60 trading days of data are available. Thus, the final sample includes 52 stocks, most of which have about 252 trading days during the sample period.[15]

Table I presents characteristics of the sample during preopening and during trading hours. The results are reported for the full sample and also arranged by quartiles, according to the daily average number of trades, with the least active firms in the first and the most active firms in the fourth quartile. At the individual firm level, the average daily number of dealers quoting during the preopening is 22. The daily average number of dealer quotes during the preopening is 47, and rises from 20 (quartile 1) to 84 (quartile 4). The average number of inside quotes per hour is 11 during the trading hours, which exceeds the preopening period by a factor of three. For the trading period, the average number of trades is 1,294 trades per day, and the daily average share (dollar) volume is 1.88 million shares (82 million dollars).

III. Characteristics of Nasdaq Preopening Quotes

A. Crossed and Locked Inside Quotes

Table II presents summary statistics of inside quotes during the preopening and trading hours. The first panel is organized by the time of day where we use the convention of assigning crosses and locks of inside quotes to the time interval when they occur; crossed and locked sequences are assigned to the time interval when they begin. Panel A shows that 34.9 percent of the inside quotes are either crossed (23.6 percent) or locked (11.3 percent) during the preopening. In the first five minutes following the market opening, the frequency of crossed and locked inside quotes drops to 4.2 percent, and thereafter drops to virtually zero during the rest of the trading day. In addition to the difference in the frequency of crosses and locks, there is also a significant difference in the size of crosses between preopening and trading hours. During the preopening, the average magnitude of crosses is \$0.72. In contrast, the size of crosses is generally below \$0.30 during morning trading

[15] The Center for Research in Security Prices (CRSP) data set is used to obtain market capitalization of sample stocks. Five securities in our sample are either foreign stocks or ADRs, and the market value of these firms is unavailable from CRSP.

Table I

Characteristics of the Sample Stocks during the Preopening and Trading Hours

The reported numbers are cross-sectional averages of the daily number of trades, the daily number of dealers during the preopening,the daily number of dealer quotes during the preopening, the daily share volume, the daily dollar volume, the daily number of market quotes (i.e., best bid-ask prices) per hour during the preopening, and the daily number of market quotes per hour during trading hours. For each variable of interest, we calculate its time-series average for each firm first, then obtain the cross-sectional average. The sample period extends from October 1, 1995 through September 30, 1996. The number of dealers, preopening dealer quotes, and preopening market quotes are from the Bridge data set. The number of trades, share volume, and dollar volume are from the TAQ database. The sample stocks are partitioned into four quartiles and sorted according to the daily average number of trades.

Sample	Daily No. of Trades	Daily No. of Dealers	Daily Dealer Preopen Quotes	Daily Share Volume (1000)	Daily Dollar Volume ($ mil.)	Daily No. of Market Quotes per Hour	
						(Preopen)	(Postopen)
Full Sample	1294	22	47	1887	82	3.3	11.0
Quartile 1 (least active)	223	13	20	432	12	2.0	3.0
Quartile 2	638	18	33	1116	33	2.4	7.3
Quartile 3	1269	24	52	2007	68	3.8	13.2
Quartile 4 (most active)	3048	32	84	3992	214	4.9	20.6

hours and rises slightly to \$0.37 in the afternoon. Hence, the size of the relatively few crosses that occur during trading hours is less than half that of crosses during the preopening. The last two columns of Table II show the average duration of crossed and locked sequences. Recall that we assign observations to the time interval in which the sequence of crossed (locked) inside quotes begins. Hence, the duration of 11.7 minutes for locks and 29.2 minutes for crosses during the preopening consists of events initiating before the opening and occasionally extending into trading hours. An analysis of the sequences that extend into trading hours suggests that most of the sequences initiated during the preopening are unlocked by the end of the first five minutes of trading. For crosses (locks) initiated between 9:35 and 10:30 a.m., the average duration is 1.8 (0.9) minutes, whereas for crosses (locks) initiated after 12:00 a.m., the duration is only 0.2 (0.1) minutes.

B. Preopening Quotes and Overnight Information Flow

To assess the informational content of the preopening quotes, we examine the association between overnight information flow and the preopening inside quotes. If locks and crosses are signals and not noise, then they should be associated with changes in the equilibrium, or close-to-close, price. We measure the information flow following Bessembinder, Chan, and Seguin (1996) as the absolute value of close-to-close price change ($|\Delta P^{cc}|$).[16] These results are reported in Panel B of Table II. The frequency of locks is relatively flat across $|\Delta P^{cc}|$. For instance, overnight changes between $\$\frac{1}{8}$ and $\$\frac{1}{4}$ have the same share of locked quotes of roughly 10 percent as do large overnight price movements exceeding \$5 in absolute value. This finding is in sharp contrast with that involving crossed inside quotes, as there is a strong positive association between $|\Delta P^{cc}|$ and the frequency of crosses: Small overnight changes again correspond to approximately 10 percent of crosses, large overnight price movements ($|\Delta P^{cc}| > \$5$) yield more than 50 percent of crossed quotes. The size of crosses also rises monotonically with the size of overnight price changes. This same pattern surfaces for the duration of crosses; the duration of locks does not show any relationship with the magnitude of $|\Delta P^{cc}|$. In terms of economic interpretation, the results suggest that larger price shocks are associated with more information uncertainty and more dispersion of opinion about the opening price among market makers as reflected by larger size crosses resulting in longer coordination spells.

C. The Contribution of the Preopening to the Daily Price Change

Having demonstrated that preopening quotes reflect overnight information, we now address two related questions: How large is the contribution of the preopening period toward daily stock price changes, and, in particular, how large is the contribution of the crossed and locked periods? Substantial

[16] We also obtain results with close-to-open price change. These results show essentially the same pattern as those reported here and are therefore omitted.

