The Microstructure Approach to Exchange Rates

Chapter 5, Section 1: A Review of Transactions Data Sets

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Chapter 5: Empirical Frameworks

This chapter covers key topics of empirical interest in FX microstructure research. Order flow features prominently, as it does in later chapters that cover work that is more macro-oriented. This is because, as we have seen, order flow plays a crucial role in microstructure models. The chapter begins with a survey of data sets—recent advances in available FX data have opened new doors for empiricists. Then I introduce the main empirical approaches within the field of microstructure, and how they are applied in FX. The closing sections review important empirical results. In particular, I present results bearing on central questions from the previous theory chapter such as "Does FX order flow convey private information?" Confirming empirical evidence opens the door to the use of information models in answering this question. Another key question is "Does incomplete risk sharing affect exchange rates?" Confirming evidence here opens the door to using inventory models as well.

For perspective, consider how the data available for research in FX microstructure have evolved over the last twenty years. The earliest work used futures data since those data are available at high frequencies (Grammatikos and Saunders 1986, and later Jorion 1996.) In FX, however, the futures market is much smaller than the spot market; it is unlikely that a significant share of price determination occurs there (Dumas 1996). Moreover, early futures data sets did not have sufficient granularity to capture agent heterogeneity, a hallmark of the microstructure approach. Work on the spot market itself grew in the early 1990s with the availability of quotes on an intraday basis (specifically, the indicative

quotes from Reuters called FXFX).[1] These quotes provide a quite accurate picture of price dynamics. More importantly, they also speak to heterogeneity issues since the names and locations of the quoting banks are available. Thus, a number of interesting questions could be addressed that earlier data did not permit. The FXFX data did not, however, leave much room for direct testing of theory since they provide no measures of order flow (i.e., signed quantities traded). As we saw in the previous chapters, order flow's role in determining price is central to microstructure theory. As order-flow data became available, more direct tests became possible.[2]

More recently, empirical work in FX microstructure has entered an exciting new phase. Within the last few years, the availability of transaction data on a *market-wide* basis has opened important new terrain. In equity microstructure, an analogous opening of new empirical terrain occurred in the early 1990s when then NYSE made available its TORQ and TAQ databases (see Hasbrouck 1992 for more on these equity databases). These new FX data allow us to test theory and measure price determination in ways not possible only five years ago.

Nevertheless, it remains true that a significant drawback of the microstructure approach to exchange rates is availability of data. Decades of macro data are readily accessible to researchers from sources like Datastream or the IMF's *International Financial Statistics*. Not so of microstructure data. It is my hope that this book might stimulate further availability, by promoting awareness among official and private institutions of the importance of these data. For my part, I have collected some of the publicly available data sets described in the next section for downloading from my web site: www.haas.berkeley.edu/~lyons. The web site also provides information on how to obtain other data sets from various sources that charge fees for public use.

5.1 FX Data Sets

Before reviewing FX data sets in detail, it may be helpful to look at the bid picture. These data sets can be grouped into three basic types, corresponding to the three trade types reviewed in chapter 3:

(1) customer-dealer trades (roughly 1/3 of total trading in $/euro and $/yen)
(2) direct interdealer trades (roughly 1/3)
(3) brokered interdealer trades (roughly 1/3)

Let us consider each of these in turn. Data on customer-dealer trades have until recently been unavailable. These data are difficult to obtain because banks

[1] See Goodhart and Figliuoli (1991) and Bollerslev and Domowitz (1993), among many others. At the daily frequency, early work includes Glassman (1987), Bossaerts and Hillion (1991), and Wei (1994).

