

**The Microstructure
Approach to Exchange
Rates**

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I dedicate this book to my wonderful wife, Jen.



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Preface

This book addresses a growing interaction between two fields—exchange rate economics and microstructure finance. Historically, these fields have progressed independently. More recently, however, they have begun to interact, and that interaction has stimulated new perspective within both. In exchange rate economics, that new perspective has given rise to a distinct approach—a microstructure approach.

A natural audience for this book includes people with expertise in only one of these two fields who are interested in learning more about the other. In the past this has not been easy—these areas have different intellectual traditions, so bridging them required a large investment of time. This book should facilitate that investment. To that end, I have tried to present material on both fields in an accessible way, so that readers lacking specialization in either one should find the material within reach. Practitioners, too, should find most of the material accessible (the empirical work in chapters 7 through 9 is most relevant to that audience).

A notable feature of this book is its treatment of both theoretical and empirical work (c.f. O'Hara's 1995 theory text). Indeed, the book is organized to highlight their interplay. Chapter 4 is dedicated to the canonical frameworks in microstructure theory. Some of these frameworks were originally developed to address the New York Stock Exchange, a market with a single dealer in each stock. The circumstances under which these frameworks are appropriate for foreign exchange markets (FX) is an important topic addressed in that chapter. Chapter 5 summarizes empirical microstructure frameworks, with emphasis on those employed in FX. These empirical frameworks draw heavily on chapter four's theory. The last four chapters, chapters 7–10, are applications of tools presented in the

first six. They bring the theoretical/empirical interplay into sharp focus.

A second notable feature of this book is its emphasis on information economics rather than institutions. People unfamiliar with microstructure finance typically believe its focus is institutional (e.g., the consequences of different trading mechanisms). This is an important part of the field. But in terms of this book, it is not the most important part. The focus of this book is the economics of financial information and how microstructure tools clarify the types of information relevant to exchange rates. In keeping with this focus, I move immediately in chapter 2 to the economics of financial information, saving detailed institutional material on FX trading until chapter 3.

This book also has some notable features in terms of pedagogy. They are concentrated in chapters 4–6, the three survey chapters: microstructure theory, microstructure empirical frameworks, and exchange rate theory, respectively. In chapter 4, I begin the survey of microstructure models with the “rational expectations” model. The chapter proceeds from that model’s implicit auctioneer to the explicit auctioneer of the Kyle model. Conceptually, I consider this a more natural progression than the typical sequencing in microstructure books. To maintain focus on essentials, chapter 4 also presents the microstructure models in a common format. I close chapter 4 with an appendix that collects several important technical tools for easy reference. On the empirical side, chapter 5 opens with a survey of available data sets and information on accessing them via the Internet (several are available from my web site: www.haas.berkeley.edu/~lyons). Data quality has increased substantially in recent years (in large part due to the shift to electronic trading), and this survey provides an easy reference for familiarizing oneself. Chapter 6 is the transition from the earlier, more micro-oriented chapters, to the later, more macro-oriented chapters. That chapter begins its survey of exchange rate theory with a treatment of “valuation,” which includes traditional definitions of exchange rate “fundamentals.” This should help readers whose perspective on valuation comes primarily from the dividend-discount models used in equity markets. Chapter 6 also highlights the parallels between exchange rate models and microstructure models (such as the conceptual link between portfolio balance models and inventory models).

This book also contains new work. For example, some of the material in chapters 7 and 8 is new to the literature, and most of

the material in chapter 9 is new. Many of the arguments and points made throughout other chapters are new as well (e.g., perspectives on the microstructure approach's potential applications). Much of the material in chapters 7 to 9 comes from work I have done jointly with three co-authors: Martin Evans, Mintao Fan, and Michael Moore.

For teaching, there are three types of courses for which this book would be appropriate. The first is a Ph.D. course in international macroeconomics. Of the ten chapters, the best ones for this type of course are chapters 1, 4, 6, 7, 8, and 9. A second course for which the book would be appropriate is a Ph.D. course in market microstructure. The best chapters for this type of course are 1, 2, 3, 4, 5, and 10. A third course for which the book would be appropriate is a Master's course in international finance. The best chapters for a course at this level include 1, 3, 6, 7, and 9.

Some caveats are in order. Like microstructure theory in general, my treatment of the microstructure approach emphasizes the role of order flow (signed transaction quantities) in price determination. This emphasis aligns closely with my own interests and my own work. Though much of the material I present is not my own, my work plays a more prominent role than it would in a balanced survey. To borrow the words of one reviewer, this book is more of a personal synthesis than a professional consensus. I apologize in advance to those whose work is underrepresented. (For those interested in a survey, let me recommend Sarno and Taylor 2000a.)

A second caveat is my use of the term "microstructure approach." Though there is no consensus definition of what constitutes a microstructure model, it is safe to say that the definition I adopt is rather broad. For me, the microstructure approach is not just a rich set of tools for addressing the issues, but also a way of framing those issues. Indeed, the framing *per se* is an important aspect of the approach's value. If I have done my job, the chapters that follow should make this point increasingly clear.

To these previous caveats I must add another. The tone of parts of this book may to some readers seem a bit missionary. This is particularly true of chapter 1, where I address the book's overarching themes. (Exchange rate economists will find these themes more provocative than will people in microstructure finance.) At the risk of appearing to over-sell, I felt it best to address these themes early. Most of the evidence that supports these themes appears in later chapters.

