Measuring and explaining liquidity on an electronic limit order book: evidence from Reuters D2000-2[1]

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Abstract

The conference presentation focused on recent results on dynamic trading patterns in limit order markets, primarily foreign exchange and money markets. Clear feedbacks are observed between liquidity, volatility and volume. These results suggest that any regulatory regime for market liquidity should appreciate these feedback rules, and treat liquidity risk as endogenously determined, rather than an exogenous process.

1. Introduction

Liquidity risk has emerged as one of the most significant risk factors in the global financial economy, being a significant contributor to several financial crises such as the 1987 stock market crash and the Russia crisis of 1998. In spite of the importance of liquidity for financial stability, academic understanding of liquidity is very limited. On a general level, liquidity facilitates trading, where a liquid market is one in which participants can trade desired amounts quickly, cheaply and without greatly affecting prices.

The objective of this presentation is to discuss how methodologies developed in the field of market microstructure can aid in understanding liquidity in a particular trading venue or market. The task of studying liquidity within this context is complicated by the fact that no single definition of liquidity exists. However, Kyle's (1985) three component classification of liquidity, covering tightness, depth and resilience, is well known, and serves as a useful starting point. Unfortunately, not only do most extant empirical studies of liquidity fail to fully explore Kyle's notions,[2] we feel that his concept of liquidity is limited in the sense that it only reflects a static picture of market conditions, and not the dynamic environment of modern financial markets. This is especially important in the study of financial stability where it is necessary to explicitly consider the evolution of liquidity over time, and the interdependence of liquidity with other market variables, eg prices. Given the importance of liquidity, any threat to liquidity supply has the potential for adverse economic implications.

Daníelsson and Payne (2002a) analyse the dynamics of liquidity using one week of transaction data for the USD/DEM spot rate on the Reuters D2000-2 system. The properties of this data set are extensively documented in Daníelsson and Payne (2002b).[3] Since the data are unusually detailed, containing information on all D2000-2 orders whether or not they were traded, while market participants only see a subset of the data, it is possible to analyse market dynamics which are beyond

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[2] Most empirical studies focus solely on tightness, ie spreads. There are many reasons for this. First, the inventory control and asymmetric information literature developed in the 1970s and 1980s gives clear predictions regarding the determination of bid-ask spreads; see eg Ho and Stoll (1983), Glosten and Milgrom (1985) and Easley and O'Hara (1987). Second, estimators of spread components were successfully developed based upon these theories; see eg Roll (1984), Stoll (1989) and Huang and Stoll (1997). Last, most microstructure databases contain little/no liquidity information outside the spread.

[3] Given the short temporal span of the data, the analysis is limited in the types of empirical analysis that can be conducted. For example, macro-level analysis of exchange rate determination is clearly not possible.

the scope of most other market microstructure studies, eg high-frequency order placement decisions. The study by Daníelsson and Payne (2002b) casts light on the strategic trading behaviour of market participants, and documents the resulting trading patterns. On a theoretical level, it argues that most of the observed results are consistent with asymmetric information theories.

Daníelsson and Saltoglu (2002) take advantage of the insights of Daníelsson and Payne (2002a) in their analysis of the recent Turkish financial crises, and find that market microstructure liquidity patterns played a key role in the evolution of the crises.

The key objective of the papers discussed above is the analysis of various aspects of liquidity. First, the determination of conditions when liquidity is supplied or demanded. Second, the impact of trading strategies on liquidity supply/demand. Third, to what extent changes in liquidity supply/demand and trading strategies help predict market crashes. Finally, what is the dynamic relation between liquidity, volatility, volume and financial crises.

2. Data and models

In recent years, electronic brokers have become increasingly important in inter-dealer FX trading. The data set used by Daníelsson and Payne (2002a) (DP) consists of one week of trading in the USD/DEM spot rate on the Reuters D2000-2 electronic broking system. The D2000-2 is one of the two main electronic brokers in the market, the other being EBS.

D2002 operates as a pure limit order market governed by rules of price and time priority. A D2002-2 screen displays to users the best limit buy and sell prices as well as quantities available at those prices and a record of recent transaction activity for up to six currency pairs. It is important to note that, unlike many other limit order markets, information about limit orders away from the best prices is not available to users, ie the order book is *closed*. In addition, orders are not allowed to "walk up the book". The data set used by DP contains all orders entered into the system, both limit orders and market orders, making it possible to construct the entire order book in real time. This enables DP to analyse the role of information and how traders form expectations and react to unexpected events in this type of limit order markets.

An example of these order books is given in Figures 1 and 2.

