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

Ian Domowitz and Benn Steil*

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* Department of Economics and Institute for Policy Research, Northwestern University, and International Economics Programme, the Royal Institute of International Affairs, respectively.

1. Introduction

Since the early 1980s, innovations in information and communications technology (ICT) have infused the securities industry on a large scale. The process of trading in particular has been heavily affected: share and portfolio analytics, order processing and routing, order matching and trade execution, clearance and settlement, and trade reporting and publication have all been transformed by computer automation.

The impact of ICT on trading has gone far beyond a simple acceleration of activity and decline in costs. The way in which trading is conducted has been heavily influenced by the use of computers in trading system design. New means of processing and matching orders have been made possible, changing the way in which investment decisions are translated into actual transactions. Providers of trading services have themselves changed significantly. Brokers now effectively compete with exchanges for order matching business using identical technologies, and exchanges have been transforming their governance structures to compete more effectively with brokers for institutional order flow.

This paper analyses the impact of ICT on trading costs and competition from a number of angles. An industrial organization framework is applied in section 2, focused on contestability theory and network economics, to examine the way in which automation is transforming the natural industrial structure of the securities trading industry. The impact of automation on implicit trading costs is discussed in section 3, based on an examination of the findings of studies which have compared bid-ask spreads, informational efficiency, and price volatility across automated and non-automated markets. In section 4 we present the results of our study of trading costs at a major US fund manager, covering a five-year period. The firm has been an exceptionally large-scale user of non-intermediated electronic trading systems, allowing us to make direct comparisons of explicit and implicit trading costs across intermediated and non-intermediated structures. Finally, our approach and conclusions from the analysis are summarized in section 5.

2. Trading Automation and Industrial Structure

Much of the current structure of the US and European securities trading industry is a remnant of the pre-computer era, and is reinforced by a combination of first-mover advantages, network externalities, and regulation.

The move from single-price call market trading to continuous trading on the NYSE in c.1870 was forced on the Exchange by the inability of non-automated auction processes to establish equilibrium prices for large numbers of stocks, being bid and offered by large numbers of brokers, within a single trading day. The NYSE has since organized its floor-based market exclusively on a continuous-auction basis, with the exception of the specialists' opening call auction procedure (which remains unautomated). This is in spite of the fact that 1980s computer applications supported large-scale single-price (zero-spread) call market trading with virtually unlimited trader participation, as well as completely decentralized continuous trading via wide-area telecommunications networks. Likewise the Exchange remains a fixed-size mutual organization, limiting trading access to member-firm broker-dealers, in spite of the fact that corporate entities have been accommodating unlimited-access automated trading since the 1970s.

In section 4 of our paper we analyse the cost-reduction benefits of automated trading, which derive from the ability of modern ICT to eliminate unnecessary layers of intermediation and their associated infrastructures. The adoption of such automation, however, can be slowed by both network externalities and impediments to market entry faced by alternative service providers.

Perhaps the most significant economic effect which ICT has had on the securities trading industry is to alter fundamentally its natural industrial structure. Prior to the advent of mass computerization in the 1970s, competition among trading systems had been steadily declining. As Coase pointed out in 1937, "Changes like the telephone and the telegraph which tend to reduce the cost of organising spatially will tend to increase the size of the firm" (p397). As Stedman (1905) observed, this is precisely the effect which these technologies had on the NYSE. The more widespread the instantaneous availability of NYSE stock price and quotation data became, and the quicker orders could be routed to New York, the less need there was for simultaneous auctions at exchanges elsewhere in the US. In his study of the impact of the telegraph on the structure of the US securities markets, Richard DuBoff (1983) noted that "As soon as Wall Street quotations were available the same day in Philadelphia and Boston, the need for two or three 'major auctions' vanished. Other cities fell into step with New York once the telegraph reached their exchanges. By 1860 Wall Street was connected with every major city and set prices for them all. Subsequent improvements in telegraph technology reinforced the financial dominance of New York" (p262). The current inventory of eight stock exchanges would likely be even lower were it not for SEC-mandated inter-market linkages which severely limit the ability of the NYSE to set the terms by which its price and quotation data are disseminated.

Utilizing traditional floor-based trading technology, entry costs into the trading systems industry are prohibitive. Network externalities significantly limit the incentives of members of existing exchanges to join new ones - particularly those trading identical products. As the investment in trading floor technology further represents a substantial sunk cost, exit from the industry will be an expensive proposition if competition from existing exchanges should prove an insurmountable barrier to profitability.

Recent ICT developments, however, have changed competitive conditions significantly. Whereas the telephone and telegraph had substantially increased economies of scale and scope, bringing natural monopoly features to the predominant national exchange and raising sunk cost barriers to new entry, computerization has had a much more complex effect. Whereas computerization has increased the potential for exploiting network externalities, and hence for concentrating trading, it has also introduced the possibility of product differentiation and dramatically reduced sunk cost barriers to entry.

2.1. Product Differentiation

Computerization has facilitated new modes of trading which reduce the costs of different types of trading strategies. The continuous electronic auction system, first introduced by a brokerage firm (Instinet) in the 1970s, is now employed by every stock exchange in Europe. This mode of trading allows traders to place limit orders directly on an open order book via a remote computer terminal, and to execute market orders directly against these limit orders without intermediation by a dealer, floor broker, or exchange specialist. Electronic call market trading was first introduced in 1991 (by the Arizona Stock Exchange), allowing patient traders to pool their orders for execution at a pre-set time. Such systems execute all qualifying orders at a single price, determined either within the system itself (a call auction) or on other markets (a crossing network). In the US, the Arizona Stock Exchange (AZX) operates a call auction after the close of NYSE trading, Instinet offers an after-hours closing-price cross, and Posit runs five set-time intra-day crosses based on the contemporaneous Consolidated Quotation System (CQS) mid-quote. In 1998, OptiMark will introduce an electronic trading system based on massive parallel processing or supercomputers. The system, which can be run continuously or on a call auction basis, will process orders in three dimensions. Traders will be able to specify not only how many shares they wish to buy or sell at a given price or better, but also to specify preference rankings of such pairings in graph format. Even when run on a call auction basis, trades will execute at different prices depending on the pricing "aggressiveness" of each order (unlike with the previous generation of two-dimensional call auction systems, which execute all trades at a common clearing price).

2.2 Contestability

Contestability theory (Baumol, Panzar, and Willig, 1988) highlights the theoretical and regulatory significance of potential competition. It demonstrates that allocative efficiency is achievable in an industry marked by natural monopoly production, provided that the monopolist faces the credible threat of entry by a lower cost producer. Since it had previously been generally assumed that allocative efficiency required perfect competition (a special case of "perfect contestability"), anti-trust authorities relied strongly on measures of industry concentration in devising policy towards mergers and price controls.

Since the benign economic effects of competition are potentially achievable even where actual competition is minimal or non-existent, it is important to specify the conditions under which they can be expected to obtain. "Perfect contestability" is defined by three conditions:

1. Potential entrants may operate at no disadvantage relative to incumbent firms. In particular, they must have equivalent access to production technology, inputs, and market demand information.
2. Potential entrants must face no sunk costs, meaning that they may exit the industry at any time while being able to recover their entry costs in full.
3. Potential entrants must be able to enter the industry and undercut the prices of incumbents before the latter are able to respond by lowering their prices.

The first assumption is somewhat more reasonable than the second and third, and the theory is not robust to small changes in the third. Nevertheless, there clearly do exist industries marked by low sunk costs, rapid entry capability, and rigidities in incumbent pricing responses, and empirical tests of the theory have endorsed its relevance in a number of these.

We believe that new ICT technology has significantly increased the contestability of the trading system industry. With regard to the three requirements for perfect contestability above, we make the following observations:

- **Equivalent market access and information.** Basic electronic trading architectures, in particular the continuous auction and call auction structures, have become commodity products which can be freely purchased in the market and readily modified to create new or enhanced product features. Real-time price and quotation data from other markets, as well as company and economic data, can be purchased from market data vendors (such as Reuters and Bloomberg) and incorporated into the new trading system's information and order management facilities. As such systems no longer require dedicated terminals, direct access trading software can be installed in clients' PCs in a matter of minutes, and data can flow in and out via existing high-quality data lines. New trading system providers often levy no fixed charges for making their services available, choosing instead to charge only for trades executed, thereby imposing no sign-up costs on members or clients of existing exchanges or trading networks. In the absence of regulatory barriers, then, modern ICT affords potential entrants market access on terms roughly equivalent to those enjoyed by incumbents.
- **Low sunk costs.** Whereas the sunk costs involved in establishing a traditional member-controlled floor-based exchange are very substantial, the sunk costs involved in launching proprietary (non-member-based) electronic trading systems are extremely low. The trading infrastructure itself - comprising the software, computer hardware, and telecommunications equipment - can now easily be assembled for under $10 million. The software needed to run a continuous electronic order-driven system can itself be purchased off-the-shelf for under $3 million, and computer mainframe capacity sufficient to support peak-period trading volumes in the UK equity market - roughly equivalent to three Stratus Continuum computers, together capable of processing 15 operations per second - would cost under $2.5 million. Telecommunications hardware would require roughly another $2 million investment. Options for minimizing industry exit costs are considerable. In particular, electronic trading systems can generally be adapted to handle different types of securities at very modest cost. In the case of an equity trading system, the operator can even add or switch to foreign equity trading simply by assigning codes to the new securities. Tradepoint, which in 1995 introduced automated continuous and call market trading in UK shares, has already been approached by organizations as diverse as the UK National Health Service and Milk Marketing Board regarding use of the system for hospital bed allocations and wholesale milk sales. Ancillary services can be provided by outside institutions, thus requiring no sunk cost investment from the system operator. In the case of Tradepoint, clearance, settlement, depository, data dissemination, and listing services are all provided by separate institutions, and no liabilities to any of them would result from cessation of trading. In the worst case scenario for the company, where UK equity trading proves unprofitable and no viable alternative markets can be identified, the company could be expected to recoup most of its software development costs in selling the trading system, and would need

only write off the roughly $1.5 million in legal costs (for regulatory approval) and the better part of its hardware investment. In total then , its sunk costs would amount to only about $4 million, roughly a third of which were regulatory costs.