I owe thanks to many people. The support and encouragement of Victoria Richardson and Elizabeth Murry at MIT Press are much appreciated. I also want to thank several of my colleagues who, as anonymous reviewers of early drafts, provided valuable comments. I am indebted to them. I am also indebted to Alain Chaboud, Mike Dennis, Petra Geraats, Philipp Hartmann, Harold Hau, Jen Lyons, Michael Melvin, Michael Moore, Carol Osler, Richard Portes, H  l  ne Rey, Dagfinn Rime, Andrew Rose, Patrik Safvenblad, Sergio Schmukler, Mark Taranto, and Paolo Vitale for extensive comments and suggestions. A friend and colleague, Michael Klein, planted the seed for this book and also provided many insights along the way. I thank the University of Toulouse and Stockholm University for providing generous visiting opportunities while I was writing. Financial support from the National Science Foundation is gratefully acknowledged; this book (and much of the research underlying it) is in large part the product of their investment. Finally, I'd like to thank Jim McCarthy, a long-time buddy and FX trader who introduced me to the world of FX trading.

Ten years ago, a friend of mine who trades spot foreign exchange for a large bank invited me to spend a few days at his side. At the time, I considered myself an expert, having written my thesis on exchange rates. I thought I had a handle on how it worked. I thought wrong. As I sat there, my friend traded furiously, all day long, racking up over \$1 billion in trades each day (USD). This was a world where the standard trade was \$10 million, and a \$1 million trade was a "skinny one." Despite my belief that exchange rates depend on macroeconomics, only rarely was news of this type his primary concern. Most of the time my friend was reading tea leaves that were, at least to me, not so clear. The pace was furious—a quote every five or ten seconds, a trade every minute or two, and continual decisions about what position to hold. Needless to say, there was little time for chat. It was clear my understanding was incomplete when he looked over in the midst of his fury and asked me, "What should I do?" I laughed. Nervously.

This book is an outgrowth of my subsequent interest in this area. It is principally concerned with the gap between what I knew before I sat down with my friend and what I saw when I got there. In effect, this gap is the space between two fields of scholarship: exchange rate economics on the one hand, and microstructure finance on the other. Exchange rate economists use models of exchange rate determination that are macroeconomic (i.e., rates are determined as a function of macro variables such as inflation, output, interest rates, etc.). These same exchange rate economists are largely unfamiliar with microstructure models. Most microstructure scholars, in contrast, view foreign exchange as the purview of international economists, and are unfamiliar with macroeconomic exchange rate models. Their

traditional focus is the microeconomics of equity markets, particularly the New York Stock Exchange.

Though this book has several objectives, two deserve mention at the outset. The first is to lower entry barriers faced by scholars interested in this burgeoning area. Lowering barriers on both sides—exchange rate economics and microstructure finance—will help this research domain realize its potential. A second objective is to channel past work into a more unified approach—a microstructure approach. In the 1990s, many authors applied microstructure tools to foreign exchange (FX) markets, but existing work is still largely fragmented.

Does exchange rate economics need a new approach? Yes. It is in crisis. It is in crisis in the sense that current macroeconomic approaches to exchange rates are empirical failures. In their recent survey in the *Handbook of International Economics*, Jeffrey Frankel and Andrew Rose (1995, 1709) put it this way: "To repeat a central fact of life, there is remarkably little evidence that macroeconomic variables have consistent strong effects on floating exchange rates, except during extraordinary circumstances such as hyperinflations. Such negative findings have led the profession to a certain degree of pessimism vis-à-vis exchange rate research."

In the end, it is my hope that this book might rouse a little optimism.

1.1 Three Approaches to FX: Goods, Assets, and Microstructure

Before the 1970s, the dominant approach to exchange rate determination was the goods market approach. According to this approach, demand for currencies comes primarily from purchases and sales of goods. For example, an increase in exports increases foreign demand for domestic currency to pay for those exported goods. In this simple form, the implication is rather intuitive: countries with trade surpluses experience appreciation (which comes from the currency demand created by the surplus). Despite the approach's intuitive appeal, however, it fails miserably when one looks at the data: trade balances are virtually uncorrelated with exchange rate movements in major-currency FX markets. This negative result is perhaps not surprising given that trade in goods and services accounts for only a small fraction of currency trading—less than 5 percent of the average \$1.5 trillion of FX traded daily.

In the 1970s, the asset market approach emerged. It built on the earlier approach by recognizing that currency demand comes not only from purchases and sales of goods, but also from purchases and sales of assets. For example, in order to purchase a Japanese government bond, a U.S. investor first purchases the necessary yen. In addition, the investor's dollar return will depend on movements in the yen, so his demand for the bond depends in part on his desire to speculate on those currency movements. This shift in perspective brought a shift in modeling strategy. Models began to conform to the notion of speculative "efficiency": exchange rates were modeled as efficient in that they incorporate all publicly available information, making public information useless for producing excess returns. This is a feature the goods market approach did not share.¹

Disconcertingly, empirical work does not support the asset market approach either. The macroeconomic variables that underlie the approach do not move exchange rates as predicted. The classic reference is Meese and Rogoff 1983a; they show that asset approach models fail to explain major-currency exchange rates better than a simple "no change" model. Thus, asset approach models are not even consistently getting the direction right. In his later survey, Meese (1990) summarizes by writing that "the proportion of (monthly or quarterly) exchange rate changes that current models can explain is essentially zero." (The literature documenting this poor empirical performance is vast; for surveys see Frankel and Rose 1995; Isard 1995; and Taylor 1995.)

The FX market's enormous trading volume is also problematic for the asset approach. Explaining volume is difficult because actual transactions are awarded no role in mapping macroeconomic variables into exchange rate behavior. Rather, because all macroeconomic news is publicly available, when news occurs, the exchange rate is presumed to jump to the new consensus level; the change in expectations that causes the jump does not require any trading. Differing beliefs is not a driver of trading under this approach either, because the approach assumes homogeneous beliefs.

