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# Introduction

Jeffrey A. Frankel, Giampaolo Galli,  
and Alberto Giovannini

## Why the Need for Microstructure?

Exchange rate economics has made progress since the start of the generalized floating regime in 1973. Much research has appeared, explaining important phenomena in the behavior of exchange rates, and using an ever larger set of data to test such explanations. Research in recent years has even refined our theoretical understanding, as well as the empirical analysis, of the dynamics of exchange rates within bands and the determinants of realignments.

The key theoretical insight of all recent research on exchange rates is the so-called asset market approach. The foreign exchange market is seen no longer as a market where the flow supply and demand over time determine the equilibrium price—as in the case of perishable agricultural goods—but as a market where price is determined by expectations of income that can be generated by holding assets denominated in a certain foreign currency.

The asset market approach was prompted by the observation that much of the fluctuation in foreign exchange rates is difficult to reconcile with the net flows of goods and capital that occur between countries. These fluctuations appear to be associated with political and economic news that, rather than affecting current flows, signals possible future changes in the value of the currency.

Jeffrey A. Frankel is a research associate of the National Bureau of Economic Research, where he is also director for International Finance and Macroeconomics. He is also professor of economics at the University of California, Berkeley, and senior fellow at the Institute for International Economics. Giampaolo Galli is chief economist of the Confederation of Italian Industry in Rome. When this book was written, he was head of the International Section of the Research Department of the Banca d'Italia. Alberto Giovannini is a research associate of the National Bureau of Economic Research, a research fellow of the Centre for Economic Policy Research, and senior adviser of Long Term Capital Management, L. P.

The asset market approach to exchange rates has produced a number of models that have proved useful in explaining and quantifying exchange rate movements. The first characteristic of these models is that they are macro models; that is, they are highly aggregated. They attempt to capture and make explicit all determinants of the demand for and supply of foreign exchange, including those that are quite outside the foreign exchange market *per se*. Given this general macro approach, the focus of the models is on financial asset markets, and therefore the emphasis is on the behavior of agents in these asset markets.

There is a tension between the all-encompassing macro approach and the need to highlight the dynamics of asset markets. How is this tension resolved? It is resolved with the adoption of simplifying assumptions on asset markets, not uncommon in the finance literature, that it is useful to spell out.

Agents are identical. Information is perfect. Trading is costless. Although models that relax them exist, these assumptions can be thought of as the hallmark of the asset approach to macroeconomic models of exchange rates.<sup>1</sup>

The most important implication of these assumptions is the absence of an explanation for trading in assets. Thus, asset prices adjust every period (or every instant) to make agents content with the specified amount of assets in their portfolios. The adjustment of asset prices instantaneously reflects the arrival of new information in the marketplace, which all participants observe and interpret in the same way. Hence, the basic macro model of the exchange rate implies that all information pertaining to the current and future "fundamental" determinants of exchange rates, that is, all information that implies a current and/or future change in the return on assets denominated in different currencies, has an immediate and unambiguous effect on exchange rates.

Why study foreign exchange market microstructure? The interest in the working of the foreign exchange markets stems, at least in part, from some of the problems that the asset market macro models have displayed. The first is a *prima facie* contradiction between the models and reality. As noted, such models imply the absence of trading in assets. By contrast, one of the most important empirical facts about the foreign exchange market is the high volume of transactions that occur daily.<sup>2</sup> This inconsistency raises the question of whether the failure of the standard models to account for the volume of foreign

1. Of course, there are models that relax some of these assumptions. In particular, the perfect information assumption has been modified by authors who have studied the implications of imperfect information on the dynamics of monetary policy disturbances and authors who have studied the implications of asymmetric information or differences in prior beliefs.

2. The most recent triennial surveys of the foreign exchange markets were conducted in April 1995. The Bank of England (1995) announced a 60 percent increase in trading volume over the preceding three years, to the level of \$464 billion per day, in London; the Federal Reserve (1995) announced a 46 percent increase in volume in New York over the preceding three years, to the level of \$244 billion a day; and the Bank of Japan announced a 34.3 percent increase, to the level of \$161.4 billion, in Tokyo. The rate of increase in the major centers suggests that the current worldwide total is now in the vicinity of \$1,300 billion a day.

exchange transactions is a symptom of more serious problems, which might cause the lack of success at explaining other empirical phenomena on which researchers have concentrated.