- **Ability to undercut incumbents.** Incumbents are certainly capable of reacting quickly to price undercutting by new entrants, but empirical evidence on their actual behaviour is limited and mixed. Bloomberg launched an electronic brokerage and order-matching system in January 1997, which is directly modelled on the Instinet system. Traders confirm that there is little to distinguish the two systems other than commission fees, which are roughly 50 percent lower on Bloomberg's B-Trade system. So far, Instinet does not appear to have lowered its charges in response to the new competition, apparently counting on its first-mover advantage and network externalities to forestall customer defections. On 29 July 1997, Tradepoint announced the conclusion of an agreement with three UK inter-dealer brokers ("IDBs") committing Tradepoint to processing their pre-matched trades at roughly one-third the fee which the London Stock Exchange (LSE) had set for the launch of its new order-driven system on 20 October. The LSE subsequently announced publicly that it would only commit to "reviewing" features of its order book, including transaction pricing, at some point after the launch, [1] but reversed this position in a press release dated 9 September. The release gave details of a 60 percent reduction in trading charges, below the levels adopted by Tradepoint. A day later, Tradepoint retaliated by eliminating charges entirely for marketmakers on IDB-brokered trades reported through their system. This new *status quo* has yet to be challenged by the LSE. In short, we observe that the LSE has reacted both to a new entrant's product differentiation and price undercutting by introducing a similar trading system (with a two-year lag) and reducing prices (with a one-month lag), but that these competitive responses - while clearly foreseeable back in 1995 - had been insufficient to deter Tradepoint's entry.

The best evidence available of the current level of contestability in the trading system industry is the considerable growth in PTS entry and trading volumes over the course of this decade. Figure 1 shows that the percentage of US trading volume accounted for by PTSs grew from 3 percent to 8 percent between 1990 and 1995. Instinet trading is currently estimated to account for over 20 percent of total Nasdaq volume, up from roughly 13 percent in 1994. 140 broker-dealers have notified the US Securities and Exchange Commission (SEC) of their intent to operate some form of "Electronic Communications Network" (ECN),[2] indicating the potential for considerably more industry entrants in the coming years. In Europe, Instinet and Tradepoint have recently been joined by US-based Lattice Trading. Instinet is also active in a number of Asian markets, as well as Canada. Outside of the US, however, Instinet operates overwhelmingly as an order-routing system, transmitting orders from investors' terminals to stock exchange trading systems, rather than as an order-matching system. This is because most non-US exchanges are already operating electronic order-matching system, leaving much less scope for disintermediation than in the dealer-driven Nasdaq market.

2.2.1 Implications of Contestability for Market Structure Evolution

An important general implication of contestability for pricing structures is that cross subsidies are unsustainable. As Baumol, Panzar, and Willig (1988) explain:

> In the past, at least in regulated industries, distributive concerns have explained (in part) the deliberate adoption of sets of cross subsidies; for example, urban-area consumers have been forced to help to defray the costs of transportation or communication to rural communities, younger customers have, in effect, financed the supply of services to retired persons, and so forth. To render such systems of cross subsidy financially viable for a regulated supplier, entry was deliberately impeded or ruled out altogether. But . . . in a contestable market any cross subsidies are incompatible with sustainability of prices. They always invite profitable entry into the subsidizing portion of the business, and so they cannot persist (p472).

This is undoubtedly the case in the trading industry. Often on the basis of government pressure or mandate, stock exchanges have routinely adopted rules which preference the small retail order flow which is inevitably channelled through the central auction system. This is done either by restricting

[1] "Brokers agree to use stock exchange rival", *Financial Times* 30 July 1997.

[2] SEC Release no. 34-38672, file no. S7-16-97, 1997.

the ability of traders to transact away from the central auction process ("upstairs trading"), or by requiring such traders to "interact" with the central order book.

Restrictions on upstairs trading generally take the form of prohibitions on transactions at prices outside some measure of the bid-ask spread on the order book. For example, prior to 1989 the Paris Bourse forbade upstairs trading outside the fourchette (inside spread) on the CAC order book. In the face of competition from SEAQ International, these rules were relaxed in 1989 to permit trading outside the fourchette, but requiring the member firm acting as principal to satisfy all CAC buy orders with higher price limits, and sell orders with lower price limits, within five minutes. The Paris rules were relaxed yet again in 1994, as French broker-dealers were continuing to route their upstairs trades to London for execution rather than obey the Paris interaction rules. The current regime eliminates the interaction requirement, but obliges traders to transact within the *fourchette moyenne pondereé* (FMP, or weighted average spread). This concession, agreed by the French regulatory authority (COB), attempts to accommodate block trading that cannot be transacted within the inside spread. French broker-dealers continue, however, to report the use of SEAQ International for trades they wish to execute outside the FMP, indicating the clear impossibility of cross-subsidizing the central order book via upstairs trading restrictions (which effectively raise the cost of upstairs trading) in the face of competition. Although Bourse officials are aware of this regulatory arbitrage, the COB has not to date been willing to countenance further relaxation of the upstairs trading restrictions.

The NYSE's interaction rules are similarly under threat from competition by a new entrant. The OptiMark system described earlier facilitates block trading by reducing information leakage: the system is anonymous, and gives no indication to the market of the existence of a block order if no match can be found. OptiMark has been licensed to the Pacific Stock Exchange, and trading through the system is therefore subject only to the interaction rules of that Exchange. To the extent that the system is successful in attracting block trading, NYSE specialists will lose interaction executions to their Pacific counterparts. It is important to note that the Pacific interaction rules are similarly exposed to the competitive effects of new entry.

In 1996 the LSE published its intention to impose interaction rules after the implementation of the SETS order book in October 1997. On the basis of considerable criticism focused on the unsustainability of such rules, owing to the likelihood of competitor exchanges without such rules taking away the LSE's upstairs trading business, the Exchange abandoned these proposals in April 1997. Without the effective cross subsidy for order book from upstairs trading, the Exchange has been forced to focus on improving the attractiveness of SETS as a stand-alone system. Having previously denied that changes would be considered prior to the October launch, the Exchange has now cut the planned SETS transaction charges and begun work to establish a central counterparty to eliminate credit risk and maintain complete trading anonymity.[3]

It is worthwhile noting that Tradepoint, which until recently offered no facility to accommodate trading away from its order book, has been particularly innovative in developing inducements to traders to use the book (rather than trying to *oblige* them to do so, as with traditional exchanges imposing interaction rules). Tradepoint is the only exchange of which we are aware that charges nothing for executed limited orders: only the "aggressor" *(ie*, market order trader) pays. This pricing policy is designed to encourage traders to supply liquidity to their order book: such encouragement can be particularly important where no effective cross subsidy from interaction requirements is available.

In the future, increased trading system competition may actually induce exchanges to *pay* for limit order placement. Exchange profits will then have to be derived from market orders and ancillary services, such as data provision. Such developments would be a direct result of automation increasing significantly the contestability of the market for trading systems, and thereby reducing the scope for sustaining cross subsidies from upstairs trading.

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[3] SETS orders are entered anonymously, but without a central counterparty each side of a trade must be revealed to the other in order to accommodate bilateral settlement. This raises the possibility of strategic hitting of orders on the book to discern who might be a large buyer or seller of a stock. To maintain one's anonymity then, a member-firm would be obliged to pay an IDB to place to the order, thereby inflating the cost of trading through the order book.

A related problem has to do with so-called "obligation to serve" requirements imposed (or threatened to be imposed) on national exchanges, but not on new entrant PTSs. As Baumol, Panzar, and Willig (1988) emphasize, such obligations imposed on "public utilities" lead to unsustainable prices in a contestable market. The general form such obligations take is a requirement to supply all quantities demanded at the prevailing prices: a requirement which is not imposed on new entrants. This naturally disadvantages the incumbent, as it is unable either to price discriminate or to exit unprofitable segments of the market, whereas new entrants are free to set prices and segment the market as they please. Such a situation naturally results in commercial damage to the incumbent's business, and to demands from the incumbent for reregulation to cover the new competitors' operations.

This is clearly the situation currently faced by national postal services in competition with private delivery companies and electronic services. National postal services are generally required to provide complete national coverage at a uniform price, which gives rise to massive cross-subsidization of unprofitable rural deliveries by profitable urban ones. Private firms, however, are free to service only the urban areas, and can therefore easily undercut the national services. The UK currently manages this problem by banning private delivery companies from delivering packages costing under £1, thus protecting a significant segment of the Royal Mail's monopoly.