[2] See Lyons (1995), Goodhart, Ito, and Payne (1996), Yao (1998a), and Evans (1997). For an emerging experimental literature on markets organized like FX, see Flood, Huisman, Koedijk, and Mahieu (1999). For work on information networks embedded in FX trading technologies, see Zaheer and Zaheer (1995). For work on emerging-market currencies, see Carrera (1998), Galati (2000), and Becker et al. (2000).

consider their trades with customers as highly confidential. (Recall from chapter 3 that banks have no regulatory obligation to disclose this information.) One recent data set that makes progress on this front includes all the signed customer-dealer trades at a single bank (Fan and Lyons 2000). The sample period is seven years. The bank is one of the top three banks in the world in terms of trading volume, handling more than 10 percent of worldwide customer order flow in the major FX markets. Another available data set that relates customer-dealer trading is FXFX. As noted above, FXFX data are indicative quotes (no trades) that provide non-dealer customers with real-time information about current prices. It is believed that dealers provide these prices in order to attract customer business. Because the quotes are indicative—meaning they are not committed prices—they are in effect a form of advertising. These indicative quotes lag the interdealer market slightly, and spreads are roughly twice the size of interdealer spreads. Consequently, from a dealer's perspective, the price information the FXFX quotes convey is dominated by the firm prices observable from interdealer brokers.

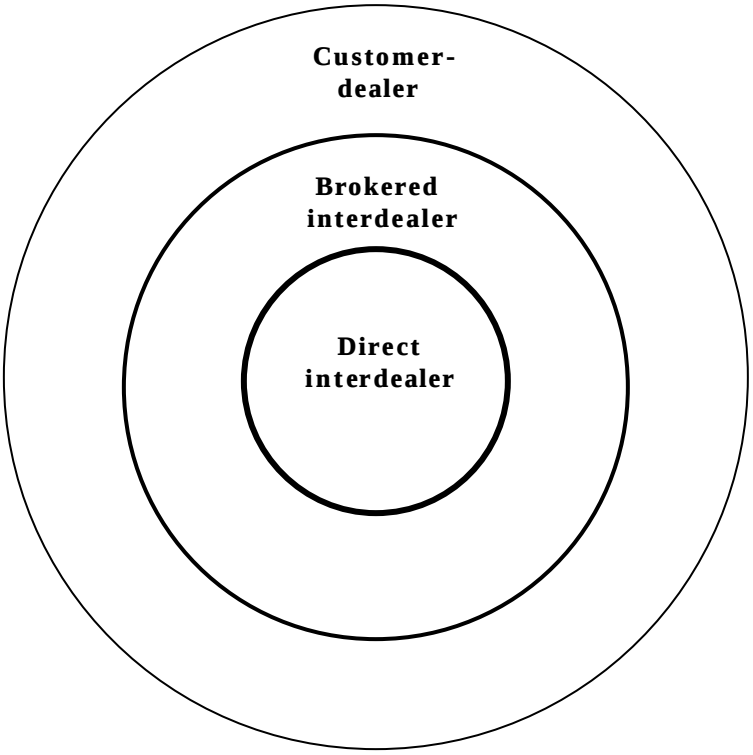
Data covering the second of the three categories—direct interdealer trades— were limited until recently to the trades of individual dealers (versus summarizing the trades of all dealers, or some large subset). In contrast to customer-dealer trades, data on direct interdealer trades are available because dealers trade directly with one another using a bilateral electronic trading system called Dealing 2000-1 (a Reuters product). Because quotes and trades are executed electronically, an electronic record is produced which can then be used for empirical analysis. In this case, researchers get their data directly from individual banks (the banks keep these electronic records on hand, temporarily, to help resolve trading disputes, etc.). Recently, Evans (1997) introduced a data set, obtained from Reuters, that includes all the interdealer trades executed through D2000-1 during four months in 1996. This data set spans a much larger slice of the total trading pie than any preceding it.

Brokered interdealer trading has also recently become measurable. The newfound accessibility of this data category corresponds to the shift in brokered trading from voice-based systems to electronic systems (see chapter 3 for details). Early data from brokered trades over the voice-based system was rather spotty (e.g., Lyons 1995). More recently, data sets have emerged from the records of the newer electronic brokers (e.g., Ito et al. 1996, Goodhart and Payne 1996, Killeen et al. 2000a). The main electronic brokers in the major spot markets are EBS and Dealing 2000-2. (Dealing 2000-2 is another Reuters product, and differs from Dealing 2000-1 in that 2000-1 is for direct interdealer trading, whereas 2000-2 is for brokered interdealer trading.) These electronic-broker data have the advantage that they reflect the activities of multiple dealers who are trading simultaneously. At present, however, the available data sets do not span the full brokered-interdealer segment because they reflect only the trading on either Dealing 2000-2 or EBS, but not both.