These negative observations do not imply that the asset market approach is "wrong"; indeed, most agree that it is, in broad terms, appropriate. Rather, it appears the approach is missing some key features—features that matter for how exchange rates are actually determined.

This book presents a new approach to exchange rates, the microstructure approach. Under this approach, like the asset market approach, the demand for currencies comes from purchases and sales of assets. In this sense these approaches are complementary, not competing. What distinguishes the microstructure approach is that it relaxes three of the asset approach's most uncomfortable assumptions:²

1. Information: microstructure models recognize that some information relevant to exchange rates is not publicly available.
2. Players: microstructure models recognize that market participants differ in ways that affect prices.
3. Institutions: microstructure models recognize that trading mechanisms differ in ways that affect prices.

People unfamiliar with microstructure believe its focus is on the third of these—the consequences of different trading mechanisms. *The focus of this book is resolutely on the first—the information economics.* (In keeping with this focus, the next chapter moves immediately to the economics of financial information; material on trader heterogeneity and trading mechanisms—points 2 and 3—is in chapter 3.)³ Empirically, it is simply not true that all information used to determine market-clearing exchange rates is publicly available. We can analyze the consequences of this—theoretically and empirically—using tools within the microstructure approach. The resulting analysis shows that the public-information assumption is not a good one: it misses much of exchange rate determination.

Consider some examples that suggest that the microstructure approach is on target with respect to these three assumptions. Regarding non-public information, FX traders at banks regularly see trades that are not publicly observable. As I show in later chapters, this information forecasts subsequent exchange rates (e.g., seeing the demands of private participants or central banks before the rest of the market). Regarding differences across market participants, traders with common information regularly interpret it differently. Another example of differences across participants is motives for trade: some traders are primarily hedgers, whereas others are primarily speculators (and even among the latter, speculative horizons can differ dramatically). Regarding trading mechanisms that affect prices, consider a market where transparency is low (e.g., where in-

dividual transaction sizes and prices are not generally observable). Low transparency can slow the updating of beliefs about appropriate prices, thereby altering the path of realized prices.

From these examples one might describe the microstructure approach as taking an in-the-trenches, trading-room perspective. Given that exchange rates are actually determined in the trading room, this would seem a reasonable starting point. But can relaxing the three assumptions above help us understand exchange rates? Relaxing the corresponding assumptions for other asset classes has certainly deepened our understanding of these other markets. The final judgment, though, will be based on specific applications of microstructure tools. The latter half of this book presents a number of applications.

In advance of those applications, I urge the reader to bear in mind the overarching fact that traditional approaches are not consistent with the data. Indeed, this fact induces Flood and Taylor (1996, 286) to conclude that

Given the exhaustive interrogation of the macro fundamentals in this respect over the last twenty years, it would seem that our understanding of the short-run behavior of exchange rates is unlikely to be further enhanced by further examination of the macro fundamentals. And it is in this context that new work on the microstructure of the foreign exchange market seems both warranted and promising.

1.2 Hallmarks of the Microstructure Approach

The previous section introduces microstructure in the context of exchange rates but does not define the term as used in domestic finance. Maureen O'Hara (1995, 1) defines market microstructure as "the process and outcomes of exchanging assets under explicit trading rules." The definition I adopt here is consistent with hers. Because her definition is so broad, though, it may be helpful to clarify further.

When one moves from a macro approach to a micro approach, two variables that play no role in the macro approach take center stage. These variables are hallmarks of the micro approach, and as hallmarks, they help to define microstructure. These variables are

1. order flow, and
2. spreads (bid-ask).

If I labeled these “quantity” and “price,” it would be clear that they are the old mainsprings of economics after all. These labels are a bit facile, though. Describing them as quantity and price viewed through a magnifying glass is nearer the truth. Let me clarify by touching on each.

Order Flow

Understanding order flow is essential for appreciating how the microstructure approach to exchange rates departs from earlier approaches. First, it is important to recognize that transaction volume and order flow are not the same. Order flow is transaction volume that is *signed*. For example, if you approach a dealer (marketmaker) and you decide to sell the dealer 10 units (shares, euros, etc.), then transaction volume is 10, but order flow is -10 : You as the initiator of this transaction are on the sell side, so order flow takes on a negative sign. The quoting dealer is on the passive side of the trade. The trade is signed according to the active, or initiating side. Over time, order flow can then be measured as the sum of the signed buyer-initiated and seller-initiated orders. A negative sum means net selling pressure over the period. Thus, despite the immutable fact that all trades involve a buyer and a seller, microstructure theory provides a rigorous way of attaching a sign to individual transactions when measuring order flow.

This definition needs to be adjusted slightly for markets that do not have dealers. Some financial markets replace dealers with something known as a “limit order book.”⁴ Here is an example of a limit order: “Buy 10 units for me when the market reaches a price of 50.” Limit orders are collected together in an electronic “book.” The most competitive orders in the book define the best available bid and offer prices. For example, the limit order to buy with the highest buying price becomes the best bid in the market. If you entered the market and wanted to sell 10 units immediately, you could sell at this best bid price, but no higher. (Think of these best limit orders as analogous to dealer bid and offer quotes in markets that have dealers.) The limit orders are the passive side of any transaction, just as the quoting dealer is always on the passive side in the previous example. When orders arrive that require immediate execution (e.g., an order to “sell 10 units now at the best available price”), these orders—called market orders—generate the signed order flow. In the example

above, as in the earlier case, executing the market order to sell 10 units produces an order flow of -10 .

