Equity Market Microstructure: *Taking Stock of What We Know*

RETO FRANCIONI, SONALI HAZARIKA, MARTIN RECK, AND ROBERT A. SCHWARTZ

RETO FRANCIONI
is the chief executive officer of the Deutsche Börse in Frankfurt, Germany.
reto.francioni@deutsche-boerse.com

SONALI HAZARIKA
is an assistant professor of finance at the Zicklin School of Business, Baruch College, CUNY, in New York, NY.
sonali._hazarika@baruch.cuny.edu

MARTIN RECK
is a managing director of the Deutsche Börse in Frankfurt, Germany.
martin.reck@deutsche-boerse.com

ROBERT A. SCHWARTZ
is Marvin M. Speiser professor of finance at the Zicklin School of Business, Baruch College, CUNY, in New York, NY.
robert_schwartz@baruch.cuny.edu

Equity market microstructure addresses issues that involve the implementation of portfolio, or investment, decisions in a marketplace. Implementation entails the placement and handling of orders in a securities market and the translation of these orders into trades and transaction prices. The process links fundamental information concerning equity valuation of primary concern to portfolio managers to prices and transaction volumes that are realized in the marketplace. The quality of the link depends on the rules, procedures, and facilities of a securities market, and on the broader regulatory and competitive environment within which the market operates.

Widespread interest on the part of the securities industry, government, and academia is testimony to the importance of market microstructure analysis. The subject addresses issues that concern investors, broker/dealer intermediaries, market regulators, exchanges, and other trading venues, as well as the broad economy. Interest in microstructure has increased sharply over the past three and a half decades, spurred in particular by three events—issuance of the U.S. Securities and Exchange Commission (SEC) *Institutional Investor Report* in 1971, passage by the U.S. Congress of the Securities Acts Amendments of 1975, and the sharp stock market drop on October 19, 1987. Further, the advent of computer-driven trading in recent years has enabled researchers to capture electronically the full record of all trades and quotes, and this has provided empirical researchers with far richer data, namely *high frequency data*, for analyzing trading and price setting.

Over the years, microstructure analysis has expanded and exchange structure has strengthened. We consider both of these developments in this article. First, we set forth the major challenges that the microstructure literature addresses. Second, we present a broad view of the direction in which microstructure analysis has been and is evolving. Third, we turn to one application—the design of an actual marketplace, Deutsche Börse's electronic trading system Xetra. The German market was the last of the major European bourses to introduce an electronic trading platform, and the result, Xetra, is state of the art, which makes Deutsche Börse a particularly interesting subject of analysis. Last, we consider the bumpy and hazardous road that takes us from theory to the development of an actual marketplace.

MICROSTRUCTURE'S CHALLENGE

Microstructure analysis has four broad applications. First, and the key focus of this article, is that microstructure analysis gives guidance to market structure development. The link between the two areas is straightforward. The critical factor that drives microstructure analysis is friction in the marketplace (i.e., the explicit and implicit costs of implementing portfolio decisions) and trading costs depend on the architecture of the marketplace, which determines how orders are handled and turned into trades. The flipside of friction is illiquidity, and a primary function of a market center is to amass liquidity.

The second application of microstructure analysis is to facilitate the development of trading strategies and algorithms for asset managers and broker/dealer intermediaries. The importance of this application is evident in the current development of computer-driven algorithmic trading. Algorithms can be fine-tuned to take into account a number of factors, such as the probability of a limit order executing; time-of-day effects, such as market openings and closings; the search for liquidity in a fragmented environment; and the choice of trading modality (e.g., continuous limit-order-book market, quote-driven dealer market, periodic call auction, block trading facility, or a hybrid combination of these modalities).

The third application of microstructure analysis concerns tests of market efficiency. In the 1970s, the efficient markets hypothesis (EMH) was widely accepted by financial economists as a cornerstone of modern portfolio theory and it continues to receive broad academic support today. The hypothesis addresses informational efficiency as distinct from operational efficiency, the latter of which refers to the containment of transaction costs by superior market design. According to the EMH, a market is informationally efficient if no participant is able to achieve excess risk-adjusted returns by trading on currently available information. Many of the EMH tests have considered a single, although major, part of the information set—market information (e.g., recent quotes, trading volume, and transaction prices). If prices properly reflect all known information, then, in a frictionless market at least, they must change randomly over time; hence the term *random walk*. Earlier studies, based on daily data, generally supported the random walk hypothesis. However, with the advent of high frequency data, the footprints of complex correlation patterns have been detected. This observation, along with superior knowledge of the impact of trading costs on returns behavior, is casting a new light on market efficiency. Regardless of whether inefficiency is thought of in operational or informational terms, the EMH is not as stellar as it once was.

In its fourth application, microstructure analysis sheds light on how new information is incorporated into security prices. In a zero-cost, frictionless environment, share values would be continuously and instantaneously updated with the release of new information. In actual markets, however, information must be received and assessed, traders' orders must be placed and processed, executions must be delivered, and accounts cleared and settled. Costs, both explicit (e.g., commissions) and implicit (e.g., market impact), are incurred throughout this chain of events. Highlighted in much microstructure literature are the costs that some participants incur when, in an asymmetric information environment, other participants receive information first and trade on it to the disadvantage of the uninformed.