With this as background, here is a model for organizing one's thinking regarding available data. The model is composed of three concentric rings, shown below in Figure 5.1.

Figure 5.1

The Three Data Groupings



The inner ring represents direct interdealer trading, the most liquid part of the market. Dealing 2000-1 data is from this inner ring. The middle ring contains brokered interdealer trading. EBS and D2000-2 data are from this middle ring. The outer ring represents customer-dealer trading. Data from this ring come directly from banks' own order-flow records.[3]

5.1.A The Inner Ring: Direct Interdealer Transactions and D2000-1

Data set 1: Lyons (1995)

The Lyons data set, like others from this inner ring of the market, comes from Dealing 2000-1 trading records. For direct interdealer trading the Dealing 2000-1 system dominates the market: it is believed to account for about 90% of the

[3] Let me offer the addresses of two web sites that are valuable for obtaining more information on the systems that produce the data. The first web site covers the Reuters dealing systems, D2000-1 and D2000-2: www.reuters.com/transactions/tran00m.htm. The second web site covers the EBS system used for brokered interdealer trading: www.ebsp.com.

world's direct interdealer volume.[4] Trades on this system take the form of electronic bilateral conversations. The conversation is initiated when one dealer calls another dealer on the system asking for a quote. Users of the system are expected to provide a fast quote with a tight spread, which is in turn accepted or declined quickly (i.e., within seconds). Acceptance of a quote constitutes a trade.

The Lyons data set chronicles the activity of a dealer in the $/DM market at a major New York investment bank. The sample spans the five trading days over the week August 3-7, 1992 (from 8:30 A.M. to on average 1:30 P.M., Eastern Standard Time). These data come from the bank's own dealing records from the Dealing 2000-1 system. This dealer uses Dealing 2000-1 for more than 99% of his non-brokered interdealer trades.

Each record from the Dealing 2000-1 system includes the first 5 of the following 7 variables. The last two are included only if a trade takes place:

(1) a time stamp (to the minute)
(2) which of the two dealers is requesting the quote
(3) the quote quantity
(4) the bid quote
(5) the ask quote
(6) the quantity traded
(7) the transaction price.

Note that these records provide firm bilateral quotes rather than just transaction prices. They also identify which counterparty is the aggressor. As such, they allow one to measure signed order flow precisely (rather than simply unsigned trading volume). Finally, these records also include firm bilateral quotes that do not generate a trade. These non-dealt quotes account for roughly 80% of all quotes over the week.

In addition to these direct interdealer records from D2000-1, the Lyons data set also includes data from the dealer's position sheets. These sheets include all his trades (i.e., in addition to his direct trades with dealers, they include his trades with customers and his brokered trades with dealers). Because the position sheets include all transactions, they provide an exact measure of the dealer's position through time. For every trade these sheets provide:

(1) the signed quantity traded
(2) the transaction price
(3) the trade type: direct, brokered, or customer.
(4) the counterparty name

Note that the bid/ask quotes at the time of the transaction are not included on the position sheets. This part of the data set includes all 1720 of the dealer's transactions over the week-long sample, amounting to $7 billion, or $1.4 billion per day on average.

[4] Though in number, fewer than 90% of the world's dealers in major spot markets use the Dealing 2000-1 system, a higher percentage of the dollar value goes through the system because the most active dealers use the system quite intensively.

The following two figures help make these data more concrete. Figure 5.2 provides an example of a Dealing 2000-1 communication, with details provided in the notes to the figure. Figure 5.3 provides a diagram of the data flow from the 2000-1 communications through time. (I do not include a figure with the position sheet's structure here because that was presented in chapter 3—Table 3.1.)