Table II

Characteristics of Locked/Crossed Market Quotes during the Preopening and Trading Hours

Reported here are the number of locked/crossed market quotes, the frequency of locks/crosses, the average size (in dollars), and the average duration (in minutes) of locked/crossed market quotes for sample stocks. A lock (or cross) is defined as a market quote where the bid price is equal to (or greater than) the ask price. The frequency of locks/crosses is the total number of locked market/crossed quotes divided by the total number of market quotes. The size of the cross is the bid minus the ask. The duration of the lock/cross is calculated from the time when the lock/cross is initiated to the termination of the lock/cross. Panels A and B present summary statistics by time of the day and the absolute value of the close-to-close price change. The sample period extends from October 1, 1995 through September 30, 1996.

Panel A: Characteristics of Locked/Crossed Market Quotes by Time of Day

	Number of		Frequency of		Average Size		Average Duration	
Time of Day	Locks	Crosses	Locks (%)	Crosses (%)	Locks ($)	Crosses ($)	Locks (min.)	Crosses (min.)
Preopening								
8:00–9:30 a.m.	5653	11796	11.3	23.6	0.00	0.72	11.7	29.2
Trading period								
9:30–9:35 a.m.	621	441	2.5	1.7	0.00	0.27	0.6	0.5
9:35–10:30 a.m.	477	253	0.3	0.1	0.00	0.25	0.9	1.8
10:30–12:00 a.m.	295	116	0.1	0.1	0.00	0.30	0.9	1.7
12:00–13:30 p.m.	194	36	0.1	0.0	0.00	0.20	0.1	0.1
13:30–14:30 p.m.	166	32	0.1	0.0	0.00	0.18	0.1	0.1
14:30–16:00 p.m.	199	53	0.1	0.0	0.00	0.37	0.1	0.2

Panel B: Characteristics of Locked/Crossed Market Quotes during the Preopening Period
(Sorted by Absolute Value of the Close-to-Close Price Change)

Abs. Value of Close-to-Close Price Change ($\lvert \Delta P^{cc} \rvert$)	Number of		Frequency of		Average Size of		Average Duration of	
	Locks	Crosses	Locks (%)	Crosses (%)	Locks ($)	Crosses ($)	Locks (min.)	Crosses (min.)
\$0–$\frac{1}{8}$	760	861	9.5	10.7	0.0	0.37	12.4	24.4
\$$\frac{1}{8}$–$\frac{1}{4}$	509	623	10.5	12.9	0.0	0.36	10.0	24.4
\$$\frac{1}{4}$–$\frac{1}{2}$	879	1302	11.2	16.6	0.0	0.46	11.1	27.0
\$$\frac{1}{2}$–1	1246	2120	12.2	20.8	0.0	0.52	9.7	24.7
\$1–2	1278	3217	12.2	31.6	0.0	0.66	9.7	25.0
\$2–5	899	3127	11.4	40.4	0.0	0.89	8.3	26.2
> \$5	102	596	10.4	56.0	0.0	2.47	13.0	31.3

price contributions from the preopening and from periods when the markets are crossed and/or locked would indicate that the preopening and the unbalanced market conditions during the preopening are important components of the price discovery process. To answer these questions, we partition the preopening and trading hours for any given day into five periods. Let i denote a particular period, and $i \in$ (pre-cross/lock, lock, cross, post-cross/lock, trading period). The first four subperiods constitute the preopening period. The *pre-cross/lock* period is from 8:00 a.m. until the quote prior to the start of the first crossed or locked market sequence. The *lock* period spans the time between the quote prior to the occurrence of a locked market sequence and the first subsequent nonlocked inside quote or until 9:30 a.m. The *cross* period is similar except that the onset of the period is the quote prior to the occurrence of a cross and it lasts until the first subsequent inside quote that is neither crossed nor locked. Finally, the *post-cross/lock* period starts when the last crossed or locked sequence unravels and it lasts until 9:30 a.m., plus the time period between any two crossed/locked periods (if there are multiple cross/lock periods). If there are no crosses or locks, the entire preopening is defined to be part of the *pre-cross/lock* period. The *trading* period is from 9:30 a.m. until 4:00 p.m.

Our measures of price contribution are inspired by the analysis of Barclay and Warner (1993). Specifically, for each stock and for a given period i, we calculate the fraction of the price change over period i relative to close-to-close price change on each day. We then weight each day's contribution of period i based on that day's contribution to the cumulative absolute price change over the entire sample period. It is important to note that the preopening period is much shorter than the trading period (1.5 hours versus 6.5 hours), and that crossed/locked periods are much shorter than the preopening period. To take the time length of each period into account, we rescale the weighted contribution of the preopening period by 1.25 hours and that of the trading period by 6.5 hours. Moreover, within the preopening period, we include the time length of each period in the weight. Using the time-weighted price change during the trading period as a benchmark, the relative time-weighted price contribution (RTWPC) for each period i is determined as:

$$RTWPC_i = \frac{WPC_i \Big/ \sum_{t=1}^{T} \text{Time}_{i,t}}{WPC_{trading} \Big/ \sum_{t=1}^{T} \text{Time}_{trading,t}}, \tag{1}$$

where WPC is the weighted price contribution of period i to daily price change. It is determined as:

$$WPC_i = \sum_{t=1}^{T} \left(\frac{|\Delta P_t|}{\sum_{t=1}^{T} |\Delta P_t|} \right) \times \left(\frac{\Delta P_{i,t}}{\Delta P_t} \right), \tag{2}$$

where $\Delta P_{i,t}$ is the total price change for period i on day t and ΔP_t is the price change for day t (e.g., from day $t-1$ close to day t close). The first term of *WPC* in parentheses is the weighting factor for each day, the second term in parentheses is the relative contribution of the price change for period i on day t to the price change on day t.[17] With the rescaling refinement appearing in the *RTWPC* measure, the results show the contribution of each period toward daily price change per unit of time relative to that of the trading period.

