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Market Liquidity and Trading Activity

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ABSTRACT

Previous studies of liquidity span short time periods and focus on the individual security. In contrast, we study aggregate market spreads, depths, and trading activity for U.S. equities over an extended time sample. Daily changes in market averages of liquidity and trading activity are highly volatile and negatively serially dependent. Liquidity plummets significantly in down markets. Recent market volatility induces a decrease in trading activity and spreads. There are strong day-of-the-week effects; Fridays accompany a significant decrease in trading activity and liquidity, while Tuesdays display the opposite pattern. Long- and short-term interest rates influence liquidity. Depth and trading activity increase just prior to major macroeconomic announcements.

LIQUIDITY AND TRADING ACTIVITY are important features of financial markets, yet little is known about their evolution over time or about their time-series determinants. Their fundamental importance is exemplified by the influence of trading costs on required returns (Amihud and Mendelson (1986), and Jacoby, Fowler, and Gottesman (2000)) which implies a direct link between liquidity and corporate costs of capital. More generally, exchange organization, regulation, and investment management could all be improved by knowledge of factors that influence liquidity and trading activity. A better understanding of these determinants should increase investor confidence in financial markets and thereby enhance the efficacy of corporate resource allocation.

Notwithstanding the importance of research about liquidity, existing studies of trading costs have all been performed over short time spans of a year or less. In addition, these studies have usually focused on the liquidity of individual securities. This is probably due to the tedious task of handling voluminous intraday data and, until recently, the paucity of intraday data going back more than a few years. Thus, virtually nothing is known about

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how aggregate market liquidity behaves over time. In particular, some basic questions remain unanswered:

- How much do liquidity and trading activity vary on a day-to-day basis?
- Are there regularities in the time-series of daily liquidity and trading activity? For example, are these variables systematically lower or higher during certain days of the week or around scheduled macroeconomic announcements?
- How does recent market performance influence the ease of trading on a given day?
- What causes daily movements in liquidity and trading activity? Are they induced, for example, by changes in interest rates or in volatility?

Aside from their scientific merit, these questions are of direct importance to investors developing trading strategies and to exchange officials attempting to identify conditions likely to disturb trading activity. In addition, given the relation between liquidity and asset returns, answering the above questions could shed light on the time-series behavior of equity market returns. Satisfactory answers most likely depend on a sample period long enough to subsume a variety of events, for only then could one be reasonably confident of the results.

We construct time series indices of market-wide liquidity measures and market-wide trading activity over the eleven-year period 1988 through 1998 inclusive, almost 2,800 trading days. The data are averaged[1] over a comprehensive sample of NYSE stocks on each trading day. Measures of liquidity are quoted and effective spreads plus market depth and the trading activity measures are volume and the number of daily transactions. The dataset is of independent interest because its construction involved the processing of approximately 3.5 billion transactions.

The studies of Hasbrouck and Seppi (2000), Huberman and Halka (1999), and Chordia, Roll, and Subrahmanyam (2000) document commonality in the time-series movements of liquidity attributes. However, these authors do not analyze the behavior of aggregate market liquidity over time. They also have a relatively short data sample, ranging from two months to one year. These studies do, however, suggest a line of future research; namely, to identify factors causing the observed commonality in liquidity.

In choosing explanatory variables for liquidity and trading activity, we are guided by prior paradigms of price formation and by intuitive *a priori* reasoning. The inventory paradigm of Demsetz (1968), Stoll (1978), and Ho and Stoll (1981) suggests that liquidity depends on factors that influence the risk of holding inventory, and on extreme events that provoke order imbalances and thereby cause inventory overload. In addition, factors such as short-selling constraints and costs of margin trading imply that liquidity should depend on the level of interest rates. Thus, our first set of candidates

[1] For the most part, we study equal-weighted cross-sectional averages. However, for completeness and as a check on robustness, we also provide results obtained with value-weighted averages.

for explanatory factors consists of short- and long-term interest rates, default spreads, market volatility, and contemporaneous market moves. The informed speculation paradigm (Kyle (1985), Admati and Pfleiderer (1988)) suggests that market-wide changes in liquidity could closely precede informational events such as scheduled Federal announcements about the state of the economy. Further, trading activity could vary in a weekly cycle, for example, because of systematic variations in the opportunity cost of trading over the week; it could vary also around holidays. We thus include indicator variables to represent days around major macroeconomic announcements, days of the week, and major holidays.

Some colleagues have argued that this paper is "atheoretical"—that we do not test a specific model of liquidity. But there has been no work on the fundamental issue of why aggregate market liquidity varies over time. We mention existing theoretical paradigms above simply to motivate our admittedly empirical investigation. The development of an explicit theoretical model of stochastic liquidity is left for future research.

Many authors, starting with Banz (1981), Reinganum (1983), and Gibbons and Hess (1981), document regularities in asset returns on a monthly or daily basis, but do not consider the time-series behavior of liquidity. In work that is more directly related to ours, Draper and Paudyal (1997) carry out an analysis of seasonalities in liquidity on the London Stock Exchange, but are able to obtain only monthly data for 345 firms. Ding (1999) analyzes time-series variations of the spread in the foreign exchange futures market, but his data span less than a year. Jones, Kaul, and Lipson (1994) study stock returns, volume, and transactions over a six-year period, but do not attempt to explain why trading activity varies over time. Pettengill and Jordan (1988) analyze seasonalities in volume, and Lo and Wang (1999) analyze commonality in share turnover, both with data spanning more than 20 years, but they do not analyze the behavior of market liquidity. Finally, Karpoff (1987) and Hiemstra and Jones (1994) analyze the relation between stock returns and volume over several years, but again do not consider market liquidity.

Foster and Viswanathan (1993) examine patterns in stock market trading volume, trading costs, and return volatility using intraday data from a single year, 1988. For actively traded firms, they find that trading volume is low and adverse selection costs are high on Mondays. Lakonishok and Maberly (1990) use more than 30 years of data on odd-lot sales/purchases to show that the propensity of individuals to sell is particularly high on Mondays. Harris (1986, 1989) documents various patterns in intraday and daily returns using transactions data over a period of three years. However, he does not have data on spreads, depths, or trading activity and consequently is unable to directly analyze the behavior of liquidity. Thus, to our knowledge, an analysis of the time-series behavior of liquidity over a long time span and its relations, if any, with macroeconomic variables has not yet been explored.

The remainder of this paper is organized as follows. Section I describes the data. Section II documents the time-series properties of our liquidity variables. Section III provides the results of the time-series regressions, and Section IV concludes.

I. Data

Data sources are the Institute for the Study of Securities Markets (ISSM) and the New York Stock Exchange TAQ (trades and automated quotations). The ISSM data cover 1988 to 1992, inclusive, and the TAQ data are for 1993 through 1998. We use only NYSE stocks to avoid any possibility of the results being influenced by differences in trading protocols.

Stocks are included or excluded during a calendar year depending on the following criteria:

1. To be included, a stock had to be present at the beginning and at the end of the year in both the Center for Research in Security Prices (CRSP) and the intraday databases.
2. If the firm changed exchanges from Nasdaq to NYSE during the year (no firms switched from the NYSE to the Nasdaq during our sample period), it was dropped from the sample for that year.
3. Because their trading characteristics might differ from ordinary equities, assets in the following categories were also expunged: certificates, ADRs, shares of beneficial interest, units, companies incorporated outside the United States, Americus Trust components, closed-end funds, preferred stocks, and REITs.
4. To avoid the influence of unduly high-priced stocks, if the price at any month-end during the year was greater than \$999, the stock was deleted from the sample for the year.

Next, intraday data were purged for one of the following reasons: trades out of sequence, trades recorded before the open or after the closing time,[2] and trades with special settlement conditions (because they might be subject to distinct liquidity considerations).[3]

Our preliminary investigation revealed that autoquotes (passive quotes by secondary market dealers) were eliminated in the ISSM database but not in TAQ. This caused the quoted spread to be artificially inflated in TAQ (see Appendix B for a description of the magnitude by which the quote is inflated). Because there is no reliable way to filter out autoquotes in TAQ, only BBO (best bid or offer) -eligible primary market (NYSE) quotes are used. Quotes established before the opening of the market or after the close were discarded. Negative bid-ask spread quotations, transaction prices, and quoted depths were discarded. Following Lee and Ready (1991), any quote less than five seconds prior to the trade is ignored and the first one at least five seconds prior to the trade is retained.

For each stock we define the following variables:

[2] The last daily trade was assumed to occur no later than 4:05 p.m. Transactions are commonly reported up to five minutes after the official close, 4:00 p.m.

[3] These settlement conditions typically exclude dividend capture trades. Although this caveat should be noted, this exclusion should not have any material impact on our results.

QuotedSpread: the quoted bid-ask spread associated with the transaction.

%QuotedSpread: the quoted bid-ask spread divided by the mid-point of the quote (in percent).

EffectiveSpread: the effective spread; that is, the difference between the execution price and the mid-point of the prevailing bid-ask quote.

%EffectiveSpread: the effective spread divided by the mid-point of the prevailing bid-ask quote (in percent).

Depth: the average of the quoted bid and ask depths.

$Depth: the average of the ask depth times ask price and bid depth times bid price.