Asymmetric information is not the only reality, however. In light of the size, complexity, and imprecision of much publicly available information, one might expect that investors in possession of the same (large) information set will form different expectations about future risk and return configurations. This situation is referred to as *divergent expectations*.[1] Asymmetric information and divergent expectations together reflect a rich set of forces that impact the dynamic behavior of security prices.

This overview of microstructure's four broad applications underscores that trading frictions are the subject's raison d'être. Participant orders cannot be translated into trades at zero cost (markets are not perfectly liquid), and trades typically are not made at market-clearing, or some might say, equilibrium, prices. Trading decision rules (algorithms) are needed because the costs of implementing portfolio decisions can sharply lower portfolio performance. In fact, much algorithmic trading is designed to control trading costs, rather than to exploit profitable trading opportunities. Today, trading is recognized as an activity that is both distinct from investing and equivalently professional. Market structure is of concern to the buyside desks precisely because markets are not perfectly liquid, nor are they perfectly efficient, informationally or operationally. Consequently, better market structure delivers superior portfolio performance for participants.

What is the economic service, one might ask, that an equity market provides? The fuzzy link that connects information and prices in the nonfrictionless environment underscores two major market functions—*price discovery* and *quantity discovery*. Price discovery refers to participants collectively searching for equilibrium prices. Quantity discovery refers to the difficulty that participants, who would be willing to trade with each other, actually have finding each other and trading when markets are fragmented. This difficulty is accentuated because some participants (primarily institutional investors) do not immediately reveal the total size of their orders, because doing so would unduly drive up their market impact costs.

Market structure affects both the accuracy of price discovery and the completeness of quantity discovery. The link between market structure and price discovery depends on the environment within which participants are operating. At one end of the spectrum, investors can be equally informed and form homogeneous expectations based on the information. At the other end, they can be differentially informed and form divergent expectations with regard to commonly shared information. When investors who share common information all agree on share values (i.e., have homogeneous expectations), prices can be "discovered" in the upstairs offices of research analysts. But when investors are not equally informed, and when they form different expectations based on common information, prices must be discovered in the marketplace. In the latter environment, the economic service provided by the exchange is clear—it "produces the price."

In handling the orders of large institutional customers, quantity discovery is a challenge. It is not at all uncommon for an institution to want to buy or sell, for example, 500,000 shares of a company that has an average daily trading volume of 300,000 shares. Executing an order of this size can easily drive prices away from the trader before the trade has been completed. The adverse price move is a *market impact cost*. Institutions attempt to control their market impact costs by trading patiently and, as much as possible, invisibly. Good market structure can help. To this end, a number of alternative trading systems have been formed in recent years, and dark, (nontransparent) liquidity pools have emerged.

When price discovery occurs in the marketplace, participants employ market trading strategies to implement their portfolio decisions. Participants, who have differential information that will soon become public, determine how best to mete their orders into the market so that prices will move to new levels at *minimal* speed. Other questions that a trader might in any event ask include the following:

- If I trade now, at the current moment, how will the price that I receive compare with the average price that shares are trading at today?
- Is price currently at a sustainable, validated level, or is it likely to move higher or lower in the coming hours, minutes, or even seconds?
- Would I do better to be patient and place a limit order, or submit a market order and get the job done right away?
- Should I attempt to trade now in the continuous market, or wait for a closing call?

The orders that a set of participants reveal to the market depend on how questions such as these are answered, and the prices that are set and the trading volumes that are realized depend on the orders that are revealed.

The categories of trading costs that receive the most attention on the part of exchanges, regulators, and academicians are generally those that are the most straightforward to measure—commissions and bid-ask spreads. With increasingly precise measures of market impact becoming available, however, the market impact cost is also now being widely taken into account. But because the opportunity cost of a missed trade is far more difficult to quantify, it is often overlooked. An even greater challenge is quantifying a cost that has received little formal attention: realizing executions at poorly discovered prices. The problem, of course, is that equilibrium values are not observable and appropriate benchmark values are not easily defined.

WHAT MICROSTRUCTURE ANALYSIS HAS TO OFFER: PERSONAL REFLECTIONS

In this section we review the development of microstructure analysis. Our objective is not to provide a comprehensive survey of the literature, but to highlight some of the important themes that can give guidance to market structure development. More detailed information can be obtained from Cohen, Maier, Schwartz, and Whitcomb [1979] who provided an early survey of the field; O'Hara [1997] who discussed important theoretical microstructure models; Madhavan [2000], Biais, Glosten, and Spatt [2005], and Parlour and Seppi [2008] who provided more recent surveys; and Hasbrouck [2007] who dealt with empirical microstructure research and research methodology. We first focus on the early literature, then turn to more recent developments, and lastly present our thoughts concerning an important direction in which future microstructure research ought to head.

The Early Focus

The first contributions to the new field in financial economics that came to be called *microstructure* were made by a couple of people who participated in the SEC's *Institutional Investor Report* [1971]. A handful of others independently started to focus on microstructure topics in the early 1970s. Eventually a few of the early researchers came to recognize the commonality of their interests and, adopting the title of Garman's [1976] well-known article "Market Microstructure," gave the field its name.