In the securities trading industry, national regulators often require or "expect" the main exchange(s) to service retail order flow on terms which are not considered excessively disadvantageous vis-à-vis institutional order flow. In the pre-1975 era of fixed minimum commissions on the NYSE, execution pricing was marked by massive cross-subsidization of smaller transactions by larger ones. Data from Jarrell (1984) indicate that the 1968 NYSE minimum commission rate of $0.39 per share resulted in dealer profits of $0.18 per share on orders of 100,000 shares and losses of $0.16 per share on orders of 100 shares. After full deregulation in 1975, commission rates rose on small retail orders and declined dramatically on large institutional orders. Average retail commissions are now roughly eight times institutional commissions. To the extent that the primary national exchanges continue to service retail order flow on uneconomical terms, PTSs will be encouraged into the industry to compete for (over-priced) institutional order flow. This has clearly been the case in the US, where fully automated PTSs - in particular, Instinet, Posit, and AZX - have competed fiercely for institutional order flow, and accumulated a rising percentage of total US trading volume over the course of the decade. It has further provoked vociferous complaints from the established exchanges that the PTSs should be subject to the same level of regulation; complaints which the SEC is now seriously investigating. In May 1997 the Commission published a major Concept Release (34-38762) examining the impact of technology on the US securities markets, and proposing various alternatives for reregulation of the industry.

For the French Treasury, implicit cross-subsidization of European retail order flow represented a major component of their negotiation position in the three-year Council of Ministers debate over the text of the Investment Services Directive (1989-1992). The Treasury argued that the diffusion of stock ownership among the general populace was an essential objective of "financial policy" in many countries, and that the organization of the European markets should be made to serve this aim by providing equal access for large and small orders, without discrimination by price. "OTC" operations were said to be prejudicial to the public interest, in that they did not guarantee equality of treatment to different bearers of the same security.

Studies have documented a significant fixed-cost component of trading, or that the cost of trading is decreasing in trade size,[4] indicating clear faults in this argument. Nevertheless, the widespread belief that the requirements of fairness, and even efficiency, dictate that small orders be accommodated on "equal" terms persists in many countries. In the US, Professor Paul Schultz[5] approvingly characterized the SEC position thus: "The SEC is moving towards one price for all trades - you will not see different markets for retail and wholesale customers". Such changes, he indicated, would include requiring dealers to deal for small investors at the same prices they give to large institutions.[6] In the UK, the LSE's decision to set a 500-1000 share minimum size (depending on

4 See, for example, De Jong, Nijman, and Röell (1995).

5 Christie and Schultz (1994) suggest Nasdaq dealer collusion.

6 Waters, Richard, "Big deal for small Nasdaq investors", *Financial Times* 9 August 1996.

value) for orders on SETS provoked widespread protests from small shareholders groups, and featured in a parliamentary committee inquiry into the Exchange's performance and prospects. Perhaps the most perverse feature of these debates is the fact that the average small investor is increasingly - and in many countries, overwhelmingly - investing his or her money via institutional fund managers. Therefore, any trading rules which preference small trades relative to large ones disadvantage the investors that politicians and regulators claim to want to help most.

2.4. Network Effects, Entry, and Standardization

An alternative view of the evolution of the securities trading industry structure is suggested by two basic observations. First, an exchange or trading system is a communications network, with sets of rules that define what messages can be sent over the network and who can send them, as well as delineating how these messages translate into trades. This is more readily apparent for an automated system than a floor-based one, but the principle applies equally for both models. Secondly, a trading services provider's decision as to whether to offer an automated market, as opposed to a traditional floor-based one, can be considered a new technology adoption choice.

Network effects, and the demand-side economies of scale often associated with them, have theoretical implications for *technology adoption*, *standardization* (*ie*, coalescing of all traders on a given system), *pricing*, and *cartelization* (*ie*, implicit or explicit mergers of systems). In the securities trading industry, there are two important effects relating to the network nature of the product. First, the benefit to an individual of the technology enabling trading increases in the number of locations from which the market may be accessed. Sometimes called the *network* or *size effect*, it appears in telephone systems and retail distribution procedures, where consumer benefit increases in the number of outlets at which a good is available.[7] Second, the benefit to an individual increases in the number of others on the system. This is sometimes called the *network externality*, because each new user confers a benefit on all other users. In trading terms, we might call this a *liquidity effect*. The liquidity effect is the source of folklore that predicts overwhelming first-mover advantages in the provision of exchange services.

The liquidity effect is very real, but the folklore is mistaken. Alternative outlets for the trading of the same stock, for example, are commonplace. This sector, in particular, is growing quickly in terms of new entry and competition between trading services providers. New entrants, almost exclusively in the form of automated markets, compete against floor venues and against each other. The potential for survival of such new entrants is illustrated by the success of Instinet and Posit in the United States. Well-established market share in derivatives trading has been achieved by the automated DTB, competing against the floor-based LIFFE, and by the floor-based SIMEX competing against the automated Osaka Securities Exchange. These examples belie the notions of irrevocable first-mover advantage and standardization of trading technology.

In the context of trading competition between floor venues and automated systems, the assumptions behind the "standard" treatment of network economies can be characterized as follows:[8]

1. Exchanges offer either open outcry floor trading or electronic automated trade execution.
2. The two technologies are incompatible: *ie*, they cannot be used together by one exchange at the same time.
3. There is free entry with respect to the supply of products embodying the technology.
4. Traders make an adoption decision, rationally forecasting future period usage of both trading technologies, and taking into account past traders' adoption choices.

Assumptions 1 and 2 are admittedly stylized, but are generally borne out in practice. Assumption 3 encompasses the first and second assumptions of perfect contestability, discussed

[7] 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.

[8] See Domowitz (1995) for descriptions of relevant models in the context of trading services provision. Underlying theoretical models are contained in Farrell and Saloner (1986) and Katz and Shapiro (1986).

previously: *ie*, there are no barriers to entry. Unlike contestability models, however, network models assume that trading services offered via either technology are supplied at marginal cost, so strategic pricing considerations are ruled out. Assumption 4 brings in the network externality: the larger the number of traders, the greater the value to the new trader making the adoption decision.

There are some general conclusions to be had from this model. Although standardization may be optimal, it is possible that it will not occur.[9] Such an outcome may arise for two reasons. First, individual traders disagree with respect to which trading technology (traditional or automated) is the more desirable. Second, each group of traders ignores the negative effects on the other, in terms of liquidity, when choosing not to standardize. When standardization does occur, the optimal technology may not be selected. The technology that is cheaper or has the larger following *at the outset* may have a *first-mover advantage* that is not overcome, even when it is socially optimal to standardize on the competing technology. In the early days of automated systems development, hardware and software development costs were much higher than they are today, making floor trading technology the cheaper alternative. This was above and beyond its advantages in terms of possessing an existing liquidity pool, or functioning network. Given this background, even if electronic trading might be superior *once a large network is achieved*, it may take a very long time for the nexus of traders on the system to be established. Early electronic traders must pay a disproportionate share of the temporary, but very real, costs associated with trading on a system that is not compatible with the floor. If early potential adopters are unwilling to incur such costs, floor trading will remain the standard in spite of the putative advantages of electronic trading at high levels of participation.

How have these core concepts have manifested themselves in practice? In the early days of exchange automation, $100 million developments were the norm, and the "market for markets" was largely confined to countries with well developed financial infrastructures, often entailing some form of floor or dealership market. Given existing pools of liquidity, the result was a cold reception to market automation in venues such as the US and the UK. Development prices dropped radically over time, however, reflecting both software and hardware innovations. Against a backdrop of static or rising costs for floor-based systems, automated markets have become the model of choice in virtually all emerging markets development efforts, where start-up cost is a significant consideration and floor trading traditions typically do not exist. In western Europe, every exchange has now implemented an electronic auction system (although in Germany and the Netherlands floor trading persists on a reduced scale). It is worth noting that the world's largest stock exchanges - New York, Nasdaq, Tokyo, and London - have been the slowest in dismantling obligatory human trade intermediation.

Thus, the "standard" theory can accommodate the coexistence of the two trading technologies and the first-mover advantages driven by cost and liquidity considerations. It cannot fully address the replacement of existing traditional markets by automated trading technology, however, or be used evaluate the potential of automated markets to become the dominant form of market structure. In order to do so, assumption 3 above must be relaxed, permitting entry barriers into the supply of the technology. It is not uncommon, for example, for a new trading market to control the property rights to the underlying technology, which would be one such barrier.

More generally, any replacement of assumption 3 that allows for strategic pricing on the part of the competing markets is sufficient to generate interesting alternative conclusions. For example, penetration pricing in early periods by the new technology provider can be offset in later periods by prices above marginal cost, once a base of users is established, given the liquidity effect. The ability to do so is aided by the lower cost of the automated trading technology.

Katz and Shapiro (1986) produce two interesting results in our context, given the possibility of strategic pricing. First, a *second mover advantage* may well exist. In other words, the theory predicts standardization on the automated trading system, given the lower costs of such a system relative to traditional trading floors, despite the fact that the floor may already be well entrenched. By definition, such a standardization result implies that the floor will disappear in favour of the automated alternative. Glosten (1994) arrives at a similar conclusion, via a different form of analysis, concentrating on trading structure and behaviour.