CompositeLiq = *%QuotedSpread*/*$Depth*: spread and depth combined in a single measure. *CompositeLiq* is intended to measure the average slope of the liquidity function in percent per dollar traded.

In addition to the above averages, we calculate the following measures of trading activity on a daily basis:

Volume: the total share volume during the day.

$Volume: the total dollar volume (number of shares multiplied by the transaction price) during the day.

NumTrades: the total number of transactions during the day.

Our initial scanning of the intraday data revealed a number of anomalous records that appeared to be keypunching errors. We thus applied filters to the transaction data by deleting records that satisfied the following conditions:

1. *QuotedSpread* $>$ \$5;
2. *EffectiveSpread*/*QuotedSpread* $>$ 4.0;
3. *%EffectiveSpread*/*%QuotedSpread* $>$ 4.0;
4. *QuotedSpread*/Transaction Price $>$ 0.4.

These filters removed less than 0.02 percent of all transaction records.[4] From this point on, our investigation focuses on daily cross-sectional averages of the liquidity and trading activity variables after employing the above screening procedure (for convenience, the same variable names are retained). Trading activity averages are calculated using all stocks present in the sample throughout the year as a divisor; for example, stocks that did not trade are assigned a value of zero for trading volume, which is, in fact, their actual volume on a day they did not trade.

The same method cannot be employed for spread or depth averages because a nontrading stock does not really have a spread or depth of zero. One possibility is to calculate averages using only stocks trading on each day.

[4] There are approximately 3.5 billion transaction records. In addition to applying these filters, we eliminated two dates from the sample: the first, October 25 1989, had no data at all, and the second, September 4 1991, had only quote data, no transactions data.

However, infrequently trading stocks probably have higher than average spreads (and lower depths), so daily changes in liquidity measures could be unduly influenced by such stocks moving in and out of the sample. An alternative is to use the last-recorded value for a nontrading stock, but of course the averages would then contain some stale data. We have done all the calculations both ways but report the results only with the latter method, filling in missing data from the past ten trading days *only* to limit the extent of staleness. Both methods yield virtually identical results; some robustness details will be provided in Sections II.A and III.D.

II. Empirical Attributes of Market-wide Liquidity and Aggregate Trading Activity

A. Levels of Liquidity and Trading Activity

Table I provides summary statistics of the basic market liquidity and trading activity measures. All variables display substantial intertemporal variation, but trading activity shows more variability than spreads as indicated by higher coefficients of variation. This might be attributable to the discrete nature of bid-ask spreads, which could serve to attenuate volatility through clustering. As can be seen, the effective spread is considerably smaller than the quoted spread, evidently reflecting within-quote trading. None of the variables exhibit any significant skewness; means are quite close to the medians. Figures 1 through 5 plot the liquidity and trading activity levels over the entire sample period. Dollar depth and dollar trading volumes are plotted in real terms after scaling by the Consumer Price Index (all items) interpolated daily.[5]

The effective spread and the proportional effective spread appear to have steadily declined in the latter half of our sample. This decline is consistent with a concomitant increase in trading activity shown in the figures for trading volume (Figure 4).

Depth and spread show an abrupt decline around June 1997 (Figures 1 and 3), which coincides with a reduction of the minimum tick size from one-eighth to one-sixteenth on the New York Stock Exchange.[6] Average dollars per trade increase from 1991 through 1996 with the level of stock prices (not plotted) and the number of transactions (Figure 5) but the trend reverses over the last two years, 1997 and 1998, perhaps reflecting the increased volume of Internet trades and their smaller per trade size.[7]

There appear to be sudden one-day changes in the number of firms trading (Figure 6), especially in the period covered by ISSM. Many such changes occur around the turn of the year, which is to be expected because we refor-

[5] If $g = \mathrm{CPI}_T/\mathrm{CPI}_{T-1} - 1$ was the reported monthly inflation rate for calendar month T, which consisted of N days, the interpolated CPI value for the tth calendar day of the month was $\mathrm{CPI}_{T-1}(1 + g)^{t/N}$.

[6] These decreases in spread and depth were predicted by Harris (1994).

[7] A turnover measure of trading activity (dollars traded/market capitalization) yielded a pattern qualitatively identical to the volume series.

Table I

Market Liquidity and Trading Activity Variables, 1988 to 1998 (Inclusive)

These are descriptive statistics for time series of market-wide liquidity and trading activity. The series are constructed by first averaging all transactions for each individual stock on a given trading day and then cross-sectionally averaging all individual stock daily means that satisfy the data filters described in the text. The sample period spans the first trading day of 1988 through the last trading day of 1998, 2,779 trading days.

	Number of Firms	Quoted Spread ($)	% Quoted Spread	Effective Spread ($)	% Effective spread	Depth (Shares)	Price ($)	Share Volume (000's)	Dollar Volume ($million)	Number of Daily Trades	$ Depth ($0000)	Dollars/ Trade ($00)
Mean	1,326	0.208	1.497	0.137	1.033	6,216	28.31	183.48	7.12	109.63	13.85	634.0
Sigma[a]	126	0.026	0.412	0.017	0.278	1,195	2.84	75.76	3.74	47.94	2.95	104.7
C of V[b]	0.0954	0.125	0.276	0.126	0.269	0.192	0.100	0.413	0.525	0.437	0.213	0.165
Median	1,344	0.217	1.490	0.138	0.993	6,478	27.97	162.21	5.72	95.84	13.77	627.1
Minimum	252	0.142	0.691	0.099	0.480	3,224	20.88	30.93	0.83	16.77	6.21	244.6
Maximum	1,504	0.282	2.819	0.203	2.052	8,584	36.52	613.95	27.76	379.22	21.77	1814.2

[a] Standard deviation.

[b] Coefficient of variation: Standard deviation /Mean; (dimensionless).

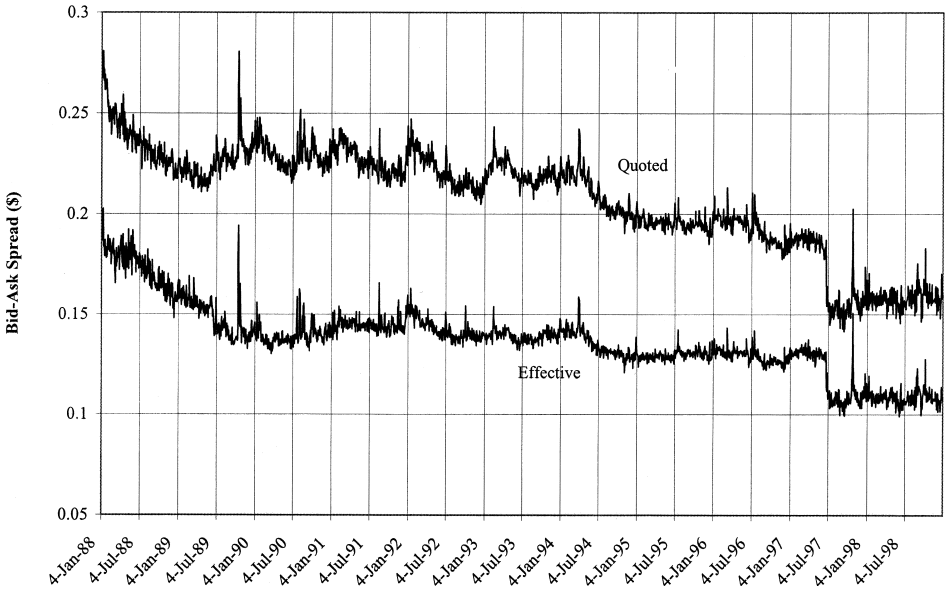

Figure 1. Average quoted and effective bid-ask spreads.

mulate the sample at the beginning of each year. But there are anomalous changes also on other dates. An extreme example occurs on Monday, September 16, 1991, when only 248 firms are recorded as having traded in the ISSM database, even though 1,219 were present on the preceding Friday and 1,214 on the immediately following Tuesday. We believe that some of these cases are just data recording errors, although others could arise because of unusually sluggish trading, for example, on days preceding or following major holidays.

Figure 6 also plots the number of stocks per day after filling in missing spreads and depths from previous values (up to a maximum of 10 past trading days). As Figure 6 shows, this number is almost constant within each calendar year, which implies that going back even further to fill in missing data would add virtually no additional stocks to each day's average. Filling in missing data mitigates concerns about the results being influenced by fluctuations in the number of traded stocks.[8] Moreover, despite sizable variation in the number of stocks actually trading, the correlation is more than 0.98 between quoted spreads averaged over trading stocks and averaged over trading and back-filled nontrading stocks. This explains why the results are not very sensitive to the specific method used

[8] After filling in missing observations with data no more than 10 days old, the average absolute change in the sample size is 0.13 firms per day. In contrast, the average absolute change in the number of *trading* firms is 7.0 per day.

