Consolidation, Fragmentation, and the Disclosure of Trading Information,

Ananth Madhavan
University of Southern California

It is commonly believed that fragmented security markets have a natural tendency to consolidate. This article examines this belief, focusing on the effect of disclosing trading information to market participants. We show that large traders who place multiple trades can benefit from the absence of trade disclosure in a fragmented market, as can dealers who face less price? competition than in a unified market. Consequently, a fragmented market need not coalesce into a single market unless trade disclosure is mandatory. We also compare and contrast fragmented and consolidated markets. Fragmentation results in higher price volatility and violations of price efficiency.

This article analyzes the impact on price information and market fragmentation of rules requiring the timely disclosure of trading information to market participants.[1] The issue of trade disclosure (one aspect of

A previous version of this article was circulated under the title "Trade Disclosure and the Integration of International Securities Markets." I thank Franklin Allen, Marshall Blume, Corrine Bronfman, Prajit Dutta, Margaret Forster, Gary Gorton, Bruce Grundy, Michel Habib, Joel Hasbrouck, D. Bruce Johnsen, Donald Keim, Rich Kihlstrom, Oded Sarig, James Shapiro, Chester Spatt (the editor), and two anonymous referees for their valuable suggestions. I also received many helpful comments from participants in presentations at Alberta, Rutgers, Wharton, and the 1993 European Finance Association Meetings. Any errors are entirely my own. Address all correspondence to Ananth Madhavan, School of Business Administration, University of Southern California, Los Angeles, CA 90089-1421.

[1] It is important to distinguish [see, e.g., Franks and Schaefer (1991)] between *trade reporting*, where exchange authorities are notified about trades, and *trade disclosure*, where trading information is publicized to market par-

The Review of Financial Studies Fall 1995 Vol. 8, No. 3, pp. 579–603

"market transparency") lies at the. heart of many recent policy debates concerning the structure of securities markets, but is also important for theoretical reasons.

From a practical viewpoint, differences in trade disclosure between markets may induce order flow migration, affecting liquidity and the cost of trading. For example, the London Stock Exchange allows dealers to delay the disclosure of large trades by 90 minutes.[2] The absence of transparency in London, it is argued, has attracted order flow from other markets where disclosure rules are more stringent.' The lack of trade disclosure is also a major concern of policy makers for markets without formal mechanisms for trade disclosure (i.e., the corporate junk bond markets) and markets in emerging economies.

Trade disclosure is also important for theoretical reasons. Several articles argue that consolidation is inevitable because traders gravitate to the most liquid and efficient market, reinforcing the dominance of the primary market.[4] Yet despite potential informational economies, markets such as the corporate bond market or the foreign exchange market, where disclosure is not mandatory, are not consolidated. This suggests a relation between fragmentation, consolidation, and disclosure. One objective of this article is to better understand this relation.[5]

This article develops a model of trade disclosure to analyze the theoretical and policy concerns discussed above. In particular, we are interested in three questions: (1) Is centralization, inevitable in a fragmented market or is some regularity impetus required to achieve order flow consolidation? (2) Is a consolidated market preferred by traders and dealers or do some participants prefer a fragmented market? (3) What are the major differences in price formation between a fragmented and a consolidated market? We examine these issues with a model where investors have heterogenous motives for trade and dealers compete to attract order flow.

---

ticipants. Virtually all markets require some form of reporting, but timely trade disclosure is the economically relevant issue.

[2] See, for example, Gemmill (1994) and Naik, Neuberger, and Vishwanathan (1994) for analyses of impact of disclosure requirements on the London Stock Exchange.

[3] See, for example, Pagano and Röell (1990b). *Economist* (1992) notes that London has attracted a third of the the volume in French and Italian blue-chip stocks. In the United States there have been proposals [see, e.g., *Wall Street Journal* (1992)] to counter the loss of order flow to London by allowing dealers up to 90 minutes to disclose trades above a certain size.

[4] See, for example, Stigler (1964, Pagano (1989), and Chowdhry and Nanda (l991), whose analyses suggest that one market will dominate because of informational economies of scale. Mendelson (1987) analyzes the effect of fragmentation in a variety of systems. Finally, Admati and Pfleiderer (1988) provide a model where trade is temporally concentrated in equilibrium.

[5] It should be noted that fragmentation in security markets **is** a complex phenomenon dependent on many factors (e.g., communications technology, inter- and intramarket competition, and trading protocols) besides transparency.

We demonstrate that a consolidated market will experience order flow fragmentation unless trade disclosure is mandatory, even if there are potential informational economies. The intuition is similar to Harris (1992), who argues that market fragmentation occurs because traders are heterogeneous and demand a variety of market mechanisms to satisfy their needs. Specifically, large liquidity and informed traders effectively "front run" their own trades in a consolidated market, raising their execution costs. In a fragmented market, these traders can obtain better executions through their dynamic trading, creating a demand for nontransparent trading systems. In turn, dealers may benefit from nondisclosure. Dealers profit from fragmentation because there is less price competition; nondisclosing dealers can selectively participate in future trading to profit from their private information on past trades. However, although fragmentation benefits large traders, it has ambiguous effects on the expected execution costs of short-term noise traders.

We also analyze the differences between centralized and decentralized markets. Fragmentation increases price volatility and induces other distortions as well. In particular, although the expected price change given the current price is zero, prices are actually inefficient in that dealers pay for order flow while matching prices that equal the expected value of the asset. Such payments usually arise because prices are discrete, but in our model they reflect the value of nonpublic trading information. Fragmentation also results in a reversal in the normal intraday pattern in bid-ask spreads. Finally, the model also provides some new insights into price dynamics in a consolidated market. Although prices are efficient, trade reversals result in larger, but less frequent, price revisions than continuations. This occurs because some traders may be "working" a large position over time, so that there is a greater revision in dealer beliefs when a reversal is observed. Further, the serial correlation in order flow implies that the expected value of the security is not the midquote of the bid-ask spread.

It is useful to distinguish between this article and recent studies examining related issues. An important question concerns the effect of disclosing information about the identity of traders or their motives for trading. Forster and George (1992) analyze a model where some market participants have private information regarding the distribution of uninformed trade. They show that anonymity significantly affects security prices and liquidity, findings that our results reinforce. Similarly, Benveniste, Marcus, and Wilhelm (1992) develop a model where dealers can partly distinguish informed and uninformed order flow.[6]

[6]Fishman and Hagerty (1991) show that corporate traders who are forced to disclose their trades

Another issue concerns the disclosure of information about pending orders. Admati and Pfleiderer (1991) provide a model of sunshine trading where some liquidity traders can preannounce the size of their orders while others cannot. Similarly, Madhavan (1995) examines the effect of disclosing order unbalances to market participants.[7] Finally, several studies [see, e.g., Diamond and Verrecchia (1991)] have examined the impact of disclosing corporate information on fundamental asset values as opposed to disclosure regarding market conditions. This issue is particularly relevant given recent concerns about the financial reporting requirements imposed on foreign companies seeking listing on U.S. exchanges. These issues, although important, lie beyond the scope of this article.

The article proceeds as follows: Section 1 describes the model; Section 2 characterizes the equilibrium for the trading game with disclosure; Section 3 examines a market where trade disclosure is voluntary; Section 4 compares and contrasts the consolidated and fragmented markets; and Section 5 summarizes the article. Proofs are contained in the appendix.

