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Liquidity at the Oslo Stock Exchange

by

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Liquidity at the Oslo Stock Exchange

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April 24, 2008

Abstract

We analyze the relationship between the long term development in liquidity at the Oslo Stock Exchange and the Norwegian economy for the period 1980 to 2007. We calculate different liquidity measures that captures various dimensions of liquidity over time and across industry groups. Overall, we find that the liquidity at the OSE has improved over the sample period. However, the improvement is most pronounced for the largest firms on the exchange. Interestingly, some measures indicate that the implicit cost of trading has been lower in earlier periods than it is today.

Another important finding is that there is a strong counter cyclical relationship between proportional transaction costs measured by the relative spread and the business cycle measured by the output gap. The average relative spread also responds very quickly to the turning points of the business cycle. This result suggest that liquidity measures provide important real time information about the current state of the economy as well as market participants expectations about future economic growth.

JEL Codes: G12; G14

Keywords: Liquidity; Market Microstructure

*The views expressed are those of the authors and should not be interpreted as reflecting those of Norges Bank.

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1 Introduction

In recent weeks we have seen two cuts in US interest rates[1] partly justified by the large decline in the stock market. It is becoming increasingly clear that the stock market is seen as an important temperature measure of the state of the economy. For financial stability, aspects of the stock market may provide important warning signals. In this paper we discuss one such aspect of stock markets, namely stock market liquidity.

Several empirically documented features of market liquidity seem important for the macro economy in general and financial stability in particular. As summarized in Brunnermeier and Pedersen (2006) liquidity can "*suddenly dry up, has commonality across securities, is related to volatility, is subject to "flight to quality" or "flight to liquidity", and co-moves with the market*". An important finding in this article is the identification of a small set of liquidity indicators that can be used to assess the fragility of the Norwegian stock market and how market liquidity varies with the business cycle.

A market is said to be liquid if traders can quickly buy or sell large numbers of shares at low transaction costs with little price impact. A closer look at this definition reveals that liquidity has several interrelated dimension; it has a *cost* dimension - what are the costs of executing a trade, a *quantity* dimension - how much can be traded, a *time* dimension - how quickly can a trade be executed, and an *elasticity* dimension - what is the price impact from a trade of a given size, and how quickly does the price revert to the true value after a temporary liquidity shock.[2]

A main challenge in empirical research on liquidity has been to construct measures that can capture all dimensions of liquidity in a satisfactory way. As a result a large number of empirical measures exists, some of which are only modestly correlated. A second challenge is the choice between ex-ante versus ex-post liquidity. Should we measure currently available liquidity or should liquidity be measured based on the history of executed trades? Order based liquidity measures such as the quoted spread and the posted depth refer to the current available (or ex-ante) liquidity in the market, while trade based measures such as turnover and trading volume refer to realized (or ex-post) liquidity. Under normal market conditions, both types of measures should provide correct signals of liquidity. However, trading activity might also be high in a crises situation when liquidity is actually low (as investors are struggling to get out of their positions). Some empirical studies document that this difference can be important.[3] Still, the overall bulk of empirical literature on liquidity rely on trade based liquidity measures. This fact is related to a third challenge in empirical research on liquidity; data-availability.[4] Ideally we would like to compute liquidity measures based on the actual sequence of quotes and trades. How-

[1]On January 22nd and 30th 2008 the Federal Reserve cut the interest rate by 0.75 and 0.50 percentage points respectively.

[2]This division is similar to Harris (1990) dimensions of width, depth, immediacy and resiliency. Kyle (1985) defines liquid market as being tight, deep and resilient without focusing on the immediacy of the market.

[3]See Aitken and Comerton-Forde (2003) and Chollete, Næs, and Skjeltorp (2007)

[4]Most order based measures require quite detailed information about the transaction process

ever, such computations require high-frequency (intra-day) data that has become available only recently. We are therefore faced with a trade-off between small samples of precisely computed measures and long time-series of more coarse measures, see Amihud, Mendelson, and Pedersen (2005).

The analysis in this paper is based on data at the daily frequency for all securities listed at the OSE over the period 1980-2007. Having a long time-series is important when we want to uncover important features of market liquidity and relate them to developments in the Norwegian economy. Also, since the liquidity indicators should be readily accessible and not to complicated to calculate, it makes sense to work with daily rather than intra-day data.

The paper is organized as follows. In Section 2, we provide some general statistics on the size and activity at the OSE over the sample period. We also describe the main changes in the organization of trading at the OSE, and relate them to some important market design issues in the literature. The long term development in a broad set of liquidity measures is presented in Section 3. We first calculate variations in the measures over time and across industry groups. We then look at the correlation structure of the measures and try to detect firm characteristics that can explain the cross-sectional variation in the various liquidity measures. In Section 4, we relate the features of market liquidity that we find in Section 3 to the development of the Norwegian economy and changes in the organization of the marketplace. We also look at the evolution of liquidity around three episodes of financial distress; the 1987 stock market crash, the Norwegian banking crisis over the 1988-1993 period, and the sub-prime market crisis in 2007. Section 5 concludes.

2 The Oslo Stock Exchange 1980-2007

The analysis in this paper is based on daily data for all listed securities at the OSE during the 1980-2007 period.[5] In this section we first present some general statistics of the development in market size and trading activity at the OSE over the sample period. We then turn to the issue of market structure. From the microstructure literature we know that market design and trading rules can have significant effects on price formation and liquidity. We should therefore have a background knowledge of significant changes in the organization of trading at the OSE over the sample period.

2.1 Descriptive statistics

Table 1 presents some general statistics on the size and trading activity at the OSE over the 1980-2007 period. There has been a strong increase in market size over the period. In 1980, 93 firms were listed at the exchange with a total market value of NOK 16.5 billions. At the end of 2007, the 241 listed firms had a total market value of NOK 1801 billions.

[5]All accounting figures, trading volume, spreads and price data are obtained from Oslo Børs Informasjon (OBI).

The increase in stock turnover over the period is also formidable. During 1980, less than 2 percent of the average firm's shares changed hands. 27 years later, the similar percentage was 136.3. The value weighted average turnover has in general been larger than the equally weighted average turnover, reflecting higher turnover in the largest firms. The significance of the stock market in the Norwegian economy has also increased dramatically over the period. To illustrate this, we show a plot of the market value of all listed stocks relative to annual GDP in Figure 1. In 1980/81, the market value of the OSE amounted to five percent of GDP, a percentage that has increased to more than 90 percent in 2007.

Table 1 The Oslo Stock Exchange 1980-2007 - Market size and trading activity

The table shows the number of listed stocks, market value in NOK billions, and value weighted and equally weighted turnover for the Oslo Stock Exchange over the 1980-2007 period. For each stock daily turnover is measured as the daily number of trades divided by the number of shares outstanding. Daily turnover is then aggregated by summing over the year. We then calculate value weighed and equally weighted averages of the resulting estimated turnovers.

Year	Number of companies	stocks	Market value (billions)	Turnover (percent) VW	EW
1980	94	96	16.5	2.30	1.82
1981	97	99	17.7	2.94	2.78
1982	113	116	16.9	3.15	3.14
1983	124	128	38.1	10.46	11.42
1984	143	148	50.8	22.44	23.24
1985	164	169	76.3	21.87	28.59
1986	171	183	75.5	13.99	18.70
1987	165	181	72.6	22.74	22.29
1988	150	163	102.4	31.25	25.43
1989	146	177	166.9	57.95	43.24
1990	148	190	156.3	47.20	42.13
1991	133	172	133.8	56.44	40.90
1992	136	172	115.2	60.81	38.37
1993	146	185	215.6	80.61	77.77
1994	157	195	254.5	63.22	55.69
1995	173	194	290.0	59.65	67.59
1996	187	206	404.5	67.42	80.09
1997	230	250	614.2	63.66	75.92
1998	245	269	460.9	49.68	53.13
1999	246	263	619.2	75.39	61.57
2000	246	259	701.9	72.18	68.08
2001	233	247	755.8	66.09	56.21
2002	222	226	562.8	57.26	51.97
2003	212	218	784.3	88.77	93.42
2004	206	207	986.9	93.32	117.47
2005	239	240	1456.7	141.80	134.17
2006	256	260	1952.7	139.89	116.85
2007	263	267	1801.4	163.90	136.30

2.2 Market structure

2.2.1 Issues in market design

Figure 2 illustrates three important issues in market design; degree of continuity, reliance of dealers, and degree of transparency.[6]

[6]For a broader discussion on the market microstructure of stock markets, see for example Næs and Skjeltorp (2006)

Figure 1 Market value of listed companies relative to GDP (percent)

The figure plots the market value of all listed companies at the OSE as a percentage of annual GDP.

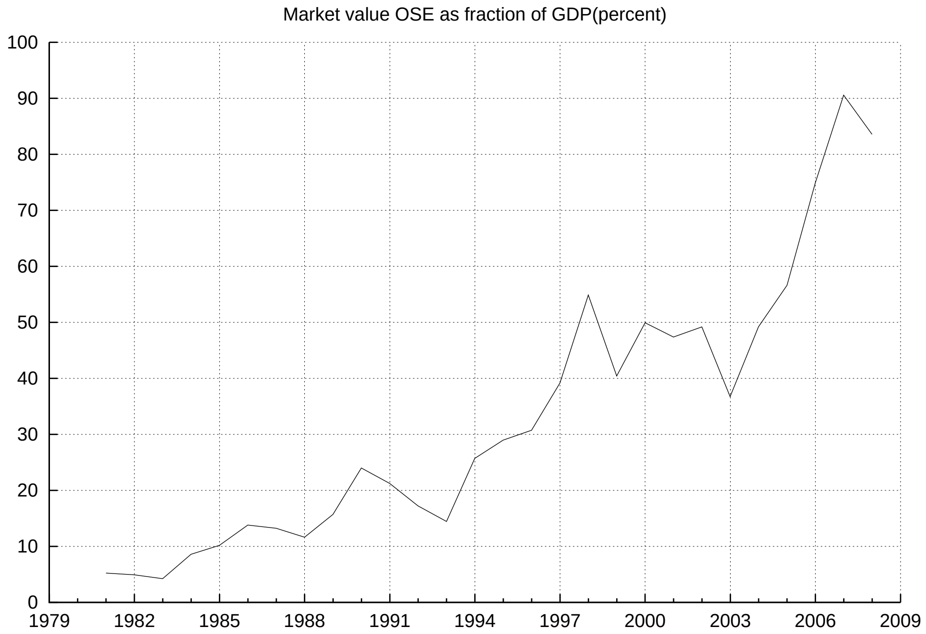
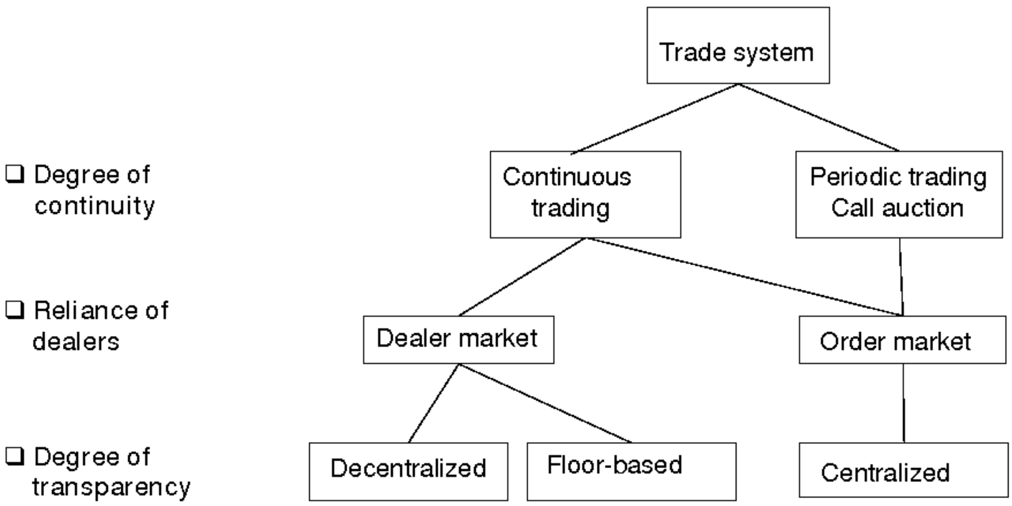


Figure 2 Market design issues

The figure illustrates three important issues in market design; the degree of continuity, the reliance of dealers, and the degree of transparency.