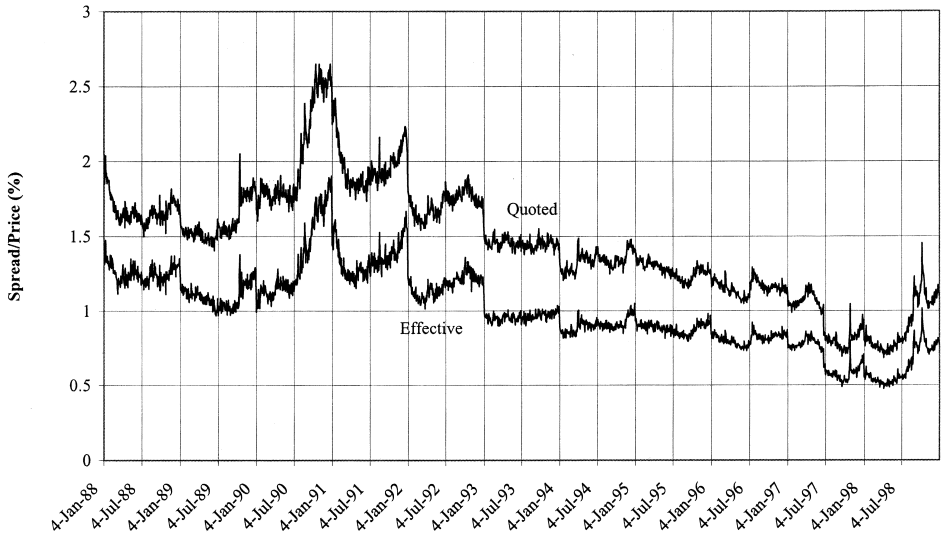

Figure 2. Average percentage quoted and effective bid-ask spreads.

to construct the liquidity index. In Section III.D, we present a robustness check of this procedure.

B. Daily Changes in Liquidity and Trading Activity

Table II presents summary statistics associated with the absolute values of daily percentage changes in all variables. (Because the sample is reformulated at the beginning of each calendar year, the first day of the year is omitted.) As suggested by coefficients of variation in Table I, there is much more volatility in volume and in transactions than in other variables. The average absolute daily change in volume, dollar volume, and the number of transactions ranges from 10 to 15 percent, but the average daily change in the spread variables is on the order of only two percent. The average absolute daily change in share and dollar depth is about four to five percent. The average absolute daily change in prices is only 0.56%. In general, one is accustomed to thinking of stock prices as highly volatile, yet they are sluggish compared to liquidity measures and to indicators of trading activity.

Table III reports pair-wise correlations among changes in the liquidity and trading activity variables. *A priori*, from reasoning at the individual stock level, one might have anticipated a positive relation between volume and liquidity and thus a negative (positive) relation between volume and spreads (depth). But although correlations between changes in the market-wide quoted and proportional quoted spread and share or dollar volume are negative, they are quite low, and the effective spread measures are actually positively correlated with either measure of volume. Further, the

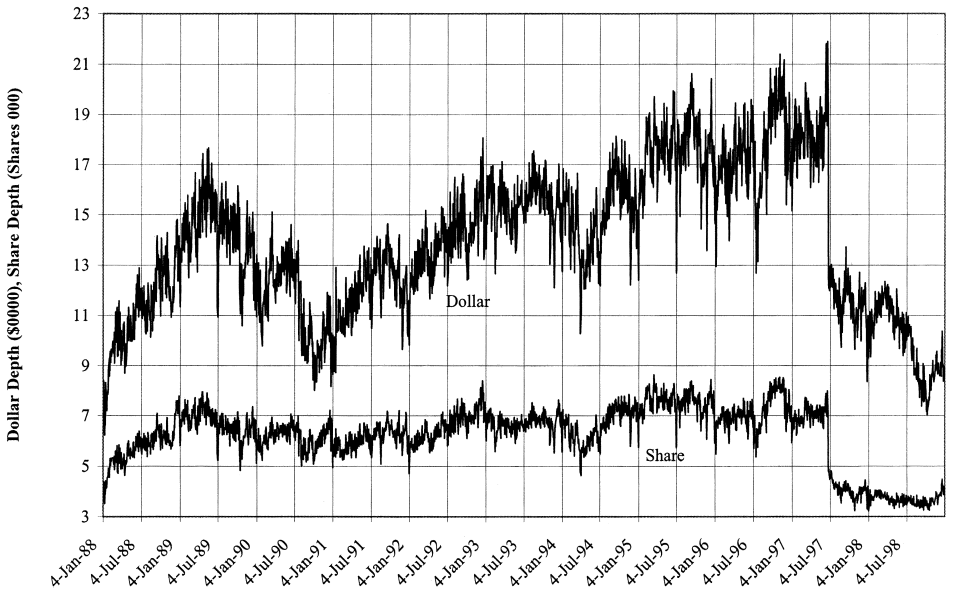

Figure 3. Bid-ask average quoted dollar and share depth.

correlations between various spread changes and the number of transactions are also positive. In contrast, depth and dollar depth display a strong correlation with volume, positive as anticipated.[9]

Not surprisingly, spread changes are negatively correlated with depth changes. Correlations between transactions and either share or dollar volume are greater than 0.80.

C. Time Series Properties of Market Liquidity and Trading Activity

Table IV records autocorrelations for percentage changes in each series out to a lag of five trading days (one week not accounting for holidays). Every series except price exhibits statistically significant negative first-order autocorrelation. There is even evidence of negative second-order autocorrelation, albeit weaker. Negative autocorrelation might be expected, because most of these series are likely to be stationary; for example, bid-ask spreads probably will not wander off to plus or minus infinity.[10] Notice too that the fifth-order coefficients are uniformly positive and about half of them are significant. This reveals the presence of a weekly seasonal.

[9] The correlation between (changes in) the quoted spread and the relative quoted spread is only about 0.75, which might appear surprisingly low. But the relative quoted spread is calculated by averaging the stock-by-stock ratios of quoted spread to price and there is substantial cross-sectional variation in prices. The correlation between the average quoted spread and the ratio of average quoted spread to average price is much higher; about 0.95.

[10] Formal unit root tests (not reported) strongly imply that daily changes of all variables are stationary.

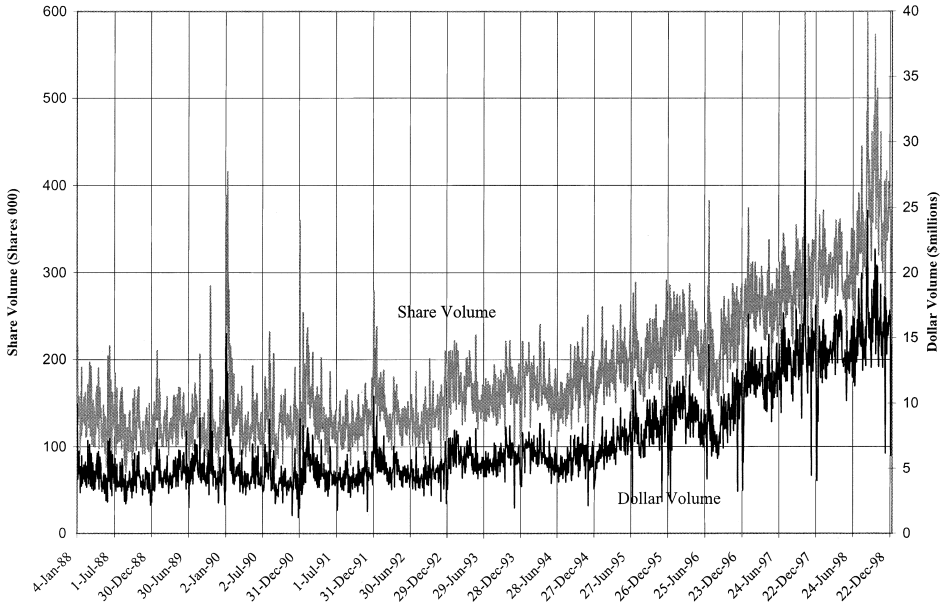

Figure 4. Average daily trading volume per stock.

Negative first-order serial dependence in spread changes could arise also from discreteness. Imagine, for instance, that most stocks have quoted spreads of either one-eighth or one-quarter, that some stocks oscillate between these discrete points daily, and that they tend to oscillate as a correlated group. This would produce negative first-order autocorrelation in the percentage change of the *average* spread. Table IV does show that the four spread measures have absolutely larger negative first-order autocorrelation coefficients than other variables.

Data recording errors are another possible source of negative serial correlation. However, we do not believe this is the main cause for two reasons. First, errors would just as likely appear in the average recorded price series, but its first-order coefficient is positive and insignificant. Second, we found that the negative serial correlation is just as strong for the quintile of largest firms and it seems unlikely that actively traded large firms would be as influenced by data recording errors. Overall, the evidence suggests that negative serial correlation is a basic feature of the true time-series process of liquidity.

III. Determinants of Liquidity and Trading Activity

This section reports time-series regressions of liquidity and trading activity measures on various potential determinants. First, some justification is provided for the explanatory variables.

