Automation, Trading Costs, and the Structure of the Securities Trading Industry

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THIS PAPER EXAMINES the impact of advances in automated trade execution on the cost of trading and the structure of the securities trading industry. The effects have been fundamental: the cost of providing exchange trading services has declined significantly, the means by which services can be delivered to investors have changed radically, and the natural industrial structure of the trading services industry has been transformed in consequence. These developments are affecting all classes of market participants: exchanges, broker-dealers, investors, and regulators.

The paper is organized as follows. At the outset, we provide an analytical description of recent industry developments in the context of the spread of technologies enabling automated trade execution. We then suggest theoretical paradigms to explain observed changes, and to assist in anticipating future changes, in trading market structure. Specific implications for the competitive behavior of industry incumbents and entrants are drawn out and compared to current and planned developments in exchange and industry structure. We then isolate those inputs into the theories that govern their predictions in order to guide empirical investigations of their significance in the development of the trading industry.

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Finally, we examine trading data corresponding to such inputs in order to evaluate the trajectory of market structure development.

Existing analyses of automated trading operations focus on the explicit trading rules of systems, the mechanics of trading under those rules, and the effects of the trading mechanism on the formation of prices. This description of the work corresponds precisely with the objectives of the various paradigms in classical financial market microstructure.[1] Aside from clear statements of the mechanics of trading, it concentrates on the characteristics of traders. This emphasis persists even in work purporting to describe competition between exchanges.[2]

In contrast, our objective is to explain changes in the structure of the trading services industry. Our maintained hypothesis is that industrial structure cannot be explained by focusing on the demand side alone—that is, on traders—and that insufficient attention has been paid to the supply side. We shall not ignore trader behavior in the analysis, but the emphasis is decidedly on the provision of alternative technologies for trading services.

Exchanges operating in a competitive environment can be analyzed as firms.[3] Firms offer different technologies for trading, including traditional floors and computerized auctions embodying automated trade execution.[4] Through these alternative technologies, transaction services are produced. Traders are consumers of trading services. They choose technologies and associated bundles of transaction services, taking explicit costs, implicit trading costs, and liquidity effects into account. Through the interaction of technology choice and trader behavior, prices are produced.

We use a combination of network economics and contestability theory to unify developments. In section 1, we analyze the rapid entry of computerized exchanges into the world market for exchange services within a network theory paradigm. We focus in particular on the interaction of development costs, operating costs, and the direct costs of delivering trading services to customers. We examine liquidity effects, which are com-

1. O'Hara (1995, p. 1).

2. See, for example, Ramanlal, Hargis, and McDonald (1997), in which competition depends only on the ratio of informed to uninformed traders and the degree of information revelation by market makers. Information asymmetries, for example, are not linked to trading mechanisms.

3. See also Arnold et al. (forthcoming) for a similar perspective.

4. There may, of course, be product differentiation within a given technological class (such as automated continuous auctions and periodic call auctions).

monly held to account for the durability of the dominant national exchanges, as a form of network externality. The rise of automated exchange systems, in the face of such externalities enjoyed by incumbent floor exchanges, is examined in terms of significant shifts in relative costs, strategic penetration pricing, and competitive efforts to achieve compatibility among electronic systems and thus to expand new networks.

The impact of trading automation on the pricing behavior of exchanges is addressed through the framework of contestability theory in section 2. We argue that automation has significantly increased market contestability, in particular via its role in reducing sunk cost barriers to entry and exit. The effect is to reduce dramatically the ability of exchanges to cross-subsidize different types of trading activity, as such behavior is incompatible with the sustainability of prices in a contestable market. We illustrate this effect by reference to the competitive erosion of long-standing exchange cross-subsidization regimes: in particular, large trades by small trades, "on-exchange" by "off-exchange" trades, and retail trades by institutional trades.

The incentive structure under which an exchange operates is heavily influenced by its governance structure, which is itself a logical product of the trading technology employed. In section 3, we discuss the role of automation in determining the governance structure of exchanges, focusing on the motivations for and effects of exchange demutualization and the emergence of nonmember-based proprietary trading systems.

In the context of trading technology adoption, the determination of market structure depends on the relative quality of the technologies and cost. Debates over the viability and future of computerized auctions relative to the floor trading alternative traditionally focus on the issue of market quality. In contrast, we suggest that consideration of trading technology adoption and subsequent market structure development needs to move from issues of "market quality" to cost. This conclusion stems from an examination of extant empirical evidence, which we carry out in section 4, comparing traditional trading venues to automated price-discovery systems. Overall, the evidence suggests that automated markets and traditional trading floors may differ in subtle and complex ways but that "market quality" is equalized across market structures.

Assessment of relative costs is a complex undertaking. Beyond the problems of valuing fixed-cost components and calculating marginal cost, trading entails a variety of implicit costs faced by the investor. In section 5, we evaluate explicit and implicit (execution) costs using a unique sample of five-year trading data from a large institutional user of proprietary electronic trading systems. Electronic markets dominate traditional brokers across-the-board for trading in over-the-counter (OTC) stocks. An analysis of total cost, including commissions, suggests that commissions are high enough to outweigh any possible gains in execution cost achieved by trading listed issues through a traditional broker. These conclusions are reinforced by an examination of costs sorted by a variety of trade characteristics.

1. Automation and Network Effects

Securities exchanges operating in a competitive environment can be analyzed, regardless of their actual governance structure, as firms offering trading products that embody particular technologies. The way in which the structure of the trading industry develops might then profitably be studied within the framework of industrial economics. Given the nature of the trading products offered in the marketplace, we argue that issues of technology adoption must be approached using industry models in which network externalities feature prominently.

An exchange or trading system is analogous to a communications network, with sets of rules defining what messages can be sent over the network, who can send them, and how they translate into trades. This is more readily apparent for an automated system than for a floor-based one, but the principle applies equally for both models.

In the securities trading industry, two important effects relate specifically to the network nature of the product. First, the benefit to an individual market participant of a specific trading system increases with the number of locations from which the system may be accessed. As in the operation of telephone and retail distribution systems, consumer benefit increases with the number of outlets at which a good or service is available.[5] Second, the benefit to an individual market participant increases with the number of other participants on the system. As the value to one trader of transacting on a given trading system increases when another trader chooses to transact there as well, such a system is said to exhibit network effects or network externalities. We believe that such network exter-

5. In the case of trading systems, this benefit can assume an additional dimension: as the number of locations increases, the variety of instruments available for trading may rise as well.

nalities are the source of the liquidity effect to which is commonly ascribed the durability of the dominant national trading markets.

The salient presence of network effects in the securities trading industry makes the adoption of technology a complex process. The cost of trading over a given system is a function of the timing of the operator's market entry compared with that of incumbents and not merely the marginal production costs of the system operator. Users derive significant positive external consumption benefits from the presence of other users and from the complementarity of the trading network with other systems designed to generate and process trades. Each of these factors has a major influence on the adoption of technology.

Network models yield important implications for the development of market structure. Clearly, traders have enormous incentives to coalesce around the system that minimizes trading costs. Yet the standardization of trading on a given system is far from straightforward. First, standardization may not occur even where it is optimal.[6] Individual traders may disagree with respect to which trading technology is the more desirable, and traders take no account of negative liquidity effects on other traders when choosing a given trading platform in preference to standardization on another. Second, when standardization does occur, the optimal technology may not be selected. The existence of a network externality can confer a significant first-mover advantage on the technology that is available earlier, or that is cheaper at the outset, and this advantage may not be overcome even when it is socially optimal to standardize on a newer alternative technology.

Given such a first-mover advantage, a potential entrant utilizing a technology of equal quality to that of the incumbent would have, at the least, to face a lower marginal cost of production. However, when the incumbent enjoys a significant network externality, this may not be sufficient. The entrant may have to engage in penetration pricing in order to establish its own viable network. Submarginal cost pricing to first-period traders can be optimal where their participation raises the value of the system to second-period traders.

In order for such strategic pricing to be a viable competitive option, the entrant must control property rights to some significant component of

6. Katz and Shapiro (1986). Optimality is social optimality or efficiency here, defined in terms of maximization of total economic surplus.

the underlying technology, or other entry barriers into the supply of that technology must exist. Otherwise pricing above marginal cost in future periods, which is necessary to recoup initial losses, will not be possible. Katz and Shapiro (1986) refer to such firms as sponsors of a given technology. By engaging in below-cost pricing early in the technology's life, the sponsor can internalize the external benefits generated when first-period traders adopt its technology.

Models of sponsorship are complex and yield markedly different welfare outcomes depending on the cost structures, entry timing, and sponsorship powers of the competitors. In the context of trading system competition, strategic pricing capability in network markets can yield results that are important not only for understanding and predicting market structure developments but also for guiding public policy toward the industry. In particular, trading system operators often face strong incentives to construct cartels among themselves in order to facilitate strategic pricing, and such cartels may actually be socially desirable. To the extent that cartels enable future period pricing above marginal cost, they generate incentives to invest in new trading technology in the presence of liquidity effects. This line of reasoning is pursued in Domowitz (1995), which notes that implicit mergers between providers are enabled in large part by the advent of automated trading system technology. Trading service providers may actually move to automated systems specifically in order to facilitate such cartel activity.

1.1. Networks in the Context of Automated Trading and Market Structure Development

1.1.1. ENTRY AND COST. In the early days of automated systems development, a quarter century ago, hardware and software development costs were much higher than they are today: developments costing $100 million were the norm at a time when listings were much fewer and turnover much lower. Given that traditional trading floors already possessed functioning liquidity pools, or networks, the cost of trading automation had to fall considerably before it would be widely adopted. This was so even if automated trading would have been superior at existing levels of floor turnover, owing to the network externalities enjoyed by the established floor-based markets.

Development costs for computerized auction markets have declined dramatically over the past decade. Against a backdrop of static or rising costs for floor-based systems, we witness automated systems emerging as the model of choice in almost all new market development efforts. Across Western and Eastern Europe, virtually every stock exchange has now implemented an electronic auction system. It is only where the network power of floor-based and dealership markets was substantial in the 1980s that resistance to full automation has been significant. The world's five largest stock exchanges—New York, NASDAQ, London, Tokyo, and Frankfurt—have been the slowest to dismantle obligatory human trade intermediation.

It is exceptionally difficult to compare the costs involved in operating automated as opposed to floor-based trading structures on the basis of cross-market expenditure comparisons. Trading volumes, ancillary services, and regulatory obligations vary markedly across exchanges. In terms of up-front construction costs, recent European automated and floor system development plans indicate that the latter are at least three to four times more costly.[7] The best we may be able to do in estimating the annual operating cost savings in switching from floor to automated trading is to rely on the proprietary estimates of exchanges that have undergone, or are undergoing, the transition. The most recent such published estimate comes from the Sydney Futures Exchange, which expects to realize savings in human resources and ancillary services of at least 40 percent.[8]

Cost is undoubtedly the most significant factor driving the rapid expansion of automated trading in the past several years. Expansion often proceeds in the face of direct competition from well-established floor-based exchanges. It is not merely the decline in development and operating costs that has driven this process, however, but also a steep decline in the direct cost of delivering automated services to customers.

Distance costs in the provision of automated trading services are small or nonexistent, whereas the cost of access to floor systems generally

7. The London Stock Exchange and Deutsche Börse each spent more than $100 million implementing their new automated auction systems, SETS and Xetra, yet Tradepoint's system was developed for less than $10 million. Relative volumes cannot account for the difference, as Tradepoint could match the capacity of either with a further technology investment of around $5 million. Yet the cost of building and technologically equipping a floor is clearly much higher. LIFFE's floor development plan, abandoned in the spring of 1998, was priced at more than $400 million. A smaller bond futures trading floor at the Chicago Board of Trade was completed in 1997 at a cost of approximately $200 million.

8. Gwen Robinson, "SFE in Push to Go Fully Electronic." *Financial Times,* April 6, 1998, p. 25.

increases with distance from the customer.[9] This derives from the requirement for the customer either to be physically present on the floor itself or to employ an agent to intermediate transactions on the floor. The removal of important legal barriers to direct cross-border electronic trading since 1996, both within the European Union and between the European Union and the United States, has allowed automated markets to expand their networks dramatically, attracting foreign traders whose cost of access to local floor markets was much higher.

Article 15.4 of the European Union Investment Services Directive gives "regulated markets" within the European Union (EU) the right to solicit "remote members" in other member states without having to secure any authorization from the foreign market regulator. Most EU screen-based equity and derivatives exchanges have now implemented remote membership. In 1997 the U.S. Commodity Futures Trading Commission (CFTC) granted the Frankfurt-based Deutsche Terminbörse (DTB) derivatives exchange the right to solicit remote members in the United States for trading in ten-year Bund futures contracts, making it the first non-U.S. exchange to be granted direct access authorization by a U.S. authority. DTB has since attracted about twenty new members based in Chicago and New York. Prior to the launch of U.S. trading, DTB's market share was about 35–40 percent for many years. The speed with which DTB moved to a 70 percent share by the spring of 1998, and a near 100 percent share by the summer, is testimony to the power of "tipping" effects in network markets. Strong positive-feedback elements in network markets generate a tendency for one system to achieve complete dominance rapidly once it has achieved an initial advantage. In dynamic network models, tipping is reflected in equilibria where new placements of the losing system dry up once a rival system becomes accepted in the marketplace.[10] This was clearly the case for the London International Financial Futures and Options Exchange (LIFFE) once DTB had surpassed the 50 percent market share barrier.