These empirical phenomena include the behavior of excess returns in the foreign exchange market, the near total inability to predict exchange rates at short horizons, the inability to explain exchange rate movements even *ex post*, and the volatility of exchange rates. Standard models have been unable to explain these phenomena satisfactorily. In particular, asset pricing formulas implicit in the standard macro models seem, to date, to have fared poorly. For example, even though the existence of *ex ante* (i.e., forecastable) returns in the foreign exchange markets can in theory be explained as risk premia, the estimated returns in practice do not match what is predicted by asset pricing models based on the covariances among asset returns.

Furthermore, models seem to have a difficult time predicting future movements in exchange rates, suggesting that the information contained in the macro variables that are usually included in these models is of limited value. Finally, the volatility of these macro variables is generally smaller than the observed volatility of exchange rates, suggesting that—unless certain variables have especially strong effects on the spot exchange rate, as, for example, in the case of large overshooting in reaction to monetary disturbances—the information affecting exchange rate movements may be in part extraneous to the variables belonging to standard macroeconomic models. Theories of rational speculative bubbles and speculative attacks can in one sense account for the existence of excess volatility. But they are inherently unsatisfying in that they have nothing to say about how or when such bubbles and attacks get started or how they end.

It is only natural to ask whether these empirical problems of the standard exchange rate models—problems that stem from the assumptions on asset market equilibrium—might be solved if the structure of foreign exchange markets was to be specified in a more realistic fashion. This suggests a sort of micro-foundations approach to the foreign exchange markets, according to which a more satisfactory description of the foreign exchange market microstructure might help sort out some of the problems displayed by existing macro models.

Thus, we have established one reason to study foreign exchange market microstructure: the dissatisfaction with the empirical performance of standard models. While we find this motivation perfectly justified, and while a research project that attempts to fix the empirical problems mentioned above by adopting a richer description of the foreign exchange markets is interesting, we also believe that it is uncertain of success. The excess volatility problem and the difficulty of explaining *ex ante* rates of return also characterize other financial markets, such as, for example, the stock market. These markets, however, are organized in a way that differs significantly from the foreign exchange market and—unlike the foreign exchange market—are also subject to sub-

stantial regulation. The fact that similar empirical problems surface in markets having microstructures that differ in some ways makes it less likely that microstructure-based models will help explain away these empirical problems. On the other hand, the markets also have some similarities, which might hold the key to the problem.

A second reason to study market microstructure is only loosely related to the first. Like any market, the foreign exchange market is an interesting subject for research that attempts to identify the economic effects of its organization. This is, as opposed to the macroeconomic approach to foreign exchange microstructure, the microeconomic approach. The questions that are addressed with this approach include, for example, transparency, decentralization, the use of brokers (vs. marketmakers, vs. auctioneers), the location of trading, the efficiency of clearing of foreign exchange transactions, the relation between spot and derivative markets, and the importance of systemic risk in the market.

Both the ambitious macro approach to the foreign exchange market and the less ambitious but equally interesting micro approach represent good reasons to take stock of the state of research on the microstructure of the foreign exchange market. We believe that this field of research is beginning to grow tremendously, and we hope that a systematic look at its progress represents a useful addition to the literature on the foreign exchange market.

## The Chapters in Part I

The study of market microstructure has already produced at least one empirical regularity: the high intraday correlation of trading volume and volatility. As noted above, standard macroeconomic exchange rate models have little hope of explaining trading volume. Typically, they assume homogeneity of market participants. If all traders are the same, why should they trade? Of course, the standard models do not attempt to explain volume, considering it of little relevance except to those who make their living trading. But the observed correlation between volume and volatility suggests something of more general interest. Frankel and Froot (1990b), for example, find a high contemporaneous correlation between volume and volatility. They also find some evidence that dispersion of traders' forecasts, as reflected in survey data, Granger-causes both volume and volatility.