Figure 5.2

Example of Dealing 2000-1 Communication

```
From CODE    FULL NAME HERE   *1250GMT  030892  */1080
Our Terminal: CODE   Our user: DMK
        SP DMK 10
# 8891
        BUY

# 10 MIO AGREED
# VAL 6AUG92
# MY DMK TO FULL NAME HERE
# TO CONFIRM AT 1.5891 I SELL 10 MIO USD
#
        TO CONFIRM AT 1.5891 I SELL 10 MIO USD
        VAL 6AUG92
        MY USD TO FULL NAME HERE AC 0-00-00000
        THKS N BIFN
#
#       #END LOCAL#
#
##WRAP UP BY DMK DAMK 1250GMT 3AUG92
#END#
```

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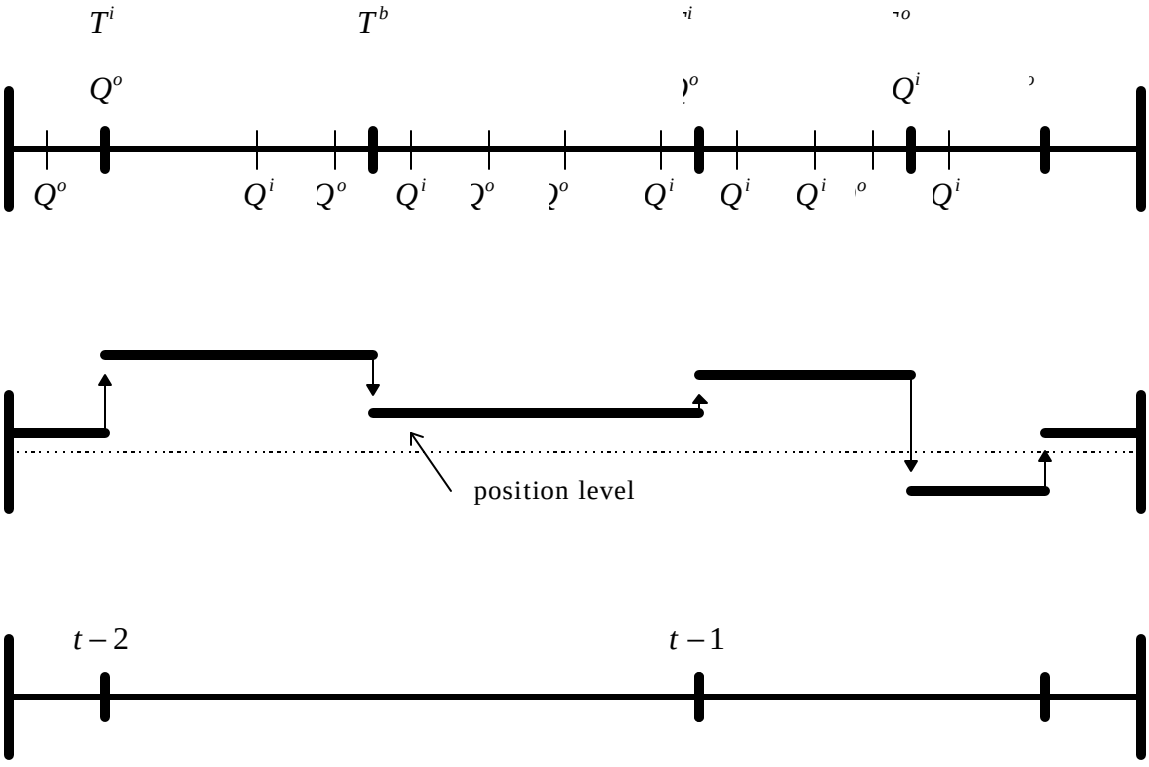
* The opening word “From” establishes this as an incoming quote request (outgoing quote requests begin with “To”); this information is crucial for signing trades. The caller's four-digit code and institution name follow; “GMT” denoted Greenwich Mean Time; the date follows, with the day listed first; the “1080” at the end of line one is simply a record number. “SP DMK 10” identifies this as a request for a spot DM/$ quote for up to $10 million; “8891” denotes a bid of 88 and an offer of 91. Only the last two digits are quoted because it involves fewer keystrokes; dealers are well aware of the first digits of the price—sometimes called the “handle.” From the confirmation that follows, one can see that the earlier bid quote was in fact 1.5888 DM/$ and the offer quote was 1.5891 DM/$. The confirmation also provides the transaction price and verifies the transaction quantity; “THKS N BIFN” is shorthand for “thanks and bye for now.”