9. The shift from open-outcry to electronic trading at the Sydney Futures Exchange was specifically motivated, according to the chief executive, by the competitive need to overcome the "tyranny of distance" (Gwen Robinson, "Screen Test Looms," *Financial Times*, July 17, 1998, p. 6), representing the cost of providing trading services to traders based at great distance from the exchange.

10. Farrell and Saloner (1986); Katz and Shapiro (1992).

Furthermore, locally established EU automated exchange members have increasingly been transferring or expanding their screen access across national borders, even where explicit legal authorization has been lacking.[11] This has allowed them to reduce trading and support costs in automated markets by creating access points where they can be most efficiently exploited.

Table 1 lists transformations from existing floor-based or dealership trading systems to automated auction systems, which were either implemented or initiated in 1997 and 1998 (floor and dealership trading remains for some products on some of these exchanges). Rapidly falling seat prices on floor-based exchanges—particularly derivatives exchanges, which have been most directly affected by cross-border automated competition—have accelerated the process.[12] The most dramatic cases of transformation involved LIFFE and MATIF (Marché à Terme International de France) in the spring of 1998. LIFFE abruptly abandoned a $400 million floor development plan in favor of accelerated development of an electronic system in the wake of the loss of the ten-year Bund futures market to DTB. MATIF had long resisted moving to screen-based trading as a precondition for a strategic alliance with DTB, yet moved quickly to adopt it after DTB merged with the Zurich-based Swiss Options and Financial Futures Exchange (SOFFEX) to create a new electronic Eurex exchange. MATIF's move created a fascinating case study of hybrid trading, as the floor was initially maintained in parallel with the new electronic system. The plan was formally abandoned within thirty trading days, after the electronic system rapidly achieved a 99 percent market share.[13]

11. Instinet and Lattice Trading direct electronic access from the United States into European automated exchange systems has never been formally authorized by the U.S. Securities and Exchange Commission (SEC). The SEC has decided not to challenge it, however, despite the fact that the European exchanges of which they are members are explicitly forbidden from placing *their own* screens in the United States. There is no logic to this disparity of treatment between exchange screens and exchange member screens: orders entered through either screen go directly to the exchange's electronic order book.

12. Seat prices on the Sydney Futures Exchange halved in the two years to April 1998. Seat prices on the Chicago Board of Trade halved in the first half of 1998 alone.

13. Automated auction trading is also rapidly expanding in U.S. derivatives exchanges. For example, the Chicago Board of Trade recently canceled evening floor trading in bond contracts in favor of trading on its electronic Project A system. More recently, the exchange petitioned the Commodity Futures Trading Commission to allow Project A trading in bond contracts during daytime floor trading hours.

Table 1. Exchanges Moving to Automated Auction Trading, 1997–98

Exchange
Athens Stock Exchange
Chicago Board of Trade
Chicago Mercantile Exchange
International Securities Market Association
LIFFE
London Stock Exchange
MATIF
Monep
NASD (OptiMark equity trading)
Osaka Securities Exchange
Pacific Stock Exchange (OptiMark equity trading)
SIMEX
Sydney Futures Exchange
Tokyo Stock Exchange
Toronto Futures Exchange
Toronto Stock Exchange

Note: Floor or dealership funding remains for some products or time periods on some of these exchanges.

1.1.2. ENTRY AND STRATEGIC PRICING. Automated exchanges have also applied strategic penetration pricing to undercut incumbents with established networks. DTB offered cut-price memberships and fee holidays on the ten-year Bund contracts in 1997, when then-floor-based LIFFE still controlled about two-thirds of the market. After abandoning the floor for screen trading in 1998, MATIF began offering five- and ten-year U.K. government bond contracts at £0.17 per trade, 40 percent less than LIFFE was charging.[14] The start-up Cantor Financial Futures Exchange, a joint venture for electronic trading of U.S. Treasury futures launched by brokerage firm Cantor Fitzgerald and the New York Board of Trade, went live in September 1998, charging 50 percent less than the incumbent floor-based Chicago Board of Trade. Tradepoint undercut the London Stock Exchange (LSE) by 75 percent in the processing of prematched interdealer broker trades in the run-up to the LSE's launch of automated auction trading in 1997.

1.1.3. ADAPTERS AND INCOMPATIBLE NETWORKS. The proliferation of incompatible automated auction systems has encouraged the growth of

14. LIFFE's fee of £0.28 per trade was already a 33 percent reduction from its £0.42 charge earlier in the year (Sara Calian, "France's MATIF Begins to Trade Contracts on Gilts," *Wall Street Journal*, July 15, 1998, p. C17).

enterprises that aim to reduce the costs of investor access by providing a standardized interface across different networks. These electronic brokerage firms correspond to the role of "adapters" in the network economics literature.[15] They become members of different automated exchanges, constructing electronic interfaces into each from their own proprietary order-entry systems. These systems are marketed to institutional investors, who use them to access multiple exchange order books directly via a single electronic entry point. Instinet, owned by Reuters, operates the largest such system, providing direct cross-border institutional access into U.S., European, and Asian stock exchange order books. Other cross-border adapters include Lattice Trading, owned by State Street Brokerage, and Credit Suisse First Boston's PrimeTrade system for listed derivatives.

1.1.4. REMOTE CROSS-BORDER TRADING. Examples of automated exchange systems offering remote cross-border access from the United States include the Chicago Mercantile Exchange's (CME) Globex (access in the United Kingdom, Hong Kong, Japan, France, and Bermuda), New York Mercantile Exchange's ACCESS (Australia, Hong Kong, and the United Kingdom), and the Chicago Board of Trade's Project A (United Kingdom). Most European exchanges now accommodate remote cross-border access, but some, such as the Madrid Stock Exchange, still do not allow *remote membership*. The latter does not require members to maintain an office in the exchange's home country and is frequently resisted by local members concerned with losing cross-border brokerage business to foreign intermediaries. As the example of DTB's U.S. expansion illustrated, remote membership can be a powerful tool for expanding networks and, hence, liquidity traceable to network effects. The fact that local members controlling an exchange often resist remote membership to protect their existing brokerage franchise raises important questions regarding exchange governance, which we discuss in section 3.

1.1.5. MERGERS AND ALLIANCES. Exchanges have begun to cooperate in the construction of their own adapters in order to enable compatibility between their networks or in some cases to merge their networks outright. As investors expand their holdings of foreign securities and intermediaries expand the geographic scope of their activities in consequence, the exter-

15. See Katz and Shapiro (1994).

nalities resulting from cross-border networking increase. The cost advantage in operating a cross-border system over multiple incompatible national systems thereby increases.

Concern has recently been spreading rapidly among exchanges in Europe and the United States that failure to participate in a major cross-border trading network will lead traders to abandon domestic systems in favor of single-entry-point access to a much wider international grouping of traders and products. This is particularly true in the wake of the July 1998 agreement between the London Stock Exchange and Deutsche Börse to develop a common trading platform for U.K., German, and other leading European shares. The perception of first-mover advantages in network markets lends a sense of urgency to exchanges considering a competitive response to such initiatives.

Table 2 documents U.S. and European automated exchange linkage strategies launched or implemented between January 1997 and April 1999. These are classified into four broad categories: strategic alliances and joint ventures, common access systems, common trading systems, and mergers.

An example of the strategic alliance strategy is that agreed by the Chicago Mercantile Exchange (CME) and MATIF. The CME will adopt the MATIF NSC-VF trading technology as the basis for its own electronic trading system, and MATIF will adopt the CME's clearing system. A deeper form of alliance is exemplified by the creation of a common electronic system to access two different exchange systems, a strategy being pursued by the three "Benelux" exchanges. The Norex alliance between Stockholm Exchanges and the Copenhagen Stock Exchange goes a step further, producing a single trading system, based on the Stockholm SAX technology, to trade both Swedish and Danish stocks. Although the exchanges will remain separate legal entities, members of one are offered free membership of the other. The CBOT and Eurex agreed and later abandoned a similar strategy, deepening an earlier one based on the model of a common access system. The most notable example of an actual exchange merger during this period is Eurex, which combined Deutsche Börse's DTB derivatives arm with the Swiss Exchange's SOFFEX derivatives arm into a single corporate entity, utilizing a common trading system. MATIF, which had launched electronic trading specifically to accommodate networking with Eurex, has agreed the outlines of a common membership scheme with the new entity, and the two are continuing to discuss the construction of an adapter system to link the

Table 2. Automated Exchange Mergers and Alliances, 1997–99

Merger or alliance	*Status*
Exchange mergers	
AEX: Amsterdam Stock Exchange and European Options Exchange	I
HEX: Helsinki Stock Exchange and SOM	I
BEX: Brussels Stock Exchange and BELFOX	I
Stockholm Exchanges: Stockholm Stock Exchange and OM	I
Vienna Stock Exchange and ÖTOB	I
Paris Bourse and Monep	I
Paris Bourse and MATIF	I
Eurex: DTB and SOFFEX	I
NYBOT: New York coffee and cotton exchanges	I
Hong Kong Stock Exchange and Hong Kong Futures Exchange	A
Stock Exchange of Singapore and SIMEX	A
Australian Stock Exchange and Sydney Futures Exchange	N
MATIF and MEFF	N
Alberta Stock Exchange and Vancouver Stock Exchange	N
Common trading system	
Oslo Stock Exchange and OM	I
Deutsche Börse and Vienna Stock Exchange	A
International Petroleum Exchange and Nord Pool	A
Norex: Stockholm Stock Exchange and Copenhagen Stock Exchange	A
Eurex and HEX	A
Globex Alliance: Chicago Mercantile Exchange, MATIF, and SIMEX	A
Norex and Oslo Stock Exchange	N
London Stock Exhange and Deutsche Börse	N
Chicago Board of Trade and Eurex	N
Common access system	
Euro NM	A
Euro Alliance: Eurex and MATIF	A
MATIF and MEFF	A
Benelux exchanges	N
Strategic alliance / joint venture	
Globex: Chicago Mercantile Exchange and MATIF	
CFFE: Cantor Fitzgerald and New York Board of Trade	I
CBB: Chicago Board of Trade and Prebon Yamane	A
Chicago Mercantile Exchange and Cantor Fitzgerald	N
International Petroleum Exchange and NYMEX	N
Eurex and NYMEX	N
Singapore-SIMEX and Australia-Sydney	N

Note: I, implemented; A, agreed; N, being negotiated.

trading systems—an initiative named Euro Alliance. Eurex is also in discussions with the derivatives arms of the Borsa Italiana, Amsterdam Exchanges, and several Scandinavian exchanges regarding possible linkages or mergers.

2. Automation and Cross-Subsidization of Trading

State-owned or protected public utilities frequently engage in cross-subsidization of products and services, pricing above marginal cost in one area to keep prices below it in others. Among the more conspicuous examples is uniform national postal service pricing, which represents a subsidy from urban to rural users. Such cross-subsidization is usually defended on the grounds of distributive concerns, although it clearly distorts market incentives and generates deadweight efficiency losses. We suggest that increased automation is now leading to the disappearance of cross-subsidization in the trading services industry. Our argument is based on a link between automation of trading and market contestability.

In markets that are contestable, cross-subsidization is inconsistent with sustainability of prices: it always invites profitable entry into the subsidizing portion of the business, thus ensuring that the cross-subsidies cannot persist.[16] The trading services industry is showing clear signs of increasing contestability. Sunk cost barriers to entry have declined rapidly over the past decade, owing in particular to the following factors:

—System development costs have plummeted, as basic auction market technology has become commoditized and computer processing power has expanded dramatically.

—The significance of geographic location has declined tremendously in tandem with the steep decline in the cost of constructing wide-area cross-border computer networks.

—Automated systems can now be tailored quickly and inexpensively to accommodate trading in a growing number of securitized products, such as equities, bonds, currencies, financial derivatives, pooled mortgages, agricultural commodities, electricity, pollution emission permits, and hospital bed allocations. This facilitates rapid and low-cost entry into different sectors of an expanding market for securitized products.