Order flow, as used in microstructure finance, is a variant of a key term in economics, "excess demand." It is a variant of excess demand rather than a synonym for two reasons, the first relating to the excess part and the second relating to the demand part. For the former, note that excess demand equals zero in equilibrium by definition—there are two sides to every transaction. This is not true of order flow: in markets organized like foreign exchange, orders are initiated against a marketmaker, who if properly compensated, stands ready to absorb imbalances between buyers and sellers. These "uninitiated" trades of the marketmaker drive a wedge between the two concepts, excess demand and order flow. The second reason the concepts differ is that order flow is in fact distinct from demand itself. Order flow measures actual transactions, whereas demand shifts need not induce transactions. For example, the demand shifts that move price in traditional exchange rate models (e.g., the monetary models reviewed in chapter 6) are caused by the flow of public information, which moves exchange rates without transactions ever needing to occur.

A distinctive feature of microstructure models, across the board, is the central role order flow plays. This across the board property deserves emphasis because it expands the applicability of microstructure enormously. Recall that order flow plays no role in the asset approach; in the asset approach, order flow is not a variable that helps us understand exchange rates. That microstructure models of all types tell us this variable is important expands microstructure from the narrow concept of "institutional structures with price effects" to the broader concept of "a new lens for viewing markets." It instructs us that order flow deserves our attention. The question of order flow's importance in FX is distinct from—and in my judgment much larger than—the question of how specific FX institutions affect prices.

Consider a simple diagram that illustrates an important feature of microstructure models that relates directly to order flow. The diagram shows that information processing has two stages. The first stage is the analysis or observation of fundamentals by nondealer market participants (mutual funds, hedge funds, individuals with special information, etc.). The second stage is the dealer's—the price setter's—interpretation of the first-stage analysis. The dealer's interpretation comes from reading the order flow. Dealers set price on the basis of this interpretation.⁵

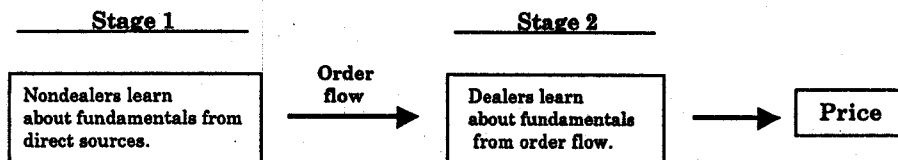


Figure 1.1
Two stages of information processing.

Order flow conveys information about fundamentals because it contains the trades of those who analyze fundamentals. In this sense, it is a transmission mechanism. Naturally, though, these informative trades may be mixed with uninformative trades, making the task of “vote counting” rather complex. In standard microstructure models, the dealer learns nothing about fundamentals that he or she does not learn from order flow. As a practical matter, this is clearly too strong. The dealer’s dependence on learning from order flow arises in these models because the information being learned is not publicly known. When information is publicly known, dealers do not need to learn from order flow. In practice, though some information relevant to FX is publicly known, some is not, so learning from order flow can be important.

Spreads

Spreads—the second hallmark variable of the micro approach—receive a lot of attention within the field of microstructure. There are three reasons for this, one scientific, one practical, and one historical. The scientific reason relates to data: spread data are a core element of most data sets, and as such, are a ready target for testable hypotheses. This stands in contrast to other features of the trading environment that are important but not as readily measurable (such as information flow, belief dispersion, and liquidity-motivated order flow). The second reason spreads receive so much attention is practical. Practitioners are intensely concerned with managing trading costs. This concern, and the resources devoted to it, has naturally influenced the course of research within microstructure. The third reason spreads receive so much attention is historical. From the beginning, the field of microstructure sought to separate itself from the literature on trading under rational expectations. Rational

expectations models abstract from trading mechanisms completely, the premise being that trading mechanisms have little effect on the relationship between underlying fundamentals and price. A natural means of distinguishing microstructure research was to orient it toward the following question: How does altering the trading mechanism alter price? This orientation led to a focus on the determination of real-world transaction prices—spreads.⁶

Though spreads receive a lot of attention, the subfield of spread determination is but one branch of the broader field of microstructure. Many microstructure models, for example, do not even include a spread (such as Kyle models, presented in chapter 4). I raise the issue early because for some people the association between spreads and microstructure is very tight. That many microstructure models have no spread should loosen this association.

Of the two hallmarks—order flow and spreads—this book focuses much more on order flow. In those instances where I do address spreads, my focus is on their information-theoretic implications, which can be substantial. For example, in chapter 2, I present evidence—gleaned from spread behavior alone—that implies that order flow forecasts price movements. This is important because it violates the premise of traditional models that all FX market participants are equally well informed: Some participants are better informed because they observe more order flow. Thus, on the basis of spread behavior alone, one reaches a rather profound conclusion: Contrary to the asset approach, exchange rate determination is not wholly a function of public news.⁷

1.3 Overarching Themes

Readers familiar with exchange rate economics are unlikely to be familiar with microstructure. For them, it may be helpful at the outset to address some of this book's overarching themes. Introducing them early provides valuable advance perspective on applications in later chapters. There are four themes in particular that exchange rate economists may find provocative.