Ensuring that buyers and sellers find one another and have the opportunity to trade when they want to, is a fundamental function of every market. Continuous trading systems allow trading at any point in time, while periodic systems allow trading only at specific points in time. There is a strong demand for continuous trading among investors. However, theory suggests that a single price call auction is the most efficient trading mechanisms, especially when uncertainty over fundamentals is large and there is a possibility for market failure (see for example Mendelson (1982)). Today most stock markets provide continuous trading and utilize the efficiency of call auctions at the times when this is particularly important, i.e. at times when uncertainty is large such as at the open and close of trading.

The procedures adopted for the matching of buyers and sellers can be quote-driven, order-driven, brokered, or some combination of the three.[7] In a pure quote-driven market, traders trade indirectly with each other through one ore more dealers.[8] Dealers quote prices and negotiate all trades. In a pure order-driven market, there is no need for dealers. Buyers and sellers either provide liquidity by placing limit orders (orders to buy or sell at a given price) or demand liquidity by placing marketable limit orders (orders that are priced in such a fashion that they cross the spread and execute immediately). Trades are arranged using rules for order precedence and pricing. In a brokered market, brokers actively search to match buyers and sellers. This structure is suitable in illiquid markets where dealers do not want to quote prices.

The emergence of electronic limit order markets has contributed to the debate on the role of dealers in the trading process. Electronic trading systems are claimed to be faster, cheaper, more efficient for users, and less prone to manipulation by dealers. Still, many stock exchanges are largely based on dealers. One explanation for this is that it becomes too costly for limit order traders to keep track of the market.[9] Another explanation is that dealers reduce the information costs in the market by having extensive contacts with brokers (Benveniste, Marcus, and Wilhelm (1992)).[10] In recent years several limit order markets have allowed listed companies to negotiate with market makers to keep maximum spreads and minimum depths in their stocks. Anand, Tanggaard, and Weaver (2005) find evidence of a significant improvement in market quality for a sample of stocks that entered into such agreements at the Stockholm Stock Exchange; quoted spreads declined and quoted depth increased throughout the order book.

Transparency refers to the quantity and quality of information provided to market participants during the trading process. A decentralized dealer market provides a low degree of transparency. An example of this market structure is the foreign exchange markets.

[7]The discussion in this paragraph is based on Harris (2003), pages 92-96 and 112.

[8]In some equity markets, dealers may be known as market makers or specialists.

[9]As shown by Copeland and Galai (1983), limit order traders offers free options to the market.

[10]However, there are also some arguments that dealers worsen adverse selection. The source of this problem is asymmetries in the timing of trading opportunities of different liquidity suppliers. When an order arrives at the floor the dealer can choose to undercut the book, to stop the order or to let it hit the book. A similar problem arises at the opening of a market, if the dealer can place his order after the public, see Stoll and Whaley (1990), and Seppi (1997).

At the other end, an open centralized limit order books display a lot of information both before (quoted, depth) and after (price, volume) trading. A number of theoretical studies have shown that increased transparency result in better liquidity and reduced transaction costs, see Admati and Pfleiderer (1991), Chowdhry and Nanda (1991), Forster and George (1992), and Benveniste et al. (1992). However, Madhavan (1995) shows that transparency can also reduce liquidity, because participants not wanting to reveal their trading interests may withdraw their orders from the market.

If we look at stock markets around the world, there are major variations in market structure. While the US stock market consists of many different trading systems, most European countries have a centralized electronic trading system. Advances in electronic communications have meant that all major stock exchanges now operate with some form of limit order book. However many exchanges remain dependent of dealers in various ways.[11]

2.2.2 Trading at the OSE

The execution system at the OSE has always been order driven, however there have been several major changes in the system over the sample period. Figure 3 illustrates the developments of market structure at the OSE over the 1980-2007 period. In 1980, trading was done using periodic auctions. For each stock, an auctioneer presided over a price setting auction once or several times a day. The periodic auction system was replaced in 1988 by an electronic trading system with continuous trading in all listed securities. Despite the electronic trading platform, the system did not enforce priority rules. A broker could freely choose what orders he or she wanted to match, independent of price. Moreover, since there was no time priority rule, traders had no incentives to submit orders "first". While competition among brokers implied that price priority was enforced in practice, the lack of time priority presumably had a negative impact on the market depth.

In 1999 the trading system was again changed, this time to a fully automated computerized trading system similar to the public limit order book systems in Paris, Stockholm, and Toronto. Automated order matching implies strict enforcement of the order handling rule. As is normal in most other electronic order driven markets, the order handling rule follows a price-time priority. The new trading system also decentralized the former trading system at the exchange, i.e. all brokers moved out of the exchange building and several internet brokerage houses serving retail investors were established. A different, although similar, trading system was introduced in the spring 2002. The reason for replacing the 1999 system was an agreement signed by OSE with the stock exchanges of Stockholm, Copenhagen and Iceland to establish a joint Nordic marketplace, known as NOREX. The NOREX exchanges are still independent entities, but the alliance has made it possible to

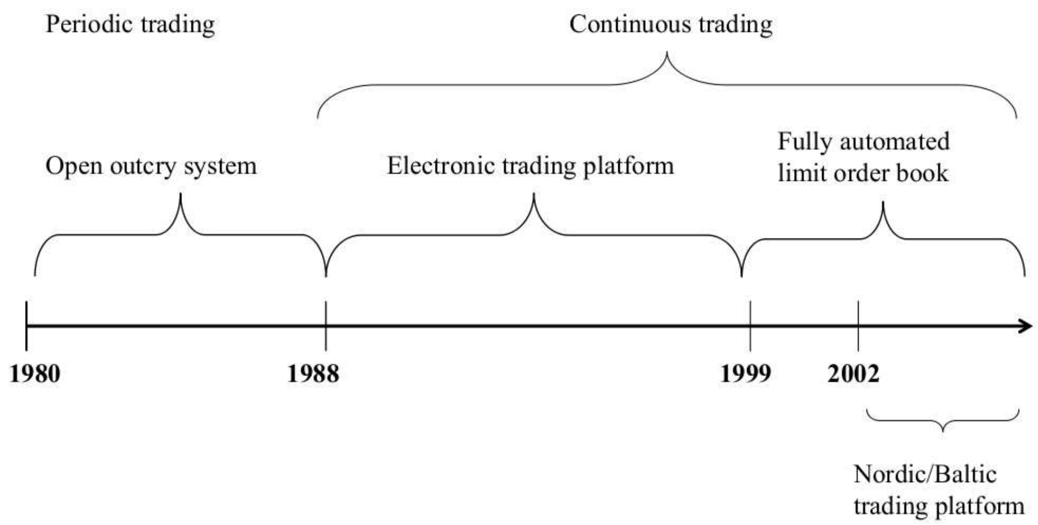
[11]The main US equity exchanges, NYSE and NASDAQ, are mixtures of both quote-driven, order-driven, and brokered markets. The NYSE is essentially order-driven but requires its dealers to offer liquidity if no one else will do so. The NASDAQ requires its dealers to display and sometimes execute public limit orders. In both markets large brokers sometimes arrange block trades.

create a joint Nordic marketplace with a common trading platform and harmonized regulations. Currently, the trading system also includes single-price auction mechanisms at the open and close of trading and after the exchange have temporarily halted the trading in a security.[12] Market maker arrangements were formalized at the OSE in the beginning of 2005. In 2007 34 companies had market maker contracts with a broker house.

Based on the discussion in 2.2.1, we would expect an improvement in liquidity at the OSE after the introduction of electronic trading in 1988. The change to a fully automated system in 1999 could also have had a positive effect on market liquidity. We also note that the market has a high degree of transparency and that there is no reliance of dealers, except for some privately arranged market maker agreements.

Figure 3 Trading system at the Oslo Stock Exchange 1980-2007

The figure illustrates the main developments in market structure at the OSE over the 1980-2007 period.



3 Long-term development of liquidity

In this section, we describe the long-term development of liquidity at the OSE based on a set of standard liquidity measures used in the empirical finance literature. We also present the correlations between different measures and analyze whether the measures can be explained by a set of firm characteristics. As discussed in the introduction, liquidity measures can be categorized along four liquidity dimensions - costs, quantity, time, and elasticity - and divided into trade and order based measures. We calculate two quantity (or activity) measures, three cost measures, two elasticity measures, and one compound measure with emphasis on the time dimension of liquidity. Except for the spread measures, all measures are trade based. 27 years of data gives us a good picture of the historical

[12]For more information about trading at the OSE, see www.ose.no.

evolution of liquidity in the Norwegian stock market along different dimensions. Since we have data for all listed firms we also evaluate cross sectional variations in liquidity over the sample period.

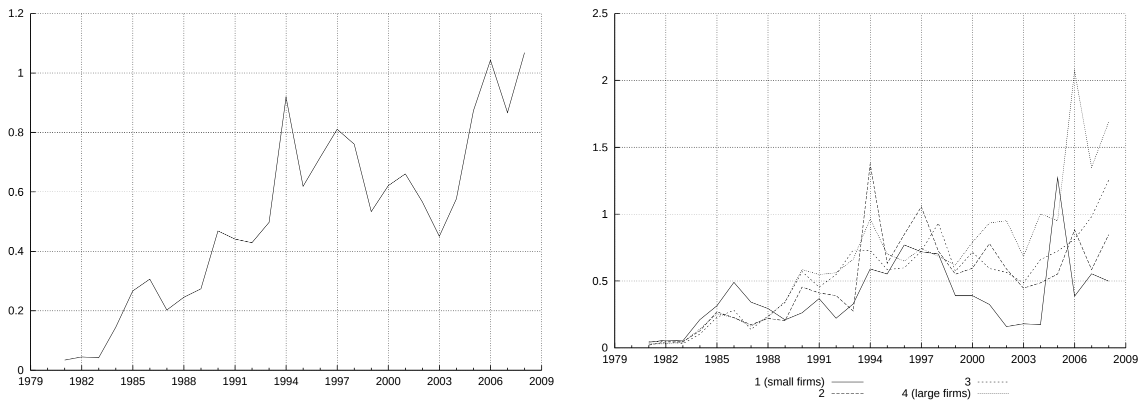
3.1 Activity (quantity) measures

Securities with high trading activity are generally thought of as being liquid, and various measures of trading activity are therefore often used to proxy for liquidity. We look at two activity measures; turnover and the number of days that a security is traded. Daily turnover is measured as the daily number of traded shares divided by the number of shares outstanding.[13] Turnover thus measures the fraction of the company shares that switches hands on a given day. The number of days that a security is traded is a simple count of days with positive trading volume during a year.

From Table 1 in Section 2, we know that turnover at the OSE has increased a lot over the sample period. Presumably, there is a strong relationship between trading activity and firm size. We therefore show annual turnover for four portfolios sorted on firm size in Figure 4.[14] The figure shows that increased turnover at the OSE is mainly driven by increased turnover in the two portfolios with the largest firms. For below median firms, the turnover today is similar to the turnover observed in the early 1990s.

Figure 4 Annual turnover 1980-2007

The figures shows a time series plot of annual turnover over the period 1980-2007 for four size portfolios. Daily turnover is measured as the daily number of trades divided by the number of shares outstanding. Daily turnover is then aggregated by summing over the year.



(a) Annual turnover (b) Annual turnover (MCAP groups)

In Table 2 we present some descriptive statistics for annual turnover. The first row in the table shows mean and median turnover over the whole sample period and three subperiods for all listed firms. The following rows show similar numbers for 10 GICS industry sectors and the four size portfolios. Similar descriptive statistics for the number of trades

[13]Daily turnover is aggregated by summing over months, quarters or years.

[14]The portfolios are sorted on market capitalization values at the beginning of each month.

is presented in Table 10 in the Appendix. The median turnover has increased quite a lot over the sample period, from 21.4 in the 1980-1989 period to 95.15 in the 2000-2007 period. Moreover, the distribution of turnover is positively skewed, i.e. some firms have a much higher turnover than the median firm.

There are large variations in turnover across industry sectors. However, the number of firms within each sector also varies significantly across sectors as well as over time. The Telecommunication sector and the Utilities sector consist of only a couple of firms from 1996 and onwards, and the Health Care sector consisted of only a couple of firms until 1994.[15] Measured over the full sample period, the two sectors with the highest median turnover are the Energy sector and the IT sector, while the lowest median turnover is found in the Utilities sector and the Financials sector. The large increase in turnover in the Energy sector in the most recent sub-period is due to the listing of Statoil in 2001, and the reclassification of Norsk Hydro from the Industry sector to the Energy sector in 2002. Mean and median number of trading days during a year largely show the same picture; increased liquidity over time, a size effect, and IT and Energy as the most liquid sectors.