Perfect contestability requires not only the absence of sunk cost barriers to entry and exit, but also that entrants face no disadvantage vis-à-vis incumbents and that they be capable of undercutting incumbents before the latter can react. The proliferation of open architecture trading services systems has greatly facilitated the integration of new trading systems with existing information and support systems, thus reducing entrant disad-

16. Baumol, Panzar, and Willig (1988).

vantage, and there is considerable evidence of price undercutting by entrants (see section 1.1.2). If the trading services market does now sufficiently approximate a contestable one, then we would expect to see evidence of the erosion of cross-subsidies employed by incumbent national exchanges.

In fact, the expansion of automated trading structures does appear to be imposing increasing external discipline on the way in which exchanges can price different types of trading. The cross-subsidy regimes that have traditionally been imposed by exchanges fall into three general categories: cross-subsidization of large trades by small trades, "on-exchange" by "off-exchange" trades, and retail by institutional trades. As automation significantly reduces the cost to system operators of focusing their competitive strategies on well-defined types of trading and traders, and of extending their competitive reach across wide geographic areas, it enables automated competitors to avoid an incumbent's subsidized market segment and to focus instead on the profitable subsidizing segment. We discuss examples of this effect below.

2.1. Cross-Subsidization of Large Trades by Small Trades

Dealer markets rely on cross-subsidy by design. One class of market participant—market makers—is assigned specific obligations that are not borne by the wider market. Such obligations include the requirement to post firm two-way quotes for a minimum number of shares for the stocks they are assigned. In some markets (for example, SEAQ-I), maximum posted spread limits are assigned. No trader would be willing to take on such obligations without compensatory privileges. The most significant of these privileges is restrictions on public limit-order display, which allows dealers to maintain privileged access to order flow information and prevents disintermediation. Some markets further mandate delayed trade publication where the market maker is dealing as principal in large size, a large minimum tick size (which generates profits deriving directly from the spread), and fixed minimum commissions.

In the case of the London Stock Exchange's dealer market, disintermediation was forestalled by an exchange rule barring market makers from posting better prices publicly than they were posting on SEAQ screens. This significantly hampered Instinet, a member firm operating an electronic order-matching system, in its efforts to disintermediate SEAQ by matching natural buyers and sellers within the posted market maker spreads. It was only after Tradepoint, regulated as an independent *exchange*, began automated auction market trading in 1995 that the LSE began seriously reconsidering the sustainability of the dealer market structure. The U.K. regulatory authorities held that LSE market makers trading on Tradepoint could not be bound by LSE rules restricting public limit-order displays, thereby subjecting SEAQ to the same competitive forces that had already undermined SEAQ-I.

Data from the LSE in the early 1990s document high market maker profits on small transactions, where dealer intermediation was rarely necessary. These profits subsidized losses on mid-size blocks, where institutional clients appeared to have strong knowledge of market order flow.[17] The continental European automated auction systems, many of which were implemented in the period 1989–91, had the effect of undermining this structure. Small transactions in continental shares rapidly migrated from SEAQ-I back to the home markets, wiping out a major source of market maker subsidy and exposing many of them to large losses at the hands of well-informed institutional clients. SEAQ-I's quoted spreads more than doubled between 1991 and 1994, as dealers abandoned formal market making in continental stocks.[18]

Given the experience of SEAQ-I, we would suggest that NASDAQ's experience in the face of Instinet's rapid rise to a 20 percent market share is also explicable in the context of conventional industrial economics. In particular, the "excessively wide" quoted spreads identified by Christie and Schultz (1994) do not necessarily require an explanation based on widespread collusion, and frequent reports of NASDAQ market makers dropping stocks in the midst of a bull market are not puzzling, as is sometimes claimed.[19] Both effects represent logical responses to the erosion of cross-subsidies in the dealer market.

17. Six to ten times Normal Market Size (NMS), NMS being equivalent to approximately 2.5 percent of average daily trading volume.

18. Pagano and Steil (1996).

19. The *Wall Street Journal* ran a story focused on this phenomenon in 1996 (Deborah Lohse, "Trading Firms Make Markets in Fewer Issues," *Wall Street Journal,* October 14, 1996, p. C1). One observer's reaction was quoted as follows: "What you are seeing is [that] even in a huge bull market, you still have market makers cutting back on stocks when logic tells you they should be increasing" (Robert Flaherty, editor of *Equities* magazine).

2.2. Cross-Subsidization of On-Exchange by Off-Exchange Trades

Many auction market operators impose “interaction” rules on members, obliging block traders transacting away from the central limit-order book to satisfy all orders on the book at equivalent or better prices. This is commonly presented as an issue of fairness regarding order book users; whatever the merits of this position, interaction rules represent a clear subsidy by off-exchange of on-exchange traders.[20]

Paris Bourse interaction rules, created in 1989 after members were permitted to trade for their own account, were significantly relaxed in 1994 owing to the effect of regulatory arbitrage in favor of London. Block traders in Paris routinely executed their block trades in London in order to avoid having to expend capital or leak information by obeying the Bourse’s interaction rules. Even under the current Paris regime, which requires only that block trading take place within a weighted-average measure of the order book inside spread, block trades are still often executed in London via SEAQ-I screens in Paris in order to avoid the market impact risk that a dealer might take on in trading within the Paris spread limits.[21]

The OptiMark call auction system, which began trading in February 1999, has been heavily marketed as a mechanism for accommodating anonymous block trading. As a facility of the Pacific Stock Exchange, OptiMark does not subject traders to the interaction rules of the New York Stock Exchange (NYSE). Thus, if the system is in fact successful in transacting blocks, the cross-subsidy enjoyed by NYSE specialists from member-firm block traders also faces erosion in the face of regulatory arbitrage toward the Pacific Stock Exchange.

2.3. Cross-Subsidization of Retail Trades by Institutional Trades

NYSE and NASDAQ rules intended to accommodate small retail-size trades on uneconomical terms are being exploited by proprietary trading

20. A counter-argument that traders must price their off-exchange deals based on order book prices, and are therefore free riding on price discovery, is only valid where the price and quotation data provided by the exchange to data dissemination systems (such as Reuters and Bloomberg) are not themselves priced at competitively determined rates. Given that data dissemination represents approximately 17 percent of European exchange revenues (Baggiolini 1996), this argument would not appear to us to have merit.

21. See Pagano and Steil (1996) for details.

systems focusing entirely on executing institutional orders. For example, NASDAQ market makers are subject to the requirements of the Small Order Execution System (SOES), which allows small orders (up to 1,000 shares) to be executed electronically against market maker quotes. Although the system was set up to ensure that retail investors could achieve timely executions, SOES is exploited by firms known widely as “SOES bandits,” which fire rapid streams of 1,000-share orders at market makers before they are able to adjust their quotes to news or trading activity. Nonexchange systems such as Instinet can “cherry pick” profitable institutional order flow, leaving unprofitable executions to the traditional exchange systems.

3. Automation and Exchange Governance

Exchanges have traditionally been organized as mutual associations, operated by member-firm brokers and dealers, under varying degrees of state control. The member firms often are the legal owners of the exchange and, in some cases, actually own shares in the exchange as a corporate entity.[22] In other cases, the exchange is legally a government entity.[23]

This mutual structure is a remnant of the era before automation, when exchanges were of necessity floor-based. The inherent limitations of floor space required access limitations. Access was rationed through the sale of a fixed number of memberships (or “seats”). Since a nonautomated trading floor itself has little more than commercial real estate value, it is logical that the members themselves should operate the floor as a cooperative. These members necessarily become intermediaries for all others wishing to trade the exchange’s contracts, and a portion of their profits derives from barriers to entry.

In an automated auction market, there is no inherent technological barrier to providing unlimited direct access. There is, therefore, no longer an economic logic to exchanges being organized as intermediary cooperatives. An automated system operator can sell access direct to all who wish to trade and charge for this service on a transaction basis. Thus we would

22. Transference of such shares is generally strictly limited. In the case of Deutsche Börse AG, for example, the sale of shares must be approved by the supervisory board.

23. This was the case with the Italian Consiglio Di Borsa, the predecessor to the privatized Borsa Italiana.

expect the operator to select its governance structure on the same basis as a normal commercial enterprise.

Whereas an automated exchange *can* be organized along traditional mutual lines, it is questionable whether such a structure is optimal in the type of competitive environment which we have heretofore described. The optimality issue is beyond the scope of this paper, however. We offer a set of more limited observations here. First, as already described, trading market automation permits demutualization, defined as separating ownership of the exchange from membership. Second, the incentive problems inhibiting demutualization are similar to some of those inhibiting the adoption of technology, namely vested financial interests. Third, demutualization is now rapidly being adopted in practice, and all such examples begin with a conversion from traditional floor trading technology to automated trade execution. Finally, for trading service enterprises with no prior history of mutual governance structure, the mutual structure is routinely avoided in favor of a for-profit joint-stock corporation structure. As automation initiatives continue to proliferate, a revealed preference argument may indeed suggest the optimality of a demutualized exchange structure relative to its mutual counterpart.

It is clear that the incentive structure under which a mutualized exchange operates is different from that under which a demutualized one does. As exchange members are the conduit to the trading system, they derive profits from intermediating nonmember transactions. This, in turn, means that members may resist innovations that reduce demand for their intermediation services, even if such innovations would increase the value of the exchange. If the members are actually *owners* of the exchange, they will logically exercise their powers to block disintermediation where the resulting decline in brokerage profits would not at least be offset by their share in the increase in exchange value.

A number of European exchanges have in the past several years chosen to demutualize, detaching ownership from membership. This transformation of governance structure has had the effect of diluting the influence of member firms over the commercial activities of the exchange. To the extent that the financial interests of nonmember owners differ materially from those of members, such a transformation could have a significant impact on the exchange's behavior.

Stockholm was the first exchange in the world to demutualize, doing so in 1993. The initiative came on the back of major competitive inroads into Swedish equity trading made by London's SEAQ-I between 1987 and 1990, a period in which Stockholm's turnover declined by a third and its market share of global reported Swedish equity turnover dropped as low as 40 percent.

Half of the shares in the new Stockholm corporate structure were retained by the members, and half were allocated to listed companies. The shares became freely tradable in 1994, and in 1998 they were listed on the exchange itself. Following the demutualization, the exchange became the first in Europe to offer remote cross-border membership (1995) and direct electronic access for institutional investors (1996), although trades must still be notionally executed via a sponsoring member. Local Swedish members resisted both of these initiatives but could not block them given their minority interest.[24] Nonmember owners, in contrast, had an unambiguous incentive to support these measures. The exchange as a commercial enterprise appeared to have performed well following the demutualization. Turnover quadrupled in the first two years of demutualized operation, and the exchange's share price rose nearly sevenfold.[25]

The Stockholm model has since been widely emulated by other automated exchanges. Table 3 documents demutualizations. The biggest difference among them has been in the initial allocation of shares. Helsinki and Copenhagen, for example, applied a 60-40 share split between members and listed companies. Amsterdam allocated 50 percent to members and auctioned off 50 percent to both listed companies and institutional investors. Australia allocated all shares to the members but listed them on the exchange itself the day following the demutualization.

Member-based exchanges are demutualizing in order to approximate better the incentive structure of a public company with a diversified shareholder base. In contrast, trading system operators in the United States and United Kingdom, which have entered the market with automated auction products, have avoided the mutual structure entirely. Such companies are widely referred to as proprietary trading system operators. Instinet (owned by Reuters), POSIT (owned by ITG), and Lattice Trading (owned by State

24. Anecdotal evidence from exchange officials suggests that smaller local members did, in fact, suffer financially from a diversion of foreign order flow to the new, larger remote intermediaries.

25. The exchange itself credits part of the increase in turnover to the removal of a 1 percent transaction tax at the end of 1991, according to Rydén (1995).

Table 3. Exchange Demutualizations

Exchange	*Year*
Stockholm Stock Exchange	1993
Helsinki Stock Exchange	1995
Copenhagen Stock Exchange	1996
Amsterdam Exchanges	1997
Borsa Italiana	1997
Australian Stock Exchange	1998
Iceland Stock Exchange	1999
Athens Stock Exchange	1999
Stock Exchange of Singapore	1999
SIMEX	1999

Street) are formally regulated as brokers but sell order-matching services on a transaction fee basis direct to institutional investor-clients. The Arizona Stock Exchange and London-based Tradepoint are classified by their respective national regulatory authorities as exchanges but operate in an identical manner. OptiMark has chosen a third route: legally it is neither a broker nor an exchange. The company licenses its trading product to existing bodies that are classified by their regulators as exchanges.

We argued in section 1 that exchanges operating in a competitive environment can profitably be analyzed as firms offering trading products in a market defined by the salience of network externalities. The degree to which this formulation approximates reality depends on the level of contestability in the market for trading services and the incentive structure under which exchanges operate. As we have argued in section 2 and here in section 3, trading automation has, in fact, significantly increased both market contestability and the incentives of exchanges to exploit network externalities. These incentives are manifested, inter alia, in the transformation of exchange governance structures toward conventional corporate models.