Second, a cartel of trading services providers may be socially desirable. Cartelization makes it easier to set prices above marginal cost, which then provides incentives to further invest in trading

[9] Optimality is social optimality or efficiency here, usually defined in terms of maximization of total economic surplus.

technology in the presence of liquidity effects. This line of reasoning is pursued in Domowitz (1995), who notes that "implicit mergers" between providers is enabled in large part by the advent of automated trading system technology. In fact, it is suggested therein that trading services providers may move to automated systems simply in order to enable such cartel activity. Current developments appear to bear out such a hypothesis. MATIF will open an automated facility next year, despite years of firm resistance, simply because it is a technological prerequisite to their participation in a merger agreement initialized by DTB and the Swiss Exchange. The partners anticipate that the union of the three exchanges will create enough trading volume in new euro contracts to compete effectively with LIFFE as the primary market in such instruments.[10]

2.5 Trading Automation and Exchange Governance

Stock exchanges have traditionally been organized as mutual associations, operated by member-firm brokers and dealers, under varying degrees of state control. Often the member-firms are the legal owners of the exchange, but in some cases - such as Italy, prior to privatization of the exchange in September 1997 - the exchange is legally a government entity.

This traditional governance structure is a remnant of the pre-computer era, when exchanges were of necessity floor-based. Floor-based exchanges must ration direct trading access owing to the existence of simple physical space constraints. A fixed number of memberships are made available to qualified financial institutions, generally involving an initial entry fee, yearly dues, and transaction charges. In the case of the NYSE, membership is available in the form of a "seat", whose price is determined on the open market. The current market value of an NYSE seat is approximately $1.5 million, near its all-time high, reflecting the value of direct (rather than intermediated) access to the Exchange's trade execution process.

Fully computerized trading systems do not require access limitations, as they do not utilize physical trading areas. Exchanges operating such systems generally do not, therefore, limit the number of memberships available: all qualified institutions are offered membership, allowing such exchanges to grow more rapidly and cheaply as trading volumes increase. In the case of EU exchanges, implementation of the Investment Services Directive in 1996 accorded them the right to accept "remote members" from other EU member states without requiring the approval of the foreign regulator. Regulatory barriers notwithstanding, then, participation on a computerized exchange is not subject to the capacity constraints which accompany floor-based exchanges.

Most exchanges operating fully computerized trading systems still impose qualification requirements which exclude institutions - such as fund management companies - which do not provide intermediation services. In many cases, the determination of what type of financial institution is qualified for membership is specified in national law. Generally, these specifications act to limit membership to traditional securities companies, and in some cases to banks as well.

Recently, however, new electronic exchanges have been created on a purely corporate basis, doing away with the concept of membership as a requirement for direct access. The Arizona Stock Exchange, founded in the US in 1991, and Tradepoint, founded in the UK in 1995, operate as private companies offering trade execution services to other corporate entities on the basis of individual transaction charges (and, in the case of Tradepoint, a £1000 annual participation fee). Institutional investors have full direct access to Tradepoint on the same basis as securities houses and banks, although provisions of the 1934 US Securities and Exchange Act require formal broker intermediation of AZX trades (even though the brokers only provide an electronic gateway). The participating brokers are not "members" of the Exchange, but rather just *ad hoc* participants.

In a floor-based trading environment, trade intermediation is a necessary corollary to immutable physical access constraints, but in a fully electronic trading environment exclusive member access often imposes redundant intermediation barriers on investors. This raises the question of why electronic exchanges should continue to be run as member-controlled mutual associations, when member intermediation is no longer a technological necessity.

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[10] See *The Economist*, September 20, 1997, pp. 82-84, "Derivative Exchanges: First Love, Then Marriage?"

Intermediaries will naturally tend to resist reforms which reduce demand for their intermediation services, from which they derive their profits. Exchange governance reform, therefore, is often a pre-condition for the efficient implementation of trading automation. Yet a strong measure of inter-exchange trading competition is often necessary to persuade members to relinquish strategic and operational control of the exchange, and to allow the construction of a governance structure which better aligns the commercial interests of the exchange with the demands of its clients: investors and issuing companies.

Such inter-exchange competition has been a conspicuous feature of the European equity markets over the past ten years, following on from the London “Big Bang” reforms of 1986 and the establishment of SEAQ International. One of the continental exchanges most severely affected by London competition, the Stockholm Stock Exchange, was the first to “demutualize” in 1993, selling half of the shares to issuing companies. The shares are now freely tradable, and the Exchange has over 120 shareholders. With the ending of exclusive intermediary control over the Exchange’s trading rules, the Exchange also became the first in Europe to implement remote membership for foreign intermediaries (1995) and electronic trading access for institutional investors (1996) - although the latter must still be via an electronic gateway operated by a member-firm. The Helsinki Stock Exchange demutualized in 1995 (60/40 member-issuer share split), Copenhagen in 1996 (60/40 member-issuer share split), and Amsterdam (50/50 member-issuer/investor share split) and Milan (share split not yet determined) in 1997.

The logical conclusion of the exchange governance reform process is the PTS (such as AZX and Tradepoint), which involves no intermediary access barrier whatsoever. The Stockholm exchange has moved furthest along this transformation route. It will be interesting to see whether newly emerging economies continue to mimic the developed markets by setting up “national exchanges” as member-controlled public utilities, or whether they will cordon on to the logic of “corporate exchanges” in the computer age. At least one new exchange - the Yerevan Stock Exchange in Armenia - has already chosen to establish itself as private company with diversified shareholdings.

3. Implicit Transactions Costs and Automated Markets

The form of the trading institution affects trader behaviour, welfare, and the properties of quoted and transactions prices.[11] We focus on the latter in this section, to the extent that prices yield information on implicit transactions costs across market structures.

A precise definition of implicit transactions costs is open to debate. Liquidity is clearly a factor, but liquidity is a multidimensional concept in practice. One measure is the bid-ask spread. The spread, in particular, might be considered an explicit cost of trading, but we include it here as one of the facets of liquidity. Depth of market, however measured, is another such dimension. Relative informational efficiency also plays a role. In this regard, we consider both adverse selection effects in asymmetric information environments and the speed with which information is captured in prices. Closely related to both liquidity and informational efficiency is volatility. We examine both unconditional and conditional volatility characteristics, with special attention paid to the dynamics of the price volatility process.

General conclusions with respect to such concepts across market structures require both intra-day data and a variety of market comparisons. The data requirements are simply too large for any single research project. We rely, therefore, on a variety of existing studies for our information. Although growing, the literature is thin, and we are able to cover most of it in what follows. Since our treatment proceeds by topic, and not by individual paper, Figure 2 summarizes the contributions for reference.

Some of these papers provide more direct evidence than others, and the emphasis in individual papers also differs in many cases. Studies of the Bund futures contract are popular, given the overlap of trading times on the automated DTB market and the LIFFE floor, as well as the close similarity of

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[11] This list is generated by theoretical and experimental work on auctions (e.g., Friedman, 1993), as well as by the related literature on financial market microstructure (e.g., Madhavan, 1992).

contracts traded in the two venues.[12] The same might be said for comparisons of the automated Osaka Stock Exchange and floor trading in Singapore on SIMEX, although there are differences across markets unrelated to automation, which will be brought out in evaluating the results. Interpretation of a study of Globex and the Chicago Mercantile Exchange is complicated by natural deficiencies in liquidity endemic to an overnight market; the results are of general interest simply because the comparison is often favourable to the automated market, despite its relatively thin trader population. The work on India is in the form of a time-series event study of the introduction of automation in the Bombay market, as opposed to a comparison of automated and floor auctions operating over the same time period, but nevertheless sheds some light on the issues. The work on 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.[13] Finally, comparisons of automated auctions with dealer markets have focused on the Paris CAC and German IBIS auction systems, on the one hand, and the London SEAQ International (SEAQ-I) dealer market on the other. As detailed in Pagano and Steil (1996), the findings of these studies are rife with ambiguities. Beyond any problems with data interpretation, dealer markets are quite different than auction markets generally, whether the latter be automated or floor-based. Evidence based on such studies must, therefore, be considered the most indirect, and is included largely for completeness.

3.1 Bid-Ask Spreads

The size of the bid-ask spread is the most commonly quantified measure of liquidity across markets. Theory tells us that the spread is composed of an order processing component, inventory cost, and an adverse selection component. The studies above generally do not differentiate between them, but some information is available with respect to adverse selection, and we will consider this component separately below. Studies do distinguish between *quoted* and *realized* spreads, however, since this distinction is a feature of the data itself. In an auction environment, the quoted spread is the difference between the best posted bid and offer. In dealer markets, the quoted spread is the difference between the price at which the dealer is willing to buy and that at which the dealer is willing to sell, and is set by the dealer, not by general trading interest. In both cases, the quoted spread is associated with the posted size of transaction that may be carried out at the quotes. Such size information often is not available, complicating interpretation of quoted spreads in terms of transaction costs. Actual transactions also may be accomplished at prices that differ from the quotes, sometimes owing to size considerations. The realized spread is an imputed measure of the difference between best buy and sell prices in the market, inferred directly from the transactions prices themselves.

Studies of trading on DTB and LIFFE are in general agreement with respect to realized spreads. They are found to be smaller, or at least no larger, in the automated market compared to the floor market. Pirrong (1995), for example, reports that DTB spreads are a statistically significant 5 percent lower than on LIFFE. Results in Kaufman and Moser (1995) vary, depending on the method of calculation, but they cannot reject the statistical equality of the spread across trading venues even in the worst case. Similar findings are contained in Coppejans and Domowitz (1997) for the case of stock index futures trading, despite the relative illiquidity of the Globex market in dimensions other than size of spread.