1. The Model

The model is based on the dealer market model of Glosten and Milgrom (1985). Unlike Glosten and Milgrom (19851, however, there are three types of traders and successive trader arrivals are not independent. A risky security trades at dates 0 and 1.8 The risky security pays a stochastic liquidating dividend, denoted by v, which is realized in period 2 after trading is completed. The liquidation value in period 2 can be high or low depending on the state of nature, and we denote these values by v, and v_L respectively. All trading takes place with M (where $M \geq 2$) risk-neutral dealers. At the start of each trading round, dealers simultaneously set irrevocable bid and ask prices at which they will buy or sell the security? Dealers can be individual market makers or may represent spatially separated exchanges or markets.

We begin by analyzing a system where trade disclosure in mandatory and thus dealers have homogeneous information. Even though

can profitability manipulate prices. In their model, only insiders know whether their trades are liquidity or information motivated, so that disclosure can mislead other traders.

[7]Disclosure is also an issue in models of dual trading [see. e.g., Röell (1990) and Fishman and Longstaff (1992)] because brokers may be able to identify certain customer trades as liquidity motivated

[8]ln addition, we assume the existence of a riskless security whose rate of return is normalized to zero.

[9]The restriction to one unit per period follows from Glosten and Milgrom (1985).

individual trades may be executed in different market centers, dealers have homogeneous beliefs and therefore quote identical prices. We refer to this system as a *consolidated market.* Later, we consider a market where trade disclosure is voluntary for dealers, Fragmentation is said to occur in this regime if some dealers do not disclose trading information, so that dealers have heterogeneous beliefs, and prices may differ across market centers at a given point in time. Of course, if all dealers commit to disclose their trades, the market is consolidated in an economic sense.

There are three types of traders in the model. The first type, referred to as *noise traders,* buy or sell one unit of the security for exogenous liquidity reasons including portfolio diversification, life-cycle consumption savings decisions, and transitory shocks to income. These traders' demands can be filled in a single transaction and they trade at only one date. The second type, referred to as *large liquidity* traders, wish to buy or sell two units of the security for exogenous liquidity or portfolio-hedging reasons. These traders, who can be thought of as large institutional traders, have relatively large orders which can only be filled by trading in both periods. The third type, referred to as *informed traders,* possess private information about the fundamental value of the security. Let θ_1 represent a single-period noise trader, θ_2 represent a two-period liquidity trader, and θ_3 represent an informed trader. The set of trader types is denoted by $\Theta = \{\theta_1, \theta_2, \theta_3\}$. To distinguish between trading types in period 0 and 1, let $\theta^0 \in \Theta$ denote the type trading in period 0, and similarly define θ^1 as the period 1 type.

To complete the description of the trading environment, we must specify the arrival process of the various types of traders. In period 0, one trader type is randomly selected. The probabilities that a noise trader, liquidity trader, or informed trader are present at period 0 are given by $2u_1$, $2u_2$, and 2λ, respectively, where u_1, u_2, and λ lie in the interval $(0, 0.5)$ and $2u_1 + 2u_2 + 2\lambda = 1$. In period 0, a trader is equally likely to buy or sell, so u_1, u_2, and λ represent the (unconditional) probability that a noise, liquidity, or informed trader, respectively, buys in period 0.

The probability of a particular trader type being present in period 1 depends on the trader type present in period 0. If a single-period noise trader arrives in period 0 (i.e., $\theta^0 = \theta_1$), then another single-period noise trader arrives in period 1 and buys or sells one unit of the security with equal probability. This assumption captures the fact that neither informed nor large liquidity traders need be present in the market at all times. However, if a large liquidity trader (type θ_2) was present in period 0, and sold (bought) in that period, then this trader would like to sell (buy) again in period 1. The latent demand of the large liquidity trader does not assure execution because he or she must compete to place an order in period 1 with single-period noise traders. We assume for simplicity that both types of traders have equal chances of execution, so that $\Pr[\theta^1 = \theta_2 \mid \theta^0 = \theta_2] = \Pr[\theta^1 = \theta_1 \mid \theta^0 = \theta_2] = \frac{1}{2}$. Similarly, if nature selects an informed trader (type θ_3) in period 0, this trader must also compete for execution with an independently selected noise trader in period 1, and we again assume equal probabilities of execution.

Traders are rational and submit their orders to obtain execution at the best possible prices. For single-period noise traders, this means finding the lowest ask or highest bid price. For 'large' traders (informed or liquidity traders) who wish to trade in both periods, this assumption means placing orders strategically to obtain the best overall (two-period) expected execution, taking into account the disclosure policy of dealers. We assume that the informed trader wants to buy in both periods if the asset is undervalued and sell otherwise; we show that this strategy is optimal in the appendix. Figure 1 illustrates the structure of the trading game. The figure shows the probability a trader is selected at time 0, the possible actions in period 0, the conditional probabilities for the various trader types in period 1, and the possible period 1 actions.

Let q_t denote the order flow in round t (t = 0,l) where q_t equals -1 for a sell order and +l for a buy order. For simplicity, we assume the high and low states are equally likely so that $E[v] = (v_H + v_L)/2 = v_0$. Then, $v_H = v_0 + \sigma$ and $v_L = v_0 - \sigma$ where $\sigma = (v_H - v_L)/2$ is the standard deviation of the asset's fundamental price. Denote by p_0 and p_1, the transaction prices in periods 0 and 1, respectively. Let H_0 and H_1 denote the history of trading in periods 0 and 1, i.e., $H_0 = \{(q_0, p_0)\}$ and $H_1 = \{(q_1, p_1), (q_0, p_0)\}$. In setting prices, dealers condition on the fact that an order was submitted for execution at their quotes. So, as in Glosten and Milgrom (1985), prices are *ex post* rational or regret-free given beliefs about the strategies of the informed trader and the history of trading. Thus, the price in period *t* is a function of the incoming order, given the history of trading, denoted by $p_t = p_t(q_t; H_t)$. The bid-ask spread in period *t* is implicitly defined by the quotation function, and is denoted $s_t = p_t(+1) - p_t(-1)$.

The trading model described above is an extensive-form game with incomplete information, because dealers do not observe a trader's type. A natural solution concept for games of this sort is a subgame-perfect Bayes-Nash equilibrium: Strategies are optimal in every subgame of the extensive-form game given the dealers' posterior beliefs about the traders' information, and these beliefs in turn are consistent with Bayes' rule and the observed actions. Later we extend the model to consider the case where dealers select disclosure policies prior to