4. Market Quality Comparisons

Network models rely largely on two factors for their explanatory power: the quality or efficiency of the alternative trading technologies and relative cost. Early conceptual arguments over the introduction of computerized markets focus exclusively on the issue of “market quality” relative to the floor trading alternative.[26] We argue that debates over the adoption of trading technology and the consequent development of market structure need to move from considerations of market quality to issues of cost. We offer evidence supporting this position in this section.

In the absence of a precise definition of market quality, we focus on liquidity, informational efficiency, and volatility. Liquidity is a multidimensional factor, which we address through consideration of the size of the bid-ask spread and measures of market depth. We would concede that all aspects of what we call "market quality" can ultimately be characterized by the term "cost," which is borne by some party in the trading process. This is most clear in the case of bid-ask spreads. In other cases, the link is not so easy to quantify. Consider informational efficiency, for example. Greater speed of value revelation through the trading mechanism should lower the cost of trading in terms of the formulation and implementation of order submission strategies, but the linkage is complex and indirect. Our cost measures applied in section 5, however, are much more direct and disaggregated than those encompassed in market quality measures.

General conclusions, to the extent that they may be obtained, require intra-day data and multiple market comparisons. The data requirements are too large for any single research project. We rely, therefore, on a variety of existing studies for our information. The relevant literature is not extensive, and we cover most of it in this section. Because our treatment proceeds by topic, and not by individual study, table 4 summarizes the contributions for reference.

Some of these papers provide more direct evidence than others, and the emphasis in individual studies differs. Studies of the Bund futures contract benefit from the overlap of trading times on the automated DTB market and the LIFFE floor, as well as the close similarity of contracts traded in the two venues.[27] Comparisons of the automated Osaka Securities Exchange and floor trading on the Singapore International Monetary Exchange (SIMEX) share these advantages, but there are differences

26. The earliest mention seems to be in SEC (1963), in H.R. Doc. 95, 88 Cong., 1 sess., pt. 2, pp. 358, 678. The Commodity Futures Trading Commission organized a conference around the topic in 1977, summarized in CFTC (1977) and Melamed (1977).

27. Shyy and Lee (1995) also consider the Bund market, but the overlap of emphasis between their work and others considered here is large enough not to merit separate consideration.

Table 4. Implicit Trading Cost Studies for Automated Markets

Study	*Automated market*	*Traditional market*	*Instrument*
Coppejans and Domowitz (1997)	Globex	CME floor	Futures
Franke and Hess (1995)	DTB	LIFFE	Bund futures
Grunbichler, Longstaff, and Schwartz (1994)	DTB	FSE	DAX futures
Kofman and Moser (1997)	DTB	LIFFE	Bund futures
Pagano and Roell (1990)	Paris Bourse	SEAQ-I	Stocks
Pirrong (1996)	DTB	LIFFE	Bund futures
Sandmann and Vila (1996)	OSE	SIMEX	Nikkei futures
Schmidt and Iversen (1993)	IBIS II	SEAQ-I	Stocks
Shah and Thomas (1996)	BOLT / NSE	Bombay	Stocks
Vila and Sandmann (1996)	OSE	SIMEX	Nikkei futures

across markets that are not related to automation. Interpretation of a study of Globex and the CME floor is complicated by natural deficiencies in liquidity endemic to an overnight market. Work on India is in the form of a time-series study of the introduction of automation, as opposed to a comparison of automated and floor auctions operating over the same time period. Analysis of computerized DAX futures trading relies on a comparison of the futures contract with aggregate trading in the underlying index, reflecting different forms of trading activity as well as variations in market structure.[28] Finally, comparisons of automated auctions with dealer markets have contrasted the Paris CAC and German IBIS auction systems with the London SEAQ-I dealer market. The findings of these studies are favorable to computerized markets, but rife with ambiguities. Beyond problems of data interpretation, dealer markets are quite different from auction markets generally, whether the latter be automated or floor-based. Although we include these studies for completeness, we do not discuss details of the comparisons.[29]

4.1. Bid-Ask Spreads

The size of the bid-ask spread is the most commonly quantified measure of liquidity across markets. All studies, with the exception of those comparing auction and dealer markets, rely on the computation of realized, as

28. A similar contribution is made by Kempf and Korn (1996).
29. See Pagano and Steil (1996) for an overview of results and a detailed critique.

opposed to quoted, spreads. The realized spread is an imputed measure of the difference between the best buy and sell prices in the market, inferred directly from the transaction prices themselves.

Studies of trading on DTB and LIFFE agree that spreads are smaller, or at least no larger, in the automated market than in the floor market. Pirrong (1996), for example, reports that spreads are 5 percent lower on DTB than on LIFFE. Results in Kofman and Moser (1997) vary, depending on the method of calculation, but they cannot reject the statistical equality of the spread across trading venues. Coppejans and Domowitz (1997) present similar findings for stock index futures trading.

Vila and Sandmann (1996) report substantially larger spreads in the Osaka market relative to floor trading on SIMEX.[30] The tick size in Osaka is twice that on SIMEX, however, biasing the comparisons. Orders also tend to be much larger in this automated market, naturally raising spreads in Osaka, relative to SIMEX.

4.2. Depth of Market

Assessment of relative market depth is plagued by measurement problems. Depth cannot be measured solely by trading volume. Changes in volume can occur independently of market structure considerations.[31] Some studies simply use a measure of volatility, which conflates the information effects, depth, volume, and spread size. A variety of different market microstructure models, however, relate the variance of price changes to a function of traded volume.[32] The coefficient quantifying the impact of volume on the variance of returns is an inverse measure of liquidity or market depth. As this parameter decreases, the sensitivity of price changes to volume falls, and the market is seen to be deeper or more liquid.

Some variant of this model is represented by regression formulations in studies of Bund and Nikkei 225 futures trading. The implied volume coefficient in the comparison of Osaka and SIMEX is lower in the auto-

30. Vila and Sandmann (1996). Coppejans and Domowitz (1997) also find larger spreads on Globex for currency futures, but this is explained by higher adverse selection costs due to operation of the overnight interbank currency market.

31. For example, Shah and Thomas (1996) report large increases in volume following automation of the Bombay market, but this effect can be ascribed to large numbers of new listings that had little, if anything, to do with the switchover.

32. See, for example, the trading models in Kyle (1985); Blume, Easley, and O'Hara (1994); Coppejans and Domowitz (1996); Domowitz, Glen, and Madhavan (1997).

mated market, based on Vila and Sandmann (1996), implying greater depth in Osaka. Pirrong (1996) splits volume into expected and unexpected components. He finds that the coefficient on unexpected volume is approximately zero for DTB, while significantly positive for LIFFE. Similar results are obtained for expected volume. This implies a deeper market in the automated venue.[33]

4.3. *Informational Efficiency*

Relative informational efficiency across computerized and traditional trading venues has been a topic of debate since the work of Melamed (1977). It represents a facet of market quality in at least two ways. The first dimension pertains to asymmetric information considerations, captured in the adverse selection component of the bid-ask spread. The second pertains to the transmission of information into prices: slower value revelation raises the cost of trading in terms of ex ante order submission strategies.

4.3.1. ADVERSE SELECTION. Asymmetric information effects may be exacerbated in automated markets, relative to their floor counterparts. The perceived problems are the openness of automated limit-order books and the time required to cancel orders. One possibility is reluctance to submit limit orders in the face of potential adverse selection, inhibiting liquidity provision. For uninformed traders, the problem is one of the free option that a firm quote presents to the market, permitting trades that disadvantage the liquidity provider. For informed traders, the issue is information that might be revealed by submitting large orders to the book.

Indirect evidence contrary to this view is provided by Vila and Sandmann (1996), who show that the Osaka computerized system handles larger orders than are processed on SIMEX. The average number of contracts per trade is about fifty-two on the automated market, as opposed to fourteen on the floor. The comparison is even stronger in monetary terms, because SIMEX contracts are valued at 500 times the futures price, while the Osaka contract is worth 1,000 times the price. Adverse selection problems that may be due to automated system design do not necessarily inhibit large orders and trades, as compared with a floor auction market.

33. Only Franke and Hess (1995) suggest greater depth in the floor market. Their result is questionable, however. They use the volatility of prices, as opposed to the volatility of price changes, in their regressions, biasing statistical inference for technical reasons.

Direct evidence on adverse selection as a cost of trading is given by Coppejans and Domowitz (1997). The adverse selection component of the bid-ask spread is estimated to be 17 percent higher on the CME floor than in the Globex trading system for stock index futures contracts. Since the index spreads are approximately equal across the two trading venues, adverse selection effects in absolute, as well as proportional, terms, also are lower on the automated system.

Comparisons across markets are narrow and few in this regard. The free option problem is undoubtedly an issue in automated settings and deserves further examination.[34] For example, in reference to the study on the CME and Globex, the possibilities for adverse selection may be lower in the overnight market for the stock index than in day trading on the floor. In contrast, the Globex market for foreign currency futures operates in the shadow of the overnight interbank currency market. Trading in the latter exacerbates the potential for adverse selection on Globex. Indeed, in the case of currency futures, Globex adverse selection components exceed their floor counterparts by an average of 26 percent across currencies.[35]

4.3.2. TRANSMISSION OF INFORMATION TO PRICES. The speed at which information is transmitted to prices is generally analyzed by calculating correlations between current and past returns. Shah and Thomas (1996), for example, compute such correlations over various time spans before and after the introduction of automated execution in Bombay.[36] The correlation between current and lagged returns drops sharply following automation, suggesting greater informational efficiency in an automated environment.

Vector autoregressive (VAR) models are used for much the same purpose by Kofman and Moser (1997) and by Sandmann and Vila (1996). The VARs allow an assessment of information transmission within a single market and between markets. In both studies, price adjustment within a single market and adjustment to shocks in the alternative market are found

34. In fact, new technological developments in automated market design are largely oriented toward large-order processing and increased possibilities for liquidity provision.

35. Kofman and Moser (1997) also find adverse selection effects to be stronger on DTB than on LIFFE. Their evidence is indirect, however. They find that serial correlation in expected returns is higher in the automated system and infer that informational asymmetry is greater in the automated market. Coppejans and Domowitz (1997) find no such correlation on either Globex or the Chicago Mercantile Exchange and therefore cannot support such inference.

36. This includes the introduction of the BOLT system on the Bombay Stock Exchange itself and the introduction of the fully automated National Stock Exchange.

to be faster in the traditional trading venue, but differences are small. The flow of information through pricing is bidirectional. Both papers conclude that there is no obvious price leadership differentiated by market structure.

In contrast, Grunbichler, Longstaff, and Schwartz (1994) find that the automated market absorbs information much more quickly than the floor. Coppejans and Domowitz (1997) attempt to control for the effects of asymmetric information, inventory control, and speculative demands based on order flow. They find no substantive difference in informational efficiency between automated and traditional market structures.

4.4. Volatility

Price volatility has conceptual links to information flow and liquidity. There is, however, no theoretical reason to expect higher or lower volatility in automated markets, relative to their traditional counterparts.[37]

The available evidence suggests that volatility in an automated market is generally equal to, and sometimes less than, volatility in the traditional market.[38] Shah and Thomas (1996) present such results, based on daily returns. Kofman and Moser (1997) find that return volatility on a minute-by-minute basis is higher on LIFFE than on DTB. Corresponding calculations for those markets on a daily basis show no difference across venues; Vila and Sandmann (1996) obtain the same result. Only Coppejans and Domowitz (1997) contradict such findings, but their results are attributable to sharply lower liquidity in the overnight market in dimensions other than price variability.

Volatility comparisons with respect to dynamics involve severe interpretation problems in assessing cross-market characteristics.[39] We mention

37. The only work on this point seems to be the simulation study of Bollerslev and Domowitz (1991). They predict lower volatility in an automated market, compared to the floor, based on the smoothing of transaction flow through the electronic book.

38. Shah and Thomas (1996). Unconditional volatility dropped 2.2 percentage points after the introduction of automated trading in Bombay. Spread-corrected volatility measures showed no difference following automation. See also Kofman and Moser (1997); Franke and Hess (1995); Vila and Sandmann (1996); Coppejans and Domowitz (1997).

39. For example, it is tempting to ascribe high serial correlation in volatility to poor information transmission. However, a larger serial correlation coefficient in an automated market, relative to its floor counterpart, may simply be an artifact of the mechanics of limit-order books, having nothing to do with information effects; see Bollerslev and Domowitz (1991).

only two results, relating to cross-market information linkages and market share considerations.

First, Kofman and Moser (1997) model cross-market transmission of volatility. Volatility is transmitted bidirectionally across market structures. In two of five weeks, it appears that LIFFE responded much more sluggishly to volatility shocks originating from DTB. The evidence is too weak to suggest more efficient information handling in the automated market, but equality across markets may be a reasonable conclusion.