Comparisons of automated markets and the SEAQ-I dealer market generally focus on quoted spreads. Pagano and Roell (1990), for example, find that the spread on SEAQ-I for French stocks is 1.52 percent on average, compared to 0.41 percent on the Paris CAC system. The qualitative nature of this result persists when the Paris weighted-average spread is compared to London, for orders sizes ranging from half to twice the SEAQ “Normal Market Size”, or “NMS” (which is equivalent to approximately 2.5 percent of average daily trading volume). Similar results are reported by Schmidt and Iversen (1992), with respect to trading on the German IBIS II system, with an average spread for the latter calculated to be 0.91 percent, compared to 1.25 percent on SEAQ-I, for a small matched sample of German stocks.

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

[13] A similar contribution is made by Kempf and Korn (1996).

Pagano and Steil (1996) criticize the use of quoted spreads in comparisons with dealer markets. The argument is that the quotes overestimate trading costs, because a significant fraction of trades takes place within the market makers' quotes. The study by de Jong *et al* circumvents this problem by examining realized spreads across the Paris and London markets. These authors continue to find that the automated market has a transactions cost advantage, in terms of the spread, even at trade sizes of twice NMS. Yet as we emphasize in section 3.5, the spread can be a poor proxy for trading costs when comparing auction and dealer markets. For example, the cited work does not take explicit commission costs into account. Such costs are not included in the realized spreads observed in the Paris market, while they are a component of the realized spread in the London market.

In summary, spreads are, at the least, no worse in automated markets as compared with traditional trading venues, and sometimes appear to be smaller in the automated market. The only negative note in this regard is sounded by Vila and Sandmann (1996), who report substantially larger spreads in the Osaka market, relative to floor trading on SIMEX.[14] The tick size in Osaka is twice that on SIMEX, however, biasing the comparisons. Orders also tend to be larger in this automated market, which also would naturally raise spreads in Osaka, relative to SIMEX.[15]

3.2 Depth of Market

Market depth cannot be measured simply by trading volume, especially since changes in volume can occur independently of market structure considerations.[16] Some studies simply use some measure of volatility, which is discussed separately below. In order to make sense of results in various papers that might be interpreted in terms of depth, it is necessary to call on a small piece of theory, which is not made explicit in such studies. A variety of different market microstructure models yield a relationship of the form

$$\sigma^2(\Delta p) = \omega + \lambda f(V)$$

in which the left hand side is the variance of price changes, ω is base-level volatility relating to information, and f(V) is some function of traded volume.[17] The key point is that in all such models, the parameter λ is an inverse measure of liquidity or market depth, often derived as a function of the number of traders in the market, the precision of prior information, and risk aversion on the part of traders. As λ decreases, the sensitivity of price changes to volume falls, and the market is seen to be deeper or more liquid. This accords naturally with intuitive notions of "depth of market". It is also now clear why volume alone, or even overall volatility, cannot provide information on market depth.

Some variant of this model is represented by regression formulations in three studies. The implied λ in the Osaka/SIMEX comparison is lower in the automated market, based on Vila and Sandmann (1996), implying greater depth in Osaka.[18] Pirrong (1995) splits volume into expected and unexpected components. He finds that the coefficient on unexpected volume is approximately zero for

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[14] Coppejans and Domowitz (1997) also find larger spreads on Globex for currency futures, but this is explained by increased adverse selection costs due to the operation of the overnight interbank currency market.

[15] The last two caveats also apply to the SEAQ comparisons, albeit in a different fashion. Paris trades are, on average, smaller than London trades. Explicit transactions costs also are lower in London. Pagano and Steil (1996) report, for example, that for a transaction on the order of Ffr 7 million, taxes and commissions (the latter bundled into the dealer spread, where trades are done on a net basis), such costs are 0.14 percent of value in London, compared to 0.5 percent in Paris.

[16] 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.

[17] Although many micromarket structure models deliver the general relationship, the function, f, varies across models. Examples include the expectation of the level of volume, the square of that expectation, and expectation of squared volume. Compare, for example, the trading models in Kyle (1985), Coppejans and Domowitz (1996) and Domowitz, Glen, and Madhavan (1997), which yield the same sort of relationship based on very different underlying assumptions.

[18] In that study, a reverse regression is estimated, allowing only a qualitative comparison here, as opposed to being more quantitatively precise, i.e., giving the difference in percentage terms.

DTB, while significantly positive for LIFFE. The results also are striking for expected volume. In this case, the DTB measure is positive only for one month of the twelve studied, and is even negative in some cases. In contrast, the LIFFE coefficient is positive and statistically different from zero for five months of the study. The implication is, again, a deeper market in the automated venue.

Only Franke and Hess (1995) report results suggesting greater depth in the floor market. Their result is questionable, however, owing to the use of the volatility of prices, as opposed to that of price *changes*, in their regressions. The former is generally not well-defined statistically, due to the extreme dependence between time-adjacent prices in financial markets, biasing statistical inference.

3.3 Informational Efficiency

Relative informational efficiency across computerized and traditional trading venues has been a topic of debate at least since the work of Melamed (1977). It represents an implicit cost of trading in at least two dimensions. Slower value revelation raises the cost of trading in terms of *ex ante* order submission strategies. The second dimension pertains to asymmetric information considerations, captured in the adverse selection component of the bid-ask spread. As such, its influence on trading costs is more direct. We discuss these two aspects separately below.

3.3.1 Adverse Selection

The openness of automated limit order books and the time required to cancel orders, compared with the relative opacity of price information and flexibility with respect to order withdrawal on trading floors, suggests that asymmetric information effects may be exacerbated in automated markets. A possible result is reluctance to submit limit orders in the face of potential adverse selection. For uninformed traders, the problem is one of the “free option” that a firm quote presents to the market, permitting trades at a sure profit that disadvantage the liquidity provider. For informed traders, the issue is revelation of information that might be obtained from the submission of large orders to the book.

Indirect evidence contrary to this view is provided by Vila and Sandmann (1996). They show that the computerized system actually handles larger orders than are processed on SIMEX. The average number of contracts per trade, derived from their data, is about 51 on the automated market, as opposed to 14 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 1000 times the price. Thus, it is not necessarily the case that adverse selection problems inhibit large orders and trades in an automated setting, as compared with a floor auction market.[19]

Direct evidence on adverse selection as a cost of trading is given only 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, compared to 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.

We note, however, that the possibilities for adverse selection may be lower in the overnight market for the stock index, compared with day trading on the floor. This observation may account for part of the result. Such intuition is reinforced by examination of the adverse selection component of the spread in foreign currency futures. In that case, the Globex market operates in the shadow of the overnight interbank currency market. Trading in the latter generates information at high speeds, exacerbating 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

[19] Such indirect evidence is not uniform across markets, however. The major counterexample pertains to dealer markets, compared to automated auctions. Pagano and Steil (1996) note that few Paris trades exceed SEAQ NMS, while the 90th percentile of trade size in London is in the vicinity of five times NMS. Such opposing evidence may simply reflect differences between traditional auction and dealer markets, instead of saying anything substantive about automation; see, for example, Madhavan (1992).

across currencies. Such results reinforce the notion that the "free option" problem is very much an issue in automated settings.[20]

3.3.2 Transmission of Information into Prices

Investigation of the speed of transmission of information into prices is generally based on more or less sophisticated calculations of correlations between current and past price returns. A simple example is provided by Shah and Thomas (1996), who calculate such correlations over five and ten day spans before and after introduction of automated execution on the Bombay Stock Exchange.[21] They find that the correlation between current and lagged returns drops sharply post-automation, suggesting greater informational efficiency in an automated environment.

Sophisticated vector autoregressive models (VARs) are used for much the same purpose by Kaufman and Moser (1995) and Sandmann and Vila (1996). Such models allow for an assessment of information transmission within a single market and between markets. In both studies, within and across market price adjustment is found to be slightly faster in the traditional trading venue, but differences are not large. Information flow through pricing is found to be bi-directional, and both papers conclude that there is no obvious price leadership differentiated by market structure.

In contrast, Grunbichler *et al* (1994) find that the automated market absorbs information much more quickly than the floor, but we have already noted the indirect nature of such evidence. The work of Coppejans and Domowitz (1997) falls in between these extremes. Controlling for the effects of asymmetric information, inventory control, and speculative demands based on order flow, no substantive difference in informational efficiency can be found between automated and traditional market structures.

In summary, the evidence for greater efficiency in traditional auction markets, relative to their automated counterparts, is weak, and contradicted in some cases. A balanced view of the evidence is that there are no material differences across market structures.

3.4 Volatility

Financial economists are fascinated by volatility, because of its obvious links to information flow and liquidity. We split our review of the evidence into considerations of overall, or static, volatility comparisons and dynamic aspects, including effects on market share in dual-listing settings.

3.4.1 Static Comparisons

There is no theoretical reason to expect higher or lower volatility in automated markets, relative to their traditional counterparts.[22] Unconditional volatility calculations may nevertheless be of interest, given their relationship, albeit indirect, to liquidity.

The available evidence suggests that volatility in an automated market is generally equal to, and sometimes less than, that in the traditional market. Shah and Thomas (1996) produce mixed results that nevertheless correspond to this description, using volatility of price returns on a daily basis.[23] Kaufman and Moser (1995) find that return volatility on a minute-by-minute basis is higher

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[20] Kaufman and Moser (1995) also find adverse selection effects to be stronger on DTB, compared to LIFFE. Their evidence is indirect, however, in that they don't estimate spread components directly. Rather, 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 CME, and therefore cannot support such inference.