Table 2 Descriptive statistics for annual turnover

The table shows descriptive statistics for annual turnover for all companies, 4 size portfolios (based on firms market capitalizations), and the GICS industry sectors. Means, medians and standard deviations are calculated for the whole sample period as well as for three sub-periods. Daily turnover is measured as the daily number of trades divided by the number of shares outstanding. Daily turnover is then aggregated by summing over the year.

Annual Turnover	Whole sample		1980–1989		1990–1999		2000–2007	
	mean	median	mean	median	mean	median	mean	median
All securities	61.78	34.04	25.04	13.25	65.45	47.94	85.31	43.36
Grouped by industry(GICS)								
10 Energy and consumption	103.55	58.20	37.27	26.21	74.63	56.58	158.01	111.67
15 Material/labor	54.31	31.70	24.95	11.34	84.69	95.86	50.90	30.62
20 Industrials	52.47	28.84	29.12	18.95	53.83	40.88	71.34	28.65
25 Consumer Discretionary	43.28	22.26	22.20	10.41	53.04	28.14	40.73	39.30
30 Consumer Staples	40.25	20.25	16.19	9.85	41.96	41.05	72.56	59.33
35 Health Care/liability	60.85	43.20	19.67	16.62	72.42	74.18	54.54	36.56
40 Financials	44.84	21.09	17.27	9.30	54.57	44.29	49.66	20.85
45 Information Technology	95.65	74.79	32.98	15.46	108.54	112.16	122.54	90.34
50 Telecommunication Services	71.39	75.68			40.90	42.49	84.75	102.57
55 Utilities	25.87	12.99			64.82	62.60	15.25	5.87
Grouped by firm size(MCAP)								
1 (small)	50.54	21.03	33.43	18.95	57.37	31.59	50.51	17.41
2	59.11	32.44	19.14	10.71	69.21	47.78	69.01	41.64
3	72.52	45.38	24.38	13.94	71.54	51.28	105.37	64.33
4 (large)	55.73	49.63	26.11	19.58	62.78	57.98	93.51	87.96

3.2 Cost measures

A security is more liquid the less costly it is to trade it. Thus, measures of trading activity and trading costs should be negatively related. However, the relationship may become

[15]For a detailed list of the number of firms in each sector, see Table 2 in Næs, Skjeltorp, and Ødegaard (2008).

positive during periods of distress, as traders are willing to suffer high costs to get out of their positions quickly.[16] Thus, a one-sided focus on trade based activity measures can be misleading. Activity measures should always be coupled with some measure of trading costs.

3.2.1 Spread measures

A frequently used cost measure of liquidity is the spread between bid and ask prices. Spread costs are observed in dealer markets as well as in limit order markets, and there are several empirical measures available including quoted spread, relative quoted spread, effective spread, and amortized spread. The **quoted spread**, s, is simply the difference between the best ask quote and the best bid quote, i.e.

$$s = P^1_{ask} - P^1_{bid} \tag{1}$$

where p^1_{ask} is the best ask quote, and p^1_{bid} is the best bid quote.[17] The midpoint between the best bid and ask quotes,

$$\bar{p} = \frac{P^1_{ask} + P^1_{bid}}{2} \tag{2}$$

is often used as an estimate of the true value of the security.[18] Hence, a trader who wants to buy one share of the stock has to pay a price that is one half-spread above the true value of the stock, whereas a trader who wants to sell one share of the stock gets a price that is one half-spread below the true value. The **relative quoted spread**, s_{rel}, is the quoted spread divided by the midpoint price, i.e.

$$s_{rel} = \frac{s}{\bar{p}} \tag{3}$$

One half of the relative spread gives the percentage one-way cost of buying or selling one share of a security relative to the midpoint price. In theoretical market microstructure models, spread costs are explained by two effects; a compensation for inventory costs and a compensation for adverse selection costs, i.e. the risk of selling to or buying from a better informed trader. This decomposition of the spread is illustrated in figure 5.

A problem with the use of quoted spreads as a measure of trading costs is that many trades execute inside or outside of the quotes. Large trades will for example typically trade at a worse price than the best quote. If the total volume at the best ask quote is lower than an aggressive buy order, the average trade price will be higher than the best quote, as the order has to "walk-the-book" to fully execute. The **effective spread**, s_{eff}, is defined as the

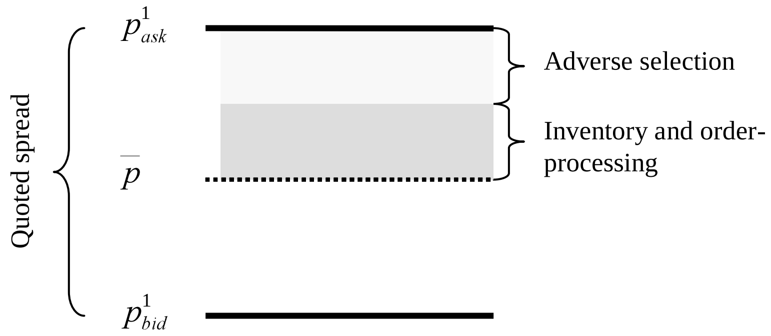
[16] see for example Aitken and Comerton-Forde (2003).

[17] The subscript denotes price level, i.e. 1 denotes the best quote. In a limit order market, there is normally also quotes at other prices than the best quotes. Thus, if the volume quoted at the best quote is less than a traders liquidity demand, the order will execute at several prices.

[18] Using midpoint prices in this way makes sense if the quotes are based on full information and are symmetrically distributed around the true stock value.

Figure 5 Spread decomposition

The figure illustrates that the spread can be decomposed into an adverse selection component and an inventory/order-processing component. The true value of the security is denoted by $\bar{p}$, the best ask price as p^1_{ask}, and the best bid price as p^1_{bid}. The superscript 1 denotes the first price level at which the security can be traded.



difference between the actual trade price and the prevailing midpoint price, i.e.

$$s_{eff} = |p - \bar{p}| \tag{4}$$

where p is the actual trade price. Since the effective spread takes into account that actual trades might execute at other prices than the prevailing quotes, it is often considered a more appropriate measure of trading costs than quoted spreads.

There is a large literature on the role of transaction costs in asset pricing. A much cited hypothesis in this literature is that the impact on required returns from spread costs is determined by the length of investors' expected holding periods.[19] Thus, if share turnover varies a lot across stocks, stocks with similar effective spread need not have similar liquidity premiums. Using the inverse of stock turnover as a proxy for average holding period, the **amortized spread**, s_{am}, suggested by Chalmers and Kadlec (1998) incorporates investors' holding periods into the trading costs. Chalmers and Kadlec define the daily dollar spread as the sum, over all trades, $t = 1, ..., T$, of the product of the effective spread and the number of shares traded v_t. The daily amortized spread for day T is then defined as the daily dollar spread scaled by the company's market value at the end of day T, i.e.

$$s_{am} = \frac{\sum_{t=1}^{T} s_{eff,t} \times v_t}{p_T \times n_T} \tag{5}$$

where n is the number of shares outstanding. Note from equation (5) that the amortized spread is approximately equal to the relative effective spread times turnover (v/n) or the relative effective spread divided by the average holding period (1/turnover).

A problem with both the effective spread and the amortized spread is that one needs intra-day data to calculate prevailing midpoint prices. Since we only have access to daily data, we cannot calculate effective spreads[20]. To get around this problem, we approximate

[19] See for example Amihud and Mendelson (1986).

[20] Roll (1984) suggests a way to estimate the effective spread without observing the actual quotes. His

the daily amortized spread as the relative spread times turnover, i.e.

$$s_{am} \approx s_{rel} \times \frac{v}{n} \tag{6}$$

Plot (a) and (b) in Figure 6 shows respectively the average monthly quoted spread and relative spread for all listed firms over the 1980-2007 period. We also show two corresponding plots, (c) and (d), for the four portfolios sorted on firm size. Two distinct patterns in the figure are worth noting. First, plot (a) and (c) show that quoted spreads were considerably higher and more volatile in the eighties than in the nineties, possibly with an exception for the largest firms in the sample. This pattern coincides quite well with the seminal change in trading system at the OSE in 1988 from a manual open outcry system to an electronic trading platform. More interesting, plot (b) and (d) shows that relative spreads have followed a cyclical pattern, with cycles of around 10 years. Plot (d) shows that the cyclical pattern is most pronounced for the smallest firms, although the pattern is also evident for the largest firms. In Section 4 we provide some evidence that the cyclical pattern in proportional spread costs is related to business cycles.

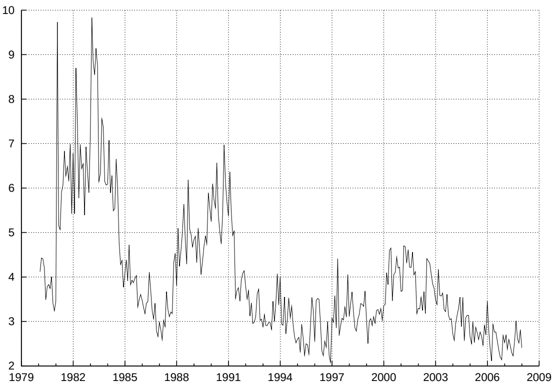
There is a monotonic increase in the relative spread from the largest firms to the smallest firms for all months. For quoted spreads, the relationship with firm size is less clear. The transition to a fully automated trading system in 1999 does not seem to have a large impact on the spread costs. In fact, the average quoted spreads seem to have increased somewhat after the transition. From plot (c) we can see that this is mainly due to an increase in the spreads of the smallest firms. The quoted spreads for the group of the largest firms is currently at a historical minimum. These features suggest that the fully automated trading system works better for large firms than for small firms.

In table 3, we present descriptive statistics for the relative quoted spread. Similar statistics for the quoted spread and the amortized spread are presented in respectively Table 11 and Table 12 in the Appendix. Averaged over all companies, the mean and median **relative spread** were 4.7 percent and 2.7 percent respectively. Lower medians than means are evident across industry groups and size portfolios as well, suggesting that some firms have quite high relative spreads. One important thing to note is that, unlike the activity measures of liquidity, proportional spread costs have not decreased over the sample period. For the portfolio of the largest firms, the average median relative spread was actually a bit lower measured over both the 1980-89 period and the 1990-99 period than over the most recent period 2000-2007. Measured by the median relative spread costs over the full sample period, the most liquid sectors are the Energy sector and the Health Care sector, while the least liquid sector is the Consumer Discretionary sector. **Quoted spread** is even more positively skewed than relative spread. We also note a strong decrease over

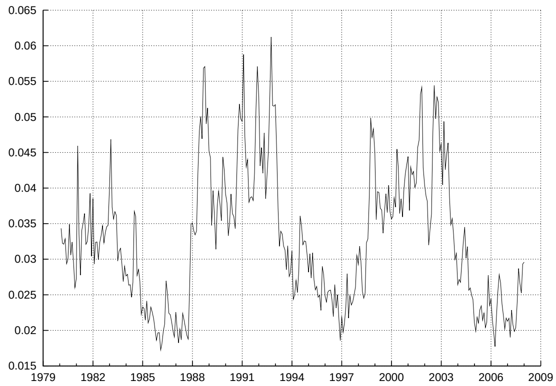
spread measure, s_{roll}, assumes that buys and sells are equally likely (serial independent), and that trades are independent of the true value innovations. Under these assumptions, Roll calculate the effective spread as twice the square root of the negative of the estimated price change serial covariation. For a security i this can be estimated as $s_{roll,i} = 2\sqrt{-cov(r_t, r_{t-1})}$ where r_t is return in period t. The Roll measure can be calculated at any frequency, however, at daily or larger frequencies, the estimator performs poorly.

Figure 6 Daily spreads 1980-2007

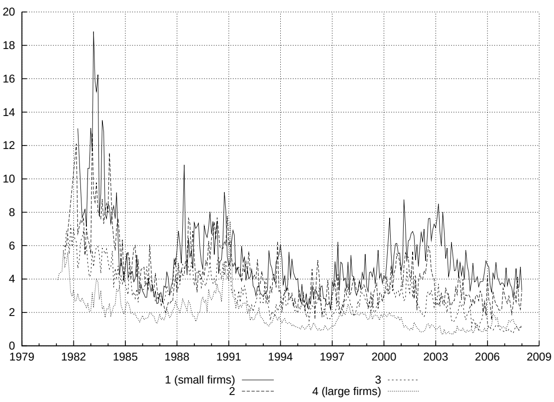
The figures shows the time series plot of the cross-sectional average spreads averaged over each month through the sample from 1980 through 2007. Figure (a) shows the quoted spread in NOK, figure (b) shows the relative quoted spread (the quoted spread divided by the quote midpoint), figure (c) shows the quoted spread for four size portfolios and figure (d) shows the relative spread for the same size portfolios.