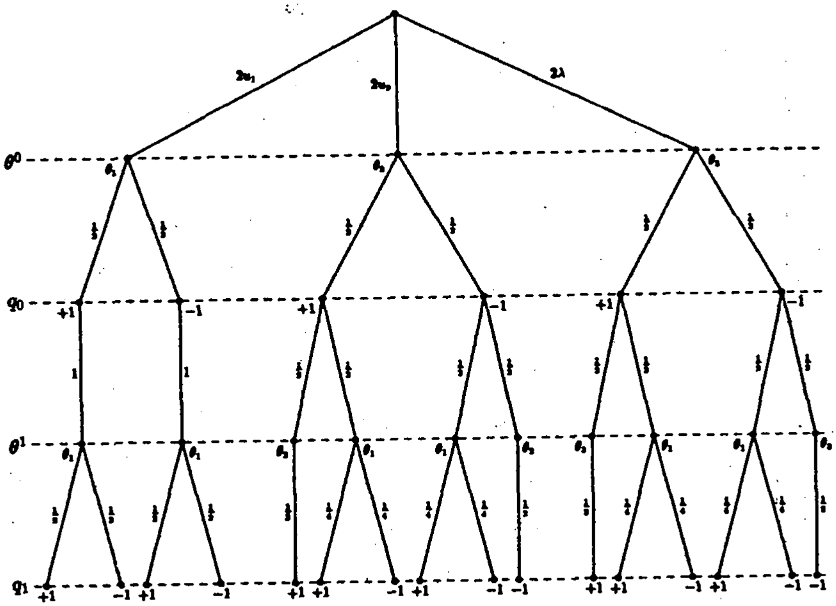

Figure 1
The figure illustrates the possible histories of trading and associated probabilities in periods 0 and 1 corresponding to the arrival of three types of traders: single-period noise traders, type θ_1; large liquidity traders, type θ_2; and informed traders, type θ_3. In each period $j = 0, 1$, θ^j denotes the type of trader, and q_j denotes the quantity traded.

playing the trading game. We discuss this pregame in detail in Section 3, but first consider the base case where disclosure is mandatory.

2. Mandatory Trade Disclosure

The following proposition characterizes the Bayes-Nash equilibrium in a market with mandatory trade disclosure.

Proposition 1. *There exists a Bay-Nasb equilibrium for tbe extensive form trading game. In period 0, the equilibrium price quotation function is*

$$p_0(q) = v_0 + \alpha_0 q_0 \tag{1}$$

where $\alpha_0 = 2\lambda\sigma$. The equilibrium price quotation function in period 1 is

$$p_1(q_1; q_0) = \begin{cases} v_0 + \alpha_1 q_1 & \text{for } q_1 = q_0 \\ v_0 - \alpha_2 q_1 & \text{otherwise} \end{cases} \tag{2}$$

where

$$\alpha_1 = \frac{3\lambda\sigma}{1 + u_2 + \lambda} \tag{3}$$

$$\alpha_2 = \frac{\lambda\sigma}{2u_1 + u_2 + \lambda} \tag{4}$$

Dealers make zero expected profits in both periods.

In the consolidated market where disclosure is mandatory, all dealers possess the same information. Competition forces prices in each period to equal the expected value of the asset conditional on past trades and the current order quantity. However, the equilibrium in the consolidated market differs from that of Glosten and Milgrom (1985) in important respects, as described by the following proposition.

Proposition 2. In equilibrium in the consolidated market

- *Transaction prices follow a martingale (i.e., $E[p_1 \mid p_0] = p_0$) prices are efficient, i.e., $p_t = E[v \mid H_t]$.*
- *The absolute price change associated with a trade reversal is larger than the price change associated with a continuation.*
- *Beliefs are path dependent* in *the sense that $E[v \mid (q_0; q_1)] \neq E[v \mid (q_1; q_0)]$ for $q_0 \neq q_1$.*
- *The bid and ask prices in period 1 are not symmetric around the precious transaction price. In particular, the midquote following a sell (buy) is lower (higher) than the previous transaction price.*
- *The bid-ask spread* in *period.1 is smaller than that in period 0.*

Proposition 2 illustrates the key differences between the equilibrium in our model and the equilibrium in Glosten and Milgrom (1985). As in their model, prices exhibit the martingale property and are efficient. From an empirical perspective, however, Proposition 2 offers new testable hypotheses. The model implies that the absolute price movements associated with reversals and continuations are asymmetric. A trade reversal (e.g., a sell followed by a buy) leads to an absolute price change of $|\alpha_0 - \alpha_2|$, whereas a continuation (e.g., a sequence of sell orders) leads to a smaller absolute price change of $|\alpha_0 - \alpha_1|$. Intuitively, a continuation is more likely than a reversal because informed and liquidity traders wish to trade on the same side of the market in both periods. Consequently, a reversal results in a greater change in beliefs (and hence prices) than a continuation.

Beliefs are also path dependent. Intuitively, information asymmetry is greatest at the beginning of the day so the initial trade has a larger price impact than later trades. Consequently, a buy order followed by a sell order results in a higher price than a sell order followed by a buy order.[10] Also, unlike Glosten and Milgrom (1985), the bid-ask spread is not set symmetrically around the previous transaction price. The spread is typically not symmetric about the previous transaction price in models where dealers are risk averse or bear inventory carrying costs.[11] However, these frictions are not present in our model. The asymmetry. here arises because successive trader arrivals are not independent so that order flow is serially correlated.

Finally, the spread narrows over the day because market makers learn from order flow, thereby facilitating price discovery. This result is consistent with a recent empirical study by Chan, Christie, and Schultz (1993) who show that spreads for NASDAQ stocks decline over the day.[12]

3. Trade Disclosure and Market Fragmentation

To examine whether consolidation is inevitable, we now consider a market where disclosure is not mandatory. To extend our framework to accomodate this decision, we assume there is a pretending game where dealers select whether or not to disclose trades and this (irrevocable) choice is made public prior to any trading activity. We refer to this game as the *disclosure game* to distinguish it from the subsequent trading game.

Given a particular set of disclosure policies, dealers' (Bayes-Nash) equilibrium actions in the subsequent extensive-form trading game define their respective total two-period payoffs corresponding to that combination of disclosure policies in the disclosure game. Repeating this exercise for all combinations of disclosure policies defines the payoffs for the strategic-form disclosure game. In the appendix, we characterize all the pure strategy Nash equilbria in the disclosure game, but we focus attention on the Nash equilibrium that survives the elimination of weakly dominated strategies.[13]

To specify the payoffs when disclosure is voluntary; some additional structure is required. Traders contact dealers to determine prices bilaterally. When dealers do not disclose transaction or quotation in-

---

[10]See also Easley and O'Hara (1992).

[1]See for example, Amihud and Mendelson (1980), Ho and Stoll (1983), and O'Hara and Oldfield (1986)

[12]By contrast, there is evidence that spreads in NYSE stocks exhibit a U-shaped pattern over the day. This difference may arise because NASDAQ operates as a dealer market (as assumed here) while the NYSE is an auction market with a designated dealer, the specialist.

[13]Note that in a perfect equilibrium [see e.g., Selten (1975)], strategies are the limit of totally mixed strategies that put some weight on each pure strategy, so that Nash equilibria involving weakly dominated strategies can be eliminated. The set of perfect equilibria coincides with the set of sequential equilibria [see, e.g., Kreps and Wilson (1982)] in almost all games.

formation, they set prices without any information on other dealers' past trades or quotes.[14] As in Glosten and Milgrom (1985), there is only one arrival per period and only one trade per period. The model can be extended, at the cost of additional complexity, to allow trading in all markets at all times without altering our major conclusions.

We consider two cases in this section. In the first case, disclosure is no longer mandatory for all dealers, while in the second case, disclosure is mandatory for dealers in some markets but not in others.

3.1 Voluntary trade disclosure

Proposition 3 describes the equilibrium in the case where disclosure is no longer mandatory for all dealers in the market.