Much of the early literature focused on dealers and exchange specialists. These market makers were viewed as the suppliers of immediacy to investors, and the spread was considered the price they charged for providing this service in an environment where order arrival is non-synchronous. Of key importance was the relationship between spreads and the costs of market making.

The earlier market-maker studies were in large part motivated by a desire to determine whether intermediaries were realizing monopoly profits and, if so, whether their profits were attributable to market making being a natural monopoly. Spreads that are greater than the costs of market making would be taken as an indication of monopoly power on the part of the dealers, and spreads that were negatively related to trading volumes would indicate economies of scale in market making, which could imply a natural monopoly (Stigler [1964]). Spreads were indeed found to decrease with transaction volume, but reasons other than market making being a natural monopoly were advanced (Smidt [1971]; Tinic [1972]).

The general picture which emerged was that the trading costs incurred by investors could be lowered by strengthening competition between market-maker intermediaries. In particular, competition in the New York Stock Exchange (NYSE) market was deemed inadequate because specialists and the exchange itself were viewed as having monopoly positions. Each stock was assigned to just one specialist according to the NYSE order consolidation rule (Rule 390), which precluded in-house executions by requiring that exchange members send their orders for NYSE-listed securities to an exchange. In addition, commissions were fixed and unjustifiably high (Tinic and West [1980]).[2]

Not surprisingly, the focus on the market-maker firms led several researchers to model market-maker pricing decisions (i.e., the setting of their bid and ask quotes). These studies include Bagehot [1971], Stoll [1978], Amihud and Mendelson [1980], Ho and Stoll [1980, 1981, 1983], and Mildenstein and Schleef [1983]. With the one exception of Bagehot, the early formulations focused on inventory considerations. A market-maker firm holding an undesirably long position would lower its quotes; that is, it would lower the offer, or ask, in order to sell more shares, and reduce the bid to discourage others from selling shares to it. Reciprocally, a market maker who was short would raise its quotes. This response on the part of the public—buy more shares when the market maker's offer is lower and sell more shares when the market maker's bid is higher—is evidence that the public's demand to hold shares of any specific stock is downward sloping. A variety of mathematical tools were used to solve for optimal market-maker quotes. These models also gave further insight into the cost components of the market maker's spread (Stoll [1989]).

While insightful, the early inventory-based pricing models suffered several shortcomings. First, the early formulations typically assumed monopoly market makers, even though some of these models were applied to markets, such as the NYSE, where exchange specialists were competing with other floor brokers and customer limit orders (Demsetz [1968]). The application of theory further suffered from the reality that the price of immediacy for an investor is not the spread of an individual market maker, or even an average market-maker spread, but the *inside spread* (i.e., the lowest ask across all market makers minus the highest bid).[3] It is important to note that dealer spreads can individually remain relatively invariant with respect to transaction volume, while the inside spread falls appreciably.

A further shortcoming of most of the earlier models is that they did not take into account a major cost incurred by market makers, the losses generated by trading with better-informed investors. Recognition of this reality led to a development that did much to establish microstructure as an important new field in financial economics. This development was the introduction of market-maker models that were based—rather than on inventory management—on controlling the costs incurred when some investors possess information that the market maker and other investors have not yet received. Bagehot [1971] was the first to embark on this line of thought. He was later followed by, among others, Gloston and Milgrom [1985] and Kyle [1985].

With information asymmetries, the market maker always loses when trading with a better-informed participant. For microstructure theorists at that time, this meant that, for the dealer market not to fail, some investors must trade for reasons unrelated to information.[4] Liquidity (i.e., an investor's personal cash flow needs) was one such motive for public buying and selling. A third type of participant was also introduced along with the liquidity traders—noise traders. A noise trader trades on price moves as if the moves contain information, when in fact they do not. This trio of informed traders, liquidity traders, and noise traders was used to show how markets could function and, in so doing, enable new information to be incorporated into security prices (Grossman and Stiglitz [1980], Milgrom and Stokey [1982], Kyle [1985], Glosten and Milgrom [1985], Copeland and Galai [1983], and Easley and O'Hara [1987, 1991, 1992]).

At this early stage of development, the microstructure pricing models were predominantly market-maker models. One exception should be noted, however. A National Book System proposed by Mendelson, Peake, and Williams [1979] contained a comprehensive description of an order-driven automated trading system that provided guidance for designing the first exchange-based electronic trading system.[5] Most equity markets around the globe are now order-driven, limit-order-book markets, which might include market makers in a hybrid structure, such as the NYSE, but are no longer basically quote-driven, or dealer, markets, as were the old NASDAQ and London Stock Exchange. The limit-order-book markets are driven by orders placed by investors themselves, not by market-maker intermediaries.

The Current Focus

Over the years, microstructure analysis has grown extensively on both theoretical and empirical fronts. Concomitantly, the security markets themselves have evolved, becoming ever more technologically developed and more global in outreach, but also more fragmented between different trading facilities. One important new direction that microstructure research has taken is to model the order-driven market. The order-driven market is an environment in which natural buyers and sellers provide immediacy to each other; those who are patient are willing to post limit orders, while those who demand immediacy choose to submit market orders that execute against the posted limit orders. Understanding the costs of, and motives for, placing limit orders, as distinct from market orders, was necessary.