Given that trading volume seems to be relevant, there are two possible broad interpretations. One is that the market is processing information in an efficient way. Here, *efficient* is not to be understood as in the narrowest definition of the efficient markets hypothesis, where all traders are homogeneous, all information is instantly and fully reflected in the market price, and there are no profits to be made by trading. Rather, the microstructure perspective presupposes heterogeneity, is often based (more specifically) on asymmetric information, and allows that relatively more skillful or informed traders may succeed at the expense of those who are less skillful or less informed or of customers who must transact because they need to eliminate exposure ("liquidity traders"). The first

interpretation is simply that the market works to aggregate the individual bits of information available to each trader in a relatively rapid and smooth way. The chapters here shed light on a number of leading models of asymmetric information and the need for liquidity.

What constitutes information in the foreign exchange market is less obvious than it is in the equity market, where, for example, individual analysts have information on individual corporations. But, in much of the work in this book, orders from customers (especially nonfinancial corporations) constitute the bits of information to which some traders have access and others do not. Lyons (1995) follows the behavior of a particular marketmaker over the course of five days.<sup>3</sup> Lyons sheds some light on how bits of such information are processed, in the form of a statistically significant effect of orders received by traders on the prices at which they transact. (Earlier high-frequency data, e.g., Goodhart's thirteen weeks of "indicative quotes" obtained from the Reuters screen, did not include actual order flow or transaction prices [see Goodhart and Figliuoli 1991].)

The alternative interpretation, which often goes by the name *noise trading*, is that trading volume can itself generate "excessive volatility" (see, e.g., Tobin 1978; Goodhart 1988; De Long et al. 1990; and Frankel and Froot 1990a). In a well-known study of the stock market, French and Roll (1986) found that, when the market closed for election days or special shutdowns, volatility was not "stored up" to await the reopen of the market, even though the generation of new information continued. Rather, it seemed, volatility depended directly on trading volume, holding information flow constant. Global foreign exchange markets are open twenty-four hours a day, with the result that a repeat of the French-Roll experiment is not easy. One attempt is Ito and Roiley (1990). Some of the work in this volume may shed light on the French-Roll hypothesis that trading volume can gratuitously generate volatility.

Writing quite soon after the beginning of the floating-rate era, McKinnon (1976) claimed that exchange rates were excessively variable owing to a deficiency of stabilizing speculation. One would think that banks would be the best candidates to take open positions in a currency considered undervalued relative to fundamentals and to hold such positions for however many months it took to correct the "misalignment." Banks are reluctant, however, to take large positions overnight. Others confirm that, even though typical traders incur high exposure during the day, they try hard to close out their positions overnight (Fieleke 1981). Lyons (1995) finds evidence of an inventory effect during the course of the day in addition to the information effect: when the outstanding position is large, traders modify their bid and ask prices so as to discourage further exposure in that direction.

In chapter 1 of this volume, Philippe Jorion seeks to test one important mi-

3. More specifically, the data set consists of time-stamped quotes and trades, the marketmaker's indirect (brokered) trades, and the time-stamped prices and quantities for transactions mediated by a broker.

crostructure theory, that of Tauchen and Pitts (1983). The theory says that the correlation between trading volume and volatility should be positive when the source of trading volume is disagreement (heterogeneity of beliefs) and negative when volume is determined by the number of traders, owing to averaging over larger numbers (liquidity). He finds support for the theory in that the variance is observed to depend positively on volume and negatively on a time trend intended to reflect the steadily growing number of traders. He uses options prices to obtain a measure of the anticipated component of the variance, which has not previously been studied in this context.

Jorion also looks at the bid-ask spread, the standard measure of transactions costs. He confirms earlier findings (Glassman 1987; Bessembinder 1994) that the spread widens before weekends and holidays, supporting the liquidity effect. He also confirms earlier findings that the bid-ask spread depends positively on the variance but negatively on volume. (He, like Wei [1994], uses the option-implied volatility for this purpose. Glassman [1987], Boothe [1988], Bollerslev and Domowitz [1993], and Bollerslev and Melvin [1994] used GARCH models of the variance rather than the option-implied volatilities.)

The presumption here is that information is processed efficiently. At a time when beliefs are particularly heterogenous and therefore trading volume is particularly high, the presumption is that the market is responding to a rapid generation of information.