Second, several authors model the choice between automated and floor markets as a function of volatility. Given the theoretical correlation of information arrival and volatility, most possible explanations suggest the choice of floor venue. For example, higher volatility increases the value of the free option stemming from the provision of liquidity to the limit-order book. This might encourage traders to shift to the floor. Similarly, higher information intensity reduces the relative importance of order book information, given higher intensity of floor trading. Periods of higher information intensity and concomitant volatility also increase the likelihood of adverse selection, and adverse selection effects may be higher on automated systems.

Despite the logic of such arguments, the evidence is mixed. Studies by Franke and Hess (1995) and by Vila and Sandmann (1996) estimate identical models relating automated market share to lagged share and current and lagged values of price volatility. Higher volatility is found to decrease DTB market share. In the comparison of Osaka and SIMEX, higher volatility generates a move to the automated market.[40]

4.5. What Have We Learned about Relative Market Quality?

Distinctions between various dimensions of market quality are not as sharp as our taxonomy may suggest. Whereas tradeoffs may exist between

40. Franke and Hess (1995). Vila and Sandmann (1996) offer the following resolution. In a larger market, uninformed traders may be less concerned with adverse selection risk and therefore do not reduce trading activity in periods of high volatility. They simply shift to the larger market. LIFFE and Osaka had market shares of approximately 65 and 60 percent, respectively, relative to the floor at the time of the studies. There is an obvious endogeneity problem with such reasoning, however, because the market's average size may be related to its structure.

some markets, our reading of the evidence is that market quality is roughly equal across automated and floor technologies.

Bid-ask spreads are approximately the same across automated and traditional trading venues. Considerations of market design tell us little about the anticipated size of relative spreads. The openness of automated limit-order books does, however, suggest higher costs in terms of the adverse selection component of the spread. Available evidence supports such intuition in environments characterized by a high probability of adverse selection effects. Theoretically, the spread is composed of the sum of adverse selection costs, inventory costs, and order processing costs. Given that the inventory component is found to be very small in all studies that attempt to break it out separately, the results suggest that order processing costs are generally lower in automated markets. These conclusions must be tempered by considerations of the relative size of processed orders and explicit costs that may or may not enter the spread calculations. It is not generally true that automated systems handle only small orders, however, as exemplified by the comparison of Osaka and SIMEX. Larger spreads are a feature of markets, automated or not, that process larger orders on average.

It is often argued that automated markets do not foster good market depth, due to the high visibility of order book information and order cancellation delays. Neither average trading volume nor average volatility in isolation provides a good measure of depth, obviating some evidence on this point. Based on parametric estimates, using data on volatility and volume combined, market depth is generally found to be greater in the automated market.

Average volatility is at least as low in computerized markets as in floor-based markets. It is not clear exactly what dimension of market quality is being measured, however. This confusion may explain the mixed results on volatility dynamics and the effect of volatility on market share. There are also conflicting interpretations of volatility persistence, in terms of information and market design.

Mild differences in informational efficiency across trading technologies are observed, but these differences disappear once such models are augmented by additional trading information. There is no evidence supporting price information leadership across market structures, with regard to either prices or volatility characteristics. Traders do not necessarily migrate to floors in the presence of high volatility, despite anecdotal arguments to the contrary.

One explanation of the equality of market quality across trading structures lies in a peculiar form of what statisticians call selection bias. The term is commonly reserved for situations in which the sampling information is not random in some dimension. This lack of randomness is exemplified here, since all cross-market comparisons depend on the survival and stability of two markets trading the same securities, usually with heavy overlap in terms of time zone. One might, therefore, reasonably conclude that both floor and automated auctions serve traders well, even if they do so along different dimensions. The quality of market may differ between competing structures in some aspect, which is offset in another.

This rough equality across auction mechanisms does not imply that dual market structures will continue to exist over the long run. The consumers of trading system services also face a combination of implicit and explicit costs, and we now turn to some new evidence on this point.

5. Transaction Costs, Intermediation, and Market Structure

An important implication of automation is the potential for institutional investors to obtain direct market access.[41] Access to traditional trading floors requires the use of brokers with exchange membership. Intermediation in dealership markets is built into trading protocols by design. In contrast, an institutional trader can place orders directly in automated venues such as Instinet, POSIT, and the Arizona Stock Exchange.[42]

Why might this distinction matter in practice? The first answer concerns the choice of trading venue. In an intermediated setting, the broker determines where execution will take place. If the broker is representing the best interests of the trader, choice of trading location would be rationally based on price and quality of execution. This hypothesis appears to be refuted in practice. For example, most trades in NYSE issues that are exe-

41. Although this may eventually also be true for retail customers, capital requirements typically exclude direct access for noninstitutional traders.

42. Technically, an institutional trader cannot place an order directly on the Arizona Stock Exchange. Because the company is legally regulated as an exchange, the SEC requires intermediation by a registered broker. However, the broker merely places the order and receives only a small payment for the service.

cuted off the NYSE floor happen when the execution venue is posting inferior quotes. This indicates that location is often determined for reasons other than best pricing.[43]

Discussions with institutional investors suggest a second response, pertaining to information. Once an order is placed with a broker, information about the trade is no longer private, and information leakage can occur. If so, some information is reflected in quotes prior to trade execution, adversely influencing execution costs on the part of the original investor. Keim and Madhavan (1996) argue that such leakage is greater for trades in small capitalization stocks, large block transactions, and high-volatility environments.

A simple alternative explanation is that human intermediation services are often unnecessary. The investor is nevertheless obliged to pay for such services when trading through a traditional broker. Automated trading enables institutions to avoid paying for intermediation services they do not require. On simpler trades, the trading expertise of the broker may not be sufficient to compensate for the lower commissions that automated services invariably levy.

Common to each explanation is the importance of transaction cost, whether explicit or implicit. We have already stressed the contribution of cost considerations to theoretical predictions concerning market structure. We now examine explicit and implicit costs, concentrating on commissions and fees, realized bid-ask spreads, and price impact.

Excepting the spread analyses in the previous section, work on transaction costs across trading venues has concentrated on comparisons among the NYSE, NASDAQ, and the regional exchanges in the United States.[44] Such studies do not compare costs across intermediated versus nonintermediated venues or traditional versus electronic trading arenas.[45]

43. Blume and Goldstein (1997). U.S. law mandates that brokers provide "best execution," described by the SEC (1996) as to "seek the most favorable terms reasonably available under the circumstances for a customer's transaction." Macey and O'Hara (1996), however, note the absence of specific definitions of best execution or of an explicit best execution rule. A variety of studies also show that trades are often executed at prices superior to the posted quotes, suggesting the possibility that trades executed at the inside quote might have received better execution at an alternative venue; see Petersen and Fialkowski (1994); Bessembinder and Kaufman (1996); Blume and Goldstein (1997).

44. Keim and Madhavan (1998) provide a survey of the literature on transaction costs, with a brief review of individual contributions.

45. Bessembinder and Kaufman (1997) discuss the Cincinnati Stock Exchange, however.

We compare transaction costs for trades executed through traditional brokers with those incurred through nonintermediated trading in automated markets. Explicit costs in terms of commissions, as well as implicit costs embodied in the prices at which trades are completed, are considered.

There are two possible levels of interpretation for the results that follow. Cost comparisons are most directly interpretable in terms of intermediated versus nonintermediated trading. No ambiguity is associated with this particular exercise. The vast majority of trades handled through brokers are executed through the NASDAQ market and on the NYSE or regional floors. To the extent that broker order flow, representing institutional orders in particular, is not directed to automated venues, the comparisons may be interpreted as between automated and traditional trading markets.

5.1. The Data

The data consist of information reflecting the trading activity of a U.S. mutual fund managing, at the time of this study, approximately $44 billion in equity assets. We refer to this institution hereafter simply as "the fund." The data are averages of cost components and related variables for trades over six-month periods between 1992 and 1996, as reported by their trading cost consultant, SEI. The data are available for thirty-five traditional brokers and four electronic brokers. The latter include Instinet's continuous order-matching system, the Instinet Crossing Network, POSIT, and the Arizona Stock Exchange call auction. Thus we have one continuous auction system, two periodic crossing systems, and one call auction in our sample of electronic brokers.[46]

We have identified as electronic brokers only those that specialize in electronic order execution. Those that use electronic systems exclusively to route orders to exchanges are classified as traditional brokers. The distinction is somewhat arbitrary for listed stocks. For example, Instinet is often used for order-routing on NYSE issues (through the DOT system), making it similar in function to some other brokers, which we have classified as traditional. Our categories distinguish, as accurately as allowed by

46. It has been suggested, especially for the early period of our sample, that the Arizona Stock Exchange is effectively a crossing network, as orders entered into the system are almost invariably priced passively; that is, orders are typically placed at the NYSE closing price for the stock.

the data, between those brokers that intermediate trades and those that allow buyers and sellers to interact directly, without human intermediation.

For each broker and time period, trades are broken down into those in OTC issues (i.e., NASDAQ) and those in exchange-listed issues. Trade direction is identified. When we refer to buy trades, for example, we mean that the fund initiated the trade as a buyer. The number of trades of each type that enters the six-month averages is known. Information is available on shares per trade, market capitalization of the stock traded, market beta of the stock, daily volatility of stock returns, and average stock price. Data on transaction costs are included in the form of explicit costs (fees) and implicit costs for each broker and time period. We return to the construction of implicit costs below.

Like some other proprietary databases, the data come from only a single trading entity. There is potential selection bias in the choice of brokers by time period or market conditions, which cannot be effectively corrected with the limited number of observations and variables available. Similarly, variation in investment style cannot be used as an input to transaction cost benchmarks.[47] The analysis also is conditional on trade execution; that is, we exploit no information regarding delays in execution or whether an order was executed in the particular venue to which it was originally sent.

There are characteristics of these single-institution data that make them very appropriate for our analysis, however. First, the fund has no "soft commission" arrangements with brokers, as a matter of company policy. In effect, funds that pay soft commissions are paying for services not related to execution via trade execution fees, complicating the task of measuring the true costs of trade execution. The fund data are relatively immune to this distortion.[48] Second, the fund is an exceptionally large-scale user of nonintermediated electronic trading services. The fund accounts for approximately half the total trading volume going through such systems on

47. As in Keim and Madhavan (1997), for example.

48. Soft commissions represent payments made directly from client funds to brokers for research and other services, which are effectively embedded in the fees that the fund pays for each trade. Generally, funds that pay soft commissions commit in advance to paying a minimum annual level of commissions to the broker in return for services. The fund does not commit to minimum volume levels with any broker to obtain research, information, or trading system services. This does not eliminate the possibility that the company is implicitly securing such services by de facto maintaining large volumes with a given broker, but it does mitigate the distortionary effects of explicit soft commissions.

the full SEI database, which comprises data from thirty-three institutional clients. It is one of the few funds in the world for which there are sufficient data to allow valid comparisons of trading cost between traditional and electronic trading mechanisms.

Finally, most cross-exchange comparisons are made using trade-by-trade data, while our information is restricted to activities across days. The conceptual cost experiment in the former case is one of immediate turnaround on the next trade.[49] In contrast, the data here compare costs embodied in prices against what would happen if turnaround occurred in one or two days, depending on the measure. Regardless of the reader's preferences with regard to this tradeoff, our approach is the only one feasible. Available trade-by-trade information does not allow discrimination between automated and traditional trading venues or between intermediated and nonintermediated trades.[50]

5.2. The Definition of Transaction Costs

The appropriate construction of implicit cost measures is often debated. We only have access to the information provided to the fund by SEI, and not to the underlying database, however. We must use the implicit cost measures provided by the consultant, as opposed to developing our own. Nevertheless, the available measures correspond to commonly used definitions.

Let V_{it} denote the true economic value of security i at time t, for which some observable proxy must be used in applications. Define

$$\text{effective half-spread} = 100D_{it}(P_{it} - V_{it}) \,/\, V_{it} \text{ and}$$
$$\text{realized half-spread} = 100D_{it}(P_{it} - V_{it+n}) \,/\, V_{it}$$

where P is the transaction price of the security, n is a time increment, and D is a binary variable taking on the value of 1 for buy orders and –1 for sell orders.[51] The effective half-spread is a measure of the proximity of the

49. More formally, the cost might include the difference between the actual post-trade value and the value if the investor had been instantaneously able to transact the desired quantity at a net price equal to the fair value of the asset.

50. For example, in the TAQ database available from the NYSE, trades executed on Instinet are reported as NASD trades and cannot be identified separately. Trade-by-trade data also force the researcher to infer trade direction, introducing estimation error, while trade direction is unambiguously identified here.

51. Following Huang and Stoll (1996); Bessembinder and Kaufman (1997).

trade price to the underlying value. This provides an estimate of the percentage execution cost paid by the trader. It has the advantage of reflecting savings due to trading inside the quoted spread. The realized half-spread is the difference between the effective spread and decreases in asset value following sells and increases in asset value following buys. The latter measure, sometimes called price impact, reflects the market's assessment of private information conveyed by the trade.[52] The realized spread may also be interpreted as a measure of the reversal from the trade price to post-trade economic value.