Proposition 3 *There exits an equilibrium for the disclosure game where dealers do not disclose their trades. In the subsequent trading game, dealers' period 0 price functionals are given by*

$$p_0(q_0) = v_0 + \beta_0 q_0 \tag{5}$$

where $\beta_0 = \alpha_0 - \pi > 0$ *and*

$$\pi = \frac{1}{4}(2u_1 + 1)(\alpha_1 + \alpha_2) \tag{6}$$

In period 1, the dealer who did not trade in period 0 quotes prices given by

$$p_1(q_1; q_0) = v_0 + \alpha_1 q_1 \tag{7}$$

and the dealer who did trade (marginally) improves these quotes if and only if $q_0 \neq q_1$. *Dealer's total expected profits from their trading in periods 0 and 1 are equal to zero.*

Proposition 3 implies that without mandatory disclosure, consolidation is not inevitable, despite potential informational gains. The intuition is straightforward. Dealers are willing not to disclose trades because they profit from the associated reduction in direct price competition, while large traders prefer less transparent mechanisms.

A dealer who does not disclose trades makes positive expected profits in period 1 from observing the past trade. Trading information is valuable because large traders tend to trade on the same side of the market. Thus, reversals are less likely than continuations if an informed or liquidity trader is present in the market. Consequently, a dealer who observed (but did not disclose) a sell in period 0 can

[14] We assume it is not feasible, perhaps because of reputational considerations, for dealers to Infer the reservation prices of their competitors by acting as investors.

offer a lower ask price for a buy in period 1 than a dealer who did not observe the trade and still make positive expected profits because there is no direct price competition among dealers. By contrast, dealers who choose to disclose trades face price competition from nondisclosing dealers and earn zero expected profits. Consequently, in the absence of mandatory disclosure, a market will not naturally consolidate.[15] It is important to keep in mind, however, that fragmentation depends on many factors other than trade disclosure. We discuss these issues in Section 4.3 when we consider the robustness of our conclusions.

3.2 Heterogeneous disclosure requirements

We turn now to the case where disclosure is mandatory for at least one dealer but is voluntary for other dealers, possibly because the dealers are in different nations or are regulated differently. Proposition 4 describes the equilibrium in the case where some dealers are unconstrained, that is, they are not required to disclose their trades.

Proposition 4. When trade disclosure rules differ across dealers, there exists an equilibrium in the disclosure game where unconstrained dealers do not disclose trading information.

- *If more than one dealer is unconstrained, the equilibrium price schedules are described by Proposition 3.*
- *If only one dealer is unconstrained, the period 0 quotation function of disclosing dealers is $p_0 + \alpha_0 q_0$, and the nondisclosing dealer (marginally) improves these prices. In period 1, the price quoted by disclosing dealers is $v_0 + \alpha_1 q_1$, and the nondisclosing dealer (marginally) improves this price only when $q_1 \neq q_0$. The nondisclosing dealer makes positive expected profits.*
- *Relaxing the disclosure requirements on constrained dealers may narrow bid-ask spreads.*

The expected trading volume of dealers who do not disclose is higher than the volume of dealers who are required to disclose their trades.

The economic intuition behind Proposition 4 is straightforward. A dealer who is legally required to disclose trades cannot extract any rents from trading in the first period because this information must be publicized. By contrast, a dealer who does not disclose a trade can profit from this private information in later trading because there is

[15] There are other Nash equilibria, but these involve weakly dominated strategies. However, the case where all dealers disclose is not a Nash equilibrium.

no direct price competition.[16] This dealer can undercut the disclosing dealer's quotes and still earn positive expected profits. As a result, the expected volume of a dealer who does not disclose is strictly higher than that of a dealer who does disclose. This result is consistent with arguments that the loss of order flow to London from other European markets is attributable to looser disclosure requirements on the London Stock Exchange.

Finally, Proposition 4 shows that looser disclosure requirements may result in narrower spreads. Intuitively, less stringent disclosure requirements may increase competition among nondisclosing dealers to attract valuable order flow, leading to a reduction in bid-ask spreads.

4. Fragmentation and Consolidation

In this section, we examine the differences between fragmented and consolidated markets in terms of various measures of market quality. We begin by analyzing the effect of fragmentation on security prices and then examine the question of whether fragmentation can benefit some market participants.

4.1 Security prices in a fragmented market

Proposition 5 characterizes the impact of market fragmentation on security prices.

Proposition 5. *In a market without mandatory trade disclosure*

- *Price volatility, measured by the expected absolute change in price* $(E[|p_1 - p_0|])$, *is higher than in a consolidated market. The absolute price change following a reversal exceeds that of a continuation, as in a consolidated market.*
- *The intraday pattern in bid-ask spreads is the opposite of that in a consolidated market,* i.e., $s_0 < s_1$.
- *Transaction prices exhibit the martingale property, i.e.,* $E[p_1 \mid p_0] = p_0$, *but prices are not efficient because they do not (in general) equal the expected value of the asset given the history of trading, i.e.,* $E[v \mid H_t] \neq p_t$.

These results also apply to the case where disclosure is mandatory for some, but not all, markets.

[16] This is consistent with evidence from the London equity markets reported by Franks and Schaefer (1991). who note that "Conversations with market makers, both on SEAQ and NASDAQ. strongly suggested that the informativeness of trade publication is closely linked to the number of competitors."

The proposition summarizes the main differences in price dynamics between markets with and without mandatory trade disclosure. Fragmentation increases price volatility because less information is impounded in prices. Further, under fragmentation the intraday pattern in bid-ask spreads is' precisely the opposite of that in a consolidated market, and spreads increase from period 0 to period 1. Intuitively, dealers with rational expectations recognize that the lack of disclosure in the initial period increases their uncertainty and widens bid-ask spreads. This suggests that stocks traded actively in international markets without timely trade disclosure may exhibit different temporal patterns in spreads than stocks whose markets are primarily or wholly domestic.

It is also apparent that nondisclosure induces price distortions. Of particular interest, the expected price change in a market without disclosure given the period 0 price is zero. Thus, the market may appear efficient in an *ex post* sense to an econometrician with historical price data, although prices are inefficient in the sense that they do not equal the expected value of the asset. More precisely, in the initial trading period, dealers in a fragmented market set prices that equal the expected value of the asset and 'pay' traders for order flow. To see this, recall from Proposition 1 that the quote in the consolidated market is the expected value of the security given the trade, i.e., $p_0 = E[v \mid q_0] = v_0 + \alpha_0 q_0$, while the price in the fragmented market (using Proposition 3) is $p_0 = v_0 + \beta_0 q_0 = E[v \mid q_0] - \pi q_0$, where $\pi > 0$ represents the order flow payment. Note that in U.S. markets, payment for order flow may arise because the minimum price variation is one-eighth, whereas here the order flow payment reflects the value of the trading information or 'print.'

One consequence of order flow payments is that dealers make expected losses in the initial period. These losses are offset by the expected profits from trading in period 1, conditional on the (nonpublic) trading information obtained in period 0. The intuition is similar to that of Leach and Madhavan (1993), where dealers quote bid and ask prices to elicit more informative order flow that is valuable in setting future prices. Unlike their model, competition among dealers does not force expected profits in each period to equal zero since trading histories are not made public. Rather, competition forces the *total* two-period expected profits to zero. It follows that the amount of the order flow payment, π, must be equal to the dealer's expected profits in period 1 given that the dealer traded in period 0. It can be shown that π is equal to the product of the probability of a trade reversal and the expected profit from trading conditional upon a reversal. The probability of a reversal increases with the probability of a single-period noise trader arriving, that is, u_1. However, the expected profit conditional upon a reversal is increasing in the degree of risk and the amount of asymmetric information, so that π increases with σ and λ.