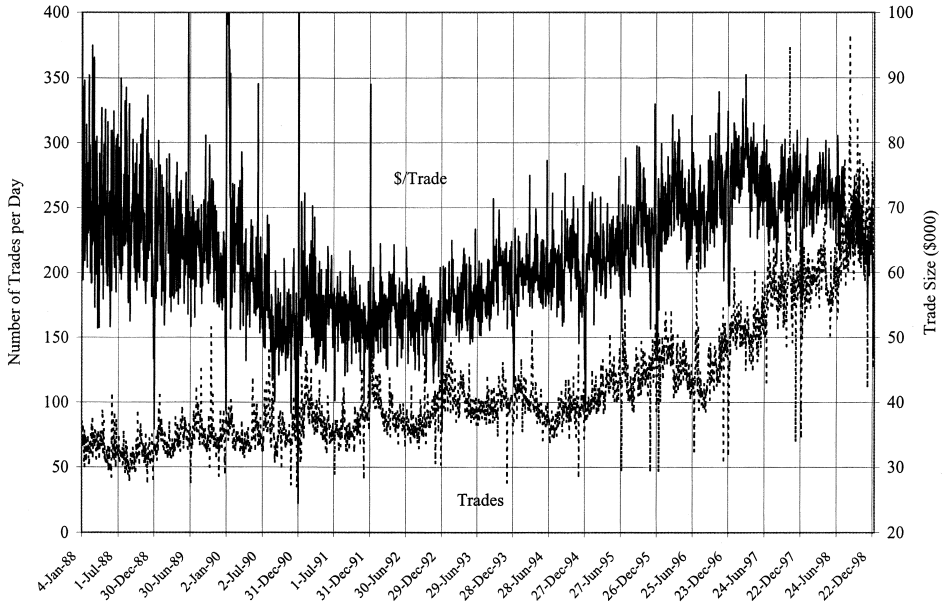

Figure 5. Average number and size of daily transactions.

A. Explanatory Variables

The inventory paradigm introduced by Demsetz (1968) and developed further by Stoll (1978) and Ho and Stoll (1981) suggests that liquidity depends on inventory turnover rates and inventory risks. In addition, frictions such as margin requirements and short-selling constraints imply that liquidity should depend on interest rates. By reducing the cost of margin trading and decreasing the cost of financing inventory, a decrease in short rates could stimulate trading activity and increase market liquidity. An increase in longer-term Treasury bond yields could cause investors to reallocate wealth between equity and debt instruments and thus stimulate trading activity and affect liquidity. An increase in default spreads could increase the perceived risk of holding inventory and thereby decrease liquidity. Consequently, as plausible candidates for determinants of liquidity, we nominate the daily overnight Federal Funds rate,[11] a term structure variable, and a measure of default spread.

Equity market performance is another plausible causative candidate. Recent stock price moves could trigger changes in investor expectations while also prompting changes in optimal portfolio compositions. In addition, the direction of stock market movements could trigger asymmetric effects on

[11] We repeated all calculations using the one-year Treasury Bill rate as a proxy for dealer financing costs, but found that the Federal Funds rate is a better determinant of daily liquidity variations. The results are otherwise essentially identical.

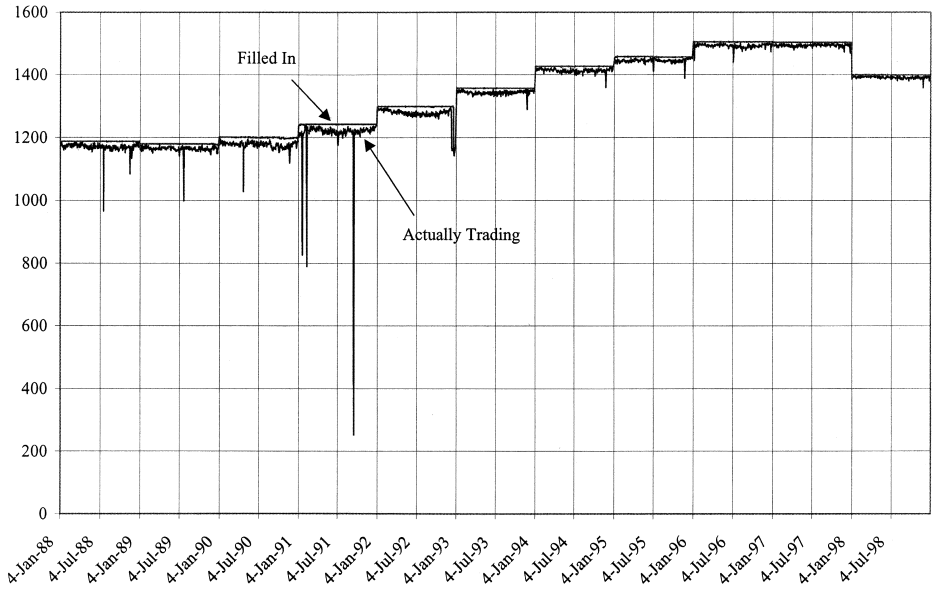

Figure 6. Number of stocks in the daily sample.

liquidity. For example, sharp price declines could induce relatively more pronounced changes in liquidity to the extent that market makers find it more difficult to adjust inventory in falling markets than in rising markets. We thus consider the signed concurrent daily return on the CRSP index.

Additionally, we include a measure of recent market history. The rationale is based on the notion that momentum or contrarian strategies[12] and various techniques for "technical analysis" involve past market moves, thereby creating a link between trading activity and recent price trends. To proxy for such activity, we include a signed five-day moving average of past returns (ending the day prior to the observation date).

Because volatility should influence liquidity and trading activity through its effect on inventory risk as well as the risk of engaging in short-term speculative activity, we include a measure of recent market volatility. Our proxy is a five-day trailing average of daily absolute returns for the CRSP market index.

Trading activity might also be influenced by the opportunity cost of devoting time to trading decisions. Simple behavioral arguments (such as fluctuations in investor mood or sentiment over the week) suggest that trading activity could show systematic seasonal patterns. Work by Admati and Pfleiderer (1989) or Foster and Viswanathan (1990) implies that liquidity

[12] See Lakonishok, Shleifer, and Vishny (1994) and Chan, Jegadeesh, and Lakonishok (1996) for evidence on the performance of momentum and contrarian strategies.

Table II

Absolute Percentage Daily Changes in Market-wide Liquidity and Trading Activity

These are descriptive statistics for absolute values of daily percentage changes in the variables described in Table I omitting the changes at the turn of each year. There are 2,768 observations. The acronyms *QuotedSpread, %QuotedSpread, EffectiveSpread, %EffectiveSpread, Depth, $Depth, CompositeLiq, Price, Volume, $Volume*, and *NumTrades* denote market-wide equal-weighted averages of, respectively, the quoted spread, the percentage quoted spread, the effective spread, the percentage effective spread, share depth, dollar depth, *%QuotedSpread*/*$Depth*, the average price of stocks that traded, share volume, dollar volume, and the average number of transactions per stock. A preceding Δ denotes the daily percentage change in the variable.

	Liquidity Variables							Trading Activity Variables			
	|Δ*Quoted Spread*|	|Δ*%Quoted Spread*|	|Δ*effective Spread*|	|Δ*%Effective Spread*|	|Δ*Depth*|	|Δ*$Depth*|	|Δ*Composite Liq*|	|Δ*Price*|	|Δ*Volume*|	|Δ*$Volume*|	|Δ*Num Trades*|
Mean	1.572	1.671	1.906	2.227	4.039	4.843	5.767	0.555	14.35	15.37	10.54
Sigma[a]	1.563	1.664	1.945	2.142	3.513	4.242	5.181	0.560	19.57	21.21	14.91
Median	1.170	1.240	1.415	1.708	3.194	3.795	4.421	0.403	9.889	10.84	7.307

[a] Standard deviation.

Table III

Correlations of Simultaneous Daily Percentage Changes in Market-wide Liquidity and Trading Activity

These are correlations among daily percentage changes in the variables described in Table I omitting the changes at the turn of each year. The acronyms QuotedSpread, *%QuotedSpread*, *EffectiveSpread*, *%EffectiveSpread*, *Depth*, *$Depth*, *CompositeLiq*, *Price*, *Volume*, *$Volume*, and *NumTrades* denote market-wide equal-weighted averages of, respectively, the quoted spread, the percentage quoted spread, the effective spread, the percentage effective spread, share depth, dollar depth, *%QuotedSpread*/*$Depth*, the average price of stocks that traded, share volume, dollar volume, and the average number of transactions per stock. A preceding Δ denotes the daily percentage change in the variable.

	Liquidity Variables							Trading Activity Variables		
	Δ*Quoted Spread*	Δ*%Quoted Spread*	Δ*Effective Spread*	Δ*%Effective Spread*	Δ*Depth*	Δ*$Depth*	Δ*CompositeLiq*	Δ*Price*	Δ*Volume*	Δ*$Volume*
Δ*%QuotedSpread*	0.749									
Δ*EffectiveSpread*	0.782	0.581								
Δ*%EffectiveSpread*	0.492	0.568	0.686							
Δ*Depth*	−0.464	−0.355	−0.323	−0.181						
Δ*$Depth*	−0.460	−0.375	−0.316	−0.213	0.923					
Δ*CompositeLiq*	0.623	0.628	0.458	0.362	−0.882	−0.948				
Δ*Price*	−0.150	−0.293	−0.192	−0.273	0.183	0.247	−0.303			
Δ*Volume*	−0.051	−0.138	0.091	−0.018	0.310	0.347	−0.308	−0.052		
Δ*$Volume*	−0.039	−0.142	0.095	−0.028	0.273	0.322	−0.290	−0.024	0.975	
Δ*NumTrades*	−0.034	−0.059	0.151	0.112	0.241	0.256	−0.204	−0.066	0.838	0.834

Table IV

Autocorrelations of Liquidity and Trading Activity Variables

These are autocorrelation coefficients for the variables described in Table I, after omitting the changes at the turn of each year. The acronyms *QuotedSpread, %QuotedSpread, EffectiveSpread, %EffectiveSpread, Depth, $Depth, CompositeLiq, Price, Volume, $Volume*, and *NumTrades* denote market-wide equal-weighted averages of, respectively, the quoted spread, the percentage quoted spread, the effective spread, the percentage effective spread, share depth, dollar depth, *%QuotedSpread*/*$Depth*, the average price of stocks that traded, share volume, dollar volume, and the average number of transactions per stock. A preceding Δ *denotes the daily percentage change in the variable*. *Numbers in boldface type indicate a p*-value less than 0.0001 for an asymptotic test that the autocorrelation coefficient is zero.