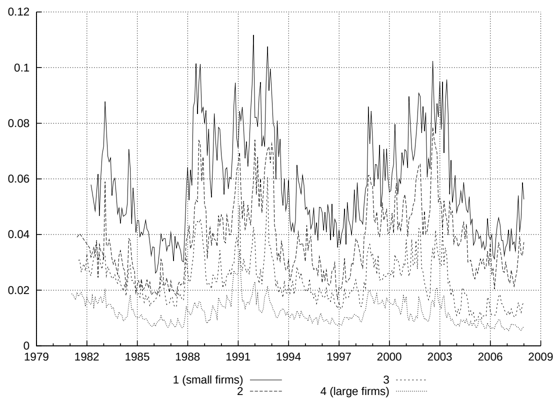
(a) Quoted spread



(b) Relative spread



(c) Quoted spread (MCAP groups)



(d) Relative spread (MCAP groups)

time in quoted spreads after the 1980-89 period. The two sectors with the lowest median quoted spread cost over the full sample period are the Material sector and the Telecommunication Service sector, while the sector with the highest median quoted spread cost is the Consumer Discretionary sector. **Amortized spread** takes holding period into account in the sense that high turnover stocks will have higher amortized spread costs than low turnover stocks, all else equal, i.e. the measure adjust upwards the proportional trading costs in stocks that are heavily traded. Scaling with turnover does not remove the size effect, but the ranking of industry sectors change somewhat, the most liquid sectors now being Utilities and Consumer Staples, while the Consumer Discretionary sector remains the most illiquid sector.

Table 3 Descriptive statistics for relative spread

The table shows descriptive statistics for relative spreads for all companies, 4 size portfolios (based on firms market capitalizations), and the GICS industry sectors. Means and medians are calculated over the full sample period as well as for three sub-periods.

Monthly avg relative BA Spread	Whole sample		1980–1989		1990–1999		2000–2007	
	mean	median	mean	median	mean	median	mean	median
All securities	3.56	2.43	3.48	2.43	4.19	2.90	3.40	1.96
Grouped by industry(GICS)								
10 Energy and consumption	2.40	1.64	2.80	2.03	3.06	1.93	2.12	1.42
15 Material/labor	3.38	2.35	3.09	2.04	3.96	2.10	4.83	3.82
20 Industrials	4.61	2.97	4.27	2.43	5.25	3.60	4.54	2.19
25 Consumer Discretionary	4.44	3.20	3.24	2.48	5.48	4.54	5.36	3.74
30 Consumer Staples	2.94	2.30	3.05	2.38	4.39	2.86	2.26	1.78
35 Health Care/liability	2.31	1.83	1.49	1.09	2.59	0.96	2.88	1.88
40 Financials	3.77	2.76	3.45	2.53	3.67	2.48	3.91	2.75
45 Information Technology	3.26	2.33	3.27	2.67	3.87	2.80	2.86	1.99
50 Telecommunication Services	1.96	1.82	3.24	3.24	1.15	1.10	1.27	0.96
55 Utilities	3.12	2.34			1.76	1.67	3.28	2.56
Grouped by firm size(MCAP)								
1 (small)	5.42	4.21	5.68	4.71	6.43	5.09	5.05	3.35
2	3.54	2.39	3.44	2.51	4.15	3.07	3.50	2.01
3	2.38	1.66	2.23	1.72	2.55	1.75	2.21	1.29
4 (large)	1.23	0.75	1.27	0.93	1.56	0.96	0.57	0.40

3.2.2 The LOT cost measure

Lesmond, Ogden, and Trzcinka (1999) suggest a measure of transaction costs (hereafter the LOT costs) that does not depend on information about quotes or the limit order book. Instead, the LOT measure is based on the occurrence of zero returns . Consider a simple market model,

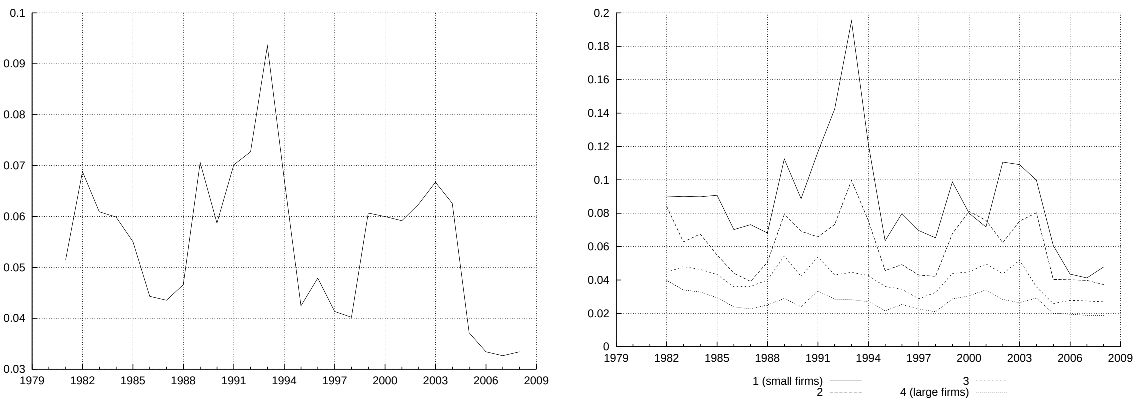
$$R_{it} = a_i + b_i R_{mt} + \varepsilon_{it} \tag{7}$$

where R_{it} is the return on security i at time t, R_{mt} is the market return at time t, b is a regression coefficients, a is a constant term, and ε is an error term. The LOT cost is an estimate of the implicit cost required for a firm's price *not* to move when the market as a whole moves. The idea underlying the measure is the following. For *any* change in the market return, the stock return of security i should move according to b_i. If it does not, it could be that the price movement that *should* have happened is not large enough to cover the costs of trading. Lesmond et al. (1999) estimate how wide the transaction costs band around the current stock price has to be to explain the occurrence of no price movements (zero returns). The wider this band, the larger must the expected price movement be to cover the transaction costs, and the less liquid is the security. Note that, unlike the other cost measures we calculate, the LOT cost measure is trade based.[21]

Figure 7 plots the annual LOT cost averaged over all listed securities (a) and the four size portfolios (b), and Table 4 presents mean and median annual LOT costs measured over the full sample period and three sub-periods. Figure 7 shows large variations over time in the LOT costs and a positive relationship between LOT costs and firm size for all years. The variations over time in the LOT costs coincide well with the cyclical patterns observed for the relative quoted spread in Figure 6(b). Measured by median LOT costs over the full sample period, the most liquid sectors are the Consumer Staples sector and the Health Care sector, while the most illiquid sector is the Consumer Discretionary sector.

Figure 7 The annual LOT cost measure 1980-2007

The figures shows the time series plot of the cross-sectional averaged annual LOT cost measure from 1980 through 2007. Figure (a) shows the average (equally weighted) LOT cost and figure (b) shows the LOT costs for the four size portfolios.



(a) Annual LOT measure

(b) Annual LOT measure (MCAP groups)

3.3 Price impact (elasticity) measures

We now turn to the elasticity dimension of liquidity. The elasticity measures of liquidity tries to take into account how much prices move as a response to the trading volume. Thus, cost measures and elasticity measures are strongly related. We examine two simple, but popular, price impact measures.

Kyle (1985) defines price impact as the response of price to order flow. Amihud (2002) proposes a price impact measure that is closely related to Kyle's measure. The daily Ami-

[21]Quoted spread, relative spread, and our version of the amortized spread are all order based. The effective spread is a hybrid with respect to the order-versus-trade dimension.

Table 4 Descriptive statistics for annual LOT cost

The table shows descriptive statistics for the annual LOT cost for all companies, 4 size portfolios (based on firms market capitalizations), and the GICS industry sectors. Means and medians are calculated over the full sample period as well as for three sub-periods.

LOT	Whole sample		1980–1989		1990–1999		2000–2007	
	mean	median	mean	median	mean	median	mean	median
All securities	0.0580	0.0428	0.0577	0.0461	0.0599	0.0436	0.0486	0.0305
Grouped by industry(GICS)								
10 Energy and consumption	0.0421	0.0320	0.0531	0.0464	0.0467	0.0354	0.0282	0.0241
15 Material/labor	0.0563	0.0417	0.0487	0.0387	0.0742	0.0303	0.0497	0.0379
20 Industrials	0.0712	0.0511	0.0694	0.0524	0.0731	0.0507	0.0608	0.0311
25 Consumer Discretionary	0.0688	0.0528	0.0600	0.0526	0.0758	0.0708	0.0628	0.0528
30 Consumer Staples	0.0444	0.0352	0.0454	0.0377	0.0456	0.0296	0.0300	0.0244
35 Health Care/liability	0.0423	0.0321	0.0319	0.0324	0.0429	0.0416	0.0454	0.0321
40 Financials	0.0544	0.0409	0.0548	0.0431	0.0472	0.0378	0.0527	0.0333
45 Information Technology	0.0555	0.0442	0.0552	0.0467	0.0577	0.0508	0.0451	0.0343
50 Telecommunication Services	0.0226	0.0230			0.0257	0.0248	0.0156	0.0157
55 Utilities	0.0395	0.0405			0.0336	0.0311	0.0402	0.0416
Grouped by firm size(MCAP)								
1 (small)	0.0841	0.0643	0.0826	0.0667	0.0890	0.0658	0.0622	0.0501
2	0.0585	0.0476	0.0573	0.0486	0.0669	0.0489	0.0531	0.0348
3	0.0386	0.0308	0.0418	0.0332	0.0372	0.0304	0.0295	0.0241
4 (large)	0.0262	0.0220	0.0232	0.0211	0.0276	0.0213	0.0163	0.0146

hud (2002) measure is calculated as,

$$ILLIQ_{i,T} = 1/D_T \sum_{t=1}^{T} \frac{|R_{i,t}|}{NOKVOL_{i,t}} \tag{8}$$

where D_T is the number of trading days within a time window T, $|R_{i,t}|$ is the absolute return on day t for security i, and $NOKVOL_{i,t}$ is the trading volume in NOK on day t. It is standard to multiply the estimate by 10^6 for practical purposes. The Amihud measure is called an illiquidity measure since a high estimate indicates low liquidity (high price impact of trades). Thus, the illiquidity measure captures how much the price moves for each volume unit of trades.

The Amihud (2002) measure is essentially the inverse of another well known price impact measure, the Amivest liquidity ratio. While the Amihud measure look at how much prices move with respect to a unit trade volume in NOK, the Amivest ratio measures how much NOK value of trading that would occur if prices changed by 1 percent,

$$AMIVEST_{i,t} = \frac{NOKVOL_{i,t}}{|R_{i,t}|} \tag{9}$$

The Amihud measure is undefined for days with zero trading volume and the Amivest measure is undefined for zero-return days. Since there are more days with zero-returns than there are days with no trading activity, there seem to be a preference for the Amihud measure in the literature.

Figure 8 shows the annual time series of the Amihud and the Amivest measure averaged over all listed securities and for the four size portfolios. Both plots suggest improved liquidity over the period, i.e. reduced price impact costs over time. The Amihud measure reflects that the price movement from a trade volume of NOK 1 has decreased, and the Amivest measure shows that the volume required to move the price by NOK 1 is increased over time. We also see from figures 8 (c) that the Amihud illiquidity measure decreases monotonically with firm size and from (d) that the Amivest liquidity measure increases with firm size.

Table 5 shows descriptive statistics for the Amihud measure. Similar numbers for the Amivest measure is presented in Table 13 in the Appendix. The distribution of the Amihud measure is highly positively skewed suggesting that trading in some firms implies large price impacts. The size effect is evident overall as well as over all three sub-periods. Based on average median price impact costs, the most liquid sectors are the Telecommunication Service sector and the Health Care sector, while the most illiquid sector is the Consumer Discretionary sector. Except for some differences in the liquidity of the industry sectors, the Amivest measure provides similar information about price impact costs as the Amihud measure.

Table 5 Descriptive statistics for the annual Amihud illiquidity measure

The table shows descriptive statistics for the Amihud's illiquidity ratio for all companies, 4 size portfolios (based on firms market capitalizations), and the GICS industry sectors. Means, medians and standard deviations are calculated for the whole sample period as well as for three sub-periods. The Amihud ratio is measured as $1/D_T \sum_{t=1}^{T} \frac{|R_{i,t}|}{NOKVOL_{i,t}}$ where D_T is the number of trading days within a time window T, $|R_{i,t}|$ is the absolute return on day t for security i, and $NOKVOL_{i,t}$ is the trading volume in NOK on day t. The estimates are multiplied by 10^6 for practical purposes.