Finally, it is useful to consider some limiting cases of the model to better understand where the distortions induced by the lack of disclosure have the most effect. It is easy to show that as the probability of informed trading, A, tends to zero, the expected differences between the transaction prices in the consolidated and fragmented market in each period vanish. Similar remarks apply as the volatility of the asset, measured by σ, tends to zero. This is consistent with the stylized fact that concern about disclosure is greatest for thinly traded securities where volatility is high and information asymmetries are severe. It is also straightforward to show that in the absence of noise traders (in both periods) the equilibrium in a fragmented market without disclosure coincides with the equilibrium in a market with mandatory disclosure. This may explain why transparency is not a major issue in markets (e.g., foreign exchange) dominated by large traders.

4.2 Fragmentation and the costs of trading

We turn now to the question of how the various market participants are affected by fragmentation arising from the nondisclosure of trading information. As traders are heterogeneous, fragmentation is likely to affect traders in different ways. In particular, the lack of disclosure is likely to benefit informed traders who are able to conceal their initial trades, and thereby capture more of the value of their information through dynamic trading. Similarly, large liquidity traders pursue dynamic strategies, so this intuition applies to them as well. However, since dealers break even on average, these gains come at the expense of noise traders. The following proposition characterizes the effects of fragmentation induced by nondisclosure on the various agents in our model.

Proposition 6. *Compared to a consolidated market, informed traders and large liquidity traders who pursue dynamic trading strategies in a market without disclosure are strictly better off because they obtain higher revenues when selling and incur lower outlays when buying. However, the effect of nondisclosure on noise traders is ambiguous; compared to a consolidated market, initial bid-ask spreads without disclosure are narrower but spreads* in *the later period are wider.*

Proposition *6* confirms our intuition that the lack of disclosure benefits informed traders because it enhances their ability to extract rents from their information through dynamic trading. The same logic ap plies to the large liquidity traders who alsobenefit from being able to conceal their initial trades, so that the expected cost of filling a sequence of orders on the same side of the market is smaller in a fragmented market. There is also a shifting of costs across different periods. Relative to a consolidated system, the period 0 costs of trading in a fragmented market are lower because positive expected profits in period 1 allow dealers to undercut prices in period 0 that equal the expected value of the security. All period 0 traders benefit from nondisclosure because they face an effective spread of $2(\alpha_0 - \pi)$, which is smaller than the spread $2\alpha_0$ under full disclosure. This shifting comes at the expense of single-period noise traders who arrive later, because these traders effectively subsidize the profits of larger traders.[17]

These results suggest a possible explanation for why, despite theoretical arguments to the contrary, one market has not emerged to dominate fragmented markets. Proposition 6 implies that even if it were feasible to create a unified tradedisclosure system, large liquidity traders or information-motivated traders who would like to trade in more than one period benefit from not disclosing their trades. Intuitively, large traders essentially "front-run" their own trades, and nondisclosure allows these traders to obtain better execution overall. This natural demand for less transparent trading systems suggests that some degree of fragmentation may be inevitable unless there is mandatory trade disclosure.

4.3 Discussion

The model was based on a number of simplifying assumptions, and at this point it is useful to assess the impact of relaxing these -assumptions on our conclusions. 'In our model, the lack of mandatory disclosure (or more precisely, last trade reporting) results in market fragmentation because the information gained from trading provides opportunities to make profits in later trading while putting disclosing dealers at a disadvantage. Underlying this intuition is the assumption that orders are executed sequentially, so that last-trade reporting provides important information to potential competitors. There may, however, be other factors that induce dealers to desire greater transparency in other forms. Chowdhry and Nanda (1991) provide a model where market makers voluntarily make information public to discourage insider trading while making the market more attractive to uninformed traders. A market that can develop a reputation for being 'clean" may benefit from reduced adverse selection costs. Similarly, if insider information is long-lived, informed traders may avoid markets

[17] Pagano and Roell (1990a) analyze execution costs and note that large trades prefer markets such as London where trades are not reported immediately.

with disclosure to avoid revealing their private information, creating incentives for dealers to disclose trades, These considerations may explain why some markets appear to desire greater transparency while others prefer less.

It is worth considering the sensitivity of the results to our simplifying assumptions about the process governing trader arrivals. The assumption that noise traders have an equal opportunity to trade, given that a liquidity or informed trader wishes to trade, was made purely for notational simplicity. It is easy to generalize the model to allow a higher or lower probability of trading by noise traders without affecting our qualitative conclusions. A related concern is that noise traders have no discretion over the timing of their trade. One approach is to introduce a third type of liquidity trader who wishes to trade one unit but can choose when to trade, as in Admati and Pfleiderer (1988). Discretionary liquidity traders will concentrate their trading in the period with the smallest bid-ask spread, but the underlying economic intuition concerning the nature of market fragmentation is otherwise unaffected.

5. Conclusions

This article examines the relation between market integration and the disclosure of trading information to market participants. This issue lies at the heart of many important policy questions concerning the design of trading systems, the integration of international markets, and the regulation of securities markets.

We showed that certain types of market participants prefer to trade in a fragmented market where their trades are not disclosed. In particular, large traders, whose orders are filled with multiple trades, obtain lower expected execution costs in a market where their trades are not disclosed. Conversely, nondisclosure benefits short-term noise traders who do not pursue such dynamic strategies. Finally, nondisclosure benefits dealers by reducing direct price competition. Thus, contrary to common belief, trading in a fragmented market will not inevitably gravitate to a single market.

We also compared and contrasted consolidated and fragmented markets. Although prices in a fragmented market may appear efficient *ex post,* dealers are willing to undercut quotes that equal ‘the conditional expected value of the asset. Ask (bid) prices may be below (above) the expected value of the security. Fragmentation also results in a reversal in the normal intraday pattern in bid-ask spreads and an increase in price volatility. Further, easing disclosure rules may, in certain cases, improve market quality by allowing dealers who were constrained to report trades to compete more effectively with nondisclosing dealers. The model also provides new insights into price dynamics in a consolidated market. Even though prices exhibit the martingale property, trade reversals result in larger revisions in dealers' beliefs, and hence prices, than continuations because some traders may be "working" a large position over time. Further, the expected value of the security is not the midquote of the bid-ask spread because of serial correlation in order flow.