	Order (Lag in daily observations)				
	1	2	3	4	5
Liquidity Variables					
Δ*QuotedSpread*	**−0.295**	**−0.131**	−0.048	−0.032	**0.081**
Δ*%QuotedSpread*	**−0.221**	**−0.127**	−0.002	−0.018	0.047
Δ*EffectiveSpread*	**−0.306**	**−0.093**	−0.072	−0.017	0.035
Δ*%EffectiveSpread*	**−0.291**	−0.075	−0.031	−0.021	0.046
Δ*Depth*	**−0.188**	**−0.212**	**−0.117**	−0.015	**0.229**
Δ*$Depth*	**−0.218**	**−0.179**	**−0.106**	0.001	**0.140**
Δ*CompositeLiq*	**−0.198**	**−0.178**	**−0.096**	−0.005	**0.130**
Trading Activity Variables					
Δ*Price*	0.006	0.019	0.013	0.025	−0.030
Δ*Volume*	**−0.266**	**−0.107**	−0.042	−0.017	**0.095**
Δ*$Volume*	**−0.268**	**−0.099**	−0.038	−0.020	**0.097**
Δ*NumTrades*	**−0.259**	**−0.097**	−0.036	−0.007	0.033

could exhibit predictable patterns through time.[13] To investigate such regularities, we include indicator variables for days of the week as well as for days preceding and following holiday closures.

Information-based trading (based on the asymmetric information paradigms of Kyle (1985) and Admati and Pfleiderer (1988)) suggests another group of proximate determinants. As firm-specific information is more likely to induce information-based trades, sensible proxies would be dummies for earnings announcement dates. These dates, however, are not well coordinated across companies. Further, conversations with accounting researchers revealed that information about earnings is often conveyed to the market sometime before the official earnings announcement date. Thus, estimates of earnings with significant information content are often prereleased by managers (see, for example, Ruland, Tung, and George, 1990, and Baginski, Hassell, and Waymire, 1994); such prerelease dates are completely discretionary.

[13] These papers do not explicitly specify which days of the week should involve high/low liquidity.

Because of these concerns, we decided to focus on information associated with macroeconomic announcements. We include dummy variables for macroeconomic announcements about Gross Domestic Product (GDP), the unemployment rate, and the Consumer Price Index (CPI). Separate dummies are provided for the day of the announcement and for the two days preceding the announcement.

B. Explanatory Variable Definitions

The explanatory variables are:

ShortRate: the daily first difference in the Federal Funds Rate.

TermSpread: the daily change in the difference between the yield on a constant maturity 10-year Treasury bond and the Federal Funds rate.

QualitySpread: the daily change in the difference between the yield on Moody's Baa or better corporate bond yield index and the yield on a 10-year constant maturity Treasury bond.[14]

MKT+: the concurrent CRSP daily index return if it is positive, and zero otherwise.[15]

MKT−: the concurrent CRSP daily index return if it is negative, and zero otherwise.

(Appendix A reports summary statistics for the debt and equity market variables above.)

MA5MKT+: the past five trading-day CRSP daily index return if it is positive and zero otherwise.

MA5MKT−: the past five trading-day CRSP daily index return if it is negative and zero otherwise.

MA5|MKT|: the past five trading-day average of CRSP daily absolute index returns.

HOLIDAY: 1.0 if a trading day satisfies the following conditions: (1) if Independence Day, Christmas, or New Year's Day falls on a Friday, then the preceding Thursday, (2) if any holiday falls on a weekend or on a Monday, then the following Tuesday, (3) if any holiday falls on another weekday, then the preceding and following days,[16] and 0 otherwise

Monday–Thursday: 1.0 if the trading day is a Monday, Tuesday, Wednesday, or Thursday, and 0 otherwise.

GDP(0): 1.0 on the day of a GDP announcement, and 0 otherwise.

[14] All interest rates are from the Federal Reserve Web site, http://www.bog.frb.fed.us/releases/H15/data.htm. We thank Yacine Aït-Sahalia for directing us to this site. The Federal Reserve uses the daily yield curve to calculate the yield on a constant maturity Treasury bond on a daily basis.

[15] The equal-weighted (value-weighted) CRSP index is used for regressions with equal-weighted (value-weighted) liquidity and trading activity dependent variables.

[16] This is always the case for Thanksgiving.

GDP(1–2): 1.0 on the two trading days prior to a GDP announcement, and 0 otherwise.

UNP(0), UNP(1–2), CPI(0), CPI(1–2): Defined as for GDP but for unemployment and CPI announcements, respectively.

C. Regression Results

Time-series regression results are reported in Table V for the scaled spread measures Δ*%QuotedSpread* and Δ*%EffectiveSpread*, for Δ*CompositeLiq*, for the dollar values of depth, Δ*$Depth*, and volume, Δ*$Volume*, and for the number of transactions, Δ*NumTrades*. (The "Δ" prefix denotes the daily percentage change in the corresponding variables described earlier.) To conserve space, results for the nonscaled spreads, *QuotedSpread* and *EffectiveSpread*, and for share depth and volume are not reported. They are qualitatively similar and will be provided upon request.

Since OLS runs indicated a high Durbin–Watson test statistic in all regressions, a consequence of the previously noted negative dependence in all of the dependent variables, we applied the Cochrane/Orcutt iterative correction procedure (first-order only) in the time-series regressions.[17] The Durbin–Watson statistics from the final iteration of the Cochrane/Orcutt regressions were within the significance bounds.

The sample size is 2,694 in the Panels A and B regressions. We started with 2,779 trading days, eliminated the first day of the calendar year for 1989 to 1998 (ten observations) and lost five days at the beginning to accommodate the lagging five-day market trend. In addition, bond market data were unavailable for 35 holidays when the stock market was open (King's birthday, Columbus Day, and Veterans' Day, though not every year). This brought a further reduction of 70 (35×2) observations because the interest rate variables are first-differenced. The total reduction is 85. Panel C has a different sample size and is explained below.

The adjusted R^2s in Panels A and B range from 18 to 33 percent; that is, the explanatory variables capture an appreciable fraction of the daily time-series variation in market-wide liquidity and trading activity.

The day-of-the-week dummies for Tuesday, Wednesday, and Thursday are significantly negative in the spread regressions and significantly positive for depth and the trading activity regressions.[18] This is compelling evidence that market liquidity declines and trading activity slows on Friday. Usually, Tuesday has the largest absolute coefficient, suggesting that liquidity and

[17] The results obtained using OLS do not differ qualitatively from those obtained from the Cochrane/Orcutt method. The OLS results are available from the authors upon request.

[18] Note that our regressions use daily percentage changes in the liquidity and trading activity variables, and not the levels of these variables. The expected change in a left-hand variable on a given weekday, holiday, or a macroeconomic announcement day can be calculated using the means of the right-hand variables. These expected changes are of the same sign and the same order of magnitude as the original indicator coefficients in every case.

trading activity appreciably increase on Tuesday.[19] The composite liquidity measure shows a pattern that is similar to the individual liquidity and depth variables.

The regression intercepts are all strongly significant, positive for spreads and negative for depth and trading activity. Although one cannot rule out the possibility that significant intercepts are caused by omitted explanatory variables or by a departure from linearity, the most likely explanation is a large decrease in liquidity and trading activity on Fridays (when the four day-of-the-week dummies are zero). If Tuesday instead of Friday is the zero base case for day-of-the-week dummies, the sign of every intercept is reversed and its significance is actually increased (not reported, but available on request.)

Trading activity also slows down around holidays, as evidenced by the negative and significant coefficient for the holiday dummy in the $\Delta\$Volume$ and $\Delta NumTrades$. The slowed trading activity appears to cause a decrease in market depth and an increase in quoted spreads, as evidenced by the negative and positive coefficients on the holiday dummy in the quoted spread and depth regressions, respectively. The holiday dummy for the composite liquidity variable ($CompositeLiq = \%QuotedSpread/\$Depth$) is also highly significant.

There is a distinctly asymmetric response of spreads to up and down markets. They weakly decline in up markets and strongly increase in down markets. The opposite is true for depth. This suggests that inventory accumulation concerns are more important in down markets.

Depth increases significantly in up markets. One possible explanation is that market makers attempt to manage inventory by quoting higher depth on the bid side but the same or only slightly lower depth on the ask side such that average depth increases. Note that the trading activity variables show a symmetric response; they increase in both up and down markets.