Table III presents the cross-sectional average of the contribution of each time period to the daily price change. Results are reported for each period for the full sample and for each of the trade frequency quartiles. The results show that the price contribution per unit of time during the preopening is slightly larger than that during the trading period, with a ratio of 1.1. Across the four quartiles this ratio remains roughly the same ranging from 0.8 (quartile 2) to 1.4 (quartile 4). Prior to either crosses or locks there is little price contribution, with a ratio of 0.5 for the full sample that varies only slightly across the different quartiles. In comparison to the contribution of trading periods, the contribution of the locked periods is larger by a factor of 3.0, and the contribution of crosses is larger by a factor of 9.0. There is some variation in the price contribution of locks for the least and most active firms. The former have a 5.8 ratio and the latter (i.e., quartile 4) show the relative price contribution of locks to be only 1.2 times the price contribution of trading. Besides the fact that the relative price contribution of crosses is overall much more important, this dominant effect of crosses appears to vary and depends on the trading activity of firms. For the least active stocks, the ratio is as high as 17.3, and for the most active there is a smaller, though still important, 5.5 ratio for the price contribution of crosses relative to trading. Finally, the contribution of the post-cross/lock period is larger than the trading period by a factor of 2.6. It is interesting to note that the post-cross/lock contribution is about the same, for both the full sample as well as the individual quartiles, as the lock period's contribution. The finding that price contribution is roughly equal for the preopening and trading periods indicates that trade, or binding commitments to trade, are not necessary for price discovery. Further, the higher price contribution measure during crosses shows that the ability to cross the inside quote, instead of walking the inside quote by the minimum tick, facilitates preopening price discovery by moving prices quickly.

It is worthwhile to point out that several recent studies report that price adjustments to overnight news announcements are much faster for Nasdaq stocks than for the NYSE/AMEX stocks. Masulis and Shivakumar (1997)

[17] As noted by Barclay and Warner (1993), the *WPC* measure serves the purpose of reducing the heteroskedasticity in the observations since the relative rather than absolute price contributions of each day t are used. To justify the weighting scheme, consider the situation where the price change during the preopening is +7/8 and the price change during the trading hours is −3/4. Hence, the daily price change is 1/8. Without weighting, the percentage of preopening contribution is 700 percent. The weighting scheme downweights observations when the absolute value of daily price change is small. It is also worth observing that the measure avoids the pitfalls of zero price change.

Table III
Contributions of Preopening and Trading Periods to Daily Price Change

The reported statistics are the time-weighted daily stock price change attributable to the preopening period, the pre-lock/cross period, the lock period, the cross period, and the post-lock/cross period. They are expressed relative to the daily stock price change during trading period. The preopening period is from 8:00 to 9:30 a.m., the pre-lock/cross period is from 8:00 a.m. to the time of the first locked/crossed market quote, and the lock (cross) period is from the occurrence of a locked (crossed) market quote until the first subsequent nonlocked (noncrossed) market quote. The post-lock/cross period is from when the last locked/crossed market is unlocked/uncrossed until the first market quote after 9:30 a.m., plus the time period between any two lock/cross periods (if there are multiple locks), and the trading period is from the first market quote after 9:29 a.m. to 4:00 p.m. The sample period extends from October 1, 1995 through September 30, 1996. For each stock and for a given period i, where $i \in$ (preopen, pre-lock/cross, lock, cross, post-lock/cross, or trading period), each day's price change is weighted based on its contribution to the cumulative absolute price change over the sample period. Specifically, the relative time weighted price contribution (RTWPC) for period i is determined as

$$RTWPC_i = \frac{WPC_i \Big/ \sum_{t=1}^{T} \text{Time}_{i,t}}{WPC_{trading} \Big/ \sum_{t=1}^{T} \text{Time}_{trading,t}},$$

where

$$WPC_i = \sum_{t=1}^{T} \left(\frac{|\Delta P_t|}{\sum_{t=1}^{T} |\Delta P_t|} \right) \times \left(\frac{\Delta P_{i,t}}{\Delta P_t} \right), \Delta P_{i,t}$$

is the total price change for period i on day t, and ΔP_t is the total price change on day t. The first term in parentheses is the weighting factor for each day. The second term in parentheses is the relative contribution of the price change of period i on day t to the daily price change.

		Pre-Open				
Sample	RTWPC (Preopen)	RTWPC (Pre-lock/Cross)	RTWPC (Lock)	RTWPC (Cross)	RTWPC (Post-lock/Cross)	RTWPC (Trading)
Full sample	1.1	0.5	3.0	9.7	2.6	1
Quartile 1 (least active)	1.3	0.6	5.8	17.3	4.9	1
Quartile 2	0.8	0.4	2.8	11.8	2.9	1
Quartile 3	1.1	0.2	2.3	4.6	1.8	1
Quartile 4 (most active)	1.4	0.7	1.2	5.5	1.1	1

examine the speed of price adjustment to overnight SEO announcements, which are typically unexpected and represent significant price shocks. For NYSE/AMEX stocks, they find that the market reaction occurs primarily during the first trading day following the announcement. Partitioning the one-day announcement period into subintervals reveals that about 30 percent of the price adjustment is reflected in the opening price, and the other 70 percent occurs from the open to the close on the first trading day following the announcement. In contrast, approximately 10 percent of the price adjustment for Nasdaq stocks is reflected in the first preopening quote, and an additional 60 percent of the price adjustment occurs during the preopening period. Most importantly, the price change during the subsequent trading period is statistically insignificant for Nasdaq stocks. Greene and Watts (1996) document similar differences between NYSE and Nasdaq stocks using earnings announcements. Our results provide a natural explanation for why the price reaction to the overnight announcements on the Nasdaq is faster, particularly when the overnight price shock is large. Market makers credibly signal their estimate of the effect of overnight news through locked/crossed quotes; hence, less-informed market participants have more information with which to update their own expectations prior to trading.