Appendix

Proof of Proposition 1. With complete disclosure, competitive dealers with identical information make must quotations in each period that are *ex post* rational. Thus, the transaction price must equal the expected value of the asset conditional upon the trading history. The price in period 0 is

$$p_0(H_0) = \sum_{\theta' \in \Theta} E[v \mid \theta^0 = \theta', H_0] \Pr[\theta^0 = \theta' \mid H_0] \tag{A1}$$

In period 0, a dealer's posterior beliefs about the trader's type can be computed from Bayes' rule. The probability the trader is an informed trader, given a sell, is

$$\begin{aligned} \Pr[\theta^0 = \theta_3 \mid q_0 = -1] &= \frac{\Pr[\theta^0 = \theta_3] \Pr[H_0 \mid \theta_3]}{\sum_{\theta' \in \Theta} \Pr[\theta^0 = \theta'] \Pr[H_0 \mid \theta']} \\ &= \frac{2\lambda(\frac{1}{2})}{2u_1(\frac{1}{2}) + 2u_2(\frac{1}{2}) + 2\lambda(\frac{1}{2})} \end{aligned} \tag{A2}$$

A dealer's conditional mean for all arrivals other than an informed trader is v_0, that is, $E[v \mid \theta_i, H_0] = v_0$ for $i = 1, 2$. The dealer's conditional expectation of the asset's value given a sell order by an informed trader is $E[v \mid \theta_3, H_0] = v_L$, assuming the informed trader sells when $v = v_L$ and buys if $v = v_H$. Then,

$$\begin{aligned} p_0(-1) &= E[v \mid H_0] \\ &= v_0(1 - \Pr[\theta^0 = \theta_3 \mid H_0]) + v_L \Pr[\theta^0 = \theta_3 \mid H_0] \end{aligned} \tag{A3}$$

Then, using the fact that $v_L = v_0 - \sigma$, it follows that $p_0(-1) = v_0 - \alpha_0$ where $\alpha_0 = 2\lambda\sigma$. By symmetry, $p_0(+1) = v_0 + \alpha_0$, and we have characterized the price schedule in period 0. Observe that bid and ask prices are placed symmetrically around dealer's prior conditional expectation of the asset's value, v_0.

Now consider a dealer's inference problem in period 1. Suppose that a dealer observes a sequence of sell orders, that is, $H_1 = (q_0, q_1) =$

(-1, -1). This trading history could be generated by (1) the independent arrival of single-period noise sellers in periods 0 and 1, (2) the arrival of a liquidity seller in period 0 who stays through period 1, (3) a liquidity seller in period 0 followed by a noise seller in period 1, (4) the arrival of an informed seller in period 0 who remains in period 1, or (5) an informed seller in period 0 followed by a noise seller in period 1.

It is straightforward to compute the conditional probabilities of cases (4) and (5) given the observed trading history. For case (4), Bayes' rule yields

$$\Pr[\theta^0 = \theta_3, \theta^1 = \theta_3 \mid H_1] = \frac{2\lambda(\frac{1}{2})^2}{2u_1(\frac{1}{2})^2 + 2u_2(\frac{1}{2})^2 + 2u_2(\frac{1}{2})^3 + 2\lambda(\frac{1}{2})^2 + 2\lambda(\frac{1}{2})^3} \tag{A4}$$

Simplifying and using the relation $2u_1 + 2u_2 + 2\lambda = 1$, we obtain

$$\Pr[\theta^0 = \theta_3, \theta^1 = \theta_3 \mid H_1] = \frac{2\lambda}{1 + \lambda + u_2} \tag{A5}$$

Similarly, if is easy to show that

$$\Pr[\theta^0 = \theta_3, \theta^1 = \theta_1 \mid H_1] = \frac{\lambda}{1 + \lambda + u_2} \tag{A6}$$

Observe that in cases (1) through (3) above, the expected value of the security given the trader types is v_0; in cases (4) and (5) where the informed trader sells, the expected value of the security is v_L. Let $\gamma = \Pr[\theta^0 = \theta_3, \theta^1 = \theta_3 \mid H_1] + \Pr[\theta^0 = \theta_3, \theta^1 = \theta_1 \mid H_1]$ represent the probability that an informed trader sold in period 0. Then, it follows that $p_1(-1; -1) = E[v \mid q_0 = q_1 = -1]$, where

$$E[v \mid q_0 = q_1 = -1] = v_0(1 - \gamma) + \gamma v_L \tag{A7}$$

Using the fact that $v_L = v_0 - \sigma$, we obtain $p_1(-1; -1) = v_0 - \alpha_1$ where

$$\alpha_1 = \frac{3\lambda\sigma}{1 + \lambda + u_2} \tag{A8}$$

By symmetry, it follows that $p_1(1; 1) = v_0 + \alpha_1$, so that $p_1(q_1; q_0) = v_0 + \alpha_1 q_1$ for $q_0 = q_1$.

Now suppose there is a reversal of trade, say $q_0 = -1$ and $q_1 = +1$. This trading history can be generated by (1) a single-period noise seller in period 0 and a noise buyer in period 1, (2) a liquidity seller in period 0 followed by a noise buyer in period 1, or (3) an informed trader who sells in period 0 but who is followed in period 1 by a noise buyer. Using Bayes' rule to compute the dealer's conditional expectation (as above), we obtain $E[v \mid q_0 = -1, q_1 = +1] = v_0 - \alpha_2$ where

$$\alpha_2 = \frac{\lambda\sigma}{2u_1 + u_2 + \lambda} \tag{A9}$$

By symmetry, the price in period 1 is $p_1 = v_0 - \alpha_2 q_1$ if $q_1 \neq q_0$. Finally, observe that prices always lie within the relevant interval, that is, that $p_0(-1) > v_L$ and $p_1(-1; -1) > v_L$, and conversely for buys, so the optimal strategy for the informed trader is to sell (if possible) in both periods if $v = v_L$. ■

Proof of Proposition 2.

1. Recall that $p_t(H_t) = E[v \mid H_t]$. By the law of iterated expectations, $E[p_1 \mid p_0] = E[E[v \mid H_1] \mid H_0] = E[v \mid H_0] = p_0$, showing that prices follow a martingale.
2. The expected absolute price change associated with a trade reversal is larger than the price change associated with a continuation. To see this, note that, relative to the previous transaction price, the absolute price impact is $|\alpha_0 - \alpha_2|$ if $q_1 \neq q_0$ and $|\alpha_0 - \alpha_1|$ if $q_1 = q_0$. From the definitions of α_0, α_1, and α_2 from Proposition 1 and the fact that $2u_1 + u_2 + \lambda = \frac{1}{2}(2u_1 + 1)$ it is straightforward to show that

$$|\alpha_0 - \alpha_2| = \frac{2\lambda\sigma u_1}{2u_1 + u_2 + \lambda} > \frac{2\lambda\sigma u_1}{1 + u_2 + \lambda} = |\alpha_0 - \alpha_1| \tag{A10}$$

3. From Proposition 1,

$$\begin{aligned} E[v \mid (q_0 = 1; q_1 = -1)] &= v_0 + \alpha_2 > v_0 - \alpha_2 \\ &= E[v \mid (q_0 = -1; q_1 = 1)]. \end{aligned}$$

4. The bid and ask prices in period 1 are not, in general, symmetric around the previous transaction price. Consider the spread following a sell at price $v_0 - \alpha_0$. If a trader sells in period 1, the bid price is $v_0 - \alpha_1$; if the trader buys, the ask price is $v_0 - \alpha_2$, so the midquote of the bid-ask spread is $v_0 - (\alpha_1 + \alpha_2)/2$. For the midpoint of the spread to equal the previous transaction price, we require $\alpha_0 = \frac{1}{2}(\alpha_1 + \alpha_2)$. Using the definitions of α_0 and α_1 in Proposition 1, we note that $\alpha_2 < \alpha_0 < \alpha_1$, and from part 2 above, *we also have* $\alpha_0 - \alpha_2 > \alpha_1 - \alpha_0$, which establishes that the previous transaction price (given a sell) is higher than the midpoint of the posttrade quotes.