[21] This includes the introduction of the BOLT system on the BSE itself, and that of the fully automated National Stock Exchange.

[22] The only work on this point seems to be the simulation study of Bollerslev and Domowitz (1991), which predicts lower volatility in an automated limit order book market, compared to the floor, based on smoothing of transactions flow through the book.

[23] Unconditional volatility drops by 2.2 percentage points after the introduction of automated trading in Bombay. Spread-corrected volatility measures show no difference post-automation.

on LIFFE than on DTB. Corresponding results for those markets on a daily basis (Franke and Hess, 1995) show no difference across venues. The same result is obtained by Vila and Sandmann (1996).[24] Only Coppejans and Domowitz (1997) contradict such findings, but those results are attributable to sharply lower liquidity in the overnight market in dimensions other than price variability.

3.4.2 Volatility Dynamics

Volatility comparisons become much more interesting in dynamic settings. Consideration of volatility dynamics allows inference with respect to order book effects, cross-market information linkages, and market share considerations. We consider each in turn.

3.4.2.1 Autonomous and Cross-Market Dynamics

Autonomous dynamics in volatility refers to the correlation between current period and lagged volatility in a single market. There are two, possibly conflicting, interpretations of a large correlation coefficient in this regard. The first is that a high correlation signals a slow speed of information transmission. While this may be intuitively pleasing, given analogous reasoning with respect to correlations between price returns, it has no basis in theory. The second interpretation is derived from the model of Bollerslev and Domowitz (1991). In that model, dynamics in volatility arise from serial correlation in the spread. It is shown there that such serial correlation arises naturally from the existence of the limit order book. To the extent that consolidated limit order books are lacking in floor or dealer markets, serial correlation in volatility should be greater in automated markets, regardless of speed of information transmission.

Unfortunately, existing results are ambiguous overall, implying no clear inference regardless of the reader’s interpretation. Shah and Thomas (1996) use GARCH models for volatility before and after introduction of automation in Bombay, finding that serial correlation in volatility increased post-automation. Coppejans and Domowitz (1997) provide sharp results in a stochastic volatility framework. The correlation between current and lagged volatility is found to be 0.92 on Globex, compared with only 0.23 on the CME floor, averaged across contracts. Sandmann and Vila (1996) also employ a stochastic volatility model, but find correlation coefficients of 0.93 in the automated market, and 0.95 on the SIMEX floor. Analogous results are reported by Kaufman and Moser (1995) in their DTB/LIFFE comparison, using GARCH models.

The latter paper presents the only attempt to model cross-market transmission of volatility in a dynamic setting. Since their estimates are presented by day, it is difficult to provide a precise characterization of overall behaviour. Broadly speaking, volatility transmission is bi-directional across market structures. In two of five weeks, it appears that LIFFE responded much more sluggishly to volatility shocks originating from DTB, suggesting more efficient information handling in the automated market. Results from only a single study should be interpreted cautiously, however.

3.4.2.2 Market Share and Volatility Dynamics

Where do traders go when volatility is high, given a choice between an automated and a floor market? Given the theoretical correlation of information arrival and volatility, there are several suggestions, most of which point towards the choice of the floor venue. Higher volatility increases the value of the free option stemming from providing liquidity to the automated limit order book. This would encourage traders to shift to the floor. Similarly, higher information intensity means that the relative importance of order book information is reduced, 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 do appear to be higher on automated systems.

Despite the logic of such arguments, the evidence again is mixed. Franke and Hess (1995) and Vila and Sandmann (1996) estimate identical models relating automated market share to lagged share and current and lagged values of price volatility. In the first case, higher volatility is found to decrease DTB market share. In the second, the result is completely reversed, with higher volatility generating a move to the automated market.

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[24] These authors do find that volatility is somewhat higher in Osaka based on minute-by-minute return data, but differences in tick sizes, over such a short period of time-aggregation, conceivably account for the result.

There is one possible resolution of such ambiguity offered by Vila and Sandmann (1996). Suppose one market is larger, on average, for reasons unrelated to volatility. 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. LIFFE and Osaka are the larger markets, with market shares of approximately 65 percent and 60 percent, respectively, on average. The argument is that uninformed traders simply shift to the larger market. There is an obvious endogeneity problem with such reasoning, however, given that the average size of market may be related to market structure considerations in the first place.

3.5 What Have We Learned About Implicit Transactions Costs?

Distinctions between various dimensions of implicit trading costs are not necessarily as sharp as our taxonomy may suggest. Explicit costs and features of system design also enter into any assessment of overall transactions cost. We now attempt to summarize the evidence, keeping such caveats in mind.

Bid-ask spreads appear to be approximately equalized across automated and traditional trading venues, with this cost being lower in automated markets in some instances. Considerations of market design tell us little about the anticipated size of relative spreads. The openness of automated limit order books does suggest higher costs in terms of the adverse selection component of the spread, however. Available evidence supports such intuition, especially 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. The results therefore suggest that order processing costs are generally lower in automated markets.[25] These conclusions must be tempered by considerations of 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, exemplified by the Osaka/SIMEX comparison. It is the case, however, that larger spreads are a feature of markets, automated or not, that process larger orders on average. This consideration explains the sharp results pertaining to the Paris CAC/SEAQ-I comparisons (smaller spreads in the automated market) and Osaka versus SIMEX (smaller spreads on the floor). Further, higher explicit costs are observed for the automated market in the latter case, and lower explicit costs characterize the dealer market in the former. Pagano and Steil (1996) emphasize the critical importance of these caveats in comparing CAC and SEAQ-I trading costs. As with dealer markets in general, SEAQ-I trades are significantly larger than those executed through its auction market counterpart (CAC). Roughly half of all London trades exceed NMS, whereas very few Paris trades exceed this size. Viewing trade size from another angle, Nijman and Röell (1995) point out that the 99th percentile in Paris is just around NMS, whereas the 90th percentile in London is already around five times NMS. The initiator of a large trade must generally pay a higher transaction cost, reflecting the anticipated market impact when the trade is revealed or "worked off" by the dealer, thus casting doubt on the relevance of trading cost comparisons across auction and dealer markets where trade size is not explicitly accounted for. Nijman and Röell (1995) also point out that explicit transaction costs are higher in Paris than London (by roughly 9 basis points for a Ffr 7m trade), largely reflecting the fact that London deals are generally done "net" of commissions, and that this London advantage is not accounted for in measuring the realized spread. Such considerations further motivate the conclusion that spreads, as a trading cost, may on balance be considered to be roughly equal across automated and floor-based systems.

Relative transparency considerations suggest that automated markets do not foster good market depth, due to the visibility of order book information. The transparency provided by automated order books potentially discourages the placement of limit orders, especially for large size. We made a similar argument earlier in the context of adverse selection, and the general principles apply here as well. Neither average trading volume nor average volatility in isolation provide good measures of depth, however, obviating some evidence on this point. Studies that attempt to measure depth parametrically, using (at least implicitly) data on information-based volatility and volume combined, do not support the intuition above. Market depth is generally found to be greater in the

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[25] The inventory component of the spread is found to be very small in all studies that attempt to break it out separately, and therefore does not affect our qualitative conclusions here.

automated market. Such results are restricted, however, to comparisons between auctions. There is no evidence, one way or the other, with respect to dealer markets. One difficulty with the latter is that spreads, as a cost of trading, are closely linked to depth behind dealer quotes, and comparisons, even if they existed, cannot be expected to be unambiguous as a result.

Similar remarks might apply to volatility comparisons. Price volatility involves consideration of information effects, market depth, spread size, and trading volume. Although average volatility is found to be at least as low in computerized markets as in their traditional counterparts, it is not clear exactly what is being measured. There is no cross-market comparison study that has attempted to pick apart all these pieces. This remark may also explain why results on volatility dynamics, and the effect of volatility on market share, are also mixed. Confusion in the latter case is exacerbated by conflicting explanations of volatility persistence, in terms of information and market design.

Studies differ most radically, in terms of methodology, in the measurement and comparison of informational efficiency across market structures. This should not be surprising: informational efficiency is so "implicit" that it is understandably difficult to measure, prompting a variety of techniques. Market structure is clearly important, but simple comparisons with respect to transparency, for example, are not sufficient to delineate differences in efficiency (*eg*, Madhavan, 1995). Simple statistical techniques also fail, because they do not take into account issues of strategic trader behaviour in a convincing way. It should, therefore, also not be surprising that the evidence is a bit mixed.

The surprise is that the results are not really as equivocal as the preceding discussion suggests. Returns correlation studies based on VAR techniques suggest very mild differences across trading regimes, and these differences disappear once such models are augmented by information pertaining to inventory and speculative order imbalances. Even when the analysis of returns might imply faster speed of adjustment to information, volatility dynamics suggest the opposite (Kaufman and Moser, 1995). There is no evidence supporting "price information leadership" across market structures, either in terms of prices or volatility characteristics.

If implicit transactions costs are roughly equalized across floor and automated market structures, and markets differ in complex ways, what further explanation can be offered, and what conclusion remains? The explanation 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, in the sense that 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, conclude that both floor and automated auctions serve the trading community well. Costs may differ between competing structures in some dimension, which then may be offset in another. Were the situation otherwise, one of the two markets would cease to function, since traders would abandon it in favour of the less costly alternative. The last statement should be tempered by political and regulatory considerations, which may contribute to the continued existence of an otherwise inefficient market.