IV. Is There Leadership in Price Discovery among Market Makers?

Peiers (1997) studies nonbinding interbank foreign exchange quotes during trading hours and identifies price leadership of Deutsche Bank up to 60 minutes prior to Bundesbank interventionary reports. We explore similar issues and focus on the coordination strategies that market makers use during the preopening price discovery process.[18] Does a particular market maker or a small group of market makers take a leading role in sending credible signals to others when they possess valuable information? Such a leadership pattern would strongly reinforce the hypothesis that a coordination game occurs during the preopening.[19] Furthermore, the suggestion that crosses are strong signals whereas locks are weak ones hints at different strategies used by different market makers. This raises the question of whether there is heterogeneity of strategies among agents. Related to this question is how the distinction between sending a weak signal versus a strong signal is used as a strategic tool. Although the theoretical and experimental literature have generally assumed a single type of signal, there is no ex ante reason not to expect more than one type of signal in an actual market. Finally, we examine whether there is any relationship between preopening price leadership of

[18] We note that price signaling also occurs in many goods markets. We therefore expect to see leadership patterns in such markets as well. A particularly well-documented case is the airline industry; see for instance Borenstein (1992) for further discussion.

[19] See Farrell and Rabin (1996) for a discussion of the impact of leadership in establishing a desirable outcome in signaling games where each player has a unique preferred outcome.

market makers and the privileged relationship between a firm and brokerage firms who are lead underwriters in initial public or seasoned equity offerings.

A. Does Each Market Maker Contribute Equally to Price Discovery?

Under the null of no leadership, there should be no significant difference between the importance of a dealers' contribution to price discovery and the frequency with which that dealer quotes during the preopening.

Our inquiry starts with separately identifying market makers who *initiate* the crossed and locked sequences since we consider the initiation of a sequence to correspond to sending a signal to the market. We calculate the frequency of crossed and locked sequences attributable to each market maker for each stock, and test whether the distribution of locked and crossed sequence initiation is equal to the distribution of quotes for all market makers. The test strongly rejects the null that the distribution of initiation of crossed and locked sequences is the same as the distribution of market maker quotes. We also strongly reject the null hypothesis that each market maker initiates crossed (or locked) sequences with equal probability as would be the case if crossed and locked sequence initiation was consistent with a uniform distribution.[20] Overall, these results suggest that there exist different patterns of behavior in terms of cross and lock initiations across market makers.

As noted before, in order to uncover potential leadership among market makers, it is important to identify market makers who make a significant contribution to the price change during both crossed and locked periods. To gauge the contribution of each market maker during locks, we use a measure similar to the weighted price contribution in equation (2). A measure for crosses can be defined similarly, but for the sake of simplicity we only describe the case of locks. Specifically, for a given stock, the weighted price contribution during locks (WPCL) by market maker k is defined as:

$$WPCL_k = \sum_{t=1}^{T} \left(\frac{\left| \sum_{j=1}^{N_t} \Delta P_{j,t} \right|}{\sum_{t=1}^{T} \left| \sum_{j=1}^{N_t} \Delta P_{j,t} \right|} \right) \times \left(\frac{\sum_{j=1}^{N_t} \Delta P_{j,t} I_{j,k}}{\sum_{j=1}^{N_t} \Delta P_{j,t}} \right), \tag{3}$$

where N_t is the number of locks and crosses on day t, $\Delta P_{j,t}$ is the price change during the jth lock or cross on day t, and $I_{j,k}$ is a dummy variable with value one if the jth event is a lock initiated by market maker k and with value zero otherwise. The first term in parentheses is the weighting factor for each day. Each day's weight is determined by that day's contribution to the cumulative absolute daily price change across all locks and crosses

[20] We rely both on χ^2 goodness-of-fit tests and on sign tests to compare the distribution of quotes and crossed/locked sequences across market makers.

over the entire sample period. The second term in parentheses is the contribution of the price change during locks initiated by market maker k on day t relative to total price change across all locks and crosses on day t.

Summary statistics of the percentage of price contribution, percentage of locked/crossed sequences, and percentage of quotes for the top three market makers are reported in Table IV. The top three are selected on the basis of weighted price contribution. Panel A pertains to locks, Panel B explores crossed markets. It is important to note that the top three market makers for locks are not necessarily the same as the top three for crosses. First, we discuss results for the top three locking market makers. Across all stocks, the number one, two, and three market makers initiate 9.6, 6.2, and 5.4 percent of the locked sequences, and their price contributions are 8.2, 4.8, and 3.8 percent, respectively. However, the frequency of preopening quotes is virtually flat: 3.0, 3.0, and 2.9 percent for the top three market makers. In addition, both price contribution and locked sequences by the top three market makers are far beyond their respective shares of quotes: 16.8 and 21.2 percent versus 8.9 percent. The conclusion is that there is a subset of market makers that dominates the initiation of locks in each stock, but that locks are a relatively weak signal as reported in Section III.