The cost measure supplied by the fund represents an interpretable combination of these concepts as well as proxies for the underlying true value of the security. Specifically, setting $n = 1$ day in the definitions above, we define

$$\text{execution cost} = D^{*}[(\text{effective half-spread})\ (\text{realized half-spread}) \\ -\ \text{index return}]$$

where the index return is calculated for the day after the trade, based on a specific industry index appropriate for the particular security under consideration. Effective and realized half-spreads typically are analyzed separately. This permits, for example, the price impact effects to be isolated directly through the difference between the two measures. In our case, for small movements in index returns within days, the cost measure is approximately the square of the geometric average of effective and realized spreads.

SEI uses the trading day closing price as a proxy for V_{it} and the next day closing price as a proxy for V_{it+n}. The product of the two half-spreads is then modified by a measure of the index performance of the relevant industry group with which the stock is associated from trade day until close of the next day. On the buy side, a positive value of the term within the brackets represents favorable execution cost, while the opposite is true on the sell side. For example, suppose this cost is computed for a buy trade as ninety-nine basis points. The impact is favorable: it may be a result of the stock price moving up on trade day and down by more the next, yet not by as much as the composite of stocks in the same industry group. In other words, the stock price performed well after the trade relative to the industry group performance, even though the investor actually lost money on the

52. Bessembinder and Kaufman (1997).

transaction. Thus D^* now takes on the value of -1 for buy orders and 1 for sell orders. The example above represents a savings of ninety-nine basis points. Finally, we define *total trading cost* to be the sum of execution cost and fees for the trade.

5.3. Average Trading Costs

Table 5 reports cost as a percentage of value traded. Data means are disaggregated into trading categories, differentiating between OTC and exchange-listed shares and between buy and sell activity. The percentage of dollar volume for all market categories and for individual electronic markets is also provided.

On the basis of unconditional average total trading costs, the automated systems outperform the traditional brokers across-the-board. For listed buys, traditional brokers generate costs 429 percent higher than electronic venues, while for OTC buys the gap is 217 percent. For listed sells, traditional broker costs are only 6.7 percent higher than costs in the electronic markets, while for OTC sells the difference is 26 percent.

One might reasonably expect cost savings to be larger when disintermediation potential is larger, as it is in the OTC market. The evidence is consistent on the sell side, but not for buy trades here. This intuition is better supported once trading characteristics are taken into account below. The volume data also reflect differences in potential cost savings. Dollar volume directed to electronic markets for OTC trades is about five times that of electronic brokerage in listed issues. Most of this variation is for trades using Instinet's continuous market. Relative dollar volumes on the periodic markets differ little and unsystematically between listed and OTC stocks.

Keim and Madhavan (1998) suggest that crossing systems offer substantially lower fees than commissions charged by traditional brokers and mention a figure of \$0.01 to \$0.02 a share. We also observe large differences between traditional brokers and periodic automated systems in terms of fees calculated in percentage terms. Fees for Instinet continuous trading, even in OTC issues, are also substantially lower than those charged by traditional brokers for listed trades. Traditional brokers charge about twice as much as the continuous automated auction.

These preliminary results could be due to the special nature of our single-institution data. The range of the results is generally in accordance

Table 5. Average Total Trading Costs

	Total trading cost	*Fees*	*Percentage of dollar volume*
OTC buy trades			
All brokers	0.22	0.04	100.00
Traditional	0.38	0.00	38.50
All electronic	0.12	0.06	61.50
Crossing / call	0.15	0.05	6.08
Instinet	–0.23	0.03	1.98
POSIT	0.25	0.06	3.52
AZX	0.83	0.04	0.58
Instinet continuous	0.11	0.07	55.40
OTC sell trades			
All brokers	1.37	0.05	100.00
Traditional	1.60	0.00	30.90
All electronic	1.27	0.07	69.10
Crossing / call	0.73	0.06	7.68
Instinet	0.61	0.04	2.47
POSIT	0.83	0.07	4.45
AZX	0.52	0.04	0.76
Instinet continuous	1.33	0.08	61.50
Listed buy trades			
All brokers	0.33	0.12	100.00
Traditional	0.37	0.13	88.60
All electronic	0.07	0.05	11.40
Crossing / call	0.09	0.04	7.38
Instinet	0.21	0.03	2.55
POSIT	–0.04	0.05	3.93
AZX	0.25	0.03	0.90
Instinet continuous	0.05	0.07	3.99
Listed sell trades			
All brokers	0.47	0.16	100.00
Traditional	0.48	0.17	88.30
All electronic	0.45	0.06	11.70
Crossing / call	0.33	0.04	6.63
Instinet	0.20	0.04	2.50
POSIT	0.42	0.05	2.86
AZX	0.39	0.03	1.27
Instinet continuous	0.61	0.08	5.10

with that of other studies, however. Keim and Madhavan (1998) report average commissions of approximately 0.20 percent over the 1991–93 period, which is close to that calculated by Stoll (1995) for 1992. Our data represent trading over more recent periods, and commissions have been falling. For listed stocks traded through traditional brokers, commissions are in the range of 0.13 to 0.17 percent. The ratio of traditional broker commissions to crossing fees should be on the order of 3.73 based on other studies.[53] For listed stocks, we find the ratio to be 3.75 on average. It is more difficult to compare our numbers for execution cost to the half-spreads in the literature, given the different methods of computation. Our geometric average of half-spreads for traditional broker trading activity is very close, however, to the effective spreads reported by Bessembinder and Kaufman (1997), for example.

The data also exhibit striking absolute and relative variation in performance across buys and sells. On average, trading cost is much higher for sells than for buys, and the difference is particularly marked for OTC stocks. Similar results are noted in other studies.[54] The finding is apparently unrelated to automation effects, and we simply continue to condition our subsequent analysis on buy and sell initiations separately.

5.4. A Benchmark Correction for Trade Difficulty

Execution costs differ with respect to the relative difficulty of making the trade. Trade characteristics matter in assessing costs, making unconditional comparisons less than fully informative. In this section, we construct a benchmark against which other costs may be measured. Although our variables and technique differ somewhat, the exercise follows the regression approach suggested by Keim and Madhavan (1997). The goal is to judge whether trading costs vary systematically between traditional brokers and electronic markets, controlling jointly for variation in a set of economic characteristics. The general approach is analogous to risk-adjusted return measures in the performance evaluation field.

We estimate a panel data model of the form

$$C_{it} = \alpha_i + \beta' x_{it} + \varepsilon_{it}$$

in which the *i*'s index variation over traditional brokers and electronic markets, and t denotes time. We take C_{it} to be execution cost and use the full

53. This rough calculation is based on Edwards and Wagner (1993), who find average commissions in dollar terms to be about $0.056. Compare this number with $0.015 per trade on a crossing network, as suggested by Keim and Madhavan (1998).

54. Keim and Madhavan (1998).

sample to estimate the slope coefficients.[55] The vector of trade characteristics, x_{it}, includes shares per trade (*sh/tr*), market capitalization of the stock (*mktcap*), the market beta of the stock, annualized daily standard deviation of returns for the traded issue (*vol*), and the inverse of the share price (*p*). This list is similar to that used by Bessembinder and Kaufman (1997) and others in the calculation of economic characteristics of trading costs. Execution costs may diminish with firm size, owing to relatively better liquidity and reduced informational asymmetries. Larger trades should be more difficult, hence more costly, possibly due to larger inventory costs in intermediated settings or because of information content. Costs rise with volatility, especially in intermediated venues, given some degree of risk aversion. Trading costs are related to price levels, and the use of the inverse follows Harris (1994).

There are some specific estimation issues to be addressed. The α_i represent individual broker effects. They are treated as fixed, as opposed to random, given potential correlation of the effects with other variables in the model. Our data are unbalanced; that is, we have different numbers of time-series observations for each broker and electronic market. The fixed-effects estimator for unbalanced panels discussed in Domowitz, Glen, and Madhavan (1997) is used, with one modification.[56] The estimator is adapted to generalized least squares, given that all data are averages. The number of trades for each broker and for each time period is used in the weighting scheme, an otherwise standard correction for averaged data.

Estimation is based on a cross section of thirty-nine traditional brokers and electronic markets and an average of seventeen time periods per broker. The cost measure is calculated from the regression estimates as

$$\begin{aligned}\tilde{C}_{it} = {} & 0.003(sh/tr)_{it} - 0.013(mktcap)_{it} + 0.001(beta)_{it} \\ & + 0.009(vol)_{it} + 0.061(p)_{it}\end{aligned}$$

We will refer to $\tilde{C}_{it}$ as benchmark cost.[57] Unlike Bessembinder and Kaufman, we do not use estimated fixed effects as a measure of cost

55. Qualitative results using total cost measures are very similar and not reported. One could also use different regressions for different categories of trades, for example, for OTC versus exchange listed issues or for buys versus sells. Sample size and selection considerations make such estimates unstable, however.

56. Domowitz, Glen, and Madhavan (1998).

57. Since we are not interested in inference with respect to coefficient estimates, standard errors are omitted. They are generally small, with the exception of the coefficient on inverse price, and the regression R^2 is 0.09.

differences after adjusting for economic heterogeneity in trades.[58] Instead, we compare the benchmark to actual execution cost. Realized cost embodies any broker-specific attributes that may increase or decrease cost relative to the cost predicted by trade characteristics alone.

5.5. Execution Costs Relative to Benchmark Costs

Median execution costs (i.e., excluding commissions) and benchmark costs for overall market activity are reported in panel A of table 6. The electronic systems are handling easier trades at lower cost. Execution cost is 20 percent higher for traditional brokers relative to their electronic counterparts. On the other hand, benchmark costs in the electronic venue are about 22 percent less than those predicted for traditional brokers, indicating less difficult trades.

We differentiate between OTC and listed trades in panel B. For OTC stocks, differences in trade difficulty, as measured by the benchmark, are small, but the transactions are done much more cheaply electronically. Execution cost for traditional brokers in OTC transactions is 89 percent higher than for electronic systems, while the benchmark cost difference is only 29 percent.

For listed stocks, the situation is reversed: trades done electronically look extremely easy according to the benchmark, but trading costs are only slightly lower than those incurred by traditional brokers. Realized costs are only 13 percent higher for traditional brokers, while the benchmark is 173 percent higher, relative to electronic venues.

Benchmark costs are higher for sell trades than for buys. This observation provides one explanation for the cost asymmetry between buy and sell transactions. Sells appear to be done under more difficult conditions, on average.[59] On the other hand, percentage differences between the realized costs of buy and sell transactions, holding type of broker constant, exceed those observed for the benchmark costs. Thus market conditions alone cannot explain the disparity between costs on the two sides of the market, regardless of type of broker.

In table 7, we report the median ratio of execution costs to the benchmark by type of trade. We interpret this measure as cost relative to the

58. The conditioning set is incorrect for this interpretation, given our econometric method. Bessembinder and Kaufman (1997) transform their variables somewhat differently.

59. This is consistent with Keim and Madhavan (1998), who attribute larger costs to larger sizes on the sell side.

Table 6. Realized and Benchmark Median Execution Costs

	All brokers	*Traditional*	*Electronic*
Overall market activity			
Execution cost	0.310	0.325	0.270
Benchmark cost	0.349	0.355	0.278
OTC versus listed			
Execution cost			
OTC	0.520	0.660	0.350
Listed	0.220	0.220	0.195
Benchmark cost			
OTC	0.502	0.528	0.409
Listed	0.241	0.270	0.099
Buy versus sell			
Execution cost			
Buy	0.175	0.220	0.105
Sell	0.520	0.480	0.555
Benchmark cost			
Buy	0.331	0.335	0.264
Sell	0.363	0.370	0.323

difficulty of the trade. A ratio greater than 1 indicates costs in excess of those expected based on trade characteristics. Conversely, ratios less than 1 suggest that the trades are done more cheaply than would have been suggested by their relative difficulty.

For OTC stocks, the electronic systems are handling easier trades, but much more cheaply than traditional brokers, relative to trade difficulty. The traditional brokers' ratio is 50 percent higher than that observed for electronic systems. A breakdown of OTC trades into buy and sell transactions reveals superior performance of electronic systems in both cases, but much of the relative advantage is on the buy side.

For listed issues, however, it appears that traditional brokers outperform electronic systems. Traditional brokers exhibit a cost ratio close to 1, while the figure for electronic systems is just over 2. Relatively lower cost compared to the benchmark characterizes traditional brokers' operations, regardless of whether the transaction is on the buy or the sell side.