The rough equality of implicit costs across auction mechanisms does not imply that dual market structures will continue to exist over the long run. In fact, such equivalence, combined with our discussion of network effects and market development costs in the last section, might suggest precisely the opposite conclusion. The consumers of trading system services face a combination of implicit and explict costs. Automated market development and maintenance is far cheaper than in floor venues. It is therefore possible for automated markets to cut the explicit component of trading costs, relative to charges in the floor market. As total trading costs decline with technological advance, the network externalities enjoyed by established floor-based exchanges, such as the NYSE, may become a less powerful advantage for the first-movers than they appear to be at present. The result could be considerable trader migration to the automated markets.

4. Transactions Costs, Intermediation, and Market Structure: an Empirical Analysis

An important implication of the automation of trading market structure is the potential for direct market access on the part of institutional investors.[26] Market 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 (AZX).[27]

Why might this distinction matter in practice? The first answer concerns the precise choice of trading venue. In an intermediated setting, the broker determines where execution will take place, not the trader. Standard theory would suggest that, if the broker is representing the best interests of the trader, choice of trading location would be rationally based on price and execution quality. This hypothesis appears to be refuted in practice. Blume and Goldstein (1996), for example, show that most trades in NYSE issues executed off the NYSE floor happen when the execution venue is posting inferior quotes. This suggests, at the minimum, that location is often determined for reasons other than best pricing.[28]

Discussions with institutional investors suggest a second response, pertaining to information. Once an order is in the hands of a broker, information about the trade is no longer privy to the investor, 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 more difficult trades, including those in small capitalization stocks, large block transactions, and higher volatility environments.

A further, and much simpler, explanation would be that human intermediation services are often unnecessary for the investor, yet the latter is obliged to pay for such services in all circumstances when trading through a traditional broker. Automated trading enables institutions to avoid paying commissions on intermediation services they do not actually require. On simpler trades, the trading expertise of the broker may not be sufficient to compensate for the lower commission charges which automated services invariably levy.

With the exception of the two-market comparisons analysed in the previous section, work on transactions costs across trading venues has largely concentrated on comparisons between the NYSE, NASDAQ, and the various regional exchanges in the U.S.[29] With the exception of some sporadic information with respect to the illiquid Cincinnati Stock Exchange, such studies do not compare costs across intermediated versus non-intermediated venues or traditional versus non-traditional (automated) trading arenas.

We take a different approach in this section. Using proprietary data from a major US institutional investor, we compare transaction costs for trades executed through a variety of brokers with those incurred by non-intermediated 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 to follow. Cost comparisons are most directly interpretable in terms of intermediated versus non-intermediated trading. There is no ambiguity associated with this particular exercise. On the other hand, the vast majority of trades

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[26] Although this may eventually also be true for retail customers, capital requirements to ensure market stability, for example, typically exclude direct access for non-institutional traders.

[27] Technically, an institutional trader cannot place an order directly on AZX. Because the company is legally regulated as an "exchange", the SEC requires registered broker intermediation. However, the broker is merely placing the order, and receives only a small payment for the service.

[28] U.S. law mandates that brokers must 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 Peterson and Fialkowski (1994), Bessembinder and Kaufman (1996), and Blume and Goldstein (1996).

[29] Examples include Lee (1993), Huang and Stoll (1994), Battalio (1996), and Bessembinder and Kaufman (1997), in addition to those cited in the footnote just previous.

handled through brokers are executed through the NASDAQ market and on 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.[30]

4.1 Data and Definitions

Our data consist of detailed information reflecting the trading activity of a large US mutual fund managing approximately $44 billion in equity assets. For convenience, we refer to this fund hereafter as "US Fund". The data reflect daily averages of a variety of cost components and related variables over seven six month periods between 1992 and the middle of 1996, as reported by their trading cost consultant, SEI. The data are available in disaggregated form, broken down by "buys" and "sells", across 41 "traditional brokers" (primarily telephonic brokers) and four "electronic brokers": Instinet's continuous order matching system, the Instinet Crossing Network, Posit, and the AZX call auction. The AZX system is effectively a crossing network, as orders entered into the system are almost invariably priced "passively": that is, the NYSE closing price typically is used for orders that indeed receive execution. Thus we have one continuous auction system, and three periodic crossing systems in our electronic broker sample.

For the purposes of this exercise, we have identified as "electronic brokers" only those brokers which provide internal electronic order-matching services. Those whose electronic services are exclusively order-routing to exchanges are classified as "traditional brokers". The distinction is somewhat arbitrary for listed stocks, as Instinet is used primarily for order-routing on NYSE issues (through the DOT system), making it very similar in function to ITG, which we have classified as "traditional". However, we defend our classification on the grounds that it allows us to distinguish as accurately as possible, given the contours of the data, between those brokers which *intermediate* trades and those which allow buyers and sellers to *interact directly*, without human intermediation at any point in the process.

While the data analysed are from a single institution only, it is important to highlight some exceptional characteristics of this particular data set which make it very appropriate for our analysis. The first is that "US Fund" is a relative rarity among US fund managers in that the company has no "soft commission" arrangements with brokers, as a matter of company policy. Soft commissions represent payments made directly from client funds to brokers for research and other services which are effectively "embedded" in the commission fees which the fund pays for each trade. Generally, funds which pay soft commissions commit in advance to paying a minimum annual level of commissions to the broker in return for these services. In effect, then, funds which pay soft commissions are paying for non-execution-related services via trade execution fees, thus complicating the task of measuring their true costs of trade execution. The "US Fund" data are relatively immune from this distortion, as the company does not commit to minimum volume levels with any broker, whether to obtain research services from a broker or "third party" services, such as information and trading systems. 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. Secondly, "US Fund" is an exceptionally large-scale user of non-intermediated electronic trading services: indeed, they represent approximately half the total trading volume going through such systems of the full SEI database, which comprises data from 33 institutional clients. It is one of the few funds in the world for which there are actually sufficient data to allow a valid trading cost comparison between traditional and non-traditional trading mechanisms.

The uniqueness of this data set does not come without some cost relevant to the analysis. First, 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

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[30] For example, although Instinet handles a fairly large proportion of NASDAQ trades, the overwhelming majority of such trades are inter-dealer, and do not reflect institutional customer order flow.

immediate turnaround on the next trade.[31] In contrast, the data here benchmark 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 was the only one possible: available trade-by-trade information does not allow discrimination between automated and traditional trading venues or between intermediated versus non-intermediated trades.[32] Further, commissions are not available based on trade-by-trade information sets, while we wish to separate commissions from other execution costs. Second, we have access only to the information provided to "US Fund" by SEI, not to the underlying database. The issue is one of cost measurement. Effectively, we must use the cost measures provided by the consultant, as opposed to developing our own. Nevertheless, the available measures do correspond to definitions previously used in the literature, and we now make this explicit.

Let V_{it} denote the true economic value of security i at time t, for which some observable proxy must be used in applications. Following Huang and Stoll (1994) and Bessembinder and Kaufman (1997), define

$$\textit{effective half-spread} = 100D_{it}(P_{it} - V_{it})/V_{it}$$

and

$$\textit{realized half-spread} = 100D_{it}(P_{it} - V_{it+n})/V_{it}$$

where P is the transaction price of the security, and D is a binary variable taking on the value of one for buy orders and negative one for sell orders. The effective half-spread is a measure of the closeness of the trade price to the underlying value, providing 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 the price impact, reflects the market's assessment of private information conveyed by the trade (Bessembinder and Kaufman, 1997). Another interpretation of the realized spread is that it measures the reversal from the trade price to post-trade economic value.

The cost measure supplied by "US Fund" represents a combination of these concepts, as well as proxies for the underlying true value of the security. Specifically, setting n=1 in the definitions above, we define

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

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. SEI use 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 99 basis points. The impact is favourable: this 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 transaction. Thus, D^{*} now takes on the value of negative one for buy orders and positive one for sell orders. The example above represents a savings of 99 basis points. Finally, we define *total trading cost* to be the sum of execution cost and commissions for the trade.

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[31] 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.

[32] For example, in the TAQ database available from the NYSE, trades executed on Instinet are reported as NASD trades, and cannot be separately identified. Trade-by-trade data also force the researcher to infer trade direction, introducing estimation error, while our data permit an explicit breakdown into buy and sell orders and transactions.

4.2 Trading Costs and Alternative Systems

As a first attempt to gauge the effect of automation on the cost of trading services, we calculate average commission, execution, and total trading costs for each of "US Fund's" brokers tracked by SEI between January 1992 and June 1996. We then compare the performance of "US Fund's" four "electronic brokers" with the average for the "traditional brokers". We further break out the three call market systems from the electronic group, in order to enable comparisons between periodic and continuous trading. Average trading costs are calculated using the individual broker figures, weighted by relative dollar trading volume. Summary statistics are provided in Figure 3. We discuss the findings below.

The most significant general finding is that the automated systems significantly outperform the traditional brokers across the board, with the exception of listed sells, where their performance advantage is marginal. The smaller gap on listed sells owes to underperformance by the Instinet continuous system, which offset most of the trading cost advantage established by the three call market systems.

The three call auctions produced significantly better than average performance across the board, with the single exception of AZX on OTC buys, where the systems accounted for a minuscule 0.58% of "US Fund's" dollar trading volume. The call markets also significantly outperformed the Instinet continuous system on sells, although they slightly underperformed on the buys.