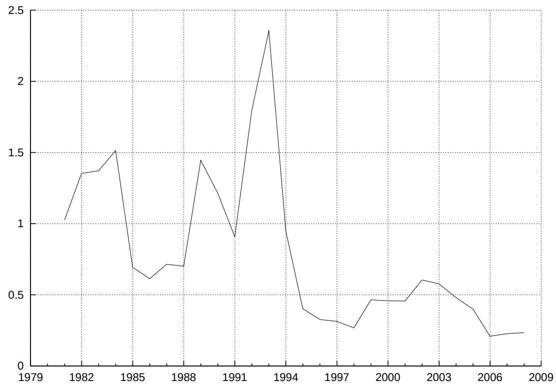
Amihud Illiq	Whole sample		1980–1989		1990–1999		2000–2007	
	mean	median	mean	median	mean	median	mean	median
All securities	0.70	0.26	1.05	0.46	0.71	0.19	0.41	0.10
Grouped by industry(GICS)								
10 Energy and consumption	0.39	0.08	0.71	0.41	0.59	0.08	0.08	0.01
15 Material/labor	1.18	0.21	1.08	0.31	1.32	0.10	1.18	0.24
20 Industrials	0.88	0.40	1.26	0.61	0.84	0.34	0.62	0.16
25 Consumer Discretionary	0.97	0.46	1.29	0.62	1.01	0.63	0.84	0.57
30 Consumer Staples	0.47	0.28	0.59	0.38	0.32	0.32	0.17	0.07
35 Health Care/liability	0.27	0.08	0.30	0.19	0.43	0.08	0.26	0.11
40 Financials	0.69	0.33	1.02	0.45	0.50	0.18	0.41	0.24
45 Information Technology	0.52	0.18	1.05	0.64	0.60	0.17	0.22	0.07
50 Telecommunication Services	0.01	0.00			0.02	0.01	0.00	0.00
55 Utilities	0.34	0.22			0.06	0.05	0.38	0.29
Grouped by firm size(MCAP)								
1 (small)	1.47	0.72	2.20	1.21	1.39	0.65	0.76	0.41
2	0.68	0.34	0.97	0.60	0.87	0.20	0.44	0.11
3	0.29	0.07	0.38	0.22	0.35	0.06	0.08	0.02
4 (large)	0.10	0.01	0.09	0.03	0.12	0.01	0.00	0.00

3.4 A compound measure with emphasis on trading speed

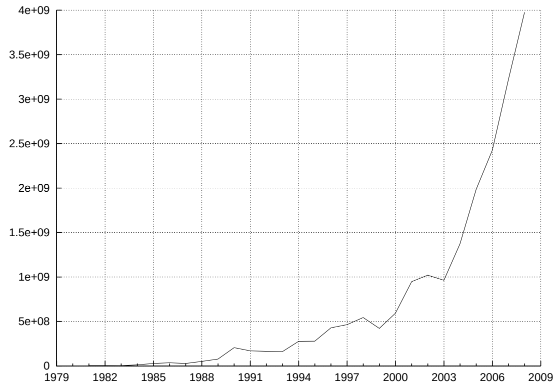
Liu (2006) suggests a compound liquidity measure that emphasizes trading speed (or the

Figure 8 Amihuds illiquidity measure and the Amivest liquidity measure 1980-2007

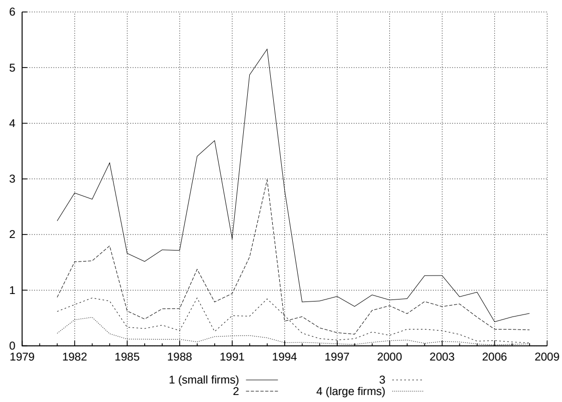
The figures shows the time series plot of the cross-sectional average annually calculated Amuhid illiquidity measure and the Amivest liquidity measure through the sample from 1980 through 2007. Figure (a) shows the average (equally weighted) Amihud measure and figure (b) shows the Amivest liquidity measure. Figures (c) and (d) shows the Amihud measure and Amivest measure respectively for the size portfolios.



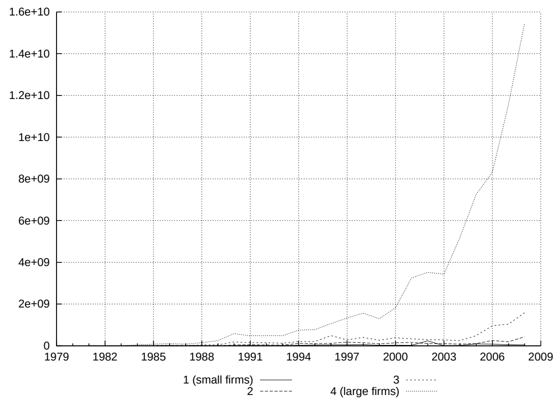
(a) Annual Amihud illiquidity measure



(b) Annual Amivest liquidity measure)



(c) Amihud illiquidity measure (MCAP groups)



(d) Amivest liquidity measure (MCAP groups) continuity of trading). The Liu measure is defined as the standardized turnover-adjusted number of zero daily trading volumes over the prior x months,

$$\mathsf{LM}x = \left[\text{No of zero volume days in prior } x \text{ months} + \frac{1/x\text{-month turnover}}{\text{Deflator}}\right] \times \frac{21x}{\mathsf{NoTD}} \quad (10)$$

where x*-month turnover* is the turnover over the prior x months. This is calculated as the *sum of daily turnover* over the prior x months where daily turnover is the ratio of the number of shares traded on a day to the number of shares outstanding at the end of the day, NoTD is the total number of trading days in the market over the prior x months, and *Deflator* is chosen such that

$$0 < \frac{1/x\text{-month turnover}}{\text{Deflator}} < 1 \quad (11)$$

for all sample stocks. The Liu measure is mainly intended to capture the intuition that investors dislike stocks with high "lock-in-risk". The turnover adjustment implies that two stocks with the same number of zero trading days can be distinguished.[22] It also implies that the measure capture the quantity dimension of liquidity to some extent. Moreover, from the description of the LOT measure in section 3.2.2, we can see that the measure reflects the cost dimension of liquidity.

Figure 9 shows the annual time series of the estimated Liu measure, averaged over all listed securities and for the four size portfolios.[23] Plot (a) suggests improved liquidity over time. However, plot (b) shows that this is not true for the smallest firms (except for the last year in the sample). Looking at means and medians of the Liu measure in Table 6, we see that it provides quite similar information as measures along the activity and elasticity dimensions, i.e. improved liquidity over time and a size effect. The most liquid sectors are the Telecommunication Service sector and the Utilities sector, and the most illiquid sector is the Consumer Discretionary sector.

3.5 Correlation between liquidity measures

So far, we have looked at the the long term development in different empirical liquidity measures. In this subsection, we investigate more directly the extent to which the measures are interrelated. Table 7 shows the rank correlations between all the described measures at the annual frequency. Correlation coefficients above 0.30 are in bold.

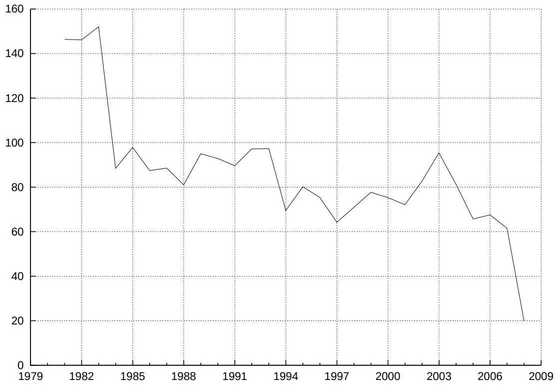
The correlation coefficients support the notion that different liquidity dimensions are interrelated (26 out of 36 coefficients are greater than or equal to 0.30). As expected, the Liu measure has a high correlation with all other measures. This is also the case for the two activity measures. In fact, based on rank correlation, the Liu measure is almost iden-

[22]The factor $21x/\mathsf{NoTD}$ standardizes the number of trading days in a month to 21. This standardization is necessary to make the liquidity measure comparable over time.

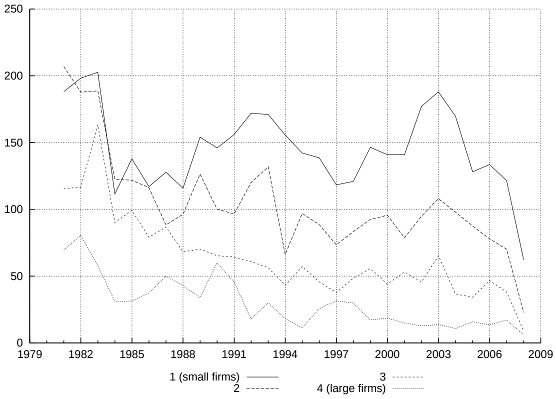
[23]Liu uses a deflator of 11,000 in constructing $\mathsf{LM6}$ and $\mathsf{LM12}$, and a deflator of 480,000 for $\mathsf{LM1}$. We start out our calculations of the measure using the same values, but also check that the condition holds.

Figure 9 The annual Liu (2006) measure 1980-2007

The plots are time series plot of the cross-sectional averaged annual liquidity measure in Liu (2006) from 1980 through 2007. Plot (a) shows the average (equally weighted) Liu (2006) measure and plot (b) shows the Liu (2006) measure for the four size portfolios.



(a) Annual Liu (2006) measure



(b) Annual Liu (2006) measure (MCAPgroups)

Table 6 Descriptive statistics for the annual Liu measure

The table shows the sample statistics for the whole sample and sub-periods across all companies, size groups (based on firms market capitalizations) and industry groups (GICS industries).

Liu LM12	Whole sample		1980–1989		1990–1999		2000–2007	
	mean	median	mean	median	mean	median	mean	median
All securities	84.24	57.89	101.02	99.79	77.74	45.69	70.69	24.12
Grouped by industry(GICS)								
10 Energy and consumption	45.52	10.04	63.02	24.18	45.73	13.31	24.84	0.00
15 Material/labor	82.51	86.69	90.12	87.35	55.28	10.99	87.39	69.24
20 Industrials	92.42	81.33	105.68	99.79	91.41	83.67	80.27	19.08
25 Consumer Discretionary	103.68	114.74	118.66	128.37	108.03	120.17	99.13	105.57
30 Consumer Staples	84.90	72.29	117.68	127.49	72.30	82.67	39.67	6.55
35 Health Care/liability	50.34	7.97	72.67	53.12	50.13	1.01	44.63	12.49
40 Financials	108.42	107.21	114.38	121.71	88.68	60.72	113.44	131.31
45 Information Technology	57.14	27.66	71.05	53.31	66.68	26.41	32.25	3.52
50 Telecommunication Services	11.09	0.76			22.18	1.51	0.00	0.00
55 Utilities	54.11	9.02			3.01	2.26	57.58	29.11
Grouped by firm size(MCAP)								
1 (small)	131.70	140.05	129.84	155.55	139.29	142.34	133.28	143.27
2	86.65	68.54	114.17	121.71	85.51	51.38	72.75	26.94
3	48.32	9.96	77.23	49.01	42.67	11.52	20.95	1.99
4 (large)	27.85	0.75	25.70	4.02	23.27	0.25	3.88	0.00

tical to the number of trading days (with opposite sign). Hence, it seems that the Liu measure has its highest loading on the activity dimension of liquidity. Amortized spread is the measure with lowest correlation with other measures. Note, however, that the amortized spread is considerably more related to the LOT costs than to the relative spread, suggesting that estimated LOT costs are, to some extent, adjusted for turnover. The quoted spread is little related to many other measures, notably also the relative spread. As expected the Amihud and the Amivest measures are highly negatively correlated.

As noted, correlations between order based measures of proportional costs and the trade based LOT measure are quite high. Apart from that, there seems to be a tendency that trade based measures are more correlated with other trade based measures than with the order based measures.