With limit orders, the very existence of the bid-ask spread has to be explained. When a sufficiently large number of participants place priced orders, one might expect that orders would be posted at virtually every available price point in the neighborhood of equilibrium, and that consequently the bid-ask spread would disappear. Cohen et al. [1979, p. 827] made this point (and Cohen et al. [1981] analyzed the existence of the spread),[6] asserting that

> [w]ith regard to modeling the market spread, we suggest that a straightforward aggregation from individual spreads is not possible in a system where there is no clear distinction between demanders and suppliers of immediacy, and where traders meet in a dynamic, interactive environment that incorporates the impact of investor order placement strategies.

Strategic order placement clearly required further analysis.

The task, however, was not simple. Some of the first articles in this area assumed, as is true for a dealer market, that limit-order and market-order participants are two separate, exogenously fixed groups that are separated by a firewall (Glosten [1994]). This assumption, while simplifying mathematical modeling, unfortunately distills out much of the richness of an order-driven market. More recent models have eliminated the firewall (Handa and Schwartz [1996a], Foucault [1999], Parlour [1998], Handa, Schwartz, and Tiwari [2003], Faucault, Kaden, and Kandel [2005], and Goettler, Parlour, and Rajan [2005]). With the choice between a limit order and a market order made endogenously, in order for the market to function participants must divide naturally into four groups reflecting two dichotomies—one between buyers and sellers, and the other between limit-order and market-order placers—rather than the standard two groups (buyers and sellers).

With order-type selection endogenous in the order-driven market, the balance between immediacy suppliers and immediacy sellers becomes a second equilibrium that must be understood. One needs to recognize the conditions under which some participants choose to be liquidity demanders (place market orders), while others choose to be liquidity suppliers (place limit orders). If a reasonable balance is not achieved between these two groups, the order-driven market will fail, as indeed it does for thinner, small-cap stocks. Increasingly, these issues have been handled, and some sophisticated limit-order models have been developed.[7]

The microstructure analysis of trading systems has expanded to include periodic call auctions.[8] The economics of a call auction are quite different from those of continuous trading and, consequently, so too are the order placement strategies that participants should employ in a call market. Call auctions do not, by their very nature, supply immediacy. Orders that are entered during a call's book-building phase are held for a periodic crossing at a single clearing price at the generally predetermined time of the market call. Buy and sell orders submitted to a call do not execute when they arrive even if they match or cross in price. This contrasts to a continuous trading environment in which matching and crossing orders execute immediately. Limit and market orders, therefore, have a different meaning in a call; limit orders do not supply immediacy to market orders and market orders are simply extremely aggressively priced limit orders; that is, a market order to sell in a call effectively has a limit price of zero, and a market order to buy effectively has a limit price of infinity.

Today, virtually all modern, electronic exchanges open and close their continuous markets with call auctions. Consequently, participants face further decisions when operating in a call-plus-continuous hybrid market; for example, the decision of how to submit an order to a call auction that is followed by continuous trading (an opening call), and how to submit an order to a continuous trading environment that is followed by a call auction (a closing call). Taking these tactical decisions into account is part of the complexity of microstructure analysis.

Technological developments have simultaneously enabled new trading venues to emerge, which can fragment markets, while providing connectivity between them, which can consolidate markets. Concurrently, regulatory initiatives have been motivated by the desire to intensify intermarket competition. Questions can be raised, however, concerning fragmentation of the order flow. The conventional wisdom has been that the consolidation of order flow improves liquidity, and exposing each order to all other displayed orders gives investors the best prices for their trades.

On the one hand, consolidating trading in a single market provides incentives to liquidity suppliers to compete aggressively for market orders by revealing their trading interests, and by being the first to establish a more favorable price (if time is used as a secondary priority rule). On the other hand, arguments in favor of trading on multiple markets include the benefits of intermarket competition and the fact that traders with disparate motives for trading may want different marketplaces to trade in (i.e., the one-size-does-not-fit-all argument).

Thus, different markets develop to serve diverse investor needs, such as achieving a faster execution versus obtaining a better price. One growing need among large institutional investors, the ability to trade large orders with minimal market impact, has led to the advent of dark-pool, block trading facilities, such as Liquidnet, Pipeline, and ITG's Posit that aid in quantity discovery. This industry development has spawned a related line of research on off-exchange and upstairs trading (Grossman [1992], Seppi [1990], Madhavan [1995], Keim and Madhavan [1997], and Madhavan and Cheng [1996]).

A spectrum of market-quality issues have been of long and continuing importance to microstructure researchers. These include market transparency,[9] both pre- and post-trade (Porter and Weaver [1998]); accentuation of intraday price volatility; and correlation patterns, which have been observed in high frequency data (Engle and Granger [1987]). Other important issues include price clustering and tick sizes (Harris [1991, 1994]; Angel [1997]). Applications, such as transaction cost analysis and algorithmic trading, have received increasing attention (Domowitz, Glen, and Madhavan [2001]). The relative performance of floor-based versus electronic trading is another important issue (Domowitz and Steil [1999]).