Next, consider the top three crossing market makers. When only frequencies of initiation of crossed and locked sequences are considered, there is a strong similarity between crosses and locks. For example, the top three crossing market makers initiate 7.8, 7.0, and 6.0 percent of crosses, respectively. The results change substantially, however, when we consider the share of price contributions for each of the leading market makers in locks and crosses. The number one, two and three crossing market makers make 21.0, 11.3, and 7.8 percent of the price contribution. In aggregate, the top three crossing market makers contribute 40.1 percent of the price change during crossed sequences. In comparison, the price contribution by the top three locking market makers is only 16.8 percent. It appears that the incidence of initiating either locks or crosses is limited to a small group of dealers, but the impact of a lock is very different from the impact of a cross. Locks are weak signals of price movements before trading, in comparison crosses are strong signals.

We further investigate the relationship between the overnight return, the return during crosses, and the leading market makers using two regression models (not reported).[21] In the first regression model, we regress the overnight return on the compounded return for all preopening crossed sequences for those days when there is at least one crossed sequence—approximately 20 percent of the days in the pooled sample. In the second regression model, we regress the overnight return on the compounded return for all preopening crossed sequences that are initiated by the three leading market makers as identified by price contribution. The adjusted R^2 is 0.51 for the first regression and 0.30 for the second. Thus, slightly more than 50 percent of

[21] Since crosses are far more informative than locks, the regression analysis focuses on crosses.

Table IV

Price Leaders in Market Locks/Crosses for the Sample Stocks during the Preopening

Reported are cross-sectional averages of the price contribution (Price Cont.) during locks and crosses, the locked/crossed sequence frequencies, and the quote frequencies for the #1, #2, and #3 leading market makers who have the greatest relative time-weighted price contribution during locks/crosses. The top three market makers for locks are not necessarily the same as the top three for crosses. The sample period extends from October 1, 1995 through September 30, 1996. The sample stocks are partitioned into four quartiles and sorted according to the daily average number of trades. Quartile 1 contains the least active firms, quartile 4 the most active firms.

Panel A: Top Locking Market Makers

	#1 Locking Market Maker			#2 Locking Market Maker			#3 Locking Market Maker			Total (#1–3)		
Sample	% of Price Cont.	% of Seq.	% of Quote	% of Price Cont.	% of Seq.	% of Quote	% of Price Cont.	% of Seq.	% of Quote	% of Price Cont.	% of Seq.	% of Quote
Full sample	8.2	9.6	3.0	4.8	6.2	3.0	3.8	5.4	2.9	16.8	21.2	8.9
Quartile 1	13.0	14.6	3.2	7.1	8.7	3.1	6.2	9.7	3.0	26.3	33.0	9.3
Quartile 2	8.8	12.3	3.3	5.3	6.8	3.0	4.1	4.5	3.2	18.2	23.6	9.5
Quartile 3	5.5	8.5	3.1	4.0	5.7	3.2	2.9	4.4	3.1	12.4	18.6	9.4
Quartile 4	5.7	5.2	2.6	3.0	3.4	2.6	2.2	3.3	2.4	10.9	11.9	7.6

Panel B: Top Crossing Market Makers

	#1 Crossing Market Maker			#2 Crossing Market Maker			#3 Crossing			Total (#1–3) Market Maker		
Sample	% of Price Cont.	% of Seq.	% of Quote	% of Price Cont.	% of Seq.	% of Quote	% of Price Cont.	% of Seq.	% of Quote	% of Price Cont.	% of Seq.	% of Quote
Full sample	21.0	7.8	3.0	11.3	7.0	3.1	7.8	6.0	2.8	40.1	20.8	8.9
Quartile 1	29.4	11.6	2.6	14.1	9.2	3.2	9.2	9.3	3.1	52.7	30.1	8.9
Quartile 2	20.1	7.8	3.1	12.4	6.3	3.4	8.2	5.2	2.7	40.7	19.3	9.2
Quartile 3	19.9	6.4	3.3	10.0	6.3	3.1	7.1	5.8	3.3	37.0	18.5	9.7
Quartile 4	15.3	5.9	2.8	8.8	6.3	2.6	6.8	4.4	2.4	30.9	16.6	7.8

the variation in overnight return is explained by the return during all crossed sequences, of which about 60 percent is due to crossed periods initiated by the three leading market makers. This result suggests that leading market makers make important contributions to price discovery during the preopening period.

B. Heterogeneity of Dealers and Their Strategies

We find many differences between the relatively weak signal of a lock and the much stronger action of market makers who cross a market. One may ask whether market makers who engage in locking markets are the same as those causing crossed sequences. In another words, do we observe the same agents using different strategies depending on the quality and nature of their private information or do different agents intervene under different market conditions? If there is such a heterogeneity there must be features that clearly differentiate the protagonists to rationalize their different behavior.

To investigate these issues we present the identity of the leading market makers in Table V. Specifically, we list the top five crossing market makers and their occurrence as the number one, two, or three market maker for our sample stocks. The results indicate that major brokerage firms often act as leading market makers. For instance, Bear, Stearns & Co. is identified as the number one, two, or three leader in crosses for eight, four, and six stocks. Morgan Stanley & Co. takes leadership in a total of 15 stocks, followed by Goldman Sachs & Co. and Merrill Lynch. In aggregate, the top five crossing market makers, among about 200 market makers, are identified as the most important leading market maker for 23 stocks, which is close to 50 percent of our sample stocks. Thus, market makers from these full-service brokerage firms play an important role in the price discovery during the preopening.

Table V also reports the identity of the top five locking market makers. Among them, three are large wholesale brokers: Sherwood Securities Corp., Knight Securities, and Mayer & Schweitzer Inc. Note that for locks there is not much difference between total ranks of the number one (e.g., Sherwood Securities) with a total of 13 stocks, and the number five (e.g., Mayer & Schweitzer) with a total of 10 stocks. For crosses the number one leading market maker has a total of 18 stocks and the fifth ranked has fewer than half that number with only eight stocks with price leadership.