A recently falling market ($MA5MKT-$) tends to be associated with increased trading activity and decreased effective spreads. On the other hand, a recently rising market ($MA5MKT+$) appears to cause a decrease in depth but has little effect on spreads and trading activity; this might imply that market makers quote lower depth on the buy side, which leads to a smaller overall depth.

High levels of recent market-wide volatility $MA5|MKT|$ are associated with a decrease in trading activity, as might have been expected, but, perhaps surprising, they also are associated with a decrease in spreads though depth is virtually unaffected.[20] It appears that sluggish trading following recent volatility allows dealers to reduce inventory imbalances, which then prompts them to reduce spreads.

[19] A joint test that Tuesday's coefficient is the same as Monday's, Wednesday's, and Thursday's was rejected with a p-value less than 0.0001 in all regressions except $\Delta CompositeLiq$'s.

[20] In contrast to this result for recent market-wide volatility, it is well known that individual stock volatility is cross-sectionally associated with higher spreads (Benston and Hagerman (1974)), reflecting the notion that individual stock volatility is more closely associated with asymmetric information.

Table V

Time Series Regressions

Dependent variables are daily percentage changes in market-wide liquidity and trading activity as described in Table I. The acronyms Δ*%QuotedSpread*, Δ*%EffectiveSpread*, Δ*$Depth*, Δ*CompositeLiq*, Δ*$Volume*, and Δ*NumTrades* denote market-wide averages of the percentage quoted spread, the percentage effective spread, the measure of dollar depth, the percentage quoted spread divided by dollar depth (a composite measure of liquidity), dollar volume, and the average number of transactions per stock, respectively. A preceding Δ *denotes the daily percentage change in the variable*. *Explanatory variables are*: *MKT*+ (*MKT*−): the CRSP equally weighted return if it is positive (negative) and zero otherwise; *MA5MKT*+ (*MA5MKT*−): the CRSP equally weighted return over the past five trading days if it is positive (negative) and zero otherwise; *MA5*|*MKT*|: the average CRSP equally weighted daily absolute return over the past five trading days (all of the preceding variables are in percentages); *Monday–Thursday*: four variables that take on a value of 1 if the trading day is, respectively, a Monday, Tuesday, Wednesday, or Thursday, and 0 otherwise; *Holiday*: a variable that takes on a value of 1 if a trading day satisfies the following conditions: (1) if Independence Day, Veterans' Day, Christmas, or New Year's Day falls on a Friday, then the preceding Thursday, (2) if any holiday falls on a weekend or on a Monday, then the following Tuesday, (3) if any holiday falls on another weekday, then the preceding and following days (this is always the case for Thanksgiving), and 0 otherwise; *ShortRate*: the daily first difference in the Federal Funds rate; *TermSpread*: the daily change in the difference between the yield on a constant maturity 10-year Treasury bond and *ShortRate*; *Quality Spread*: the daily change in the difference between the yield on Moody's Baa or better corporate bond yield index and the yield on a ten-year constant maturity Treasury bond; *GDP(0)*: 1 on the day of a GDP announcement, and 0 otherwise; *GDP(1–2)*: 1 on the two trading days prior to a GDP announcement, and 0 otherwise; *UNP(0), UNP(1–2), CPI(0), CPI(1–2)*: Defined as for GDP but for unemployment and CPI announcements, respectively. The Cochrane/Orcutt method is employed to correct first-order serial dependence in the disturbances. Coefficients significantly different from zero at the one percent (five percent) level are indicated by ** (*).

Panel A: Equally weighted (2,694 observations)

Explanatory Variables	Δ%QuotedSpread		Δ%EffectiveSpread		Δ$Depth		ΔCompositeLiq		Δ$Volume		ΔNumTrades	
	Coefficient	*t*-statistic	Coefficient	*t*-statistic	Coefficient	*t*-statistic	Coefficient	*t*-statistic	Coefficient	*t*-statistic	Coefficient	*t*-statistic
MKT+	−0.486**	−3.74	−0.373*	−2.27	3.285**	9.07	−3.514**	−8.27	10.43**	7.19	8.871**	7.97
MKT−	−2.375**	−22.34	−2.855**	−21.27	2.936**	9.92	−5.821**	−16.78	−11.95**	−10.09	−12.32**	−13.56
MA5MKT+	0.052	1.36	0.010	0.22	−0.434**	−3.98	0.425**	3.33	−0.65	−1.49	−0.346	−1.03
MA5MKT−	0.036	0.72	0.210**	3.34	−0.151	−1.06	0.234	1.41	1.970**	3.46	1.910**	4.35
MA5|MKT|	−0.141**	−3.97	−0.124**	−2.80	−0.033	−0.33	−0.097	−0.83	−1.266**	−3.15	−1.101**	−3.56
Monday	−0.592**	−3.88	−0.573**	−2.90	0.335	0.82	−0.775	−1.61	1.484	0.90	6.656**	5.33
Tuesday	−1.400**	−10.78	−1.300**	−7.81	5.982**	16.85	−7.369**	−17.65	19.39**	13.63	11.144**	10.26
Wednesday	−0.367**	−2.75	−0.691**	−4.05	2.830**	7.74	−3.414**	−7.94	8.01**	5.47	4.555**	4.07
Thursday	−0.553**	−3.73	−0.681**	−3.54	1.460**	3.69	−2.214**	−4.74	4.81**	3.02	3.429**	2.84
Holiday	0.807**	3.40	0.161	0.54	−4.807**	−7.21	7.150**	9.16	−10.77**	−4.04	−8.792**	−4.29
ShortRate	2.485**	2.63	0.461	0.39	−5.795*	−2.21	7.910**	2.57	−32.43**	−3.08	−28.724**	−3.56
TermSpread	2.092*	2.23	−0.047	−0.04	−5.466*	−2.10	7.141*	2.34	−34.60**	−3.32	−29.582**	−3.70
QualitySpread	0.959	0.61	−0.087	−0.04	3.549	0.81	−3.354	−0.65	−1.508	−0.09	−8.983	−0.67
GDP(1–2)	−0.549	−1.91	−0.216	−0.59	1.975*	2.47	−2.384**	−2.54	12.81**	4.00	7.138**	2.91
GDP(0)	−0.242	−0.84	0.022	0.06	−0.542	−0.68	0.096	0.10	−3.485	−1.08	−1.248	−0.51
UNP(1–2)	−0.293	−1.58	−0.088	−0.37	2.046**	3.97	−2.159**	−3.57	4.561*	2.21	3.865*	2.45
UNP(0)	0.135	0.72	0.118	0.49	−1.389**	−2.66	1.522*	2.48	2.549	1.22	3.457*	2.15
CPI(1–2)	−0.166	−0.97	0.014	0.06	0.672	1.41	−0.908	−1.62	−1.539	−0.81	−0.827	−0.57
CPI(0)	−0.183	−1.06	0.078	0.36	0.302	0.63	−0.416	−0.74	1.961	1.03	0.579	0.40
Intercept	0.909**	6.02	1.005**	5.08	−2.519**	−6.31	3.923**	8.32	−7.183**	−4.48	−6.283**	−5.18
Adjusted R^2	0.288		0.270		0.290		0.334		0.206		0.179	

Table V—*Continued*

Panel B: Value-weighted (2,694 observations)

Explanatory Variables	Δ%QuotedSpread		Δ%EffectiveSpread		Δ$Depth		ΔCompositeLiq		Δ$Volume		ΔNumTrades	
	Coefficient	*t*-statistic	Coefficient	*t*-statistic	Coefficient	*t*-statistic	Coefficient	*t*-statistic	Coefficient	*t*-statistic	Coefficient	*t*-statistic
MKT+	−0.141	−1.34	0.385**	3.22	5.307**	12.89	−4.453**	−9.51	14.83**	13.98	11.27**	14.44
MKT−	−2.867**	−29.69	−3.496**	−31.80	1.992**	5.27	−5.405**	−12.58	−12.72**	−13.05	−11.94**	−16.64
MA5MKT+	0.017	0.40	0.055	1.13	−0.389*	−2.35	0.335	1.79	−0.502	−1.15	−0.115	−0.36
MA5MKT−	0.094	1.93	0.129*	2.34	−0.291	−1.53	0.435*	2.02	1.33**	2.67	1.115**	3.03
MA5|MKT|	−0.194**	−6.14	−0.300**	−8.30	−0.470**	−3.79	0.339*	2.41	−2.172**	−6.67	−1.722**	−7.16
Monday	−1.002**	−5.41	−0.851**	−4.08	−0.193	−0.27	−0.664	−0.80	−2.828	−1.58	7.315**	5.60
Tuesday	−0.769**	−4.90	−1.091**	−6.14	3.942**	6.42	−4.926**	−7.04	15.75**	10.17	10.19**	8.98
Wednesday	−0.043	−0.27	−0.513**	−2.79	0.849	1.34	−1.323	−1.83	5.82**	3.62	4.243**	3.60
Thursday	−0.178	−0.98	−0.623**	−3.06	1.058	1.49	−1.521	−1.87	1.831	1.05	3.196*	2.51
Holiday	0.432	1.51	0.377	1.16	−2.281*	−2.04	4.393**	3.46	−9.840**	−3.38	−6.933**	−3.23
ShortRate	0.797	0.69	−0.925	−0.70	−2.522	−0.56	2.542	0.49	−17.50	−1.50	−21.00*	−2.44
TermSpread	0.801	0.70	−0.868	−0.66	−1.732	−0.39	1.749	0.34	−19.42	−1.68	−21.93**	−2.57
QualitySpread	3.069	1.60	2.601	1.19	6.339	0.84	−3.633	−0.43	4.96	0.26	−3.791	−0.27
GDP(1–2)	−0.664	−1.91	−0.739	−1.86	2.339	1.72	−3.16*	−2.04	9.243**	2.63	6.510*	2.52
GDP(0)	0.398	1.14	0.100	0.25	−0.793	−0.58	0.879	0.56	−3.097	−0.88	−0.892	−0.34
UNP(1–2)	−0.557*	−2.48	−0.446	−1.75	3.752**	4.27	−4.250**	−4.26	2.981	1.32	3.077	1.85
UNP(0)	0.482*	2.12	0.259	1.00	−2.839**	−3.19	3.109**	3.07	1.577	0.69	3.821*	2.27
CPI(1–2)	−0.359	−1.72	−0.189	−0.80	1.736*	2.13	−2.208*	−2.38	−2.174	−1.04	−0.361	−0.23
CPI(0)	−0.151	−0.72	−0.206	−0.87	1.811	2.22	−1.692	−1.82	2.498	1.19	1.218	0.79
Intercept	0.500**	2.64	0.787**	3.71	−0.700	−0.95	2.350**	2.77	−2.806	−1.56	−6.013**	−4.59
Adjusted R^2	0.326		0.324		0.229		0.245		0.226		0.211	