Figure 5.3

Diagram of data structure



Definitions: Q^o is an outgoing interdealer quote (i.e., a quote made) and, if the quote is hit, T^i is the incoming direct dealer trade. Q^i is an incoming interdealer quote (i.e., a quote received) and, if the quote is hit, T^o is the outgoing direct trade. T^b is a brokered interdealer trade. Brokered trades do not align vertically with a quote because the data for brokered trades in the Lyons (1995) data set come from the dealer position sheets, and the broker-advertised quotes at the time of the transaction are not recorded. " " appears whenever a trade occurs; "|" appears whenever a non-dealt quote occurs. The disjoint segment below the top time-line presents a hypothetical path of the dealer's position over the same interval; it changes with trades only. The time-line at the bottom clarifies the definition of "periods" within the Lyons (1995) analysis: incoming trades define an event, not all trades (that model is presented in chapter 5).

Data set 2: Yao (1998a)

The Yao data set is similar in its structure to that of Lyons but has two important advantages. Like Lyons', it includes the D2000-1 records and position sheets of a spot $/DM dealer who trades in New York. The two advantages over the Lyons data are that the Yao data set covers:

(1) 25 trading days (November 1 to December 8, 1995), and
(2) a dealer with substantial customer order flow.

The Yao data set thus covers five times the number of trading days. In terms of daily average volume, the Yao and Lyons dealers are similar: $1.5 billion versus $1.4 billion per day, respectively (note, though, that roughly three years separate these data, and the $/DM spot market grew in dollar terms by about 50% over these three years).

The more important difference between the two data sets is the composition of these trades; in particular, the extent to which the two dealers trade with non-dealer customers differs dramatically. About 14% of the Yao dealer's volume comes from customer trades, whereas less than 1% of the Lyons dealer's volume comes from customers. In this respect, the mix of trades executed by the Yao dealer is more representative of market averages (in 1995, roughly 25% of total trading was customer-dealer). The fact that the Yao dealer is from a commercial bank rather than an investment bank helps explain why his customer order flow is so much heavier: in spot FX, commercial banks tend to have a more natural customer base than investment banks.

Data set 3: Evans (1997)

The data set introduced by Evans (1997) covers direct interdealer trading over a four-month period (May 1 to August 31, 1996). It contains time-stamped tick-by-tick data on all transactions for nine currencies against the US dollar. These data were collected from the Dealing 2000-1 system via a customized feed at the Bank of England. Specifically, Reuters keeps a temporary archive of all conversations on the system to settle disputes, and this archive is the source of these data. For every D2000-1 transaction, the data set includes:

(1) a time-stamp
(2) the transaction price
(3) a bought or sold indicator (for signing the trade).

For confidentiality reasons, Reuters was unable to provide the identity of the trading partners. The following table lists the nine currencies covered and the number of transactions for each over the four-month period:

German Mark	257,398
Japanese Yen	152,238
Swiss Franc	67,985

British Pound	52,318
French Franc	20,553
Italian Lira	8,466
Belgian Franc	5,256
Dutch Guilder	3,646
Danish Krona	1,488

Several features of the data are noteworthy. First, they provide transaction information for the whole interbank market over the full 24-hour trading day. This contrasts with earlier transaction data sets covering individual dealers over some fraction of the trading day (Lyons 1995 and Yao 1998a). Such a comprehensive data set makes it possible, for the first time, to analyze order flow's role in price determination at the level of "the market." (Recall that roughly half of interdealer trading is direct, and, for the largest spot markets, roughly 90% of the world's direct interdealer transactions take place through the 2000-1 system.)