Table 7 Correlation structure for liquidity measures

The table shows the rank correlations between nine different liquidity measures: annual turnover, annual average quoted spread, annual average relative spread, the annual number of trading days, the annual Amivest liquidity ratio, the annual Amihud illiquidity measure (Amihud (2002)), the LOT measure (Lesmond et al. (1999)), the annual Liu measure over the prior 12 months (Liu (2006)), and a version of the annual amortized spread in Chalmers and Kadlec (1998).

liq meas	1	2	3	4	5	6	7	8
1 Annual Turnover								
2 Annual Avg BA Spread	-0.362							
3 Annual Avg Rel BA Spread	-0.343	0.255						
4 No trading days	0.574	-0.153	-0.441					
5 Amivest	0.480	-0.087	-0.547	0.533				
6 Amihud Illiq	-0.340	0.089	0.616	-0.443	-0.732			
7 LOT	-0.300	0.170	0.680	-0.475	-0.510	0.559		
8 Liu LM12	-0.582	0.456	0.618	-0.950	-0.581	0.582	0.524	
9 Annual Amortized Spread	0.093	-0.000	0.374	-0.148	-0.262	0.293	0.425	0.209

3.6 Determinants of liquidity measures

Most liquidity measures indicate that small firms are less liquid than large firms. But other firm characteristics might be relevant for liquidity as well. In Table 8 we present the results from estimating a pooled regression model[24] for each of the liquidity measures on a set of firm characteristics.

The set of firm characteristics we include in the model are commonly found to be important for liquidity in the literature. The first characteristic we include is the $Size$ measured as the market capitalization of the firm. Smaller firms are generally found to have larger spreads, lower transaction volume and greater price impacts. The second variable we include in the model is the size of the largest owner $Largest$. This variable is motivated by the fact that the greater the ownership fraction of the largest owner, the lower fraction of the outstanding shares are traded in the market. The third characteristic we include in the model is the return $volatility$. Volatility is closely related to illiquidity as less liquid

[24]A pooled regression model is one type of panel model which implicitely assumes that the coefficients, referring to both the intercepts and slopes, are identical across groups (in our case companies). The pooled regression framework applied here simply combines or pools all the time series and cross section data and then estimates the underlying model by using ordinary least squares.

securities have a higher price impact from trades. The fourth characteristic we include is the $price$ of the security. The price level is important since it is defines the minimum tick size of the security[25] and puts a lower bound on the spread. The final characteristic we include is the book to market ratio (BM). The B/M ratio is often used as a proxy for investment opportunities, and is often considered an important risk factor in empirical asset pricing. Thus we include it to examine whether some of the liquidity variables is related to the cross sectional variation in the B/M ratio.

The model estimated for each liquidity measure is:

$$LM_{it} = Constant + \ln(Size)_{it} + Largest_{it} + Volatility_{it} + Price_{it} + BM_{it} \quad (12)$$

where LM is the liquidity variable, $Size$ is firm size, $Largest$ is the percentage of the firm owned by the largest owner, $Volatility$ is the stock volatility, $Price$ is the stock price, and BM is the book value of the firm relative to its market value. Most liquidity measures are significantly related to firm size, the size of the largest owner, the level of the stock price and stock volatility. The number of trading days and the Liu measure are also significantly related to the BM variable, i.e. investors trade more often in growth firms than in value firms.

Table 8 Determinants of market liquidity at the security level

The table presents results from pooled regressions between the annual firm specific realizations of the various liquidity variables and firm specific explanatory variables. Each column is a regression with the liquidity measure as the dependent variable and the firm characteristics as the independent variables. All variables are measured once a year. Numbers in parenthesis are p values.

	Annual Turnover		Annual Avg BA Spread		Annual Avg Rel BA Spread		No trading days	
Variable	coeff	pvalue	coeff	pvalue	coeff	pvalue	coeff	pvalue
constant	-1.714	(0.00)	24.798	(0.00)	0.186	(0.00)	-293.167	(0.00)
ln(Firm Size)	0.124	(0.00)	-1.359	(0.00)	-0.009	(0.00)	24.742	(0.00)
Largest owner	-0.853	(0.00)	3.576	(0.00)	0.025	(0.00)	-61.562	(0.00)
Stock Volatility	1.105	(0.33)	53.073	(0.00)	0.551	(0.00)	-759.017	(0.00)
Stock price	-0.000	(0.04)	0.039	(0.00)	0.000	(0.00)	-0.030	(0.00)
BM Ratio	-0.001	(0.63)	-0.005	(0.54)	-0.000	(0.24)	-0.187	(0.03)
n	2284		2276		2276		2284	
R^2	0.05		0.50		0.63		0.45	

	Amihud Illiq		LOT		Liu LM12		Annual Amortized Spread	
Variable	coeff	pvalue	coeff	pvalue	coeff	pvalue	coeff	pvalue
constant	2.916	(0.00)	0.091	(0.00)	570.492	(0.00)	0.031	(0.00)
ln(Firm Size)	-0.168	(0.00)	-0.005	(0.00)	-26.538	(0.00)	-0.001	(0.00)
Largest owner	0.376	(0.04)	0.023	(0.00)	66.217	(0.00)	-0.003	(0.00)
Stock Volatility	30.379	(0.00)	1.909	(0.00)	757.529	(0.00)	0.053	(0.00)
Stock price	0.000	(0.75)	0.000	(0.00)	0.107	(0.00)	0.000	(0.26)
BM Ratio	0.000	(0.94)	0.000	(0.77)	0.188	(0.03)	0.000	(0.80)
n	2284		2260		2254		2284	
R^2	0.23		0.78		0.49		0.42	

[25] The minimum tick size refer to the smallest price increment that can occurr in the security. E.g. the quoted spread cannot be less than the minimum tick size. At the Oslo Stock Exchange in 2007 there were 6 different minimum tick sizes: NOK 0.01, 0.05, 0.10, 0.25, 0.50 and 1.00.

3.7 Summary of findings

Our main findings with respect to the long term development of liquidity at the OSE can be summarized as follows.

- While all liquidity measures that include trading volume signal improved liquidity over time, measures of proportional trading costs do not. Instead, they signal a time varying component in proportional transaction costs. Since the LOT cost captures a similar time variations as the relative spread, we know that the different signal from activity measures and cost measures is not related to the distinction between trade- and order based liquidity. It does, however, resemble the result in several recent empirical studies that high turnover does not necessarily lead to low transaction costs, see Jones (2002), Fujimoto (2004) and Johnson (2008). We also know that our time series of trading activity must largely reflect the enormous growth in size and trading volume at the OSE over our sample period. Time variation in proportional trading costs is a main topic of Section 4.
- We find that firm size is an important determinant of liquidity. This result holds whether liquidity is measured by trading activity, transaction costs, price impacts, or trading speed. Other determinants of liquidity includes the size of the largest owner, the return volatility and the stock price level; i.e. liquidity is higher the lower the fraction of the largest owner, the lower the return volatility, and the higher the stock price level.
- We also find variations in liquidity across industry sectors. Based on the median liquidity over the full sample period, all liquidity measures rank the Consumer Discretionary sector among the two most illiquid sectors, and most measures rank the Energy sector among the two most liquid sectors. There are also notable differences in the ranking of industry sectors across the liquidity measures. Three sectors are included among both the two most liquid and the two most illiquid sectors. These measures have opposite ranking by the cost measures and the activity measures. The IT sector is for instance ranked as the most liquid sector according to turnover and as the most illiquid sector according to amortized spread (and also as quite illiquid according to the relative spread).[26]
- Changes in trading system at the OSE over the period do not seem to have have had large effects on market liquidity. There are indications of a lowering of the level and volatility of quoted spreads after the introduction of an electronic trading system in 1988. There are also indications that the transition to a fully automated limit order book in 1999 seems to have benefited large firms at the cost of small firms. However, one should be careful in attributing these changes in liquidity to the change in the trading system since there were several other significant events during these periods.

[26]The two other sectors are the Telecommunication Service sector and the Utilities sector. We should emphasize that these sectors did not exist before 1996 and consist of only a couple of firms today, see 3.1.

4 Liquidity and the macro economy

A recent discovery in the empirical literature on liquidity is that liquidity measures are correlated across stocks, and that market-wide liquidity has a time varying component.[27] The factors responsible for the time variation in liquidity are yet to be identified. Commonality in liquidity suggests, however, that underlying macro economic forces can be relevant.[28] Understanding the sources of liquidity dynamics is important, given the negative effects large drops in liquidity can have for the economy, i.e. price distortions, disruptions in risk transfer, and liquidation of real investments, see Johnson (2008).

In this section, we relate the long term development of liquidity at the OSE to business cycles in the Norwegian economy. We also relate the time-series of different liquidity measures to three well known episodes of financial distress; the 1987 stock market crash, the Norwegian banking crisis over the 1988-1993 period, and the sub-prime market crisis in the US that started in the summer of 2007.

4.1 Time variation in liquidity and business cycles

In section 3, we found evidence of a time varying component in proportional transaction costs. Due to our relatively long time series, we can examine the relationship between this variable and the business cycle. We focus on the relative spread.[29] As our proxy for economic activity we use the quarterly output gap estimates for Norway from the OECD database.[30]

In Figure 10 (a), we plot the quarterly output gap estimates for Norway (right axis) against the average relative spread at the end of each quarter[31]. The colored areas indicate periods with increasing economic activity. We see a striking counter cyclical pattern for the spread relative to the output gap. When economic activity slows down, relative spread increases (market liquidity decreases). Similarly, when economic activity increases, relative spread decreases (market liquidity improves). The correlation between the two series in figure 10 (a) is -0.67. Also note that the relative spread is observed in real time while the output gap is estimated with a lag of several quarters. Thus, the relative spread seems like a strong candidate for a predictor variable of the economic activity in Norway. Another

[27]see Chordia, Roll, and Subrahmanyam (2000), Hasbrouck and Seppi (2001), Huberman and Halka (2001).

[28]Fujimoto (2004) finds some empirical support for this hypothesis in the US stock market. Brockman, Chung, and Pérignon (2007) find evidence of commonality in liquidity across 47 stock exchanges. The commonality in liquidity within the exchanges is found to be especially strong when local macro news is released, while the commonality in liquidity across exchanges increases during US macro announcements. The results suggest that macro fundamentals is important for aggregate market liquidity, and that there is a common global liquidity factor explaining on average 20% of the liquidity variation across exchanges.

[29]An alternative would be the LOT cost measure discussed in 3.2.2. The LOT cost shows the same time series pattern as the relative spread, however, it is only estimated on an annual frequency.

[30]Output gap is commonly defined as the difference between the economy's actual output and the level of production it can achieve with existing technology and input without putting sustained upward pressure on inflation. The two most basic methods for estimating potential output is by statistical de-trending (HP filter) and estimation of structural relationships.

[31]The relative spread is smoothed by taking the average relative spread over the previous four quarters

noteworthy feature is that the average relative spread seem to respond very quickly to the turning points of the business cycle. One interpretation of this result is that the relative spread is based on investors' expectations about the future economic activity, i.e. that the changes in the spread at the turning points of the business cycles reflect revisions in expectations about the future economic activity. If this is true, relative spreads include a risk component related to business cycles.

In figure 10 (b), we plot the quarterly output gap against the average relative spread for the four size portfolios. Interestingly, we can see that the counter cyclical pattern holds for all portfolios, but the pattern gets more pronounced the smaller the firms in the portfolios are. The correlation between relative spread and the output gap is decreasing monotonically from -0.70 for the smallest firms to -0.52 for the largest firms.[32] One explanation for this systematic size effect is that liquidity is subject to "flight to quality". When future economic outlooks are bad, small and risky securities become more illiquid as investors shift their portfolios towards larger and "safer" securities. When future economic outlooks are good, the pattern reverses. If investors also shift their portfolios from equities to less risky asset classes during economic downturns, this intuition can also explain the counter cyclical pattern for the spread of the largest firms relative to the business cycle. If small firms are more sensitive to the business cycle than larger firms, the liquidity correlations we observe here may be closely related to the size premium found in asset pricing tests of the Norwegian stock market in Næs et al. (2008).