A comparison of the two lists shows that strong signals of crossing markets emerge primarily from large brokerage firms, while weak signals of locking markets are from large wholesale brokers. To rationalize why these protagonists have different strategies, we consider the difference between large brokerage firms and wholesalers. Large brokerage firms represent a preponderance of the large, institutional order flow and also possess a substantial in-house research arm. There is partial evidence from the block trading literature that institutional trades have a substantial effect on stock prices (see, e.g., Keim and Madhavan (1996)). This may reflect the informational content of institutional trades or it may reflect the costs of meeting a

Table V

The Identity of Leading Market Makers during the Preopening for Sample Stocks

Reported below are the identity of the top five Nasdaq market makers who have the greatest weighted price contribution during crosses (or locks), and the ranking of each market maker as the number one, two, or three leader based on the weighted price contribution during crosses (or locks) across all the sample stocks. Of market makers listed below, Knight Securities L.P., Mayer & Schweitzer, Inc., and Sherwood Securities Corp. are wholesale brokers; the others are full-service brokerage firms. The sample period extends from October 1, 1995 through September 30, 1996.

	Ranking			
Name of Market Maker	#1	#2	#3	Total
Crossed sequences				
Bear, Stearns & Co., Inc.	8	4	6	18
Morgan Stanley & Co., Inc.	6	7	2	15
Goldman Sachs & Co.	3	5	2	10
Merrill Lynch Inc.	2	2	4	8
Sherwood Securities Corp.	4	4	—	8
Total	23	22	14	59
Locked sequences				
Sherwood Securities Corp.	6	5	2	13
Goldman Sachs & Co.	5	5	3	13
Knight Securities L.P.	5	3	4	12
Morgan Stanley & Co., Inc.	5	3	2	10
Mayer & Schweitzer, Inc.	3	3	4	10
Total	24	19	15	58

large demand for liquidity. Whether the price impact of institutional trades is information or liquidity driven, the effect in the preopening may be similar. A brokerage house seeking to position an institutional order may signal a larger price change than a wholesaler representing retail order flow. Retail order flow is generally considered uninformed and wholesalers have little, if any, research capabilities. Also, wholesalers are less willing to commit capital to accommodating customer trades than are brokerage firms and may signal via a lock for smaller imbalances than would induce a brokerage firm to cross the market.

C. Price Leadership and IPO/SEO Activity

If the preopening is used by market makers to exchange information regarding the opening price then the leading market makers should be those who possess private information about the security. There are several types of private information that would be important. One type is superior information about the prospects for the firm. Overnight order flow is certainly another major source of private information. One candidate class of market

makers that might possess both types of information is the brokerage firm that underwrites a firm's equity securities in either an initial public offering or a seasoned equity offering.

In the aftermarket period of an IPO, studies including Schultz and Zaman (1994), Aggarwal and Conroy (1999), and Ellis et al. (2000) show that the lead underwriter in an IPO accounts for a substantial portion of market making activity immediately following the underwriting. The proportion of trading activity decreases during the support period. Aggrawal and Conroy (1999) also document that the lead underwriter is the price leader in the preopening period prior to the start of trading on the first day of the IPO. If the underwriting firm continues to attract a significant portion of the order flow, particularly the informed order flow, its preopening price quotes should be more informative to the market. The lead underwriter firm may also retain informational advantages over the longer term. Michaely and Womack (1999) describe the implicit promise made by an underwriter to have its analysts continue to follow the security in the aftermarket. Although the relationship between the firm and the underwriter's analysts is presumably strongest at the time of the underwriting, the firm may continue to provide the underwriter's analysts with better information in the long run. One may therefore ask whether there is any long-term relationship between IPO/SEO activity and price leadership of market makers.

To answer this question, we collect information about the leading underwriters of IPO/SEO's for our sample stocks from 1980 through 1995. The source of the data is Security Data Company. For the 52 firms in our sample we recover 35 IPOs. The remaining 17 firms were either introduced to the market prior to 1980 or were foreign firms without IPO information available. A total of 36 firms have at least one SEO. The IPO and SEO information for the period prior to 1980 is unavailable from the database. For firms with multiple SEOs we consider all offerings as well as the latest offering in our analysis.[22]

First, we examine in Table VI whether there is any matching pattern between the top five crossing and locking market makers and their involvement in stocks as leading underwriters. For crosses, we note that Bear, Stearns & Co. is a leading underwriter for only one SEO, for which it is also a price contribution leader.[23] Morgan Stanley & Co. is more active in underwriting. It is a leading underwriter for five IPOs and is a price contribution leader for three of those five. For SEOs the comparable figures for Morgan Stanley & Co. are nine and three. Sherwood Securities Corp., Knight Securities, and Mayer & Schweitzer Inc. do not engage in IPO/SEO activity and therefore show zero entries in Table VI. For price leadership in locks we notice again that Goldman Sachs & Co. and Morgan Stanley & Co. are both leading underwriters and leading market maker for roughly the same fraction of stocks. We also calculate, but do not report, the price contribution of all market

[22] We include subsidiary and successor firm relationships in identifying lead underwriters.
[23] In this exercise, the information of the most recent SEO is used.

Table VI

Underwriters in Market Crosses/Locks for Sample Stocks

Reported below are the names of the top five Nasdaq market makers who have the greatest weighted price contribution during crosses (or locks), the count that the market maker is the leading underwriter in the IPO in our sample stocks (leading UW), the count that the market maker is also a price leader for those same stocks (leading UW–MM), the count that the market maker is the leading underwriter in the most recent SEO for our sample stocks, and the count that the market maker is also a price leader for those same stocks. Information about the leading underwriters of the IPO/SEOs for sample stocks are collected during the period from 1980 to 1995. Among 52 sample firms, we find that 35 firms have at least one IPO and 36 firms have at least one SEO during the period of 1980 through 1995. Of market makers listed below, Knight Securities L.P., Mayer & Schweitzer, Inc., and Sherwood Securities Corp. are wholesale brokers; the others are full-service brokerage firms.