Second, these market-wide transactions data are not observed by individual FX dealers as they trade. Though dealers have access to their own transaction records, they do not have access to others' transactions on the system. These transactions data therefore represent a history of market activity that market participants can only infer indirectly (a kind of latent variable that *is* observed by the econometrician). This provides extra power for econometric analysis of how dealers learn about pressure for price adjustment.

Third, the data cover a relatively long time span (four months). This is important for two reasons. First, with a longer time span and multiple currencies the data set can address exchange-rate determination from more of an asset-pricing perspective than previously had been possible. Second, the longer time span permits estimation of intraday patterns in transaction activity with much more precision than is possible from other transaction data sets. Existing studies using the FXFX quote data have noted the importance of controlling for these intraday patterns when analyzing other features of the data [see, e.g., Baillie and Bollerslev (1991), Dacorogna et al. (1993), and Andersen and Bollerslev (1998)].

Against all these positive features one needs to acknowledge two drawbacks. First, unlike the Lyons and Yao data sets, the Evans data set does not include firm bilateral quotes communicated between dealers, but instead has only the transaction prices. This prevents direct observation of spreads. As such, the Evans data set does not help us understand the "search" process behind the trade. The fact that bilateral quotes typically do not generate a trade transaction is informative from the perspective of analyzing price discovery. (As noted above, in the Lyons data set, for example, roughly 80% of all bilateral quote requests over D2000-1 did not generate a trade.) The second drawback is that the Evans data set does not provide the inventory positions of the trading dealers. This precludes direct analysis of inventory control at the individual level. It also precludes estimation of the type of "structural" models of dealer behavior that I introduce in section 2 of this chapter.

5.1.B The Middle Ring: Brokered Interdealer Transactions and D2000-2

The second type of trading for which data sets are available is brokered interdealer trading. Like the Evans data set, these data sets cover the trading activity of multiple dealers.

Data set 4: Goodhart et al. (1996) and Payne (1999)

The first data set of this kind, introduced by Goodhart, Ito, and Payne (1996), covers only a single day and accounts for only a small fraction of daily trading volume. The authors' source was a screen from Dealing 2000-2, a system that at the time was relatively new to the market (June 1993). A later data set, used by Payne (1999), is also drawn from the Dealing 2000-2 system, but spans a longer period (one trading week), and represents a larger fraction of brokered interdealer trading.

Recall from chapter 3 that brokered interdealer trading involves prices that are advertised to dealers generally. Dealers have a choice of submitting a quote—typically on one side of the market only—or hitting the quote of another dealer. (Remember that brokers in the FX market are interdealer only; customers cannot trade on these prices, and cannot in general observe them since their access to screens is restricted by EBS and Reuters.)[5]

Data set 5: Killeen et al. (2000a, 2000b)

More recently, a new data set has appeared that includes two years of data from the larger of the two electronic interdealer brokers—EBS (at least, it is larger in the two largest FX markets, $/euro and $/yen). This data set includes, on a daily basis, all the order flow passing through the EBS system from January 1998 to December 1999. This is an important period because it spans both the year preceding the launch of the euro and the year following the launch. The first year of the sample includes order flow for $/DM, $/FF, and DM/FF. The second year includes order flow for $/euro. These order flow series are valuable for addressing hypotheses about the launch of the new currency.

The Third Ring: Customer-Dealer Trades and Indicative Quotes

Data set 6: Customer Orders Received by Banks (Fan and Lyons 2000)

This data set includes all the customer-dealer trades—signed according to the customer's direction—received by a single bank over a period of seven years

[5] Speaking of "electronic trading systems" without first separating direct and brokered trading can be quite misleading in terms of the information available to dealers while trading. The D2000-2 system, like EBS, competed with traditional voice-based brokerage, and now these systems dominate the FX brokerage business (the voice-based brokers have been driven out). Dealing 2000-1 is the electronic means for direct trading. In terms of information dissemination, though, electronic trading in these two different segments is very different: a communication over D2000-1 is strictly bilateral, whereas brokered trading communicates much more information to other dealers.

(1993-1999). That bank is among the top three banks in the world in terms of trading volume (handling more than 10 percent of worldwide customer order flow in the major FX markets).