Panel C: Equal-weighted, 1993 through 1998, for stocks that traded every day throughout the period (1,472 observations)

Explanatory Variables	Δ%QuotedSpread		Δ%EffectiveSpread		Δ$Depth		ΔCompositeLiq		Δ$Volume		ΔNumTrades	
	Coefficient	*t*-statistic	Coefficient	*t*-statistic	Coefficient	*t*-statistic	Coefficient	*t*-statistic	Coefficient	*t*-statistic	Coefficient	*t*-statistic
MKT+	−0.823**	−4.48	−0.574**	−3.16	2.793**	5.76	−3.459**	−6.06	4.241*	2.21	4.205**	2.82
MKT−	−2.563**	−17.90	−2.844**	−20.07	1.919**	5.08	−4.776**	−10.74	−9.674**	−6.48	−9.967**	−8.60
MA5MKT+	0.091	1.73	0.095	1.85	−0.35*	−2.47	0.374*	2.26	−0.259	−0.45	0.070	0.16
MA5MKT−	0.068	1.03	0.128*	1.97	−0.025	−0.14	0.125	0.60	1.680*	2.33	1.481**	2.67
MA5|MKT|	−0.121**	−2.66	−0.167**	−3.73	−0.010	−0.08	−0.081	−0.56	−0.499	−1.00	−0.616	−1.61
Monday	−0.604**	−2.68	−0.894**	−3.94	1.001	1.75	−1.437*	−2.10	3.099	1.44	9.281**	5.47
Tuesday	−1.300**	−6.88	−1.204**	−6.37	5.128**	10.51	−6.429**	−11.09	17.41**	9.22	11.51**	7.81
Wednesday	−0.276	−1.42	−0.629**	−3.23	2.067	4.09	−2.557**	−4.27	7.585**	3.86	4.963**	3.24
Thursday	−0.430*	−1.97	−0.778**	−3.53	1.482**	2.69	−2.175**	−3.29	4.150*	2.01	3.801*	2.33
Holiday	1.356**	3.86	0.839*	2.42	−4.195**	−4.49	7.203**	6.57	−9.711**	−2.59	−8.836**	−3.06
ShortRate	3.026*	2.44	2.568*	2.09	−7.592*	−2.33	11.72**	3.05	−38.84**	−3.02	−31.08**	−3.11
TermSpread	2.375	1.95	1.636	1.35	−6.735*	−2.10	10.07**	2.66	−43.76**	−3.46	−34.12**	−3.47
QualitySpread	−0.563	−0.19	2.002	0.69	−1.459	−0.19	1.662	0.18	−77.80**	−2.60	−57.63*	−2.47
GDP(1–2)	−0.656	−1.55	−0.438	−1.05	1.678	1.51	−1.867	−1.43	11.51**	2.62	8.504*	2.50
GDP(0)	0.023	0.06	−0.658	−1.57	−1.607	−1.44	1.431	1.09	−2.801	−0.64	−1.810	−0.53
UNP(1–2)	−0.347	−1.28	−0.251	−0.93	2.287**	3.20	−2.310**	−2.74	5.609*	1.99	4.782*	2.18
UNP(0)	0.221	0.82	0.165	0.62	−1.715*	−2.40	2.001*	2.38	3.065	1.09	4.419*	2.02
CPI(1–2)	0.110	0.44	0.162	0.65	0.719	1.10	−0.704	−0.91	−2.224	−0.86	−1.014	−0.51
CPI(0)	−0.241	−0.96	−0.199	−0.80	0.558	0.85	−0.698	−0.90	3.371	1.30	2.385	1.18
Intercept	0.773**	3.47	1.098**	4.85	−2.524**	−4.55	3.844**	5.74	−7.174**	−3.50	−7.475**	−4.60
Adjusted R^2	0.325		0.342		0.232		0.298		0.164		0.175	

In Table V, Panel A, the Federal Funds rate change is negative and significant in regressions for the trading activity and depth measures, but positive and significant for the quoted spread. An increase in Treasury bond yields relative to the short rate (*TermSpread*) is accompanied by significantly decreased trading activity, decreased depth, and increased quoted spreads. The composite (inverse) measure of liquidity, Δ*CompositeLiq*, has a positive reaction that is consistent with the coefficient sign on the depth variable. Overall, there is evidence that increases in either the long- or short-term interest rates have a significantly negative effect on both liquidity and trading activity. The default spread variable (*QualitySpread*) apparently has little influence on either trading activity or liquidity.

Turning to the macroeconomic variables, trading activity increases *prior* to GDP and unemployment announcements. Depth also rises but there is no significant impact on bid-ask spreads. On the day of the announcement (which occurs typically in the morning), depth falls back toward its normal level. This pattern is consistent with differences in anticipation about the forthcoming figures and a concomitant flurry of prior uninformed trading. Increased speculative trading activity allows greater depth to be quoted. This result is also consistent with an increase in the number of informed traders as the announcement date approaches. Competition among informed traders could bring additional liquidity (Admati and Pfleiderer (1988)).

Overall, the evidence can be summarized as follows:

- Quoted spreads, depths, and trading activity respond to short-term interest rates, the term spread, equity market returns, and recent market volatility.
- Depth and the composite measure of liquidity respond to recent market trends.
- Effective spreads respond strongly to equity market returns, recent market trends, and recent market volatility.
- Spreads respond asymmetrically to contemporaneous market movements, increasing much more in down markets than they decrease in up markets.
- There is strong evidence that liquidity and trading activity fall on Fridays.
- Tuesday tends to be accompanied by increased trading activity and increased liquidity.
- Depth and trading activity tend to decrease around major holidays.
- Both depth and trading activity increase prior to announcements of GDP and unemployment rates.
- Impending CPI announcements do not seem to influence either liquidity or trading activity. Evidently, inflation has been relatively easy to predict in the United States recently.

The explanatory power of these regressions ranges from 18 to 33 percent and the number of separate significant regressors is impressive. For exam-

ple, in the Δ*NumTrades* regression (Table V, Panel A), 12 of the 19 variables are significant at the one percent level and two others are significant at the five percent level. There are more significant determinants in the depth and trading activity regressions than in the spread regressions. Doubtless, the significance of some of our regressors is influenced by the large sample size. However, the magnitude of the coefficients implies economic significance as well. Here are some examples: an increase in the Federal Funds rate of 1 percent induces a spread increase of 2.5 percent and a 1 percent market decline brings about a 2 percent increase in the average relative quoted spread.

Panel B of Table V reports regressions with value-weighted liquidity and trading activity measures, where the weights are proportional to each company's total market capitalization at the end of the previous year. The stock market indexes are also value weighted. The results are qualitatively similar to those of Panel A, except that interest rate variables are no longer significant for the liquidity variables and the weekly seasonals are weaker (though mostly still significant). This may imply that inventory considerations are more important for smaller stocks and that weekly variations in trading have a larger impact on the liquidity of smaller companies. On the other hand, explanatory power is actually slightly higher in the spread regressions and for dollar volume and the number of transactions. Notice too that the unemployment announcement is now statistically significant for quoted spreads.

D. Robustness Checks

Figure 6 reveals that the number of firms trading varies daily. Hence, there is some ambiguity about average liquidity measures because spreads and depth are not available for nontrading firms. (This does not affect the trading activity measures because volume is properly counted as zero when a stock does not trade.) We addressed this issue by using liquidity measures from the last day the stock did trade, going back a maximum of ten trading days. To ensure the results are not influenced by this procedure, we reran the regressions for a sample of stocks that traded every single trading day in each calendar year from 1993 to 1998, the period corresponding to the TAQ data source. Because of aberrant variation in the reported number of stocks trading in the ISSM data, the same robustness check was not done for the 1988 to 1992 period. The resulting sample size is 1,472 days. The results, presented in Table V, Panel C, are qualitatively similar to those in Panel A. There is a loss in significance for some of the coefficients, particularly those representing the weekly seasonals, but the overall pattern of significance is unchanged (except that the effective spread also is influenced significantly by the short rate).