A major line of empirical research was pioneered by Hasbrouck [1993] who decomposed transaction prices into two components—a random-walk component and a stationary component. The random-walk component is identified with an efficient price, which the market is trying to discover. The stationary component is viewed as microstructure noise. Microstructure noise is commonly explained by features such as the bid-ask spread, market impact, and discreteness of the pricing grid. The noise component has also been attributable to price discovery being a dynamic process (Menkveld, Koopman, and Lucas [2007], and Paroush, Schwartz, and Wolf [2008]).[10]

Numerous empirical studies have focused on two of the world's premier markets, the NYSE and NASDAQ (Hasbrouck [1991, 1995], Hasbrouck and Sofianos [1993], Christie and Schultz [1994], Christie, Harris, and Schultz [1994], Bessembinder and Kaufman [1997a, 1997b], Bessembinder [1999, 2003], and Barclay, Hendershott, and McCormick [2003], among others). Many other studies have considered European, Asian, and other markets around the world (e.g., Biais, Hillion, and Spatt [1995], Sandas [2001], and Ozenbas, Schwartz, and Wood [2002]).[11] Across all of these markets, structural and performance differences have been noted, but major similarities have also been observed. It is apparent that, despite the influence of historic and cultural considerations, trader behavior and market performance around the globe depend largely on microstructure realities. Alternatively stated, trading rooms and markets around the world bear a striking resemblance to each other.

Another recent line of research has considered how search costs affect bid-ask spreads in financial markets. To this end, Duffie, Pederson, and Gârleanu [2007] presented a dynamic model of market makers under the assumptions of no inventory risk and of information being symmetrically distributed. They showed that sophisticated investors who have better search and bargaining abilities face tighter bid-ask spreads. This contradicts traditional information-based models which imply that spreads are wider for more sophisticated (i.e., better-informed) investors.

As we have noted, unlike in the frictionless market arena of the capital asset pricing model, the amassing of liquidity is a primary function of a marketplace, and market structure features are generally designed with liquidity implications in mind. Asset managers also take liquidity into account along with the two other standard variables of modern portfolio theory—risk and return. Difficulties in defining, measuring, and modeling liquidity are formidable, however, and the literature that deals directly with liquidity is relatively sparse (Bernstein [1987]). Nevertheless, liquidity considerations have permeated the microstructure literature, both explicitly and implicitly.[12]

Recalling the development of microstructure analysis, two observations stand out. First, microstructure studies have given direction in multiple ways to market structure development. Second, to a remarkable extent, the various theoretical microstructure models that are center stage today, and many empirical analyses that are based upon them, share a common structural framework—the asymmetric information paradigm. This consistency is desirable in that it implies that the field has grown by accretion rather than by replacement. Consequently, new insights are more apt to refine than to contradict old conclusions.

Consistency, however, is not desirable if the common structural framework becomes overly rigid and restrictive, and if it yields incomplete and/or misleading answers to questions involving trader behavior, market structure, and regulatory policy. At times, a literature will begin to advance along a new front. Next, we consider this possibility for the microstructure literature.

Future Directions

As we have noted, the current focus in the literature is on asymmetric information–based models, which are characterized as follows. Trading is driven by informational change, liquidity needs, and noise trading. The informational motive for trading is the first mover of the three, and liquidity and noise trading are required so the market will not fail. Further, order arrival in the continuous environment is generally taken to be asynchronous. For a continuous trading regime to function with asynchronous order arrival, the presence of a limit order book and/or a market-maker intermediary is required.

Information trading is of keen interest because it represents the process by which new information is reflected in share values. In the standard asymmetric information models, it is assumed that all participants in possession of the same information form equivalent expectations concerning future risk and return configurations. When information changes, however, all participants may not receive the news at the same time; some receive it before others, a reality that, at any point in time, can divide traders into two groups—the informed and the uninformed. Informed participants will never trade with each other and consequently, liquidity and noise traders must be present for a market to function. As noted, asymmetry of information, for the most part, lies at the heart of the standard microstructure models of today.

The standard homogeneous expectations assumption has been tempered of late. It is being recognized that some participants produce *private information*; that is, certain participants further process information so as to gain insights that are not immediately available to others. Whether participant expectations differ because of the actual production of private information, or simply because different people have varying interpretations of the same information or news announcement, the expectations of a group of investors can diverge.

Also at the heart of an asymmetric information model is the presumption that a stock has a fundamental value, which bears a unique relationship to the fundamental information that informed traders possess rather than to trader activity in the marketplace. The process of information being fully reflected in prices under asymmetric information is the act of informed and uninformed agents trading with each other until any discrepancy between a market price and a fundamental value is eliminated. The process can be viewed as arbitrage. In the earlier dealer models, the market maker was assumed to know a stock's fundamental value. In later models, informed traders (but not the market maker) were assumed to know the fundamental value (Kyle [1985]). Especially in the later models, price discovery is not instantaneous, but is a protracted process that depends on the individual strategies employed by the informed and uninformed agents.

In recent years, an alternative paradigm has been emerging—a divergent expectations environment (Miller [1977]). While institutionally realistic, this paradigm has met with considerable academic resistance. One reason for this is that homogeneous expectations environments are far easier to deal with mathematically, and homogeneity has, in many applications, proven to be a useful modeling assumption. The homogeneous expectations assumption has also been retained for another reason. As an attribute of individual rationality, it is presumed that intelligent agents facing the same information and applying the same (correct) analytical techniques will reach the same conclusions and, therefore, will have homogeneous expectations.