Chapter 2, by Hsieh and Kleidon, casts some doubt on the proposition that information is processed efficiently. The point of departure is a model by Admati and Pfleiderer. It features a crucial distinction between well-informed traders and liquidity traders, some of whom have some discretion as to when they trade and so seek to trade at a time when high volume drives down the cost of transaction (the liquidity effect on the bid-ask spread). Hsieh and Kleidon confirm the correlation of volume and volatility that the Admati-Pfleiderer model is designed to explain: there is a bunching of volume and volatility at both the open and the close in the foreign exchange market.

A deeper look, however, uncovers serious problems. First, the bid-ask spread is observed to go *up*, not down, at the open and the close, contradicting the notion that liquidity traders are deliberately bunching at these times to save on transactions costs. Second, at the close in London, when volume and volatility are high in that market, there is no detectable simultaneous effect in the open New York market. This seems to contradict existing models of asymmetric information, which presuppose a common knowledge of economic structure despite the existence of idiosyncratic information. If volatility is high in London because information relevant to the pound/dollar rate is coming out, then why shouldn't the same effect show up in the pound/dollar rate in the New York market?

Hsieh and Kleidon think that the answer lies in models where information is aggregated imperfectly and inventories are important. They take at their word traders who explain that, at morning open, they need to get a "feel" for the market, thus explaining the combination of high trading volume, high vola-

tivity, and high spreads in the morning. Toward evening close, traders are anxious to unload excess inventories, explaining the reappearance of the heightened volume, volatility, and spreads.

In chapter 3, Perraudin and Vitale build a theory that can explain why such a high percentage of trading volume takes place among dealers instead of with customers. They emphasize that, because the foreign exchange market is decentralized, order flow cannot be observed by everyone. This setup differs from most of the conventional microstructure literature, which was designed for transparent centralized markets such as the equity markets. Some foreign exchange traders acquire useful new information at intervals, in the form of orders from customers. Perraudin and Vitale model the trading process by means of which this information gets disseminated to the marketplace by dividing the interval into four stages. Those traders without information seek by their trading strategy at an early stage to tease out the information from those who have it. Informed traders in effect sell or rent private information to others. Whereas the prominent Glosten-Milgrom theory of microstructure says that traders should quote a wide spread when dealing with someone whom they believe to be better informed so as not to be “taken in,” the Perraudin-Vitale theory explains why traders would want to quote a narrow spread in such a case. They want to get the order so that they can derive information that will be useful at the next stage of trading.

One needs to test such theories of asymmetric information. The Jorion and Hsieh-Kleidon chapters gave us somewhat conflicting verdicts: the first more supportive of some theories of optimization subject to asymmetric information and the second less supportive. In chapter 4, Goodhart, Ito, and Payne suggest that a good deal of skepticism is warranted regarding such tests because they are based on “indicative quotes,” that is, the bid and ask quotes that are posted to all potential customers. Traders usually quote better prices to each other when they transact. Goodhart and his coauthors use data from a new trading system, the Reuters 2000–2, to compare actual transactions prices with the indicative quotes (“FXFX”). They find that movements in the two are very close, with the result that for some purposes either series can be used. But the behavior of the high-low spread in the Reuters 2000–2 data is quite different from behavior of the FXFX bid and ask quotes. In other words, one should not mistake the publicly posted bid and ask prices for the prices at which foreign exchange traders trade with each other.

Fortunately, Richard Lyons’s data set constitutes direct observation of trader behavior. It contains the time-stamped transaction prices and quantities at which his trader traded in the New York mark/dollar market. In chapter 5, Lyons confirms the existence of both an effect of the dealer’s inventory on transactions prices and an effect of a dummy variable indicating whether the trade was initiated by the buyer or by the seller. These significant effects confirm, respectively, an asymmetric-information channel and an inventory-control channel.

The main contribution of the Lyons chapter, however, is to test an additional



effect on the transactions price: the effect of the quantity traded. Lyons seeks to shed light on two competing theories of why trading volume is sometimes very high. What he calls the “event uncertainty” view is that high trading volume indicates that information is being processed rapidly. What he calls the “hot potato” theory is that high trading volume indicates that little information is being processed; rather, liquidity-trader customers are placing orders with their brokers, who then unload their overextended positions on other traders, who continue to pass the exposure like a hot potato. (For this second theory, he cites the Admati-Pfleiderer model of discretionary liquidity traders, tested by Hsieh and Kleidon in chapter 2.) The evidence supports the hot potato view: the quantity traded has a significant effect only when the time between transactions is long. When the time between transactions is short, the quantity traded has no significant effect on the trader’s prices, suggesting that the trader views these orders as coming from liquidity traders rather than informed traders.