5. The bid-ask spread in period 0 is $s_0 = p_0(+1) - p_0(-1) = 2\alpha_0 = 4\lambda\sigma$. In period $s_1 = \alpha_1 - \alpha_2 < 2\alpha_0 = s_0$ because (from part 4 above) $2\alpha_0 > (\alpha_1 + \alpha_2)$. ∎

Proof of Proposition 3. The equilibrium is computed by backward induction; for all possible combinations of disclosure actions chosen by the dealers, we first compute the prices in the subgames in period 1 and then compute the prices in period 0 consistent with these prices. These prices define each dealer's profits in the pretrade disclosure game, and we can compute the Nash equilibria for this game. We assume for simplicity that there are two dealers, denoted *A* and *B*, but it is straightforward to extend the proof to larger numbers of dealers. There are three relevant cases to consider: (1) both *A* and *B* choose to disclose all trades; (2) A chooses to disclose trades but *B* does not (or vice versa); and (3) both A and *B* do not disclose their trades.

Case 1: When both dealers disclose, the equilibrium is described by Proposition 1. In particular, as prices in each period are equal to the expected value of the security, it follows that expected profits in each period (and hence total expected profits) equal zero for both dealers.

Case 2: In this case, dealer A discloses while dealer *B* does not. Traders submit orders to the dealer offering the lowest ask or highest bid price in any period, provided that this strategy also yields the highest two-period revenues for a large seller or lowest two-period outlays for a large buyer. Traders condition on the disclosure policy of the dealer. In this case, dealer *B* can make strictly positive total expected profits. To see this, suppose dealer *B* were to marginally improve the period 0 price of dealer *A* without altering the price structure in period 1; then, all traders would trade with *B in the* first period. This is rational for both single-period traders and traders with dynamic order placement strategies.

The price in period 1 quoted by the dealer who does not observe period 0 trading activity is the expected value of the security given the current order and beliefs about traders' strategies; and the actions of other dealers. Dealer *A* conjectures that following an unreported period 0 sell order, dealer *B* will marginally improve *A's* ask price and will match the bid price. Thus, dealer *A* will observe a period 1 sell only if the previous trade was a sell, and correspondingly for buys. Thus, from the derivation of Proposition 1, dealer *A* (who discloses) has a conditional mean in period 0 of

$$E_A[v \mid q_1] = E[v \mid q_1 = q_0] = v_0 + \alpha_1 q_1 \tag{A11}$$

Now consider dealer *B*, who observes a. buy (sell) order in period 0, but does not disclose the trade. Clearly, if $q_1 = q_0$, the dealer's expectation of the asset's value is equal to the period 1 ask (bid) price of dealer A who did not observe the trade price, so B matches these quotes. However, suppose there is a reversal of trade, that is, $q_0 = -1$ and $q_1 = 1$. Then, $E_B[v \mid H_1] = v_0 - \alpha_2$ as given by Proposition 1, but A sets an ask price equal to $E_A[v_0 \mid q_1] = v_0 + \alpha_1$. Thus, dealer B will marginally improve the ask price of dealer A and earn an expected profit of $\alpha_1 + \alpha_2$ from the trade. These profits allow dealer B to cover the loss from undercutting A's period 0 quotes and still make strictly positive expected total profits.

To verify that this is indeed an equilibrium, observe that dealer A will not set a period 0 ask price below $v_0 + \alpha_0$ because the expected profit given that a trade does occur at this quote is negative, and these losses cannot be recovered from trading in period 1. Intuitively, sup pose a trade, occurred in period 0 with dealer A, who does disclose trades. Dealer B observes this trade (because it is publicized prior to trading in period 1) and uses Bayes' rule to update. In period 1, dealers A and B *have the* same information, and competition forces prices to equal the expected value of the asset, as described in Proposition 1. Note that both the liquidity and informed traders condition on the disclosure strategy of the dealer, and cannot do better by trading with the disclosing dealer as this makes their previous trades public. In equilibrium, the nondisclosing dealer makes strictly positive profits while the disclosing dealer makes zero expected profits.

Case *3:* As before, in period 1, the dealer who did not trade in period 0 sets quotes of $p(q_1) = v_0 + \alpha_1 q_1$. The dealer who observed a sell (buy) in period 0 will marginally improve the ask (bid) price of the other dealer and earn an expected profit of $\alpha_1 + \alpha_2$ from the trade. The pricing behavior in period 0 can be modeled as a second-price auction, where dealers bid (through their quotations) to obtain a trade and thereby earn positive expected profits in period 1 from knowledge about the trade. The expected profit from seeing the period 0 order, denoted by π, is the product of the expected profits given a reversal (i.e., $\alpha_1 + \alpha_2$) and the probability of a reversal. It is straightforward to show that $\pi = \frac{1}{2}(2u_1 + u_2 + \lambda)(\alpha_1 + \alpha_2) = \frac{1}{4}(2u_1 + 1)(\alpha_1 + \alpha_2)$. Competition implies that the period 0 quotations reflect the expected value of this information. Thus, the equilibrium price in period 0 is $p_0(q) = v_0 + \beta_0 q_0$ where $\beta_0 = \alpha_0 - \pi$. Again, it does not pay for a dealer to undercut these prices. So when both dealers disclose, the expected total profits for both dealers is then zero.

Equilibrium: The payoff structure for the disclosure game yields three Nash equilibria: (1) A does not disclose while B does disclose; (2) B does not disclose while A does disclose; (3) Both A and B do not disclose. In all three cases, there is no incentive for the dealers to deviate from the proposed actions given their rational conjectures about the other dealer's behavior. There is no Nash equilibrium where both dealers disclose trades 'because a deviation from this strategy yields strictly positive profits.

It is clear that in equilibria 1 and 2, the dealer who chooses to disclose is pursuing a weakly dominated strategy in the sense that the payoffs from nondisclosing are greater than or equal to the payoffs from disclosing. These equilibria are not robust to small "trembles" in dealer strategies, and hence are not perfect equilibria. Only equilibrium 3 survives the elimination of weakly dominated strategies. In this equilibrium, neither dealer chooses to disclose their trades. ■

Proof of Proposition 4.

1. Let N denote the number of dealers who need not disclose their trades. When $N = 1$, the dealer who is not required to disclose trades makes zero expected profits by disclosing trades, but strictly positive expected profits from not disclosing. The prices and strategies are as described in case 2 in the proof of Proposition 3.
2. Now consider the situation where $N > 1$. Competition among unconstrained dealers leads to prices given by case 3 in the proof of Proposition 3. As $\pi > 0$, con&rained dealers (whose prices must equal the expected value of the asset in each period) are undercut in period 0 and match the prices of the N unconstrained dealers in period 1 only on continuations, so that the equilibrium coincides with that described in Proposition 3. The volume results follow immediately from the derivation of the equilibrium price schedules.
3. Suppose that there are three markets, A, B, and C, and suppose that markets A and B must disclose trades while C does not. Now suppose market B is not required to disclose. It is straightforward to show that price competition between B and C narrows spreads from $2\alpha_0$ to $2(\alpha_0 - \pi)$ in period 0; spreads in period 1 would remain at $2\alpha_1$. ■

Proof of Proposition 5.