It might be conjectured that trading in an alternative venue would be especially valuable for OTC orders, but this is not always the case. For listed buys, traditional brokers generate costs 429 percent higher than electronic venues, while for OTC buys the gap is 217 percent. Intuition with respect to better savings for OTC stocks through alternative venues is supported for sell orders, however. For listed sells, traditional broker costs are only 6.7 percent higher than in the electronic markets, while for OTC sells the difference is 26 percent.

The data further illustrate rather marked 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. The finding is apparently unrelated to automation effects, in that it is evident for both traditional and electronic brokers. There is one distinction, however, that merits comment. Selling stock in continuous markets, whether via a traditional broker or via Instinet, is significantly more costly than selling in call markets. The finding is suggestive with respect to haste in continuous trading. The performance gap between buys and sells overall might reasonably be ascribed to anxiousness in unloading positions, in contrast to the more organized process of accumulating positions based on portfolio decisions. Such an effect would be especially evident in the continuous markets. Call markets slow down the trading process, however, and appear to yield significant trading cost savings as a consequence. This hypothesis would seem to draw some support from our discussions with institutional traders. We fully accept, however, that alternative explanations may be equally plausible, and the differences across buy and sell orders clearly merit attention in future work.

A more finely tuned study of trading cost performance is also necessary to draw more robust conclusions regarding the benefits of automated trading. It is widely accepted that trading costs differ with respect to the relative difficulty of obtaining "good" execution, making simple comparisons of costs across intermediated and nonintermediated markets less than fully informative. For example, execution costs should fall as the market cap of the stocks rises, owing to relatively better liquidity and reduced informational asymmetries. Large trades are also generally more difficult than small ones, and costs should therefore increase. This effect may be partially ascribed to larger inventory costs in intermediated settings, and partially to information content. Intermediaries are risk-averse, with the implication that costs, especially in intermediated venues, rise with volatility. The main direction for future research in this area is therefore to examine whether trading costs vary systematically between traditional brokers and automated markets, controlling jointly for variation in relevant sets of economic characteristics.

5. Summary and Conclusions

Previous analyses of the impact of automation on exchanges and trading have largely concentrated on specific micro-effects relating to improvements in information dissemination, order routing, and trading practices, such as program trading. Our analysis suggests that the impact of ICT advances has been far more fundamental, significantly transforming the natural industrial structure of the trading services industry. In particular, technological advance has severely eroded the natural monopoly characteristics which national stock exchanges have enjoyed throughout most of this century.

The use of classical industrial organization models to underpin our analysis, and the concomitant focus on *both* explicit and implicit cost structures in the industry, distinguishes our work from that of our fellow financial economists. Whereas we conceptualize trading systems as firms *producing* both transaction services and securities prices, market microstructure researchers model trading systems simply as hierarchies of rules, which determine the parameters in which heterogeneously endowed traders strategically interact. "Equilibrium" securities prices are presumed to be determined independently of the trading technology applied, and explicit transaction costs are presumed to be unaffected by the trading rules, technology, operating costs, or organizational structure of the system provider. In effect, all emphasis is placed on the characteristics of the *demand side* (*ie*, the traders), whereas the characteristics of the *supply side* (*ie*, the trading systems) are either directly derived from the former or simply given as assumptions of the model. This approach naturally fails to capture the effect of ICT advances on the structure of the supply side, and how this affects the behaviour of the demand side.

We identify a number of leading developments promoting changes in industrial structure. Marked advances in computer technology over the past two decades have resulted in the proliferation of non-intermediated continuous electronic auction systems, and the revival of periodic call market trading, with human auctioneers replaced by computers. The most recent developments in this area, order processing in multiple dimensions (e.g., preference rankings of price and quantity combinations), have only been made possible by advances in massive parallel processing. The result is sharply increased product differentiation in the "market for markets", not only relative to traditional trading structures, but also within the automated market paradigm. Development and maintenance expenses for such markets have been declining sharply over time, significantly reducing sunk cost barriers to entry. Such barriers have been further reduced by major improvements in market information dissemination and order routing made possible by the laying of high quality data lines. The result is a highly increased level of realized and potential competition with respect to traditional trading venues.

These developments are analysed within the context of two established industrial organization paradigms. It is argued that technological developments have significantly increased the contestability of the trading services industry. This implies a high level of allocative efficiency in the market for markets, and the unsustainability of cross-subsidizing on-exchange with off-exchange trading activities (for example, via the imposition of "interaction rules" obliging block traders to satisfy limit orders on a centralized auction system). Contestability theory enables such performance evaluations, but cannot deliver predictions with respect to the eventual structure of the industry. Our characterization of trading markets as communications technologies, combined with rules for admissible information and trade execution, suggests the use of models of network economies to address this question. We first attempt to explain current industry structure, with its mixture of traditional trading services in some venues, automated systems in others, and the coexistence of both automated and floor markets in yet other contexts. Applying the insights of network models against the backdrop of contemporary competitive developments in the equity and derivatives markets, we suggest the eventual domination of the industry by automated market structures. An interesting implication of the application of network models is that cartels of automated trading services providers are both likely and socially desirable. The recently announced merger of the DTB, Swiss Exchange, and Matif trading systems into a single "Eurex" market is a significant early manifestation of network forces at work.

The common theme that runs through the theoretical analyses is cost. We first note that development and maintenance costs for automated markets are a relatively small and declining fraction of those required for floor markets. We then adopt two different approaches to the issue of relative costs of trading between automated and traditional trading systems.

Using a variety of cross-market comparisons, we first analyse the implicit costs of trading. Across several dimensions - comprising bid-ask spreads, market depth, informational efficiency, and volatility considerations - implicit transactions costs are roughly equalized across floor and automated market structures. This equivalence does not imply that both types of markets will coexist over the long run, however. The consumers of trading system services face a combination of implicit and explicit costs. Given their development cost advantage, automated venues are capable of sharply cutting the explicit cost component, relative to charges in the floor market. Total trading costs, therefore, will be cheaper under automation, and it is anticipated that such cost considerations will encourage migration to electronic systems.

We then focus on the cost implications of direct market access on the part of institutional investors, which is uniquely enabled by the automation of trading market structure. Using proprietary data from a major institutional investor, we compare transactions costs for trades executed through brokers with those incurred by non-intermediated trading in automated markets. Our results are most readily interpretable in terms of intermediated versus non-intermediated trading. To the extent that broker order flow representing institutional orders is not directed to automated venues, the comparisons also may be interpreted as between automated and traditional trading markets. Our results are only preliminary at this stage, and much further work needs to be done. We have compelling evidence, however, that total transaction costs, including both implicit and explicit components, are generally significantly lower in automated markets. Further analysis is expected to yield explanations which account explicitly for relative trade difficulty and variations in trading behaviour across buy and sell activity.

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Figure 1

PTS Trading in the United States:

Estimated Trading Volumes

	1990	1995
Shares traded	2.3 billion	15.7 billion
Share of total US trading	3.1%	8.1%
Of which:		
Instinet		76%
Posit		15%
AZX		2%
Others		6%

Source: Toronto Stock Exchange

Figure 2

Studies on Implicit Trading Costs

Study	*Automated Market*	*Traditional Market*	*Instruments*
Coppejans and Domowitz (1997)	Globex	CME floor	futures
de Jong, *et al* (1995)	Paris Bourse	SEAQ-I	stocks
Franke and Hess (1995)	DTB	LIFFE	Bund future
Grunbichler *et al* (1994)	DTB	FSE	Dax future
Kaufman and Moser (1995)	DTB	LIFFE	Bund future
Pagano and Roell (1990)	Paris Bourse	SEAQ-I	stocks
Pirrong (1995)	DTB	LIFFE	Bund future
Sandmann and Vila (1996)	Osaka SE	SIMEX	Nikkei future
Schmidt and Iversen (1992)	IBIS II	SEAQ-I	stocks
Shah and Thomas (1996)	BOLT/NSE	Bombay SE	stocks
Vila and Sandmann (1996)	Osaka SE	SIMEX	Nikkei future

Figure 3

Trading Costs: Traditional versus Electronic Brokers

Listed Buys

	Total Trading Cost	of which, Commissions	% of Total $ Volume
Average: all brokers	0.33	0.12	100
Average: traditional	0.37	0.13	88.63
Average: all electronic	0.07	0.05	11.37
Average: call markets	0.09	0.04	7.38
Instinet crossing	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 Sells

	Total Trading Cost	of which, Commissions	% of Total $ Volume
Average: all brokers	0.47	0.16	100
Average: traditional	0.48	0.17	88.28
Average: all electronic	0.45	0.06	11.72
Average: call markets	0.33	0.04	6.63
Instinet crossing	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

OTC Buys

	Total Trading Cost	of which, Commissions	% of Total $ Volume
Average: all brokers	0.22	0.04	100
Average: traditional	0.38	0.00	38.52
Average: all electronic	0.12	0.06	61.48
Average: call markets	0.15	0.05	6.08
Instinet crossing	-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	55.41

OTC Sells

	Total Trading Cost	of which, Commissions	% of Total $ Volume
Average: all brokers	1.37	0.05	100
Average: traditional	1.60	0.00	30.87
Average: all electronic	1.27	0.07	69.13
Average: call markets	0.73	0.06	7.68
Instinet crossing	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	61.46