## The Chapters in Part II

Part II provides clues as to the potential relevance of microstructure for understanding exchange rate dynamics, especially in times of crisis. A widely reported phenomenon during the European currency crises of 1992 was the use of dynamic hedging strategies that caused increased sales of the currencies under attack following defensive interest rate hikes by central banks (G-10 1993). Sterling and, perhaps more intensely, the Swedish krona and the lira were reported to be subject to this source of pressure. The sales were undertaken by the institutions that needed to hedge short positions in put options on these currencies.

Standard assumptions of macroeconomic models (in particular, gross substitutability among assets) make it difficult to understand how interest rate hikes could intensify pressure on a currency. The debate regarding the European Monetary System (EMS) crises of 1992 and 1993 has pointed to the possibility that large interest rate hikes aggravate domestic economic conditions (especially where large debt overhangs are a problem), thus inducing markets to expect very low interest rates in the future and weakening the currency.

While “wrong” own-price effects are not unknown to macroeconomists, it should be noted that the economics of dynamic hedging is not related to expectations about the future evolution of exchange rates or other asset prices: as is well known, arbitrage considerations alone (plus the Wiener process assumption on the underlying asset) are required for deriving the most commonly used formulas for option prices and delta hedging. The issue is instead closely related to so-called stop-loss and portfolio-insurance strategies, which have been extensively analyzed after the stock market crash of 1987 in the Brady Commission (1988) report and in subsequent professional literature. “Portfolio insurance” (the behavior that results from aggregating the customer, who holds a put option, and the bank, which hedges its short option position) is a positive

feedback strategy (buy high and sell low): hence it implies unconventional own-price derivatives.

The added twist in the case of delta hedging on currencies analyzed in chapter 6 by Garber and Spencer is the extension of unconventional signs to the interest rate effect. The questions that can be asked are very much the same as those that have been asked in the stock market literature: to what extent these strategies are still efficient when the standard distributional assumptions are violated or there is a likely discontinuity in the market; what utility function may justify a demand for insurance that appears to be insensitive to relative prices; and whether mechanical trades are likely to have a major effect on market prices.

The first question seems to be particularly relevant in the case of pressures against a pegged exchange rate, when central banks' actions may significantly affect price dynamics. For instance, applying Krugman's (1991) smooth pasting principle to the behavior of the exchange rate within a band yields a formula that implies much smaller sales of the currency under attack than those implied by the standard Garman-Kohlhagen (1983) model. As to the second question, it should be recognized that the same bank whose option desk increases the short position in the weak currency to maintain a hedged option position may take the strategic view that the interest rate hike will reinforce the currency. It may therefore decide to reduce its aggregate short position in the weak currency rather than increasing it. The same may be done by the bank's customer who is holding a long option position. The point is that there may be a division of labor within large organizations but that the aggregate behavior of each institution may well conform to more standard economic assumptions.

Some recent microstructure literature suggests reasons why mechanical selling pressure by hedgers may instead be self-reinforcing: essentially, other, poorly informed agents infer from the price drop caused by the hedgers that an unknown negative shock has occurred and join the selling. According to Gennotte and Leland (1990), the price effects of this mechanism might be quite dramatic, even if trades undertaken by hedgers are a small proportion of total turnover. To avoid this problem, Grossman (1988) proposed to enforce publicity of the trades undertaken by certain categories of professional agents so that other agents may be able to distinguish the actions of hedgers from those that may be generated by genuine new information about economic fundamentals.

Considerable work is clearly required to assess the practical relevance of positive feedback trades in the foreign exchange markets, but data are virtually nonexistent. Central banks and international financial institutions could take the lead in this area.