Figure 1

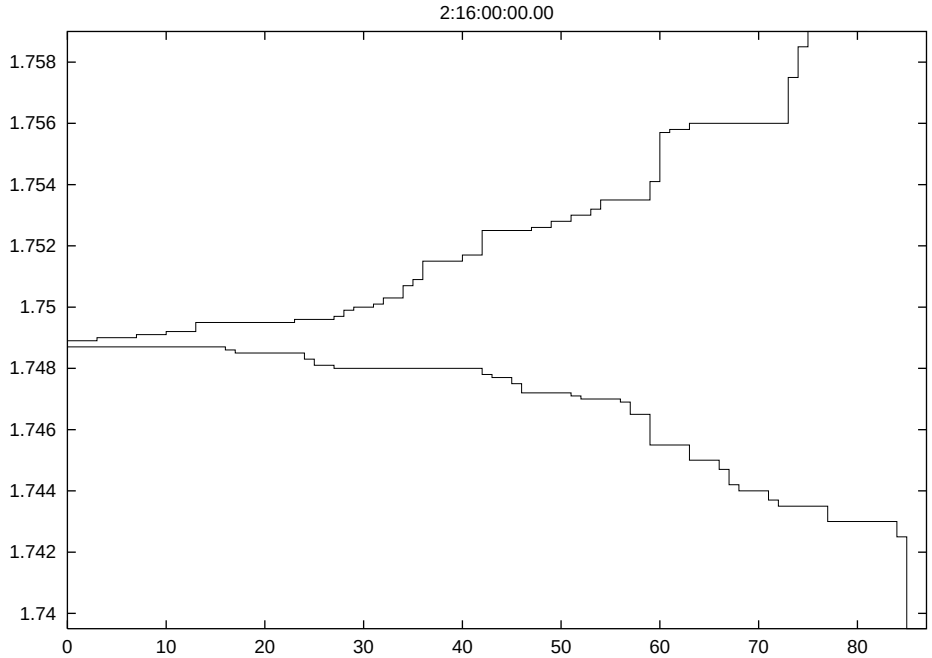

Figure 2

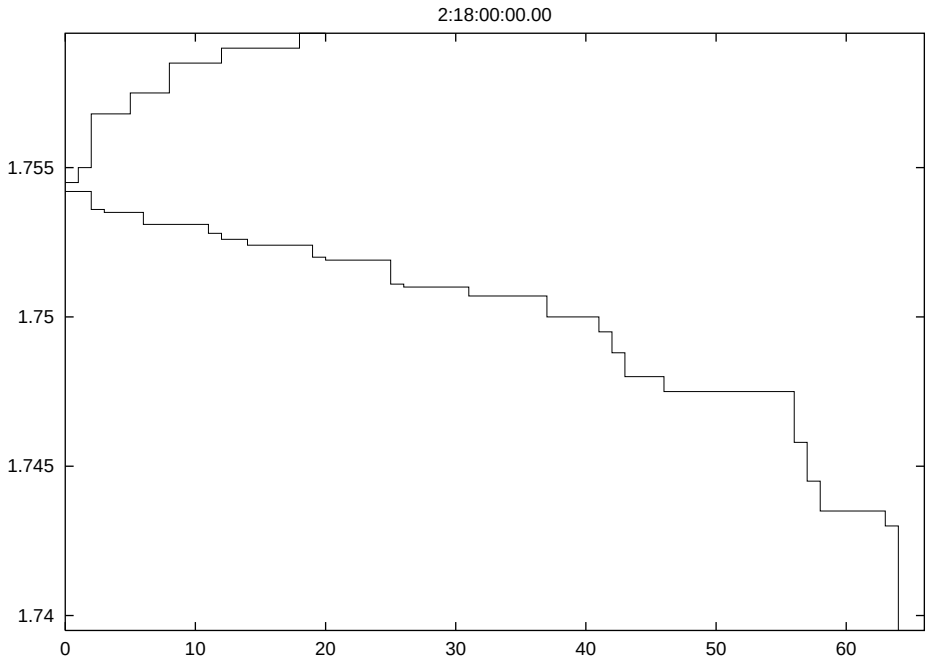

Figure 1 shows the order book at 4 pm on the second day of the sample; the best ask price is 1.749 DEM/USD with a spread of one pip (1/100 pfennig). There is about USD 80 million in the book on both the bid and ask side of the book, where the book is more or less symmetric. An interesting observation is a small amount in the book, given the overall volume in the FX markets. Indeed, on average USD 80 million enters the book each minute during peak trading times, and 80 million exits, via either trading or cancellations. This indicates that much volume sits outside the order book, ready to enter at a moment's notice. This is a key reason why DP suggest that it is important to consider the dynamic aspects of liquidity, both the dynamics of how the order book changes shape and the flow in and out of the book. The change in the order book shape is apparent in Figure 2, which shows the market two hours later. At this time the spreads are wider, and the order book contains less money, 20 million on the ask side, and 65 on the bid side. This is primarily because 6 pm is late in the day, and the trading day is beginning to wind up.