	IPO		SEO	
Name of Market Maker	Count of Leading UW	Count of Leading UW–MM	Count of Leading UW	Count of Leading UW–MM
Crossed sequences				
Bear, Stearns & Co., Inc.	0	0	1	1
Morgan Stanley & Co., Inc.	5	3	9	3
Goldman Sachs & Co.	8	2	8	3
Merrill Lynch Inc.	4	2	3	1
Sherwood Securities Corp.	0	0	0	0
Locked sequences				
Sherwood Securities Corp.	0	0	0	0
Goldman Sachs & Co.	8	3	8	4
Knight Securities L.P.	0	0	0	0
Morgan Stanley & Co., Inc.	5	1	9	3
Mayer & Schweitzer, Inc.	0	0	0	0

makers who are underwriters in IPOs and SEOs. In comparison to each of the top three leading market makers, we note that underwriters as a group have a very small fraction of the price contribution during crossed and locked sequences. For example, the total price contribution of all leading underwriters (IPO and SEO combined) is 5.6 percent during crosses (with an average of two underwriters per stock), while the price contribution of the number one, two, and three crossing market makers is 21.0, 11.3, and 7.8 percent, respectively (see Table IV). A similar conclusion can be drawn for the locked sequences. The evidence for a long-run relationship between leadership in underwriting and price leadership in market making is weak.

These results may reflect the fact that large investment firms are omnipresent in a great variety of financial market activities, including underwriting and market making. While the corporate finance department may benefit from a commitment by the trading desk to maintain an active presence in clients' stocks after the support period as described by Michaely and Womack (1999), Aggarwal and Conroy (1999) point out that market making

profit and losses accrue to the desk. There is friction between the corporate finance department and the trading desk over which stocks the firm should make markets in. Over the long horizon the profitability of the trading desk may be the determining factor, particularly where underwriting activity has ceased. One interpretation of the leadership presence of Morgan Stanley & Co. and Goldman Sachs & Co. in a few of their underwritten issues is that these are the issues where the trading desk decided to maintain an active presence independent of the previous underwriting activity. This conclusion is supported by Ellis et al. (2000) who note that frequent underwriters such as Morgan Stanley and Goldman Sachs often make markets in stocks of firms they did not underwrite, whereas infrequent underwriters typically limit making markets to the stocks they underwrite. Overall we find that there is little evidence that IPO/SEO activity spills over into price leadership in market making over a longer time horizon for our sample of large Nasdaq companies.

V. Conclusion

In spite of the occurrence of price signaling in many markets, it is a commonly held belief that nonbinding commitments do not contain any information and therefore do not contribute to price discovery. This article shows that there is price discovery through the use of market maker preopening quotes as price signals in the absence of firm commitments and trading on Nasdaq. In contrast to previous research, our paper studies the informational content of price quotation signals when there is no trading and therefore does not confound the information from signaling and contemporaneously occurring transactions. In particular, we examine all the Nasdaq market maker quotes and identities during the 90 minutes prior to the onset of trading. The Nasdaq preopening has several characteristics: (1) many Nasdaq market makers actively post quotes, (2) the preopening quotes are nonbinding commitments that can be revised, and (3) the identity of participating market makers is known to others. Hence, the preopening period provides an ideal setting to investigate whether there is price discovery through signaling in the absence of trading and binding commitments, and whether the price discovery during the preopening is a significant part of the daily price change.

To summarize the findings, we conclude that nonbinding quotations of market makers do convey information for price discovery. The contribution of the preopening period, as measured on a relative unit of time basis, is as large as that of the trading period. We uncover different types of signals and establish that there is price leadership among market makers. Our empirical evidence indicates that Nasdaq dealers use crossed and locked inside quotes as a unique mechanism to indicate to others the equilibrium opening prices conditional on the overnight information. In comparison to locked inside quotes, crossed inside quotes carry a much stronger message. We further show that among more than 200 Nasdaq market makers, only a small

fraction of them are responsible for about 40 percent of the price changes during crosses. Finally, by exploring the linkages between price leadership and IPO/SEO underwriting relationships, we find that the strong association between underwriting and market making activity over the short term, which is documented in the literature, does not appear to persist into the long run.

REFERENCES

Aggarwal, Reena, and Patrick Conroy, 1999, Price discovery in initial public offerings and the role of the lead underwriter, *Journal of Finance*, forthcoming.

Amihud, Yakov, and Haim Mendelson, 1987, Trading mechanisms and stock returns: An empirical investigation, *Journal of Finance* 42, 533–553.

Bagehot, Walter, 1971, The only game in town, *Financial Analysts Journal* 22, 12–14.

Barclay, Michael, William Christie, Jeffrey Harris, Eugene Kandel, and Paul Schultz, 1999, The effects of market reform on the trading costs and depths of Nasdaq stocks, *Journal of Finance* 54, 1–34.

Barclay, Michael, and Jerold Warner, 1993, Stealth trading and volatility: Which trades move prices? *Journal of Financial Economics* 34, 281–305.

Battalio, Robert, Jason Greene, and Robert Jennings, 1997, Do competing specialists and preferencing dealers affect market quality? *Review of Financial Studies* 10, 969–995.

Battalio, Robert, Brian Hatch, and Robert Jennings, 1997, SOES trading and market volatility, *Journal of Financial and Quantitative Analysis* 32, 225–238.

Bessembinder, Hendrik, Kalok Chan, and Paul Seguin, 1996, An empirical examination of information, differences of opinion, and trading activity, *Journal of Financial Economics* 40, 105–134.