Theme 1: Order Flow Matters for Exchange Rate Determination

Let me offer some perspective on this assertion, as it is one I will revisit. Consider an example, one that clarifies how economist and

practitioner worldviews differ. The example is the timeworn reasoning used by practitioners to account for price movements. In the case of a price increase, practitioners will assert that "there were more buyers than sellers." Like other economists, I smile when I hear this. I smile because in my mind the expression is tantamount to "price had to rise to balance demand and supply." These phrases may not be equivalent, however. For economists, the phrase "price had to rise to balance demand and supply" calls to mind the Walrasian auctioneer, which is an abstract way to think about how price adjusts to a market-clearing level. The Walrasian auctioneer collects "preliminary" orders, which he uses to find the market-clearing price. All actual trades occur at this price—no trading occurs in the process of finding it. (Readers familiar with the rational expectations model of trading will recognize that in that model, this property is manifested by all orders being conditioned on a market-clearing price.⁸)

Practitioners seem to have a different model in mind. In the practitioners' model there is a dealer instead of an abstract auctioneer. The dealer acts as a buffer between buyers and sellers. The orders the dealer collects are actual orders, rather than preliminary orders, so trading does occur in the transition to the new price.⁹ Crucially, the dealer then determines new prices from information about demand and supply that is embedded in the order flow (as suggested in the "two-stage processing" diagram above).

Can the practitioner model be rationalized? Not at first blush, because it appears that trades are occurring at disequilibrium prices (prices at which the Walrasian auctioneer would not allow trading). This suggests irrational behavior. But this interpretation misses an important piece of the puzzle: Whether these trades are out of equilibrium depends on the information available to the dealer. If the dealer knows at the outset that there are more buyers than sellers, eventually pushing price up, then it is unclear why that dealer would sell at a low interim price. If the buyer/seller imbalance is not known, however, then rational trades can occur through the transition. (Put differently, in setting prices the dealer cannot condition on all the information available to the Walrasian auctioneer.) This is precisely the story developed in standard microstructure models. Trading that would be irrational if the dealer knew as much as the Walrasian auctioneer can be rationalized in models with more limited—and more realistic—conditioning information.

Theme 2: Microstructure Implications Can Be Long-Lived

It is common to associate "microstructure" with "high frequency." The association is natural, but deceptive. It is true that empirical work in microstructure is in general high frequency, but this does not imply that microstructure tools are irrelevant to lower frequency, resource relevant phenomena. Indeed, there are ample tools within the microstructure approach for addressing lower frequency phenomena, and new tools continue to emerge, thanks in part to recognition within the broader microstructure literature that resource allocation warrants greater attention. The later chapters of this book are dedicated to examples of lower frequency relevance, particularly chapter 7.

Regarding long-lived effects, the most important point to recognize is that when order flow conveys information, its effect on price *should* be long-lived. Indeed, a common empirical assumption for distinguishing information from pricing errors is that information's effects on price are permanent, whereas pricing errors are transitory (French and Roll 1986; Hasbrouck 1991a; chapter 2 provides details). The data in equity markets, bond markets, and FX markets bear out these long-lived effects. In FX, for example, Evans (1997), Evans and Lyons (1999), Payne (1999), and Rime (2000) show that order flow has significant, persisting effects on exchange rates. Indeed, statistically these effects appear to be permanent. Among microstructure's long-lived implications, this "information" channel is definitely the most fundamental.

Let me touch on another source of lower frequency relevance: multiple equilibria that depend on microstructure parameters. Certain parameters' values can determine whether multiple equilibria within a given model are possible, and if so, which equilibrium is more likely to be selected (e.g., Portes and Rey 1998; Hau 1998; Hartmann 1998a; Rey 2001). These different equilibria apply in some models to the exchange rate's level, and in other models to the exchange rate's volatility (multiple volatility states are the focus of Jeanne and Rose 1999 and Spiegel 1998). Either way, multiple equilibria that depend on microstructure parameters open another door through which price effects are long-lived (long-lived because a given equilibrium is by nature persistent).¹⁰

An analogy may be helpful. Microstructure can speak to longer horizon exchange rates in much the same way that microscopes

speak to pathologies with macro impact. In medicine, microscopes provide resolution at the appropriate level—the level at which the phenomenon emerges. This is true irrespective of whether the phenomenon also has macro impact. Resolution at this level is the key to our understanding. Similarly, microstructure tools provide resolution at the level where its “phenomenon” emerges—the level where price is determined. What information do dealers have available to them, and what are the forces that influence their decisions? (Whether we like it or not, it is a stubborn fact that in the major currency markets, *there is no exchange rate other than the price these people set.*) Answering these questions does indeed help explain exchange rates over longer horizons. I provide evidence of this in section 7.1 and elsewhere.

Theme 3: Microstructure Is Relevant to Macroeconomists

In 1987, stock markets crashed around the world, an event that most people consider macro relevant. What analytical tools did the profession use to address the crash? The tools were microstructure tools (see, e.g., Grossman 1988; Gennotte and Leland 1990; Jacklin, Kleidon, and Pfleiderer 1992; Romer 1993). These leading papers on the crash are explicit about relaxing all three of the asset approach assumptions noted above. In particular, the richness of these models comes from (1) information structure: which participants knew what; (2) heterogeneity: what types of participant were active and what were their motives for trading; and (3) institutions: what role did each participant play in the trading process and what trading information did each have available. The microstructure approach certainly bore fruit in this case.

Macroeconomists have also applied microstructure tools to understand exchange rate collapses during the 1990s financial crises in Asia. These papers also introduce information structures, heterogeneity, and institutional factors that are not in general present within the traditional macro approach (see Chen 1997; Calvo 1999; Corsetti, Morris, and Shin 1999; Carrera 1999).

Theme 4: Exchange Rate Economics Merits an Information-Theoretic Perspective

In many ways, this theme follows from the first three. The information economics of traditional exchange rate models is rather simple.