The contrast between the results for trades in OTC and listed shares might not be surprising. The potential for cost savings through disintermediation via the electronic systems is greater for OTC trades than for trades in listed shares that already take place in an auction environment. The complete reversal of results based on the ratio of execution costs to the

Table 7. Median Ratio of Realized to Benchmark Execution Cost

	Traditional	*Electronic*
OTC	1.343	0.895
Listed	0.913	2.066
Buy	0.654	0.171
Sell	1.548	2.158
OTC buys	0.531	0.043
Listed buys	0.807	1.085
OTC sells	2.558	1.864
Listed sells	1.086	3.027

benchmark for listed trades is more surprising, given the remainder of the evidence. We investigate this point further in the context of individual trade characteristics.

5.6. Trade Characteristics and Total Trading Costs

As we have discussed, trades executed through traditional brokers appear in the aggregate to be more costly than trades done electronically. Transactions on electronic systems are easier trades with lower expected cost. Differences in trade difficulty account for some, but not all, of the electronic markets' cost advantage, however.

Excluding commission costs from our analysis, the superior performance of electronic markets is only evident for OTC stocks. For OTC trades, traditional brokers incur costs that are 34 percent higher than expected, given market conditions, while trades on electronic systems are more than 10 percent lower than would be predicted. Benchmark costs for OTC trades are more than double those for listed issues, suggesting that electronic markets do well for more difficult trades. For listed trades, however, electronic markets appear to fare much less well vis-à-vis traditional brokers. Based on the ratio of execution cost to the benchmark, electronic markets do poorly relative to expectations and relative to the performance of traditional brokers. We now attempt to shed further light on these results by extending our analysis to total trading costs (including commissions) and more disaggregated comparison data.

In table 8, total costs are sorted by values of several trade characteristics, including benchmark execution cost. The figures are constructed in the following manner. For a trading category (listed or OTC), the median

Table 8. Trading Costs Sorted by Market Conditions

	Below median		*Above median*	
	Traditonal	*Electronic*	*Traditional*	*Electronic*
OTC shares				
Shares per trade	0.543	0.452	0.967	0.825
Market cap	0.919	0.150	0.558	0.546
Beta	0.381	0.459	1.292	0.598
Volatility	0.324	0.508	1.181	0.595
Inverse price	0.502	0.461	1.016	0.714
Benchmark cost	0.386	0.524	1.053	0.649
Listed shares				
Shares per trade	0.475	0.255	0.307	0.815
Market cap	0.506	0.291	0.231	0.263
Beta	0.241	0.179	0.522	0.341
Volatility	0.232	0.286	0.529	0.262
Inverse price	0.364	0.210	0.391	0.312
Benchmark cost	0.239	0.271	0.478	0.295
OTC buys				
Shares per trade	0.255	0.293	0.017	0.051
Market cap	0.285	0.005	−0.137	0.254
Beta	−0.264	0.511	0.587	0.041
Volatility	−0.102	0.351	0.330	0.082
Inverse price	0.193	0.268	0.059	0.176
Benchmark cost	0.060	0.253	0.165	0.158
OTC sells				
Shares per trade	1.156	0.622	1.689	1.452
Market cap	1.399	—	1.558	0.823
Beta	1.104	0.700	1.984	0.893
Volatility	0.834	0.660	1.970	1.198
Inverse price	0.996	0.894	1.824	0.633
Benchmark cost	0.877	0.832	1.849	0.755
Listed buys				
Shares per trade	0.401	0.125	0.260	—
Market cap	0.472	0.106	0.149	0.137
Beta	0.061	0.018	0.601	0.207
Volatility	0.235	0.202	0.400	0.031
Inverse price	0.431	0.141	0.203	0.109
Benchmark cost	0.267	0.163	0.357	−0.227
Listed sells				
Shares per trade	0.494	0.396	0.391	—
Market cap	0.537	0.445	0.315	0.396
Beta	0.419	0.337	0.451	0.459
Volatility	0.235	0.375	0.649	0.435
Inverse price	0.336	0.530	0.531	0.285
Benchmark cost	0.184	0.392	0.614	0.715

— No observations within cell.

value of a trade characteristic (shares per trade) is calculated. Observations for a type of broker (traditional or electronic) are classified as being above or below this median value. For observations on either side of the median, average total trading costs are calculated.[60]

Costs by trade characteristic for OTC trades are contained in table 8. Electronic OTC trading costs are lower than those for traditional brokers, regardless of the size of the trade, market capitalization, or average share price. Electronic trade execution is also less costly for trades with volatility and expected cost above median values. These results support findings based on execution cost; in the OTC market, and for relatively more difficult trades, electronic markets outperform traditional brokers. Figures reported in table 8, disaggregating OTC trades into buy and sell activity, yield the same basic conclusion. Electronic brokers tend to dominate across all categories on the sell side, which we have documented as representing more difficult market conditions in this sample.

In the case of listed issues, our results suggest that large savings in explicit trading costs from electronic executions outweigh possible gains in implicit costs from trading via traditional brokers. We earlier reported a ratio of execution cost to benchmark for traditional brokers that is 55 percent below that for electronic markets. On the other hand, for benchmark execution costs above the median, *total* costs for traditional brokers are 62 percent above those for electronic markets. The difference in findings stems from commissions charged by traditional brokers, which are over 100 percent more than fees charged by electronic markets.

We also note that for listed stocks electronic brokers exhibit lower total costs for high-volatility trades, for small sizes, all price ranges, and low market capitalization. Given such results, the apparent superiority of traditional brokers based specifically on the ratio of execution cost to the benchmark stands out as an exception. We now suggest that some ambiguities in the data simply obscure the basic finding that electronic systems constitute the less costly trading technology.

We disaggregate listed activity into buys and sells in table 8, and several significant findings emerge. First, all electronic trading in this sample of listed stocks is done for trade sizes below the overall median (conditional

60. In table 8, for example, average total cost is 0.919 for traditional brokers doing OTC trades in stocks whose market capitalization is below the median for all OTC trades in the sample. The corresponding value for trades in stocks with above-median capitalization is 0.558 for traditional brokers and 0.546 for electronic venues.

on whether the trade is a buy or a sell). This implies that benchmark execution cost is lower relative to sample averages for electronic systems, raising the ratio of execution costs to the benchmark for electronic markets. This is another way of expressing a result of the potential sample selection bias noted earlier. Second, average costs for traditional brokers fall for large trades relative to small trades. The expected relation between price impact and order size may be reversed by upstairs-facilitated block trades in listed stocks.[61] Yet the benchmark cost regression indicates that for the full sample—including electronic markets, traditional brokers, and OTC as well as listed stocks—cost increases with size. Benchmark costs for traditional brokers in listed issues rise as size increases, actual execution costs fall due to block facilitation, and the ratio of execution cost to the benchmark declines.

Thus the execution cost results for listed stocks, which are favorable to traditional brokers, are due to a combination of sample selection problems and a bias in the benchmark calculations due to unobserved upstairs activity. This conclusion is supported by other information in table 8. Consider buy transactions in particular. Total trading costs are lower for automated systems for small trade sizes and for all levels of market capitalization, volatility, price level, and benchmark cost.

Owing to the complications involved in handling the listed trade data, we state our conclusions as follows. In the U.S. OTC markets, trading via electronic systems would appear to offer significant cost savings over trading via traditional brokers, even after adjusting for trade difficulty. Whereas considerably more ambiguities are present in the data for listed stocks, extending our analysis to encompass total trading costs and using more informative disaggregated data justify a similar conclusion in that market.

6. Summary and Conclusions

The classical financial market microstructure literature models exchanges as hierarchies of trading rules that determine the parameters within which heterogeneously endowed traders strategically interact. The

61. Leinweber (1995) and Keim and Madhavan (1996) document similar findings in this respect.

explicit transaction costs that traders bear are presumed to be unaffected by the technology, operating costs, or organizational structure of the exchange. Even such issues as competition between exchanges are assumed to be governed by the behavior and composition of traders. As such, the literature has little to say about the most important developments in the trading services industry today: namely, the impact of advances in computer and telecommunications technology on the cost of trading and the development of market structure. In this paper, we address these issues directly by focusing on the characteristics of exchange trading products rather than on the characteristics of traders.

We argue that exchanges operating in a competitive environment should be analyzed as firms offering trading products that embody particular technologies. The "liquidity effect," to which is commonly ascribed the durability of the dominant national exchanges, derives from the salience of network externalities in the securities trading industry. Issues of trading technology adoption require analysis in the framework of network models of industrial organization. Such models serve to illuminate increasingly prominent features of exchange competition and market structure development.

Assuming roughly equivalent product quality as between incumbent (floor auctions) and entrant (computerized auctions), an assumption whose applicability we document, new technology adoption in the face of network externalities requires clear cost advantages for the entrant. Cost therefore features as the centerpiece of our quantitative study of electronic versus intermediated trading. Yet the diffusion of new trading technology involves more complex processes. Our review of recent competitive developments in the trading industry appears to reinforce the fundamental role of the network effects postulated by this branch of industrial organization theory. First-mover advantages exist but are being eroded by relative cost movements and strategic pricing behavior. The role of technology "sponsorship" appears to be important in abetting successful entry. We observe sudden and rapid adoption of the entrant's trading technology once apparently small advantages have been achieved ("tipping"). The spread of external "adapter" systems, such as Instinet, that integrate incompatible networks, is further predicted by the theory. Finally, we examine the emergence of mergers and "cartels" among automated system operators; a development that may be socially optimal given the underlying tenets of network economics.

We discuss the role of cost in the pricing of exchange trading services in the context of increasing market contestability. Several factors bring the market for trading services much more closely into line with the assumptions of perfect contestability. These include a massive decline in the costs of developing automated systems, the elimination of "distance costs" in the provision of cross-border electronic trading services, and the expansion of securitized products. As cross-subsidization of products is inconsistent with sustainability of prices in a contestable market, this has important implications for the way in which exchanges price different types of trading. Among U.S. and European exchanges, we document salient examples of such cross-subsidization, such as large trades by small trades, "on-exchange" trades by "off-exchange" trades, and retail trades by institutional trades. We demonstrate how trading automation greatly facilitates specialization of service provision and, as a consequence, serves to arbitrage away cross-subsidies. We expect this trend to intensify. For example, limit-order traders benefit from exchange "interaction rules" obliging block traders to execute their orders. As automation increasingly facilitates the incursion of competitor block trading services, and thereby eliminates this subsidy for limit-order traders, exchanges may be compelled not merely to eliminate fees for such traders (as Tradepoint has already done) but actually to *pay* them.

The behavior of exchanges is conditioned not merely by the competitive environment, but by the incentive structure deriving from their internal governance arrangements. The traditional mutual structure of an exchange is a remnant of the pre-automation era, when the space limitations inherent to trading floors necessitated the rationing of direct access to members. As members then became intermediaries for all nonmember order flow, exchange behavior came to be partly directed by the interests of members in maintaining intermediation profits. As trading automation has facilitated unlimited direct access, it is logical that new automated entrants have chosen not to be governed as intermediary cooperatives, but rather as for-profit joint-stock companies selling execution services on a transaction basis. Member-based exchanges are increasingly trying to replicate the incentive structures of such companies by demutualizing, or divorcing ownership from membership. The historical record of such initiatives is short, but the Stockholm experience in particular would appear to indicate that innovations such as foreign remote membership and direct investor access are more easily implemented when intermediaries are minority owners and that demutualization may therefore serve to improve the performance of the exchange as a commercial enterprise.

As commercial enterprises, exchanges compete on the basis of the "market quality" that they offer as well as the cost of their trading services. In this regard, the focus of academic research has long been on measures of market quality, whereas it is our contention that a true understanding of trading technology adoption and market structure development can now be achieved only by moving the focus to cost. This conclusion stems from an examination of extant empirical evidence comparing traditional trading venues to automated price-discovery systems. Market quality is assessed using a combination of information relating to liquidity, informational efficiency, and volatility characteristics. Overall, the evidence suggests that automated markets and traditional trading floors may differ in subtle and complex ways, but that market quality is equalized across market structures.

If this is the case, measuring the actual cost of trading across traditional intermediated markets and automated nonintermediated markets becomes an important exercise. Despite the many recent transformations from floor and dealer markets to automated auction markets that we have documented, the structures still coexist in many parts of the world. Lower development and operational costs for automated structures will undoubtedly influence competitive developments, but it is the explicit and implicit (execution) costs borne by traders in each type of market that is ultimately likely to be determinant. We evaluate explicit and implicit costs using a unique sample of five-year trading data from a large institutional user of proprietary electronic trading systems.

Both categories of cost are lower for electronic systems than for traditional brokers across over-the-counter (NASDAQ) and U.S. exchange-listed stocks. To account for differences in trade difficulty across electronic markets and traditional brokers, we construct a benchmark measure of execution cost, based on trade characteristics. Analysis of execution costs, net of commissions, suggests that trades on the electronic systems are easier trades, with lower expected cost. However, we also find that electronic markets are generally less costly than traditional brokers for more difficult trades.