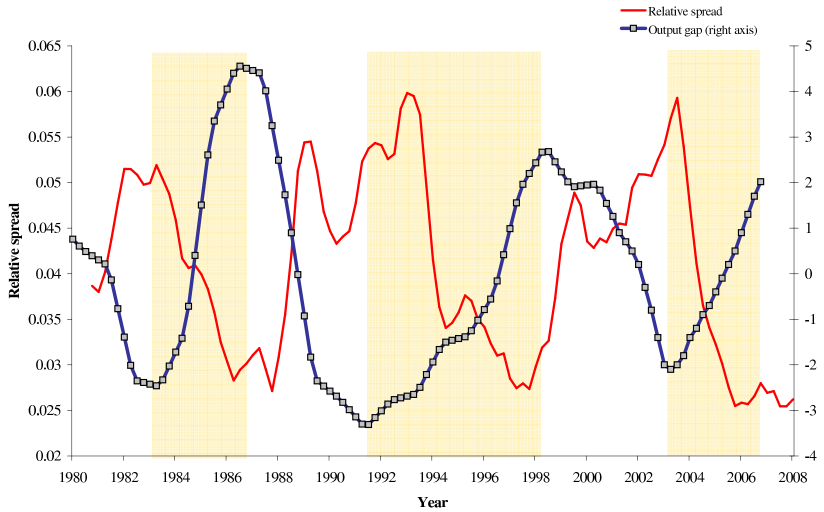
In Figure 11 (b), we show the correlations between the output gap and the average relative spread for 6 industry portfolios based on the GICS classification. The differences in the correlations between output gap and spreads across industries are quite large. The Energy sector and the Materials sectors both have a relatively low correlation with the output gap, while the Industrials sector, the IT sector and the Consumer Discretionary sector all have strong correlations with the business cycle. Financial firms have a correlation in between these two groups of sectors. One hypothesis is that the differences found in the counter cyclical pattern of spreads and output gap across industry sectors can be explained by significant differences in average firm size across the sectors. Firms within the Energy sector have the highest average market capitalization value over the period, however firms within the Materials sector are much smaller than the firms within the Industrials sector, the Financials sector and the Consumer Discretionary sector[33] Thus, we do not find a clear relationship between firms size and industry sector. An alternative hypothesis is that, since they both include firms that are large exporters, the Energy and Materials sectors are more linked to economic activity internationally and less linked to the Norwegian business cycles, compared to the other sectors. Note also that the three sectors Consumer Discretionary, Industrials and Financials are quite illiquid sectors, measured by relative

[32] See the second column of Table 9 and Figure 11 (a) .

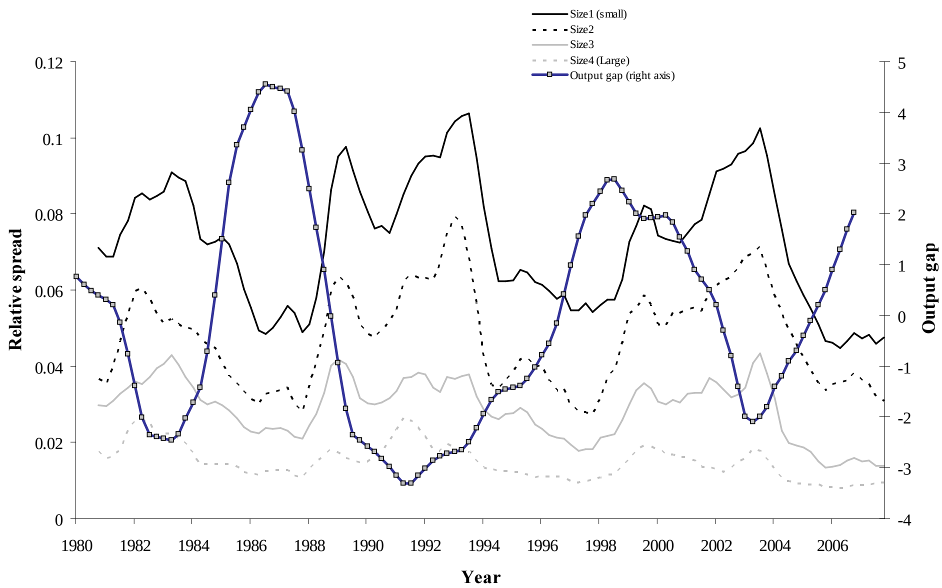
[33] For the period 1980-2006 the average market capitalization in billion NOK for the industry groups were Energy: 20.75, Materials: 6.99, Industry: 31.46, Cons.Disc.:6.15, Financials: 17.52 and IT:5.36. More information about the sector composition at the Oslo Stock Exchange during the period can be found in Næs et al. (2008).

Figure 10 Output gap and relative spread

Figure (a) shows the average relative spread measured at the end of each quarter (left axis) and the quarterly output gap estimate from OECD (right axis). Figure (b) shows the average relative spread for four size portfolios where firms are divided into four size group based on their market capitalizations at the end of the previous year. The Size1 group contains the 25% of the firms with the lowest market capitalization (MCAP) while Size4 contains the 25% largest firms.



(a) Relative spread for all companies



(b) Relative spread for size (MCAP)groups spread costs over the sample period. Thus, there could be "flight to liquidity" from these sectors and into the Energy and Materials sectors in economic downturns in Norway.

Columns 4 and 5 in Table 9 show the average relative spread for all firms, four size portfolios, and 6 industry groups during periods when the change in output gap is positive (dOG>0) and negative (dOG<0). Columns 6 shows the difference in relative spread between the two "regimes" (in percentage points), and column 7 shows t-values for the test that the difference is zero. On average, the relative spread is 1 percentage point higher in economic downturns than in economic upturns. This difference is highly significant. Note also that the relative spread difference between the two regimes decreases with firm size. Except for the Materials sector, we also find significant differences in spreads between the two regimes across industry groups.

Table 9 Output gap and relative spread

The table shows the correlations and average relative spread between output gap and relative spread for all firms, size quartiles and GICS industries. The first colum shows the correlation between relative spread and output gap (OG), the second column shows the average relative spread (in %) for for the whole sample from 1980 through 2007. The third and fourth column shows the average relative spread when the output gap is decreasing (dOG<0) and increasing (dOG>0) respectively. The last column shows the difference in spreads between the two output gap "regimes".

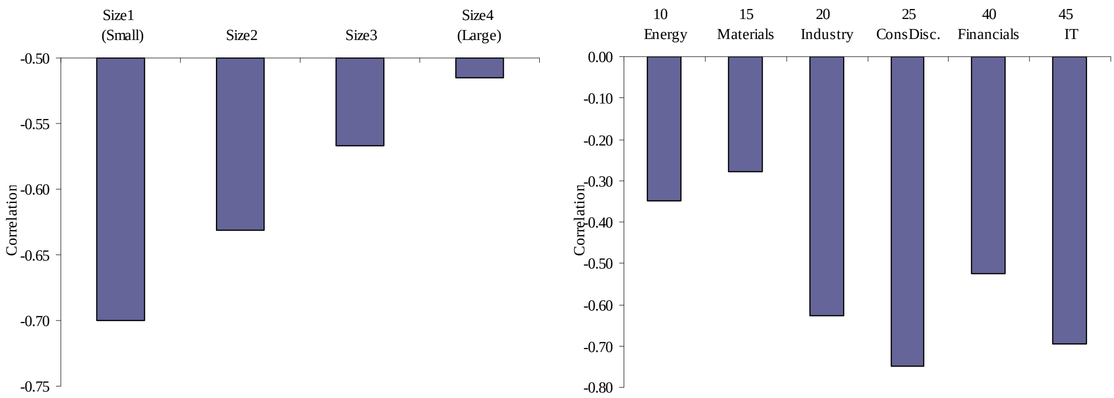
		Average relative spread (%)				
	Correlation	Whole sample	dOG<0	dOG>0	Diff.	T-test (Diff=0)
All firms	-0.673	4.1 %	4.6 %	3.6 %	1.0 %	10.47
Grouped by firm size (MCAP)						
Size1	-0.700	7.2 %	7.9 %	6.5 %	1.4 %	14.90
Size2	-0.631	4.7 %	5.2 %	4.2 %	1.0 %	10.79
Size3	-0.567	2.9 %	3.3 %	2.4 %	0.9 %	9.89
Size4	-0.515	1.5 %	1.8 %	1.2 %	0.6 %	5.86
Grouped by industry (GICS)						
10 Energy	-0.348	2.8 %	3.3 %	2.4 %	0.9 %	7.29
15 Materials	-0.278	3.6 %	3.5 %	3.6 %	-0.2 %	-1.02
20 Industry	-0.628	5.1 %	5.6 %	4.5 %	1.2 %	8.32
25 ConsDisc.	-0.748	6.1 %	6.7 %	5.4 %	1.3 %	6.59
40 Financials	-0.525	3.9 %	4.2 %	3.5 %	0.7 %	5.73
45 IT	-0.695	3.8 %	4.4 %	3.3 %	1.0 %	6.00

There is currently no established theory for the time-series behavior of aggregate market liquidity. Theoretical market microstructure models are focused on transaction costs and liquidity of *individual* stocks, where the size of the spread is modeled as a function of inventory costs (e.g. Amihud and Mendelson (1980) and Ho and Stoll (1981)) and costs related to asymmetric information (e.g. Glosten and Milgrom (1985). Based on these models, a time variation in liquidity on the security level may come through variation in one or both of these components. However, the link to aggregate liquidity variations is not obvious. Fujimoto (2004) argue that changes in economic fundamentals can alter the perceived risk of holding inventory across stocks and hence affect aggregate liquidity. However, this does not seem to be a plausible explanation in our case, since trading at the OSE has always been order-driven.

Johnson (2008) argues that the average willingness of the market to accommodate

Figure 11 Correlation between relative spread and output gap

Figure (a) shows the correlation between output gap and the relative spread for four size portfolios where firms are divided into four size group based on their market capitalizations at the end of the previous year. The Size1 group contains the 25% of the firms with the lowest market capitalization while Size4 contains the 25% largest firms. Figure (b) shows the correlations between output gap and the relative spread for 6 industry portfolios based on the GICS classification.



(a) Size groups

(b) Industry groups (GICS)

trade at prevailing prices may fluctuate as the underlying state of the economy changes. Assuming that the average investor faces solvency constraints, Liu (2006) also consider the recessionary state of the economy as a factor that can affect a firm's liquidity. One reason for the relevance of recessions is related to asset allocation, i.e. risk averse investors prefer to invest in less risky, more liquid assets in the anticipation of a recession.[34] Another reason is that it may be problematic for firms to raise capital when the economy is performing poorly.[35]

4.2 Liquidity and financial stability

By looking at the evolvement of different liquidity measures around several important events and periods of financial distress, we want to get more information about the relationship between liquidity and financial stability. Are certain types of events more likely to lead to sudden drops in liquidity than others? What liquidity dimensions are likely to be first and most affected by different types of events? For this purpose we have selected three important events during our sample period; the market crash in October 1987, the Norwegian banking crisis that stretched over the period 1988 through 1993 and the subprime crisis that caused a lot of turbulence in many markets especially during the second half of 2007.

[34]According to Liu (2006), this is consistent with the notion of "liquidity preferences" in Hicks (1967), with the findings that stock market liquidity is related to monetary policy and that there is commonality in liquidity across stock and bond markets in Chordia, Sarkar, and Subrahmanyam (2005), and the model of endogenous variations in liquidity in Eisfeldt (2004)

[35]See the liquidity-based asset pricing model in Holmstrom and Tirole (2001).

4.2.1 The market collapse in October 1987

On Monday October 19th, 1987, all major stock indices in the United States, including the Dow Jones, the Nasdaq, and the S&P 500, dropped by more than 20% on average. A particular feature of the crash was that no new events occurring over the preceding weekend could explain the magnitude of the price fall. Still, the crash caused contagion throughout the world's stock markets.[36] In Norway, the main index dropped by 20% on the 19th, and by the end of October the Norwegian stock market had declined by 28%.

There are several explanations for, but still no consensus on what triggered the 87 stock market crash. Since no external events could explain the crash, the focus was initially shifted towards internal market causes. A popular explanation was that a number of large institutions following price insensitive hedging strategies (portfolio insurance or program trading) drove prices down excessively. However, Gennotte and Leland (1990) show that the amount sold due to portfolio insurance was very low relative to the price drop, and argue that the program trading story cannot explain why prices did not rebound the moment the selling pressure stopped. Moreover, at the time, program trading strategies were used primarily in the United States. Thus, program trading cannot easily explain the contagion effect. In fact, most other markets where program trading was not prevalent experienced even larger market declines than the US market. A related explanation was that the markets experienced a sudden dry up in liquidity, i.e. that the trading mechanisms and systems in financial markets at the time were not able to deal with a large amount of sell orders relative to buy orders. Although lack of liquidity may have had a significant effect on the magnitude of the crash, it cannot explain why so many people decided to sell at the same time.[37]

The 87 stock market crash illustrates that commonality in liquidity may have important practical implications for investors as well as regulators as liquidity shocks in one market can spill over and cause large market movements in other markets.[38]

In Figure 12(a), we plot the daily average relative spread and turnover over the two months prior to the crash and the two months following the crash. We can see that the relative spread almost doubled after the crash from an average of 2.2% in the pre-crash period to an average of 4.1% in the post-crash period. The average daily turnover decreased from the pre-crash period (0.2% daily turnover) to the post-crash period (0.1% daily turnover). Reduced trading activity is consistent with an increase in implicit transactions costs. However, note that the daily turnover increased to more than 0.3% during the days immediately after the crash. This temporary positive correlation in volume and transaction costs is a feature that is observed also in other distress periods.