The Federal Funds rate is only a proxy for short-term dealer borrowing costs. To check whether the results are robust to other proxies, we were able to secure a time series of overnight repurchase agreement (repo) rates, though

for a shorter time period beginning on May 21, 1991.[21] We substituted the repo rate for the Federal Funds rate in all the interest rate variables and recalculated the regressions the resulting 1,841 daily observations. The results (available on request) were qualitatively similar to those in Table V, Panel C.

IV. Conclusions

Existing literature usually has treated liquidity as a fixed property of an individual stock, so that virtually no research has studied how aggregate market liquidity varies over time. In addition, previous studies of liquidity typically span short time periods of a year or less. In contrast to the extant literature, we study liquidity and trading activity for a comprehensive sample of NYSE-listed stocks over an 11-year period. Aggregate market spreads, depths, and volume are even more volatile than returns. Daily changes in these variables are negatively serially correlated. There has been a secular downtrend in spreads and an upward trend in depth and volume, though there have been major excursions around these trends and at least one important structural break, when the minimum tick size was reduced from one-eighth to one-sixteenth in mid-1997.

We find that liquidity and trading activity are influenced by several factors. Based on theoretical paradigms of price formation (inventory and asymmetric information) and on intuitive reasoning, we nominated candidates as possible determinants. The explanatory variables include short- and long-term interest rates, default spreads, market volatility, recent market movements, and indicator variables for the day of the week, for holiday effects, and for major macroeconomic announcements.

Equity market returns and recent market volatility influence liquidity and trading activity. Short-term interest rates and the term spread significantly affect liquidity as well as trading activity. There are strong day-of-the-week regularities in liquidity and in trading activity. Liquidity declines and trading activity slows on Fridays. This is also true for days adjacent to major holidays, while Tuesdays display the opposite pattern.

A particularly intriguing result is the asymmetric response of bid-ask spreads to market movements. Both quoted and effective spreads increase dramatically in down markets, but decrease only marginally in up markets. Indeed, the down-market variable is the most significant one in our analysis. In addition, contrary to intuition, recent market volatility tends to reduce spreads. Although informal speculation about these results is possible, a formal theoretical investigation of this result would be desirable.

Trading activity and market depth increase prior to scheduled macroeconomic announcements of GDP and the unemployment rate, whereas they fall back toward normal levels on the announcement day itself. This is consistent with increased trading induced by differences of opinion prior to the announcement, which, being conducted by uninformed traders, is accom-

[21] We are grateful to Francis Longstaff for supplying these data.

modated by dealers offering greater depth. The depth pattern would also be consistent with an increase in the number of informed traders as the announcement day approaches. Competition among this larger number of informed agents would drive down asymmetric information costs to dealers and result in higher liquidity (Admati and Pfleiderer (1988)).

The determinants investigated here explain between 18 and 33 percent of daily changes in liquidity and trading activity. This is consistent with the evidence for commonality in liquidity documented by Chordia, Roll, and Subrahmanyam (2000).

It is worth reiterating the adage pointed out, for example, by Chowdhry and Nanda (1991) and Admati and Pfleiderer (1988), that "liquidity begets liquidity." Although a return anomaly is subject to arbitrage forces, a "liquidity anomaly" is self-perpetuating; that is, as agents find out about such an anomaly, they will avoid trading in illiquid periods, which will further reduce liquidity in those periods. Thus, regularities in the time-series behavior of liquidity and trading activity should be dynamically stable.

To our knowledge, no other study has examined such a long history of spreads, depth, and trading activity, nor has any study attempted to identify their determinants. However, the sample period here, 1988 to 1998 inclusive, is a relentless bull market. It seems possible that liquidity and trading activity might behave differently in a bear market. Rising markets attract more investors and there is indeed ample evidence of steadily increasing liquidity over the past decade. Prolonged bear markets, on the other hand, could be subject to falling liquidity.

Although liquidity *levels* could vary with market trends, the determinants of day-to-day *changes* in liquidity are probably the same in most environments, though their explanatory power might very well fluctuate. For example, based on recent experience with crash events, down markets may be characterized by frenzied selling (in contrast to steady buying in rising markets), so inventory could accumulate and the impact of interest rates on liquidity could become stronger in bear markets.

Macroeconomic variables should have influences over horizons longer than those examined here. If macro-variables anticipate economic downturns, they might also anticipate lower liquidity and trading activity in equity markets. As a longer history of data becomes available, future studies will shed more light on this interesting issue.

It would be interesting also to investigate cross-sectional differences in the market-wide effects found here. For example, do interest rates and equity returns differentially influence the liquidity of large and small firms? Are the day-of-the-week effects more prevalent in actively traded stocks or the relatively inactive ones? Do default spreads influence the liquidity of small, relatively new, companies?

The implications of our results for asset pricing remain unexplored. For example, do weekly regularities in liquidity correspond to previously documented patterns in returns? Do unanticipated liquidity variations represent a risk factor priced in the cross section of asset returns? Such questions deserve definitive answers from future research.

Appendix A: Supplementary Empirical Information

Table AI. Debt and Equity Market Explanatory Variables

Summary statistics, daily, 1988 to 1998, inclusive (2,694 observations).

ShortRate: Yield on overnight Federal Funds.
TermSpread: Yield spread between the constant maturity 10-year Treasury bond and the Federal Funds yield.
QualitySpread: Yield spread between Moody's Baa or better corporate bond index and the 10-year constant maturity Treasury bond.
Stocks: Return on the equal-weighted CRSP equity index.

	ShortRate	TermSpread	QualitySpread	Stocks (%/day)
		Levels		
Mean	5.77	1.35	1.79	0.111%
Std. Dev.	1.87	1.35	0.29	0.570%
Median	5.52	1.24	1.73	0.170%
Maximum	10.71	4.24	2.77	2.760%
Minimum	2.58	−2.35	1.16	−5.432%
		Absolute Values of Daily First Differences		
Mean	0.1591	0.1682	0.0252	
Std. Dev.	0.2411	0.2411	0.0250	
Median	0.0800	0.1000	0.0200	
Maximum	2.8300	2.8600	0.2300	
Minimum	0.0000	0.0000	0.0000	

Appendix B: A Caution about Autoquotes

The widely used NYSE TAQ database includes a feature that should engender caution in market microstructure scholars. Unlike the ISSM database, the TAQ database reports "autoquotes" that are passive quotes by official dealers (often from secondary exchanges) who are not actually making a market. Such quotes usually add a mechanical fraction (e.g., 1/4 point) on either side of the posted primary market quote. Depth associated with such a quote is most often 100 shares. Autoquotes are not identified explicitly on TAQ. These facts were verified in electronic communications with Robert Wood, the primary developer of the ISSM database, and with Mark Ventimiglia of the Research and Planning Division at the NYSE.

In this study, we finessed the problem by using only BBO-eligible *primary* market (NYSE) quotes. The magnitude of this problem is illustrated in Figure B1, which plots our average quoted spread series and a corresponding series averaged over all quotes. The average quoted spread jumps from 25 cents to about 42 cents on the first trading day of 1993 when the data source changed from ISSM to TAQ. The series differ only slightly in the ISSM period because there are some legitimate non-NYSE quotes.

This potentially troubling issue should be kept in mind when using the TAQ database.

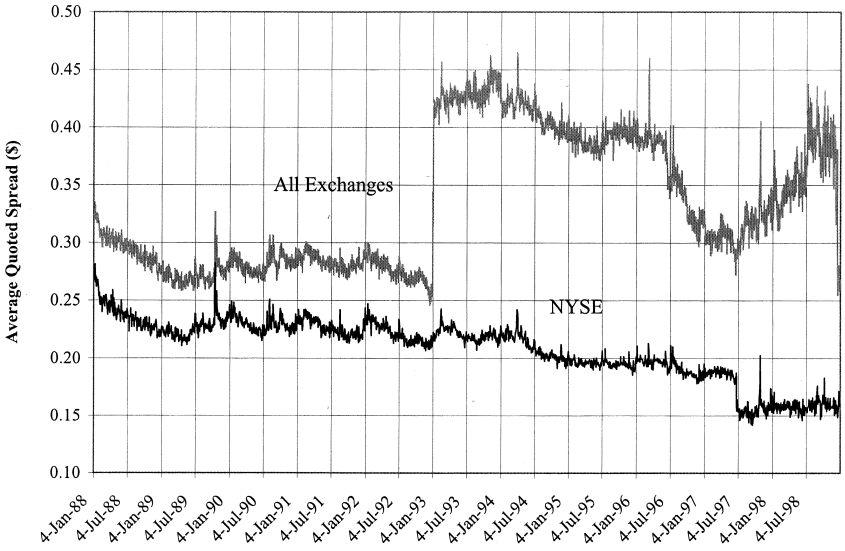

Figure B1. Quoted spread comparison; NYSE versus all exchanges.

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