The analysis of dynamic hedging suggests the possibility that different agents respond differently to the same information. The issue of heterogeneity across classes of operators is taken up explicitly in chapter 7. Bagliano, Beltratti, and Bertola analyze Italian statistics from the balance of payments and

banks' balance sheets and conclude that there is evidence of heterogeneous behavior on the eve of the September 1992 crisis. A few main facts stand out. The net (spot and forward) foreign currency position of the domestic banking system displays very small changes around zero throughout the entire year 1992. Nonbank residents instead remained net exporters of capital until August 1992, a trend that had started with the liberalization of capital movements and probably reflected gradual portfolio diversification. The pace of these outflows did not increase very much in the months preceding the devaluation. On the other hand, nonresidents continued to be net investors in lira-denominated assets. Within the nonbank domestic sector, households seem to have taken positions against the lira, while the evidence on firms is mixed: some seem to have increased their foreign currency liabilities, especially with domestic banks, while others increased their foreign currency assets.

As argued above, some sort of heterogeneity, such as dispersion of beliefs, is essential to understand why trading occurs in any asset market. The interesting suggestion of this chapter is that there are sources of heterogeneity other than heterogeneity of beliefs—linked to risk aversion, need for liquidity, and asset preferences—that may be important in determining the direction and intensity of trading by different agents. Formal or informal regulatory constraints, especially on banks, may also be an important factor. Relaxing the representative agent assumption considerably complicates the analysis, but it may in some cases usefully complement the standard tools of macroeconomic analysis.

While the relevance of microstructure analysis for exchange rate dynamics is not yet established, it is clear that macroeconomic tools alone provide unsatisfactory explanations, except possibly over long time horizons. This point is stated with particular clarity by Flood and Taylor in chapter 8. The authors carefully review the very large body of evidence on major exchange rate models: purchasing power parity, monetary models, and sticky-price, equilibrium, and portfolio-balance models. Although at one time or another each of these models has found some support in the empirical literature, the overall picture is that, for industrial countries during normal times (excluding periods of hyperinflation), conventional macro fundamental models are incapable of explaining the greater proportion of the variation in nominal exchange rates. In spite of the very large literature that followed the seminal paper by Meese and Rogoff (1983), beating the random walk still remains the standard metric by which to judge empirical exchange rate models. Improvements over the random walk have been slight and generally not statistically significant. This is true whether actual or predicted values of future explanatory variables are used in the forecasting equations of macro models.

Even for the real exchange rate, it is difficult to beat a random walk model on conventional data sets, which is often taken as evidence against purchasing power parity. Permanent real demand and supply shocks may in principle account for the random walk property of real exchange rates; this is the key point emphasized in equilibrium models. There is, however, very little evidence that

the large movements that have been observed in real exchange rates can be explained by real shocks. Moreover, according to equilibrium models, real exchange rates should be largely invariant to the choice of monetary regimes, a hypothesis that seems to be strongly contradicted by the evidence. In particular, variability of real exchange rates is much larger in floating exchange rate regimes without there generally being greater variability in macroeconomic fundamentals (Frankel and Rose 1995).

Nevertheless, some recent evidence suggests that purchasing power parity has some explanatory power over very long time horizons or across very diverse countries. Flood and Taylor add their own piece of evidence to this proposition by pooling cross-sectional and averaged time-series data on twenty-two countries and twenty years. The interpretation of their results is that simple macro fundamentals have explanatory power with respect to nominal exchange rate movements over five years or more. They conclude that further attempts to provide explanations of short-term exchange rate movements based solely on macro fundamentals may not prove successful, although the macro fundamentals are important in setting the parameters within which the exchange rate moves in the short run.

The last contribution of this book, chapter 9, takes it largely for granted that macroeconomic analysis is only part of the story: it assumes that there can be self-fulfilling speculative attacks against a pegged exchange rate or, at the very least, that crises can occur even among countries with an extremely high degree of convergence in economic policies and conditions. The belief of Eichengreen, Rose, and Wyplosz in this proposition is so strong as to lead them to state that a European monetary union will not be achieved unless the Maastricht Treaty is amended in one of the following ways. Either it is decided to eliminate the transitory stage (in which exchange rates are required by the treaty to remain within "normal" fluctuations margins), or capital controls are imposed to maintain the required stability in exchange rates during the transition. Their specific proposal is to introduce a non-interest-bearing deposit on bank lending to nonresidents. Bank lending is seen as the indispensable raw material for speculating against a currency.