Since D2000-2 is only one of the two electronic brokers operating in the inter-dealer market, and we observe neither direct inter-dealer trading nor customer-dealer activity, we are not able to provide a picture of overall FX market activity. However, since the data set is unusually rich, DP are able to analyse the codetermination of liquidity, volatility and transaction activity in a given trading venue and the richness of the data set opens the possibility of studying high-frequency order placement decisions, something not possible with most other market microstructure data sets. They employ a variety of both event and calendar time techniques. For example, they study dynamic order placement patterns in event time by looking at both multiperiod transition matrices as well as the location of new limit orders in the order book. In calendar time, they consider vector autoregressions (VAR) where order entries, volatility and traded volume are all included, explicitly taking into account trader expectations and reactions to unexpected events.

Daníelsson and Saltoglu (2002) apply the methodology and insights from this study to analyse financial crises. The data set they use consists of all transactions on the Turkish overnight repo money market from January 2000 to March 2001. This sample includes two major financial crises. The Turkish money market is also an electronic limit order market just like the Reuters D2000-2 market. They find that interest rates are significantly correlated with order flow, spreads, realised volatility and trading imbalances. Furthermore, the interrelationship between those key variables changes fundamentally around crisis periods.

3. Empirical results

The results from Daníelsson and Payne (2002a) provide new insights into the interplay between liquidity, volatility and market activity. Taken in isolation, liquidity supply is found to be self-regulating, ie low extant liquidity leads to higher liquidity supply in the future, and conversely, abnormally high liquidity tends to be reduced in the future. Furthermore, liquidity supply temporally clusters on one side of the market and removal of liquidity at the front of one side of the book implies increased probability of seeing fresh liquidity at the front of the book and lower chances of seeing subsidiary liquidity supply on that side of the book.[4] These effects are time persistent.

However, by jointly analysing liquidity supply, volatility and volume, a different picture emerges. Liquidity, volatility and volume are interrelated, with strong feedbacks between those variables.

When focusing on order submission strategies, in times of uncertainty the relative number of limit orders vs market orders increases. While this might seem to imply that liquidity increases when markets are uncertain, this liquidity supply is poorly priced, thus spreads are high and depth low. Hence, we observe a positive relationship between risk and the price of liquidity. These results are reinforced by calendar time analysis using vector autoregressions. By focusing on volatility in particular, we find that when observing episodes of high volatility, liquidity is low, and conversely when volatility is low liquidity is high. Furthermore, these patterns are self-reinforcing. Similar evidence emerges from the study by Daníelsson and Saltoglu (2002) of the Turkish financial crises, which were characterised by extreme movements in interest rates. They run a similar vector autoregression to Daníelsson and Payne (2002a), but with daily data. They find that there are significant positive feedbacks between realised volatility, liquidity and interest rate changes - exactly the same observations as were found on foreign exchange markets. Furthermore, they find that this interdependence becomes more strongly significant prior to and during crisis periods.

4. Interpretation and analysis

A key result from the previous section is the presence of feedbacks between key variables. The theoretical environment that may generate such outcomes is of some interest. There are at least two possible theoretic explanations. The first main area of microstructure research focuses on dealer inventory management issues (Amihud and Mendelson (1985), Stoll (1989) and Huang and Stoll (1997)). Lyons (1995) demonstrates that such inventory control is a very important part of FX dealer behaviour. However, we do not believe that this strand of theory can help us explain the patterns we see in the data. Rather, we appeal to the second main area of microstructure theory - asymmetric information theory.

In response to potentially informed trades, we observe that transaction activity increases subsequent volatility while reducing the liquidity, both spreads and depth. This happens because limit orders are repriced and the order book thins out as liquidity suppliers guard against being picked off by traders with superior information. Furthermore, market buy activity causes a decrease in the limit sell side depth and an increase in the limit buy side depth. This strengthens our belief that trades are providing information on the likely future direction of market prices. In a market with both informed and noise traders, we would expect an increase in the information asymmetry to widen spreads and reduce depth. A very high degree of information symmetry can easily drive extreme spreads, liquidity and volatility.

[4] By subsidiary liquidity supply we mean submission of limit orders at prices inferior to the extant best limit price.

5. Conclusion

This presentation focused on the dynamic evolution of limit order markets, in particular foreign exchange markets and emerging market interest rate markets in crisis. It is shown that clear dynamic patterns exist where key variables are jointly determined and, more importantly, jointly affect each other.

The analysis discussed above opens as many questions as it answers. The fact that the dynamic dimension of liquidity and information play such an important role in the market suggests that considerable research remains to be done before we can fully understand limit order markets. In addition, the fact that established market microstructure patterns seem to break down in crisis suggests that relying on analysis made in *normal* market conditions as a guide to how financial markets behave in crisis would seem to be misguided.

From the point of view of economic policy, we feel that these results demonstrate that market variables are determined in a dynamic environment and all are interdependent. This implies that any regulatory environment needs to consider how regulations may affect the dynamic structure of the market. Furthermore, an in-depth understanding of the market microstructure of financial markets can be invaluable to policymakers interested in financial stability and containment of financial crisis.

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