Fundamental information, however, is enormous in scope. It is complex and imprecise, and our tools for analyzing it are relatively crude. In the presence of fuzzy information, expectations can be divergent. Allowing for divergent expectations opens another path for microstructure analysis and introduces new questions concerning agent behavior, market structure, and regulatory policy. Moreover, a further element can enter the analysis in a divergent expectations environment—along with forming their own opinions, agents may also respond to the opinions of others; that is exhibit adaptive valuation behavior (Paroush, Schwartz, and Wolf [2008] and Davis, Pagano, and Schwartz [2007]).[13] Just how agents communicate with each other and respond to each others' opinions is a subject of ongoing research. The topic also opens another interface with behavioral finance.

Price discovery acquires a different meaning in a divergent expectations environment, and this new meaning has important implications for market structure. When asymmetric information characterizes a community of investors, the strategic behavior of informed agents can affect the path that price takes when news moves a share value from one equilibrium value to another. In this case, however, the new equilibrium is path independent. With divergent expectations, on the other hand, the new equilibrium is path dependent because it depends on how the opinions of a diverse set of agents are integrated (Paroush, Schwartz, and Wolf [2008]). Alternatively stated, with divergent expectations, price discovery is a coordination process and, as such, it is directly affected by market structure.

In the standard asymmetric information environment, the key dichotomy is between informed and uninformed participants. But a second dichotomy also exists—one that separates large institutional customers from small retail customers. One might expect that the informed investor set would largely comprise institutional investors. After all, the institutions are professional and can afford to continuously monitor information and they respond to news, and the institutions' very size, all else constant, reduces the per share cost of doing so. With divergent expectations, however, there is no presumption that institutional customers can, because of their size, consistently evaluate shares more accurately. On the contrary, institutions commonly disagree with each other and, as a consequence, commonly trade with each other.

In the divergent expectations environment, institutional investors do not necessarily have an advantage over retail customers as fundamental analysts. In fact, their size makes trading more difficult and they incur higher transaction costs. So what accounts for their popularity? The value added by mutual funds, pension funds, and other institutional investors comes largely from their ability to facilitate diversification. Further, they can bring a systematic, professional, and disciplined approach to portfolio management (Davis, Pagano, and Schwartz [2007]).

FROM THEORY TO APPLICATION

Microstructure analysis is inherently involved with analyzing the detailed functioning of a marketplace. The literature has a strong theoretical component and, to a large extent, is structured to yield insights into the effect of market design (structure and regulation) on market performance. Theory should be able to provide a broad roadmap for real-world market architects to follow.

Having considered the development of microstructure theory, we turn now to the designing of an actual marketplace. Our focus is on Deutsche Börse and its electronic trading system Xetra. Deutsche Börse is the dominant stock exchange in Germany, the last of the major European bourses to go electronic, and it has technology that is state of the art. Important insights were gained from the microstructure literature during Xetra's planning period and the system's implementation has marked a huge step forward for Germany's equity markets. But our roadmap, which is undoubtedly still incomplete today, was even more limited in the 1994–1997 period when Xetra was being designed. And, there is always the danger that the cartographer, whose map is being used, holds certain misconceptions; for example, believing in the existence of the Northwest Passage.

The German Equity Market in the Mid-1990s

As recently as the mid-1990s, the German market had major structural defects that would undermine its competitiveness in the European arena. In recognition of this, Deutsche Börse, the newly founded exchange operator of the Frankfurter Wertpapierbörse (FWB), became the leading force for change in the German equity market.[14]

In the mid-1990s, Frankfurt's trading floor was the major marketplace for German stocks, but the German market had become badly fragmented. Kursmaklers, the equivalent of specialists, concentrated much of the market's liquidity in their order books. By today's standards, a primitive electronic trading system, IBIS (which was owned by FWB), operated in parallel with the market's floor trading. The central component of IBIS was an open limit order book that had hit-and-take functionality, but did not match orders automatically. The electronic system captured about 40% of the trading volume in the 30 large-cap DAX stocks, but no link existed between IBIS and the floor. Seven other floor-based regional exchanges were also operating in Germany with technical infrastructures that were similar to those in Frankfurt. In total, the regionals at that time were attracting roughly10% of German exchange-based trading volume. Moreover, off-board trading has been, and still is, prevalent in Germany (Davis, Pagano, and Schwartz [2006]).

Transparency for floor trading—in particular, pre-trade transparency—was low. Quotes were not distributed publicly and were available on the floor only. Price priority between different trading venues was not enforced and orders executed in one market commonly traded through orders waiting to be executed in another market. Market manipulation and other abuses of power and position were believed to be rife on the old Frankfurt floor. Given the appreciable market fragmentation, poor transparency, imperfect intermarket linkages, and dubious floor behavior, transaction costs were high. Changes, both structural and regulatory, were called for. The result was the development of Xetra, an electronic order-driven trading system that comprises two principal modalities—a continuous-order-book platform and periodic single-price call auctions.