Biais, Bruno, Pierre Hillion, and Chester Spatt, 1999, Price discovery and learning during the pre-opening in the Paris Bourse, *Journal of Political Economy* 107, 1218–1248.

Borenstein, Severin, 1992, The evolution of U.S. airline competition, *Journal of Economic Perspectives* 6, 45–73.

Chan, K. C., William Christie, and Paul Schultz, 1995, Market structure and the intraday pattern of bid-ask spreads for Nasdaq securities, *Journal of Business* 68, 35–60.

Christie, William, and Paul Schultz, 1994, Why do Nasdaq market makers avoid odd-eighth quotes? *Journal of Finance* 49, 1813–1840.

Copeland, Thomas, and Dan Galai, 1983, Information effects and the bid-ask spread, *Journal of Finance* 38, 1457–1469.

Dutta, Prajit, and Ananth Madhavan, 1997, Competition and collusion in dealer markets, *Journal of Finance* 52, 245–276.

Easley, David, Nicholas Kiefer, Maureen O'Hara, and Joseph Paperman, 1996, Liquidity, information and infrequently traded stocks, *Journal of Finance* 51, 1405–1436.

Easley, David, and Maureen O'Hara, 1987, Price, trade size, and information in securities markets, *Journal of Financial Economics* 19, 69–90.

Ellis, Katrina, Roni Michaely, and Maureen O'Hara, 2000, When the underwriter is the market maker: An examination of trading in the IPO after market, *Journal of Finance* 55, 1039–1074.

Farrell, Joseph, 1995, Talk is cheap, *American Economic Review* 85, 186–190.

Farrell, Joseph, and Matthew Rabin, 1996, Cheap talk, *Journal of Economic Perspectives* 10, 103–118.

Forsythe, Robert, Russell Lundholm, and Thomas Rietz, 1999, Cheap talk, fraud and adverse selection in financial markets: Some experimental evidence, *Review of Financial Studies* 12, 461–479.

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

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

Glosten, Lawrence, and Paul Milgrom, 1985, Bid, ask and transaction prices in a specialist market with heterogeneously informed traders, *Journal of Financial Economics* 13, 71–100.

Godek, Paul, 1996, Why Nasdaq market makers avoid odd-eighth quotes, *Journal of Financial Economics* 41, 465–474.

Greene, Jason, and Susan Watts, 1996, Price discovery on the NYSE and the Nasdaq: The case of overnight and daytime news releases, *Financial Management* 25, 19–42.

Harris, Jeffrey, and Paul Schultz, 1998, The trading profits of SOES bandits, *Journal of Financial Economics* 50, 39–62.

Hasbrouck, Joel, 1988, Trades, quotes, inventories, and information, *Journal of Financial Economics* 22, 229–252.

Hasbrouck, Joel, 1991, Measuring the information content of stock trades, *Journal of Finance* 46, 179–207.

Huang, Roger, and Hans Stoll, 1996, Dealer versus auction markets: A paired comparison of execution costs on Nasdaq and the NYSE, *Journal of Financial Economics* 41, 313–358.

Kandel, Eugene, and Leslie Marx, 1999, Payment for order flow on Nasdaq, *Journal of Finance* 54, 35–66.

Keim, Donald, and Ananth Madhavan, 1996, The upstairs market for large-block transactions: Analysis and measurement of stock price effects, *Review of Financial Studies* 9, 1–36.

Kyle, Albert, 1985, Continuous auctions and insider trading, *Econometrica* 53, 1315–1336.

Leach, Chris, and Ananth Madhavan, 1993, Price experimentation and security market structure, *Review of Financial Studies* 6, 375–404.

Madhavan, Ananth, 1992, Trading mechanisms in securities markets, *Journal of Finance* 47, 607–641.

Madhavan, Ananth, and Venkatesh Panchapagesan, 2000, Price discovery in auction markets: A look inside the black box, *Review of Financial Studies*, forthcoming.

Madhavan, Ananth, Matthew Richardson, and Mark Roomans, 1997, Why do security prices change? A transaction-level analysis of NYSE stocks, *Review of Financial Studies* 10, 1035–1064.

Masulis, Ronald, and L. Shivakumar, 1997, Intraday market response to equity offering announcements: A NYSE/AMEX-Nasdaq comparison, Working paper, Vanderbilt University.

Michaely, Roni, and Kent Womack, 1999, Conflict of interest and the credibility of underwriter analyst recommendations, *Review of Financial Studies* 12, 653–686.

O'Hara, Maureen, 1995, *Market Microstructure Theory* (Blackwell, Cambridge, Mass.).

Pagano, Marco, and Ailsa Röell, 1996, Transparency and liquidity: A comparison of auction and dealer markets with informed trading, *Journal of Finance* 51, 579–611.

Peiers, Bettina, 1997, Informed traders, intervention, and price leadership: A deeper view of the microstructure of the foreign exchange market, *Journal of Finance* 52, 1589–1614.

Porter, David, and Daniel Weaver, 1998, Post-trade transparency on Nasdaq's National Market System, *Journal of Financial Economics* 50, 231–252.

Schultz, Paul, and Mir Zaman, 1994, Aftermarket support and underpricing of initial public offerings, *Journal of Financial Economics* 35, 199–219.

Smith, Jeffrey, 1999, The role of quotes in attracting orders on the Nasdaq interdealer market, Working paper, NASD Economic Research.

Spatt, Chester, and Sanjay Srivastava, 1991, Preplay communication, participation restrictions, and efficiency in initial public offerings, *Review of Financial Studies* 4, 709–726.

Stoll, Hans, and Robert Whaley, 1990, Stock market structure and volatility, *Review of Financial Studies* 3, 37–71.