To support their proposal, the authors provide evidence on the effectiveness of capital controls. Interestingly, their statistical tests tend to show that, while capital controls allow countries some greater degree of economic policy autonomy, they do not significantly contribute to reducing the costs of resisting speculative attacks. Reserve loss and interest rate hikes by central banks do not appear to be smaller when exchange controls are in place. This proposition may help reconcile two widely held views: one claiming that the EMS survived in the 1980s because of capital controls (e.g., Rogoff 1985; Wyplosz 1986; and Giovannini 1989) and another arguing that capital controls are usually ineffective because they can be evaded (e.g., Gros and Thygesen 1992; and Dini 1994). The underlying microeconomics—the key concern for this book—are quite clear. Since the legal risks of evading the controls are essentially a fixed

cost, agents, may be willing to forgo the (moderate) benefits of portfolio diversification in normal times, but the incentive to evade becomes very high when a large devaluation is perceived as imminent.

### **An Agenda for Future Research**

Our brief survey, together with a more careful reading of the papers and comments in this collection, provides an argument as to the importance of research on the microstructure of foreign exchange markets. The increasing availability of tick-by-tick data in the spot foreign exchange markets and in the various derivative markets (forward, swaps, options, etc.) yields an inexhaustible source of evidence against which theories can be tested. The literature on the microstructure of foreign exchange markets is bound to grow significantly in the near future. We conclude this introductory chapter by discussing the directions in which this literature is likely to embark.

This research is newborn. It has a long way to go before it can claim to produce a model of exchange rate determination. After realistic models of dealer behavior are constructed, the next step would have to be letting such dealers interact in the marketplace, in order to derive a central tendency to the torrent of bid and offer quotes and transaction prices in which each individual deals. That central tendency would be what in macroeconomic models we call *the* market-clearing exchange rate. Then the interaction among dealers would have to be embedded in the larger universe of borrowers, lenders, importers, and exporters who play a role in the foreign exchange market so that economic fundamentals could ultimately be brought back in. This is a very tall order.

Even a superficial reading of the papers in this collection should convince one of the difficulty of constructing a general equilibrium model of the exchange rate. A successful combination of microstructure theory and macroeconomic theory appears to be out of reach at this stage. From one standpoint, however, this should not be a total loss. Information on macroeconomic aggregates like monetary aggregates, gross domestic product, the balance of payments, and the components of aggregate demand arrive with a frequency that is much lower than the frequency of trading in foreign exchange markets and is affected by significant statistical errors. Information about most prices of manufactured goods and services is affected by even larger statistical errors. It is perhaps no surprise that these variables have little to do with foreign exchange markets and the short-run determination of exchange rates. The relation between these variables and exchange rates is also not very reliable in the long run. For these reasons, a theory that forces a tight link between macroeconomic prices and quantities is perhaps not especially needed.

By contrast, there are a number of important questions, confined to the working of the foreign exchange market, that we find particularly intriguing. At a minimum, the study of microstructure should provide insight into the implications of the organization of the market—and in particular its decentral-

ized nature—on the volume of trade, the determination of bid-ask spreads, and perhaps the volatility of prices.

In addition, theoretical work could help understand the behavior of foreign exchange dealers and their interaction. These models can help assess the optimality of trading techniques like stop-loss orders (Krugman and Miller 1993), “chartism” or “technical analysis” (Allen and Taylor 1989; Frankel and Froot 1990a, 1990b; Schulmeister 1987, 1988; Goodhart 1988; and Goodman 1979), and “support levels” (De Grauwe and Decupere 1992). They could ultimately describe short-run price dynamics and improve our understanding of concepts such as speculative bubbles and speculative attacks. In the international finance literature, these concepts are burdened with a considerable amount of implicit theorizing. Speculative bubbles are often taken to be the deviations of exchange rates from fundamental macro models; speculative attacks are viewed as accelerating movements in exchange rates in anticipation of large changes in underlying macroeconomic variables. Research on market microstructure can give new and more useful meaning to these ideas.

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## Trading Volume, Asymmetric Information, the Bid, and the Ask