1. In a fragmented market, the absolute change in price is $|\alpha_1 - \beta_0|$ for a continuation and $|\alpha_1 + \beta_0|$ for *a* reversal. (Note that as in the consolidated market, the price change for a reversal exceeds that of a continuation in a market without disclosure.) The corresponding absolute price changes in a consolidated market are $|\alpha_1 - \alpha_0|$ and $|\alpha_0 - \alpha_2|$ respectively. Observe that $\beta_0 < \alpha_0$, so the price change for a continuation is greater in the fragmented market. Similarly, it is easy to prove that $0 < \alpha_0 - \alpha_2 < \alpha_1 + \beta_0$, so that

the price change on a reversal is higher in a fragmented market. As the probabilities of reversals and continuations are equal in the two cases, the expected absolute price change is greater in a fragmented market than in a consolidated market.

2. Proposition 3 implies that the initial bid-ask spread without disclosure is $s_0 = 2\beta_0$ and $s_1 = 2\alpha_1$. As $\beta_0 < \alpha_0 < \alpha_1$, it follows that $s_0 < s_1$.
3. Note that $E[p_1 \mid p_0] = v_0 + \alpha_1 E[q_1 \mid p_0] = v_0 + \alpha_1 E[q_1 \mid q_0]$, since there is one-to-one mapping between q_0 and p_0. Now $E[q_1 \mid q_0] = (2\zeta - 1)q_0$ where $\zeta = 1 - u_1 - (u_2 + \lambda)/2$ is the probability of a continuation, so that we obtain

$$E[p_1 \mid p_0] = v_0 + \alpha_1(2\zeta - 1)q_0. \tag{A12}$$

From Proposition 2, the fact that prices in a consolidated market follow a martingale implies that $\alpha_1\zeta + \alpha_2(1-\zeta) = \alpha_0$. Substituting this expression into Equation (A12), we obtain $v_0 + \alpha_1(2\zeta - 1)q_0 = v_0 + [\alpha_0 - \alpha_2(1-\zeta) - \alpha_1(1-\zeta)]q_0 = v_0 + \beta_0 q_0 = p_0$, where β_0 is described in Proposition 3. This establishes that in the fragmented market, conditional upon the current transaction price, the expected change in price is zero. However, prices are inefficient in a fragmented market because prices do not equal the expected value of the asset, given the history of trading. In period 0, $E[v \mid q_0] = v_0 + \alpha_0 q_0 \neq v_0 + \beta_0 q_0 = p_0$. Further, prices in period 1 do not equal the unconditional expected values of the asset given a reversal, although they do when there is a continuation. ■

Proof of Proposition 6. Consider a trader of type θ_2 or θ_3 who wishes to buy in both periods. From Proposition 1, the total cost of a two-unit purchase in a consolidated market is $(v_0 + \alpha_0) + (v_0 + \alpha_1)$. From Proposition 3, the maximum total cost of a two-unit purchase in a fragmented market is (marginally) smaller than $(v_0 + \alpha_0 - \pi) + (v_0 + \alpha_1)$ types θ_2 and θ_3 have strictly lower execution costs when disclosure is voluntary. However, in a fragmented market, a noise buyer in period 1 pays $v_0 + \alpha_1$, which is strictly higher than the expected period 1 price in a consolidated system. Period 0 traders, however, are better off in a fragmented market, since spreads are narrower than in a consolidated market, that is, $2\beta_0 < 2\alpha_0$. In both markets, dealers make zero total expected profits. ■

References

Admati, A. R, and P. Pfleiderer, 1988, "A Theory of Intraday Trading Patterns," *Review of Financial Studies* 1, 340.

Admati, A. R., and P. Pfleiderer, 1991. "Sunshine Trading and Financial Market Equilibrium," *Review of Financial Studies,* 4, 443-481.

Amlhud, Y., and H. Mendelson, 1980, "Dealership Market: Market Making with Inventory," *Journal of Financial Economics, 8,* 31-53.

Benveniste, L, A. Marcus, and W. Wilhelm, 1992, "What's Special about the Specialist," Journal *of Financial Economics, 32,61-86.*

Chan, K. C., W. Christie and P. Schultz, 1993, "Market Structure, Price Discovery, and the lntraday Pattern of Bid-Ask Spreads for Nasdaq Securities.' working paper, Ohio State University.

Chowdhry, B., and V. Nanda, 1991, "Multi-Market Trading and Market Liquidity," *Review of* Financial Studies, 4, 483-511

Diamond, D., and R. Verecchia, 1991, "Disclosure, Liquidity, and the Cast of Capital," *Journal of Finance,* 46, 1325-1360.

Easley, D., and M. O'Hara, 1992, "Time and the Process of Security Price Adjustment," *Journal of Finance,* 47, 577-606.

Economist, 1992, *"Last Orders?"-* March 14, 91.

Fishman, M.. and K. Hagerty, 1991, "The Mandatory Disclosure of Trades and Market Liquidity," working paper, Northwestern University.

Fishman M. J., and F. A. Longstaff, 1992, "Dual Trading in Futures Markets," *Journal of Finance,*

Forster, M. M., and T. J. George, 1992, "Anonymity in Securities Markets," *Journal of Financial Intermediation,* 2, 168-206.

Franks. J., and S. Schaefer, 1991, "Equity Market Transparency," working paper. London Business School.

Gemmill, G., 1994 "Transparency and Liquidity: A Study of Block Trades on the London Stock Exchange under Different Publication Rules," working paper, City University of London.

Glosten, L, and P. Milgrom, 1985, "Bid, Ask, and Transaction Prices in a Specialist Market with Heterogeneously Informed Agents." *Journal of Financial Economics,* 14, 71-100.

Harris, L. 1992, "Consolidation, Fragmentation, Segmentation and Regulation," working paper, University of Southern California.

Ho, T., and H. Stoll. 1983," The Dynamics of Dealer Markets under Competition," *Journal of Finance,* 38, 1053-1074.

Kreps, D., and R. Wilson, 1982, "Sequential Equilibrium," Econometrica 50, 863-894.

Leach, J.C., and A. Madhavan, 1993,"Price Experiments and Security Market Structure" *Review* of Financial Studies, 6, 375-404.

Madhavan, A., 1995, "Security Prices and Market Transparency," working paper, University of Southern California.

Mendelson, H., 1987, "Consolidation, Fragmentation, and Market Performance," *Journal of Financial and Quantitative Analysis* 22, 189-207.

Naik, N., A. Neuberger, and S. Vishwanathan, 1994, "Disclosure Regulation in Competitive Dealership Markets: Analysis of the London Stock Exchange,' working paper, London Business

O’Hara, M., and G. Oldfield, 1986, "The Microeconomics of Market Making," *Journal of Financial and Quantitative Analysis,* 21, 361-376.

Pagano, M., 1989 "Endogenous Market Thinness and Stock Price Variability," *Review of Economic Studies,* 56, 269-288

Pagano, M., and A. Roell, 1991a, "Auction and Deal Markets: What is the Difference?" Discussion Paper 125, Financial Markets Group, London School of Economics.

Pagano, M., and A. Roell, 1990b, "Trading Systems in European stock Exchanges," Discussion Paper 75, Financial Markets Group, London School of Economics.

Roell, A., 1990, "Dual Capacity Trading,” *Journal of Financial Intermediation,* 1, 105-124.

Selten, R, 1975, "A Re-Examination of the Perfectness Concept for Equilibrium Points in Extensive Games," *International Journal of Game Theory,* 4, 25-35.

Stigler, G., 1964, "Public Regulation of the Securities Markets," *Journal of Business,* 37, 117-142.

Wall Street Journal 1992, *"Another SEC Curb on Stock Exchanges,"* September 2, A10.