Macroeconomic news is announced publicly, so everybody learns new information at the same time. This news can then be impounded directly in price. The aggregation of dispersed bits of information that are not publicly known is presumed to play no role. The question is, of course, whether this captures the essence of price determination, or whether it neglects something important. I address this question extensively in the next chapter.

1.4 Applying Microstructure Tools to Exchange Rate Puzzles

I turn now to puzzles within exchange rate economics and how microstructure helps to resolve them. Though later chapters address this in detail, let me offer some initial thoughts. Consider first the puzzle of the FX market's enormous trading volume (\$1.5 trillion per day, by far the largest of any financial market). In fact, the microstructure approach has made considerable progress on this puzzle. I have in mind here recent findings on the volume-amplification effects of the so-called hot potato. Hot potato trading is the passing of unwanted positions from dealer to dealer following an initial customer trade. In the words of Burnham (1991, 135): "[When hit with an incoming order, a currency dealer] seeks to restore his own equilibrium by going to another marketmaker or the broker market for a two-way price. A game of 'hot potato' has begun.... It is this search process for a counterparty who is willing to accept a new currency position that accounts for a good deal of the volume in the foreign exchange market." Thus, the passing of unwanted positions is a consequence of dealer risk management. Under the asset approach, in contrast, volume is attributed to speculation.

Understanding the causes of high volume is not as important as understanding price determination, but it is still important. Three reasons come immediately to mind. First, misunderstanding the causes of high volume can lead to bad policy. Consider the issue of transaction taxes—an issue that has attracted much attention among exchange rate economists. Proponents of levying transaction taxes tend to associate high volume with excessive speculation. If instead much of this volume reflects dealer risk management, then a transaction tax would—unintentionally—impede that risk management. Second, high volume can impede order flow's information role. As suggested above and detailed in the next chapter, order flow conveys information. The precision of that information is a function of the

underlying causes of order flow. It is important to understand whether those causes contribute to, or detract from, informational precision. Third, misunderstanding the causes of order flow can lead to bad theory. The mere existence of the volume puzzle is an indication that the asset approach is not addressing key features of the FX market. The features it is missing may not be important, but to be confident that they are unimportant requires a tremendous leap of faith.

What about the big puzzles in exchange rate economics? Chapter 7 addresses this question directly. The three biggest puzzles are¹¹

1. the determination puzzle: Exchange rate movements are virtually unrelated to macroeconomic fundamentals (at least over periods of less than about two years);
2. the excess volatility puzzle: Exchange rates are excessively volatile relative to our best measures of fundamentals; and
3. the forward bias puzzle: Excess returns to speculating in foreign exchange are predictable and inexplicable.

The microstructure approach links these puzzles to one another through expectations formation—that is, how market participants form their expectations of future fundamentals. It makes this link without departing from the asset approach convention of rational expectations. Rather, the microstructure approach grounds expectations formation more directly in a richer, information-economic setting. The focus is on information *types* (such as public versus private) and *how* information maps into expectations (e.g., whether the aggregation of order flow “votes” is efficient).¹² The issues of information type and mapping to expectations are precisely where microstructure tools provide resolving power.

Chapter 7 addresses the three big puzzles and shows that the microstructure approach has already made empirical progress. Section 7.1 addresses the first puzzle; it reviews the work of Evans and Lyons (1999), who find that exchange rate movements can be explained—they are largely a function of order flow. Section 7.3 addresses the excess volatility puzzle by focusing on recent work on the sources of FX volatility (e.g., Killeen, Lyons, and Moore 2000a; Hau 1998; Jeanne and Rose 1999). Section 7.4 offers a microstructure-based explanation of the third puzzle—forward discount bias. It would be wrong for me to suggest that these three big puzzles have

been put to rest by the above-mentioned work, but progress is being made.¹³

1.5 Spanning the Micro-Macro Divide

As noted above, a core distinction between the microstructure approach and the asset approach is the information role of trades. Under the asset approach, trades play no role (macroeconomic information is publicly announced), whereas in microstructure models trades are the driving force. It is instructive to frame this distinction with a bird's-eye view of structural models used by empiricists within these two approaches.

Structural Models: Asset Approach

Equations of exchange rate determination within the asset approach take the form:

$$\Delta P_t = f(i, m, z) + \varepsilon_t, \quad (1.1)$$

where ΔP_t is the change in the nominal exchange rate over the period, typically one month. The driving variables in the function $f(i, m, z)$ include current and past values of home and foreign nominal interest rates i , money supply m , and other macro determinants, denoted here by z .¹⁴ Changes in these public-information variables are presumed to drive price without any role for order flow (though there is of course a role for demand; recall the distinction between order flow and demand in section 1.2). If any price effects from order flow should arise, they would be subsumed in the residual ε_t . Though logically coherent and intuitively appealing, a long literature documents that these macro determinants account for only a small portion (less than 10 percent) of the variation in floating exchange rates (see the surveys by Frankel and Rose 1995; Isard 1995; Taylor 1995).

Structural Models: Microstructure Approach

Within the microstructure approach, equations of exchange rate determination are derived from the optimization problem faced by the actual price setters (the dealers).¹⁵ These models are variations on

the following specification:

$$\Delta P_t = g(X, I, Z) + \varepsilon_t, \quad (1.2)$$

where now ΔP_t is the change in the nominal exchange rate between two transactions, versus the monthly frequency of the macro model in equation (1.1). The driving variables in the function $g(X, I, Z)$ include order flow X (signed so as to indicate direction), a measure of dealer net positions (or inventory) I , and other micro determinants, denoted by Z . It is interesting to note that the residual in this case is the mirror image of the residual in equation (1.1) in that it subsumes any price changes due to the public-information variables of the asset approach.