Designing a New Trading System

Xetra's development started in 1994, and the system was launched in 1997. Strong external forces also motivated this reengineering of the Deutsche Börse market structure. These forces included regulatory reform, soaring trading volumes, pan-European harmonization of the exchange industry, vibrant cross-border competition for order flow, and rising concerns of market participants about the future performance of Germany's financial markets.

Throughout the design stage of Xetra, microstructure theory—even as it existed at the time—was an indispensable guide. This new field in financial economics, with its origin in issues concerning the competitive and architectural structure of an equity market, would be expected to guide the development of an actual marketplace such as Xetra. To some extent, it has fulfilled this promise. The microstructure literature provided a broad roadmap to Deutsche Börse and highlighted underlying relationships and other important considerations that a market architect should be aware of.

Building the Xetra model involved specifying the principles that the new market should implement and defining the system's functionality. Most importantly, the new market system was to provide equal and decentralized access to all of its participants. Further, the system's functionality and the market information delivered to users, both pre- and post-trade, were to be the same for all traders, because a trader's location should be irrelevant. With this in mind, the fundamental architectural decision of the Deutshe Börse was to structure a hybrid market that included two major modalities—a continuous electronic order-driven platform and periodic call auctions that were used primarily for market openings and closings.[15]

An absolutely critical attribute of an order-driven trading system is its ability, vis-à-vis its competitors, to win the battle for liquidity. The earlier microstructure literature provided some guidance on this matter, but liquidity is a complex attribute. Because liquidity is not easy to define and measure, it has been very difficult to model and assess. However, as previously noted, the measurement and analysis of liquidity are currently attracting considerably more attention in the microstructure literature.

Price discovery and transparency are two other areas in which the microstructure literature provided valuable guidance to the architects at Deutsche Börse. Deutsche Börse recognized that price discovery is a primary function of a market center, and thus introduced the call auctions to sharpen the accuracy of price discovery, particularly at the market's open and close. Understanding that transparency is important, but recognizing that it should not be excessive, Deutsche Börse made the decision to disclose only the indicative clearing price, rather than the full book of orders, in the pre-call, book-building period.

Microstructure literature has provided insight into the operations of the public limit order book for continuous trading. At the time Xetra was being designed, the recognition of periodic call auctions as a modality that was clearly differentiated from, but could effectively be used with, the continuous market, was just beginning to emerge. In terms of continuous trading, the microstructure analyses of the use of limit and market orders and of the interaction between these two order types proved to be most valuable. Today, a deeper understanding of the economics of an order-driven market exists than was the case in the 1994–1997 period when Xetra was being designed.

Another important contribution of microstructure theory has been the classification of traders according to their needs for immediacy and their propensities to be either givers or takers of liquidity. The differentiation between informed and uniformed traders also proved to be valuable, particularly with respect to the market-maker role that has been incorporated into Xetra. Specifically, market makers, referred to as *designated sponsors*, were included to bolster liquidity provisions for smaller-cap stocks. A balance had to be achieved between the obligations imposed on the designated sponsors and the privileges granted to them. To accomplish this, information had to be assessed concerning the role of dealers in general (e.g., NASDAQ-type market makers) and specialists in particular (e.g., NYSE-type specialists). That balance defined the designated sponsors' role in Xetra and secured their willingness to accept it. Market microstructure insights also yielded the understanding needed to transform the specialist role into the newly designed designated-sponsor role.

But designing an automated trading system is indeed a complex task, and the gap between theory and implementation is both large and intricate. Trading decisions can be made in a large variety of ways that run the gamut from humans interacting directly with humans without computers, to humans trading via electronic order handling and execution systems, to computers making trading decisions that are sent electronically to a computerized market (e.g., computer-driven algorithmic trading). Since the mid-1990s, market structure development has mainly involved the design of an electronic trading facility.

Deutsche Börse took into account the fact that automation impacts both the way in which trading decisions are made and the process by which prices are determined and trades executed in a market center. An electronic market requires the specification of an array of critical features, for example, the trading modalities employed, rules of price and quantity determination, and basic features, such as order types and trading parameters. With an electronic market, the software that implements a desired market structure must be specified on a level of detail which far exceeds what is required for human-intermediated trading.

For instance, a human agent, or specialist, has historically handled price determination at NYSE openings. This function is performed with reference to various rules, but the specialist is also free to exercise reasonable judgment. Further, human-to-human interactions can evolve naturally as problems, opportunities, and new competitive pressures arise. In contrast, with a fully electronic opening, every possible condition that can occur must be recognized and a rule for dealing with it specified; electronic interaction can be changed only by rewriting the code that specifies with step-by-step precision just how orders are handled and turned into trades and transaction prices.

How does one achieve the precise specifications that a computerized trading system must have? In 1994, the market architects at Deutsche Börse could study the operations of other electronic platforms (e.g., CATS in Toronto and CAC in Paris). Doing so was helpful, but of limited value, given that Deutsche Börse was looking to develop a distinctive system.

When moving into new territory, market structure development is a venture. How does one know in advance if it will work? How can one determine if the new system will be viable from a business perspective? Nevertheless, design decisions have to be made, technical requirements must be specified, and the system must be built. The decisions involved represent huge financial bets about whether a new market structure will attract sufficient liquidity. Prototyping a new market in the design phase helps the assessment process, but doing so in 1994 was considerably more difficult than it would be today with the advent of superior information technology and testing capabilities. In 1994, the architects were forced to rely primarily on their own educated judgments and the insights they may have gained from microstructure research.