For OTC stocks, electronic markets dominate traditional brokers across-the-board. For listed stocks, our conclusions are similar but more nuanced. The ratio of execution cost to benchmark cost is generally superior for traditional brokerage, but this statistic is not informative for listed stocks, owing to a number of features of the data, which we detail in the text. An examination of total trading costs, inclusive of commissions, reveals electronic trading to be superior to traditional brokerage by any measure of trade difficulty for buy trades and to be comparable for sells. We therefore conclude that electronic trading generally yields considerable cost savings over traditional trade intermediation.

We have tried to demonstrate in this paper the enormous impact that advances in computer and telecommunications technology have had both on trading costs and on the natural industrial structure of the securities trading industry. The implications are far-reaching for the development of market structure and the design of effective public policy. In particular, exchanges are now compelled to compete in an increasingly international market for trading services and can no longer be seen as static repositories for rules governing the transfer of ownership of securities. In our view, researchers, regulators, and traders would benefit from taking an industrial economics approach in trying to understand and react to this new market environment.

Comments and Discussion

Comment by David Cushing: My comments are made from the perspective of a practitioner and representative of one of the computerized trading systems described in the paper. I will offer more details about that system in a moment. I begin by summarizing the authors' essential points and then apply them to three case studies to see how their predictions stack up. I conclude by raising a few points for further discussion.

Summary of Authors' Essential Points

Exchanges and trading systems are best described using industrial models in which network economics in general, and the pronounced presence of network externalities in particular, figure prominently. The primary network externality associated with an exchange is that of the "liquidity effect," whereby the value of a given exchange or system to a trader is enhanced by the decision of an additional trader to transact there. The effective control of liquidity provides the dominant exchange with a considerable barrier to competition and has historically allowed it to engage in practices that would not survive under normal competitive conditions.

Contestability theory offers an explanation for how computerized exchanges and alternative trading systems have been able to overcome this barrier, gain market share, and in some cases completely dominate traditional exchange mechanisms, despite the tremendous advantage conferred by the liquidity effect that exchanges enjoy. Ian Domowitz and Benn Steil describe the attributes of a perfectly contestable market:

—New firms have no disadvantages vis-à-vis established firms.

—Sunk costs are fully recovered on exit.

—The entry lag (the time a new firm enters the market minus the time old firms know that the new firm is entering) is less than the price adjustment lag of the old firm.

Applied generically, these theories explain the following observed developments in exchanges and alternative trading systems:

—Advances in technology have dramatically increased the ratio of price to performance and thereby lowered sunk costs.

—At the same time, innovative applications of technology have lowered the explicit costs of producing new trading services as well as both the explicit and implicit costs of using the new services.

—These advances, in conjunction with more competitive governance structures, have allowed new systems to enhance network externalities by allowing for remote access.

—Meanwhile, inflexible governance structures and very high cost structures have hamstrung traditional exchanges from making a competitive response, allowing electronic systems to thrive for extended periods of time.

Conceptually, this framework makes quite a bit of sense. The next step is to apply it to a few real-world situations and see how it stacks up.

Case 1: ITG Inc

The first case study concerns the electronic trading system that is most familiar to me, ITG POSIT®. For those not familiar with either ITG (Investment Technology Group) or POSIT, let me provide a few background details:

—ITG is part agency-broker-dealer and part technology firm. Almost half of its 235 employees are involved purely in software development.

—US POSIT, our flagship trading technology, is the world's largest intra-day equity crossing system. It features total confidentiality of orders, low commissions, mid-point pricing derived from the primary market, and no market impact.

—ITG is becoming known for technology-driven, pure agency execution. We are agnostic about liquidity, and we use all available sources of liquidity. For example, we are among the New York Stock Exchange's (NYSE) largest DOT (designated order turnaround) customers.

—As a firm, we executed just under 3 billion shares in the third quarter of 1998 (47.6 million shares a day), with POSIT trades constituting about 1.7 billion shares (27.0 million shares a day).

—Our market share in the third quarter of 1998 was 3.2 percent, up from 2.2 percent in 1997 and 1.4 percent in 1996. This information is relevant to a point about "tipping" that I will make in a moment.[1]

We have contested the dominant trading networks (NYSE and NASDAQ) through the intensive application of technology. The specific market segment that we originally contested with the POSIT crossing system are quantitative and passive investors, who had to pay transaction costs associated with highly informed trades for low- or no-information trades.

We have experienced network externalities of our own in the form of a virtuous cycle of increasing liquidity as new entrants start using POSIT and existing clients begin using the system more.

Although we have increased our market share over time, we have by no means experienced the "tipping" phenomenon described in the paper, whereby some electronic systems experience explosive increases in market share after gaining an initial toehold. This is due to many factors, but at least in part to the fact that we are subject to another form of network effect: complementarity. In the same way a compact disk can only function if you have a compact disk player, POSIT as it currently exists can only operate with reference to an externally determined price because of its passive pricing mechanism.

Without the rapid explosion of technology price performance to minimize sunk costs (original POSIT development costs were on the order of $1 million), without a trading constituency that felt very strongly that they were subsidizing the market, and without an exchange governance system that made the entry lag shorter than the price adjustment lag, POSIT never would have gotten off the ground. Thus ITG makes for a fairly textbook illustration of the applicability of this theory.

What about US POSIT's offshore cousins, Australian POSIT and UK POSIT? The Aussie system has been up and running for some time now, and liquidity continues to build, yet the Australian Stock Exchange is a highly automated, highly networked, demutualized exchange. Given the Australian exchange's considerable network externalities and relatively low contestability, Australian POSIT should be having greater difficulty gaining market share than it actually is. This suggests that factors other than contestability are helping POSIT become successful. In POSIT's

1. POSIT publishes volume statistics weekly on Bloomberg (www.bloomberg.com).

case, these factors could be as simple as confidentiality and the complementarity of a passive system to an automated auction market. UK POSIT will be launched in October in a much larger and somewhat more contestable market. It will be interesting to observe our experience there.

Case 2: Instinet

The core of Instinet's liquidity today is still the dealer flow that has dominated the system for almost twenty years in its role as de facto inter-dealer broker for the over-the-counter (OTC) market. The irony is that Instinet started life in the mid-1970s as an upstart challenger for institutional order flow to the entrenched incumbents, in this case the OTC market maker system. However, it is fair to say that the market then was far less contestable on all counts, and the system was moribund, if not headed for failure. It was not until it was adapted to this novel application, as an inter-dealer broker system, that it started to succeed. In this sense, Instinet's success does not fit cleanly into the authors' framework (that is, it succeeded for reasons other than increased contestability), although its failure as an institutional system does. To add to this irony, it was not until market makers gave Instinet its critical mass that institutions began to use the system—to disintermediate the very people who made it successful.

The story gets even weirder: recently the table has turned, and Instinet has become the incumbent, with costly infrastructure and entrenched economic interests, battling upstart electronic communication networks (ECNs) like Island and Archipelago. Such new ECNs (as of this time, there are six in total) are in most cases offering better technology and lower prices; they now enjoy a 25 percent share of overall ECN volume, up from 0 percent in the first quarter of 1997![2] As if all of this were not strange enough, one of the ECNs, Strike Technologies, is a consortium of NASDAQ market makers!

Case 3: LSE, SEAQ, and the European Exchanges

As the authors point out, the London Stock Exchange (LSE) developed the SEAQ technology and began rapidly taking market share from costly, antiquated European exchanges. European exchanges fought back

2. ITG analysis of data provided by NASDAQ. As of fourth quarter 1997, NASDAQ no longer supplies these data.

by going electronic with both access and trading mechanisms (and in some cases demutualizing for more competitive governance) and have regained most of the market share they lost. This fits nicely into the network-contestability framework. Most recently, the LSE has announced plans to link order-entry platforms with Deutsche Börse, one of the very exchanges it was trying to put out of business ten years ago.

In a related point regarding trading in its own shares, the LSE deserves credit for reinventing itself from a people-based, quote-driven market to an electronic, and at least partially order-driven, market in the face of competition from Tradepoint, Instinet, and others.

I was fortunate enough to attend a panel at the 1998 Plexus conference that was composed of representatives from the New York, American, Australian, and London stock exchanges. James Cochrane, the NYSE representative, said that the NYSE was "seriously considering alternatives it would not have thought about five years ago" and that it would be "engaged in a number of partnerships in the next eighteen months." Nicola Sawford from the LSE said that their ultimate goal is to produce a "pan-European order entry platform" and that the Deutsche Börse alliance could be construed as a prelude to "one market." When asked why the Australian Stock Exchange demutualized, Chris Hamilton replied, "There were too many conflicts, and we were too slow-moving and unresponsive as a result." Incidentally, their shares were priced a week ago Wednesday at $A3.50. They were trading last night (one week later) at $A4.35, an increase of almost 25 percent. Even the market seems to agree.

Conclusions on Case Studies and Other Observations

There are numerous other real-world situations where this network-contestability framework is applicable, but these examples should lend considerable support to Domowitz and Steil's contention that this framework provides a basis for interpreting and anticipating competitive developments in the world's securities markets.

The foregoing remarks implicitly accept the authors' assertions that market quality and cost are at least as good for automated exchanges and systems as they are for traditional ones. As the authors point out, it is extremely difficult to prove these points one way or the other due in large part to the lack of truly comparable systems running in parallel, not to mention the inherent inability to know implicit transaction costs. The relative measure of transaction costs (which is what matters in this case) used in the paper seems sufficient. Admitting fully to my bias in the matter, I agree with the authors' assessment of relative market quality and cost between traditional and electronic exchanges, especially in light of informal evidence that I have seen over the years relating to the average size of orders submitted and traded, bid-ask spreads, and relative transaction costs.

It is important to remember the role that regulators have played in all of this. In the United States in particular, regulators have dramatically increased the transparency of markets and fostered competition. If they had not played this role, alternative trading systems could never have been launched.

Another important factor in the emergence of technology-driven exchanges and alternative trading systems is the explosion of professionally managed money. This growth has led to both greater demands on liquidity as assets have become more concentrated as well as sharper competition for returns. These, in turn, have dramatically enhanced the awareness of transaction costs and the impact of transaction costs on investment performance. Until relatively recently, most investment managers did not look closely at trading costs. Now that their performance, and hence their survival, hinges on their ability to control transaction costs, they have powerful incentives to minimize these costs.

In addition to exchange alliances and proprietary order-entry systems that integrate trading in different sets of securities (so-called adapters in network theory parlance), we should also see the emergence of proprietary order-entry systems that integrate access to systems competing for order flow in the same securities. For example, expect to see on the market in the next year systems that intelligently route orders to the various ECNs based on real-time and historical liquidity.

The implications for the structure of securities markets are many. For one, these systems should dramatically reduce the incumbent advantage that network externalities confer, making it easier for new competitors to enter. They should also reduce de facto fragmentation by making all liquidity available from a single point. However, they also may reduce competitive pressure and drive up costs over time as multiple systems are allowed to survive longer. Such front-end systems may end up becoming competitors to the very systems they link, perhaps by crossing offsetting order flow. It would be interesting to hear the authors' thoughts on how such systems do or do not fit into their framework.

General Discussion: Eric Sirri noted that the advent of technology has made both liquidity and volume very fluid. He questioned how regulators would respond to a large outflow of funds and trading volume from U.S. exchanges to exchanges in other countries. Benn Steil replied that the policy in Europe has been one of mutual recognition and home-country control. This means that when financial firms cross borders in Europe, they take their home-country regulator and regulations with them. Steil foresees this creating a problem in the future when the Securities and Exchange Commission has to deal with foreign regulators in U.S. markets.

Steven Wallman suggested that poor technology and communications for many years required very large and concentrated exchanges that dominated because of economies of scale. With rapid technological advances, he saw the market becoming more fragmented, allowing more exchange-like operations. Wallman expressed the fear that regulators will be unable to keep up with technological change and instead will seek to slow it down.

Steil added that the Intermarket Trading System (ITS) both promotes and prevents market fragmentation. On the one hand, regional exchanges could not survive without ITS. On the other hand, the system has created a barrier to the entry of new proprietary electronic trading systems that do not operate on a continuous basis.

Robert Litan questioned whether there was any justification left for the regulation of exchanges. He pointed to the telecommunications industry where the Baby Bells that once had monopoly power are now forced to compete with competitive local access carriers. This new competition is resulting from the 1996 Telecommunications Act, whose main purpose was to replace regulation with competition, buttressed by the antitrust laws as a backstop to ensure that competition remains viable. Steil agreed that traditional antitrust mechanisms are appropriate for exchanges as well, adding that continuing advances in technology make existing regulation more difficult to apply.

Jonathan Macey observed that nations will continue to want their home-based exchanges to maintain, if not expand, their worldwide market share. Regulators will not be able to eliminate this sort of national competition. However, he predicted that U.S.-based exchanges will be under growing competitive pressure from exchanges in other countries, as well as from a new, technologically sophisticated generation of home-grown alternative trading systems.

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