The key to spanning the micro-macro divide is the role of signed order flow X . Microstructure models predict a positive relation between signed order flow and price because order flow communicates nonpublic information, which can then be impounded in price. Empirical estimates of this relation between ΔP and X are uniformly positive and significant in securities markets generally (including stocks, bonds, and foreign exchange). It is noteworthy that these empirical estimates have been possible only a relatively short time: the switch to electronic trading means that we now have detailed records of order flows. What used to be a black box is no longer.

A Hybrid Approach

To establish the link between the micro and macro approaches, I investigate in chapter 7 equations with components from both approaches:

$$\Delta P_t = f(i, m, z) + g(X, I, Z) + \varepsilon_t. \quad (1.3)$$

These equations are estimable at frequencies corresponding to the asset approach through the use of time-aggregated measures of order flow X . The time-aggregated measures of X span much longer periods than those typically employed in empirical microstructure.

Estimates of this equation show that time-aggregated order flow has much more explanatory power than macro variables. In fact, chapter 7 shows that regressing daily changes in log DM/\$ rates on daily order flow produces an R^2 statistic greater than 60 percent.¹⁶ Figure 1.2 below provides a convenient summary of this explanatory power. The solid lines represent the spot rates of the DM and yen

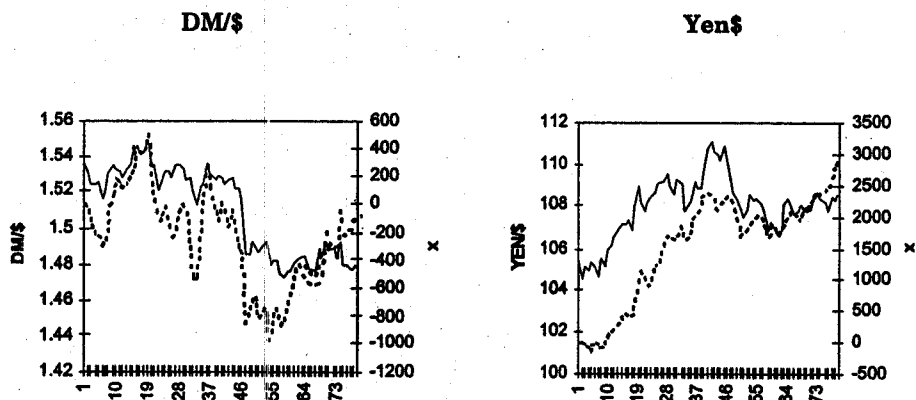


Figure 1.2

Four months of exchange rates (solid) and order flow (dashed). May 1–August 31, 1996.

against the dollar over the four-month sample of the Evans (1997) dataset (described in chapter 5). The dashed lines represent cumulative order flow for the respective currencies over the same period. Order flow, denoted by X , is the sum of signed trades over the sample period between foreign exchange dealers worldwide.¹⁷ Cumulative order flow and nominal exchange rate levels are strongly positively correlated (price increases with buying pressure). This result is intriguing. Order flow appears to matter for exchange rate determination, and the effect appears to be persistent (otherwise the exchange rate's level would reflect only concurrent or very recent order flow and not *cumulative* order flow). This persistence is an important property, one that I examine more closely in later chapters. For order flow to be helpful in resolving big exchange rate puzzles, its effects have to persist over horizons that match those puzzles (monthly, at a minimum).¹⁸

That order flow matters for exchange rate determination does not imply that order flow is the underlying cause of exchange rate movements. Order flow is a proximate cause. The underlying cause is information. How, specifically, can one identify the information that determines order flow? The notion of order flow as an intermediate link between information and price suggests several strategies for answering this question, which I touch on now and address further in later chapters (particularly in chapters 7 and 9; readers may find a quick look at figure 7.1 helpful at this juncture).

One strategy for linking order flow to underlying determinants starts by decomposing order flow. (That it can be decomposed is one of its nice properties.) In chapter 9, I test whether all parts of the aggregate order flow have the same price impact. They do not: the price impact of FX orders from financial institutions (e.g., mutual funds and hedge funds) is significantly higher than the price impact of orders from nonfinancial corporations. This suggests that order flow is not just undifferentiated demand. Rather, the orders of some participants are more informative than the orders of others. Analyzing order flow's parts gives us a view of this market's underlying information structure.

A second strategy for linking order flow to underlying determinants is based on the idea that order flow measures individuals' changing expectations. As a measure of expectations, it reflects a willingness to back one's beliefs with money—the backed-by-money expectational votes, if you will. This strategy corresponds to the following variation on equation (1.3):

$$\Delta P_t = f(z_t, z_{t+1}^e) + \varepsilon_t, \quad (1.4)$$

where z_t denotes current macro fundamentals (interest rates, money supplies, etc.) and z_{t+1}^e denotes expected future macro fundamentals. These expected fundamentals are not well captured by macro-econometric techniques: estimates are slow moving and imprecise. If order flow is serving as an expectation proxy, then it should forecast surprises in important macroeconomic variables (like interest rates). New order flow data sets that cover up to six years of FX trading provide enough statistical power to test this.