Those who are involved in the design of an actual market realize that the devil is in the details. Consider, for instance, the specification of a call auction. A call has excellent theoretical properties, but how should an actual auction be designed? It is straightforward to say that the market clearing price in a call auction should be the value that maximizes the number of shares that trade. But what should the specific rule be for selecting the clearing price if two different prices result in the same maximum trade size? Additionally, how transparent should the book be in the pre-call, order-entry period? Are further design features needed to counter the possibility of gaming? And so on.

Other considerations that for the most part were outside the scope of the microstructure literature also came into play during the design of Xetra. Information technology issues, such as scalability, open architecture, and system reliability, were of critical importance. So too were procedures for post-trade clearing and settlement. One of the final steps in the structural design of the new German market was the introduction in 2003 of a central counterparty so that counterparty risk management would be centralized and trading would become fully anonymous, both pre- and post-trade. Electronic trading was also a prerequisite for highly efficient straight-through processing, which involves all stages of a trade's life cycle. Information technology has further facilitated the timely capture of market data (all trades, quotes, market index values, and so forth) and has expedited its delivery to users. With regard to these diverse applications, Deutsche Börse achieved a closer integration between trading on Xetra and the broader market infrastructure.

THE ROADMAP AND THE ROAD

A market architect must have a roadmap that, broadly speaking, explains where to head and roughly how to get there. The microstructure literature has added clarity, articulation, and intellectual support to the market roadmap. Briefly stated, the roadmap's objective is to reduce trading frictions (costs), sharpen price discovery, and facilitate quantity discovery. The means of achieving this broad objective involve the amassing of liquidity, which is done through the appropriate use of limit order books for both continuous and call auction trading and, where appropriate, the inclusion of broker/dealer intermediaries. Further insights are gained from microstructure's in-depth analyses of trading motives, which include new information, liquidity needs, and technical trading signals. The literature has also provided guidance with regard to issues such as transparency and the consolidation (fragmentation) of order flow.

But theory, even if it does provide a good roadmap, can take one only so far. The closer one gets to the design of an actual system, the more apparent the complexities of trading and trading systems become. The road actually traveled is indeed bumpy and it is hazardous. System designers know that the devil is in the details. They have to grapple with issues ranging from scalability, reliability, and other IT requirements, to business considerations that concern the ultimate profitability of a trading venue. The market architects at Deutsche Börse recognized these issues and their new system, Xetra, has marked a huge step forward for the German equity market.

Today, important problems persist with regard to market design in Germany, as well as in all other markets around the world. What is the best way to deal with large, institutional orders? How is liquidity creation best handled for mid-cap and small-cap stocks? These are two fundamental questions concerning market architecture that have yet to be adequately answered. At the same time, important microstructure topics continue to emerge at academic research desks. Are there limits beyond which microstructure theory cannot provide guidance? Are there limits to the level of efficiency that a real-world market can ever achieve? Undoubtedly, both answers are "yes" but, without question, neither of these limits has as of yet been reached. Quite clearly, microstructure research and the design of an actual marketplace remain works in progress.

ENDNOTES

[1]For a current discussion, see Davis, Pagano, and Schwartz [2007].

[2]Another major issue addressed by the microstructure literature at that time was the impact of information on trading volume and price (Copeland [1976], Beja and Hakansson [1977], and Beja and Goldman [1980]).

[3]For further discussion, see Cohen et al. [1979].

[4]A market supported by informational trading only can function if agents trade with each other because their expectations are divergent. When the information that triggers trading is common knowledge, the condition may be thought of as one in which agents are agreeing to disagree.

[5]For a more recent discussion of automated trading systems, see Domowitz and Steil [1999].

[6]Cohen et al. [1981] described the tradeoff between execution probability and price improvement in the optimal choice between limit and market orders.

[7]See Back and Baruch [2007] for a recent discussion and further references.

[8]See Economides and Schwartz [1995] for a description of alternative call market structures.

[9]Trading systems differ in their degree of transparency. Pagano and Röell [1996] investigated whether greater transparency enhances market liquidity by reducing the opportunities for taking advantage of uninformed participants.

[10]Also see Hasbrouck [1995], Harvey and Huang [1991], and Jones, Kaul, and Lipson [1994]. Further references are provided by Menkveld, Koopman, and Lucas [2007].

[11]Also see Bessler [2006] for discussion and further references.

[12]For further discussion and references regarding liquidity see Amihud and Mendelson [1986], Chordia, Roll, and Subrahmanyam [2000, 2008], Hasbrouck and Seppi [2001], Amihud [2002], and Pástor and Stambaugh [2003].

[13]Adaptive valuation behavior refers to individual agents becoming more bullish (bearish) when they learn of the relatively bullish (bearish) attitudes of others.

[14]FWB also owned the futures and options exchange Deutsche Termine Börse. After the 1997 merger with SOFFEX, DTB became Eurex.

[15]Interestingly, the microstructure literature on call auctions was relatively sparse at that time. For an early discussion, see Handa and Schwartz [1996b].

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