Traditionally, banks have been reluctant to provide researchers access to this kind of data, given its proprietary nature. One reason the bank behind this data set was more accommodating is that the data are aggregated to daily totals (i.e., individual transactions are not available). These time-aggregated order flows are valuable for examining the link between order flows and lower-frequency price dynamics.

Because these order flows come from underlying customers, they provide a direct connection to the underlying sources of demand in the economy. The data set includes the $/yen market and the $/euro market (order flow for the euro before its launch is synthesized from its constituent currencies). These data are the basis for the material I present in chapter 9.

Data set 7: FXFX Indicative Quotes (Goodhart 1989)

As noted above, FXFX is a second type of data that relates to customer-dealer trading. These data are indicative quotes that provide customers (i.e., non-dealers) with real-time information about current prices. This source of data has many strengths. First, the data are available over long time periods—from the late 1980s to the present. Second, they are available for many currency pairs. Third, they are available on a tick-by-tick basis (typically with thousands of ticks per day in a major currency pair). Fourth, each quote is time-stamped to the second. Fifth, the bank that input each quote can be identified.

These data also has several drawbacks. First, and most important, these data do not include order flow—they are quotes only. This precludes direct testing of theory because order flow is central to the theory.[6] (Some authors have used the rate at which quotes arrive to proxy for trading volume—i.e., unsigned order flow—but the proxy is rather loose; see Goodhart et al. 1996 and Evans 1997; Hartmann 1998a, on the other hand, finds that quote arrival provides a good proxy for volume over longer horizons.) Second, the spreads in these indicative quotes tend to be clustered at specific spread sizes, while firm quotes in the market do not exhibit such clustering (see Goodhart et al. 1996 and Evans 1997). Third, a displayed indicative quote cannot be replaced with a new quote until 5 seconds have passed (Evans 1997). Fourth, the raw data are rather noisy (Zhou 1996), and even after the standard filter used in the literature has been applied (Dacorogna et al. 1993), significant outliers remain (Andersen et al. 2000).

Closing Thoughts

It is important to note that FX microstructure is evolving rapidly in terms of the available state-of-the-art data. In the future, sample lengths will surely be

[6] There is a large and important empirical body of work that is based on these FXFX data. My focus in this book, however, is order flow and its effects on price. Accordingly, work based on FXFX data does not figure as prominently here as it does in the literature. For a survey that includes much of this FXFX work, see Goodhart and O'Hara (1997)

extended, and I anticipate further integration of data from all three market-segments (direct interdealer, brokered interdealer, and customer-dealer).[7] Thus, the data sets above are perhaps best thought of as a guide to measurable variables and their sources. At present the customer-dealer segment is still thinly covered. This segment is important, though, because these trades represent the outside "shocks" to the interdealer trading at the market's core.

I chose in this section to present the FX data sets as they appear in the literature. This provides easy reference to additional detail in the corresponding papers. Another way to organize the data is according to **information sets**, that is, according to which participants have which data in real time, and how data that are not available in real time are disseminated. This would have been a much more difficult task. Consider, for example, the Evans (1997) data set that contains all the direct interdealer trading from the 2000-1 system. In that case, it is most appropriate to think of individual dealers as observing only part of those data, the part that corresponds to their own trading (both prices and order flow). But individual FX dealers do not observe these marketwide data in their entirety. And non-dealer customers do not observe any of these data. For the data sets on brokered interdealer trading (EBS and D2000-2), to organize the data according to information sets one would have to distinguish between the observability of transaction prices, and the observability of order flow. Recall from section 3.1 that while transaction prices from brokered trades are observable, the order-flow information that all dealers receive from these trades is noisy. Non-dealer customers do not in general observe these data. As for data on dealer trading with their customers, these data are quite bank-specific. Dealers at other banks do not observe them directly; other-bank dealers can only make inferences on the basis of a given dealer's behavior and any information gleaned from speaking to customers.

[7] A recently introduced data set—not summarized above—that makes progress in integrating data from multiple market segments is that in Bjonnes and Rime (2000).