Notes

Chapter 1. Overview of the Microstructure Approach

1. Another approach in exchange rate economics—the “flow” approach—is a variant of the goods market approach, so I do not include it separately in my three-approach taxonomy. In addition to currency demand from goods flows, the flow approach includes currency demand from the other main category of a country’s balance of payments—the capital account. Like its goods market cousin, the flow approach does not typically model the exchange rate in a way consistent with financial market efficiency. I return to the parallels between the flow and microstructure approaches in chapter 7.
2. The field of macroeconomics is also moving in the direction of relaxing these three assumptions. See, for example, the literatures on asymmetric information (e.g., Gordon and Bovenberg 1996; Morris and Shin 2000), non-representative-agent macro (e.g., Caballero, Engel, and Haltiwanger 1997), microfoundations of monetary policy (e.g., Rotemberg and Woodford 1997), and new open-economy macro (Obstfeld and Rogoff 1996).
3. I continue with this three-point characterization in chapter 4 (which reviews microstructure theory) by providing model summaries in three parts: Information, Players, and Institutions.
4. Markets with limit order books include the Paris and Hong Kong stock exchanges, both of which are operated electronically. Chapter 3 provides more detail along these lines.
5. That dealers learn only from order flow is too extreme. It arises in standard microstructure models because these models assume that all information is private. Macro models go to the other extreme, assuming all information is public. I return to this in chapter 7, where I present an empirical model that admits both public and private information.
6. My own view is that this central question—How does altering the trading mechanism alter price?—has unwittingly narrowed the scope of questions to which microstructure tools have been applied. I return to this issue in section 3.4, after laying more groundwork.
7. Regarding spreads, let me communicate an experience that may speak to the reader. I recall years ago presenting a paper on exchange rates that was firmly embedded in

the macro-orientation of the asset approach. Someone in the audience asked me a question about bid-ask spreads. What went through my mind—though not my lips—was “I couldn’t care less about bid-ask spreads.” To me, at the time, bid-ask spreads were simply a nuisance parameter, bad manners next to an otherwise elegant approach. At the time, spreads meant microstructure to me, and microstructure meant spreads. I no longer subscribe to this view.

8. Walrasian-style mechanisms do exist in real-world financial markets; they are often used to open trading (see, e.g., work on the pre-opening of the Paris Bourse by Biais, Hillion, and Spatt 1999). Indicative orders are collected for a period before actual trading begins, and these orders are used to determine the opening price (the orders become executable at the opening, but typically can be retracted before the opening).

9. Actual orders come in different types, which I cover in chapter 3.

10. Andersen and Bollerslev (1997) establish another link between microstructure and lower frequency relevance. They show that forecasts of low-frequency volatility are more precise when based on high-frequency data.

11. Within international finance more broadly, there are four main puzzles, the three listed above plus the “home bias” puzzle, which is that investors under-invest internationally. I do not include the home bias puzzle above because it is not clear it stems from the exchange rate, whereas the other three puzzles directly involve the exchange rate. Nevertheless, microstructure tools have already proven valuable for addressing home bias (e.g., the trading model of Brennan and Cao 1997 and the empirical results of Kang and Stulz 1997, among others).

These three exchange rate puzzles have analogs in other markets. For equities, papers recognizing the three puzzles include Roll 1988, Shiller 1981, and Mehra and Prescott 1985, respectively. (However, the equity-market version of the forward bias puzzle—the so-called equity premium puzzle—is a much looser analog than the other two: the large risk premium on equity is rather stable over time and remains positive, whereas the large risk premium in FX changes over time, including frequent changes in sign.) Microstructure tools are just beginning to be applied to those major equity puzzles (see, for example, Easley, Hvidkjaer, and O’Hara 1999).

12. Examples of information that needs to be aggregated by the FX market include information about differential interpretation of news, about changing institutional risk tolerance, and about changing hedging demands, among others (reviewed in chapter 2).

13. Of course, the microstructure approach also has its drawbacks (e.g., lack of publicly available data over long periods). I consider those drawbacks in later chapters.

14. The precise list of determinants depends on which model within the larger asset approach is selected. Here our interest is simply a broad-brush contrast between the asset and microstructure approaches. I return to precise specifications of the asset approach in chapters 6 and 7.

15. Work using structural models includes Glosten and Harris (1988), Madhavan and Smidt (1991), and Foster and Viswanathan (1993), all of which address the NYSE; structural models in a multiple-dealer setting include Snell and Tonks (1995) for stocks, Lyons (1995) for currencies, and Vitale (1998) for bonds.

16. I use the notation “DM/\$” here because I am referring specifically to the value of an exchange rate, which is quoted in the marketplace as the deutschemark price per

dollar. When referring in general terms to an FX market, practitioners typically list the dollar first: orally, they refer to this market as "dollar-mark," typically written as the "\$/DM market," or simply as "\$/DM" (the Bank for International Settlements also follows this dollar-first convention in its FX market surveys; see section 3.2). In this book, I remain true to these differing conventions. When describing an actual *rate*, precision requires me to write it as it is traded (e.g., DM/\$, yen/\$, and \$/£). When referring in general terms to a particular *market*, I always list the dollar first (\$/DM, \$/yen, and \$/£). Finally, when I use the symbol P in equations to denote the exchange rate as a price, P always denotes the dollar price of the other currency (\$/other).

17. Because the Evans (1997) data set does not include the size of every trade, this measure of order flow is in fact the *number* of buys minus sells. That is, if a dealer initiates a trade against another dealer's DM/\$ quote, and that trade is a dollar purchase (sale), then order flow is +1 (-1). These are cumulated across dealers over each 24-hour trading day (weekend trading—which is minimal—is included in Monday).

18. Readers familiar with the concept of co-integration will recognize that it offers a natural means of testing for a long-run relationship. In chapter 7, I present evidence that cumulative order flow and the level of the exchange rate are indeed cointegrated (i.e., the relationship between order flow and price is not limited to high frequencies). I also present models in chapter 7 that show why a long-run relationship of this kind is what one should expect.