In Figure 12(b), we plot, over a period from one year before the crash to one year after

[36]By the end of October, stock markets in Hong Kong had fallen 45.8%, Australia 41.8%, Spain 31%, the United Kingdom 26.4%, Canada 22.5% and New Zealand 60%.

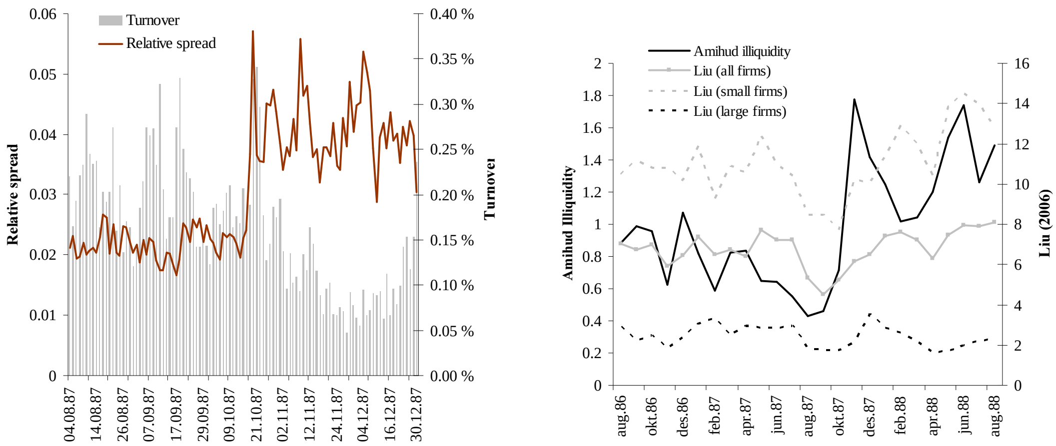
[37]Other explanations of the 87 crash include overvaluation and macroeconomic uncertainty.

[38]Hameed, Kang, and Viswanathan (2006) find that co-movement in liquidity is highest during large negative market moves.

the crash, the monthly Amihud price impact measure and three versions of the compound measure suggested by Liu (2006); one for all firms, one for the 25% smallest firms, and one for the 25% largest firms. There is a notable difference in the behavior of the two measures. The price impact measure increases sharply during October, peaks in November 1987, and remains higher after the crash month, indicating that the market became more illiquid after the crash. Except for the smallest firms, the Liu (2006) measure is much less responsive to the crash. It is also mainly the smallest firms that experience more non-trading days in the year following the crash. The reduction in the Liu measure during the months prior to the crash suggests that many firms were traded more frequently in the pre-crash months. In the months after the crash the market-wide Liu measure is marginally higher than in the beginning of 1987.

Figure 12 Liquidity around the crash of October 1987

Figure (a) shows the average daily relative spread and turnover around the market crash that occured on the 19th October 1987 in the US. Figure (b) shows the average monthly Amihud illiquidity measure and the Liu (2006) measure in the months surrounding the event.



(a) Relative spread and turnover

(b) Amihud and Liu measures

4.2.2 The Norwegian banking crisis 1988-1993

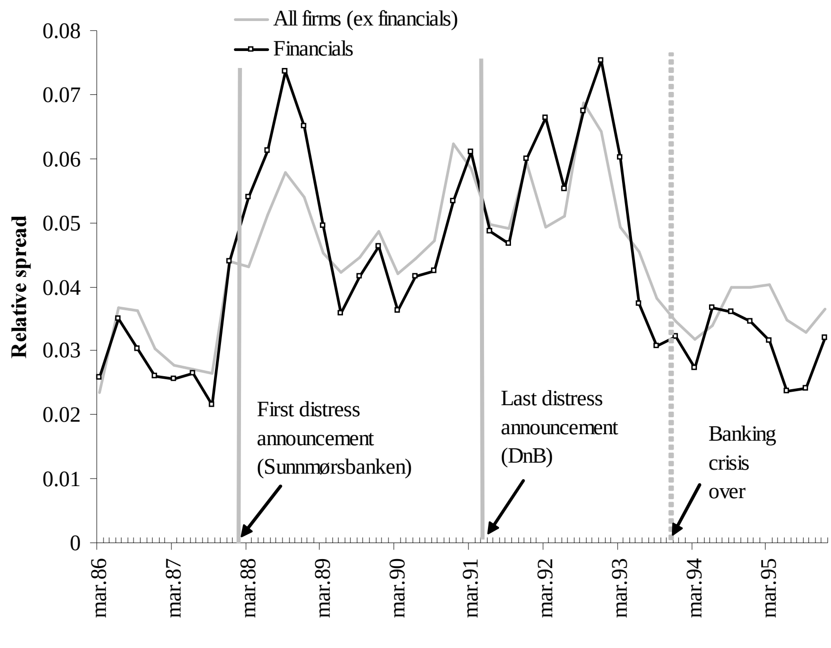
The Norwegian banking crises lasted for around six years from 1988 to 1993. During these years, banks representing 95% of all commercial bank assets in Norway became insolvent, and the Norwegian government was forced to bail out numerous financial institutions, including Norway's three largest banks at the time (Ongena, Smith, and Michalsen (2003)). The event that marked the beginning of the crisis, was an earnings report issued by Sunnmørsbanken on march 18th, 1988, stating that it had lost all of its equity capital. The last distress announcements occurred in 1991, but the banking sector did not really stabilize until 1993 when the banks began to record improved results.

Ongena et al. (2003) study the Norwegian banking crisis and find that, although the banks experienced a large and permanent downward revision in their equity capital during the period, the firms that maintained relationships with the banks did only experience small and temporary changes in their stock prices. Hence, the main conclusion from the study is that the aggregate impact of the banking crisis on the real economy was small.

In figure 13, we show the average relative spread for financial institutions and non-financial companies during the crisis period. The figure does not reveal any systematic difference between the two series. The average spread for non-financial firms over the period 1988-1992 was 5.2% and 5.4% for the financial institutions. However, the difference of 0.2% is not significant at any conventional level. It is also important to note that the first part of the Norwegian banking crisis coincide with a slowdown of the Norwegian economy, and the end of the crisis coincide with a positive trend in the Norwegian economy accompanied with declining interest rates.[39]

Figure 13 Relative spread during the norwegian banking crisis 1988-1993

The figure shows the average relative spread for financial companies and the non-financial companies.



4.2.3 The sub-prime crisis in 2007

In the late summer of 2007, the US experienced a crisis in the sub-prime mortgage market triggered by falling housing prices in the US. Both US and non-US banks and investors got affected by the collapse of the US sub-prime market. Many banks had bought up mortgages and set up so called Structured Investment Vehicles (SIV) financed by issuing securities. When the US housing market collapsed the liquidity in these securities dried up

[39]Another special feature of this time period is that there was a currency crisis during the period 1992-93.

and the crisis worsened. The banks that had set up SIVs had to honor their commitments at increasingly greater costs. However, US and European banks were not obliged to show SIV debts on their balance sheets. Consequently, the uncertainty about the individual banks' losses was high and the liquidity in the interbank market dried up. For this reason, Norges Bank offered additional liquidity to the Norwegian Banks on August 9th.

In July and August, the main index at the Oslo Stock Exchange fell by 2.3 and 4.3 percent respectively. In the media, the drop in the market was related to increased uncertainty surrounding the US sub-prime market and potential long run effects of this crisis. In Figure 14, we investigate how the sub-prime market crisis affected the liquidity at the OSE, and in particular the liquidity of the Financials sector. We look at three different liquidity measures; Amihud's price impact measure, relative spread, and turnover. Figure 14 (a) shows an increase in the price impact measure for financial firms during the sub-prime market collapse (July/August 2007). This is also reflected in an increase in the overall market illiquidity. Figure 14 (b) shows an increase in relative spreads from July. Note that although there seems to be a widening in the spread difference between financial and non-financial firms in July, the fact that the market-wide relative spread also increased may reflect that investors were uncertain about the long run effects of the crises. Figure 14 (c) shows that the turnover increased for both financial firms and all firms from July to August. For financial firms the monthly turnover almost tripled from 4% to 11.5%, while the average across all companies increased by about 2% points.

5 Conclusion

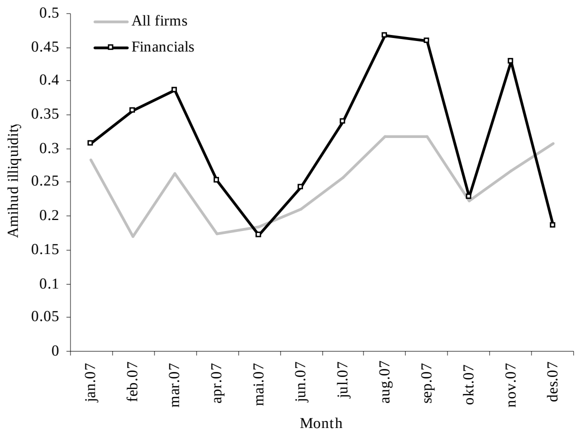
In this paper we have analyzed the relationship between the long term development in liquidity at the OSE and the Norwegian economy. We have also described how different liquidity measures behave around several episodes of financial distress. Liquidity measures are trade- or order based and can be constructed to capture one or more dimensions of liquidity. We calculate a broad set of liquidity measures that captures all liquidity dimensions, quantity, costs, elasticity, and time, and includes both trade- and order based measures.

Two results from the analysis show that developments in the stock market is informative about the state of the overall Norwegian economy. First, we find a strong counter cyclical relationship between proportional transaction costs measured by the relative spread and the business cycle measured by the output gap. We also find that the average relative spread responds very quickly to the turning points of the business cycle. These findings indicate that proportional trading costs reflect a business cycle risk component. Since relative spreads are observed in real time while the business cycle is estimated with a lag of several quarters, the relative spread may prove as a strong candidate for being a predictor variable for the level of activity in the Norwegian economy.

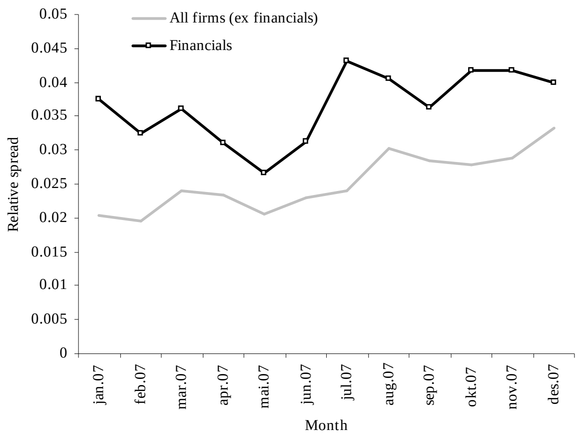
Second, by examining three events of financial distress, we find that relevant informa-

Figure 14 Liquidity measures during the sub-prime event in 2007

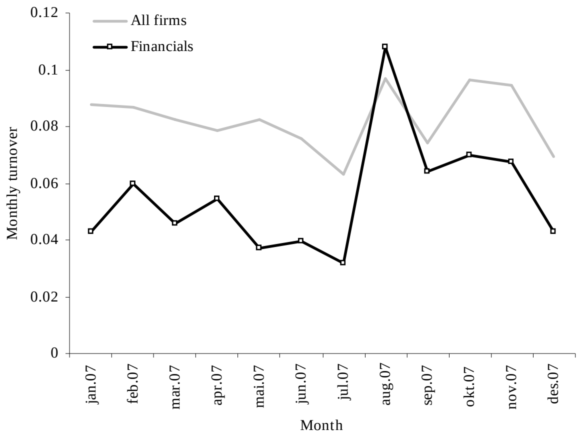
Figure (a) shows the monthly Amihud illiquidity measure for 2007 for the whole market and for the financial companies. Similarly, figure (b) and (c) shows the monthly average relative spread and turnover for the same period respectively.



(a) Amihud illiquidity measure



(b) Relative spread



(c) Turnover

tion may be gained from monitoring various liquidity measures over time. For example, since the relationship between trading activity and trading costs often becomes positive during periods of distress, a single focus on trading activity could be misleading. We find that several measures provide useful ex post information about which sectors and types of firms that was most effected by the crisis, and in what ways. Whether a shock to market liquidity is permanent or temporary may also prove useful when selecting market segments or industry sectors that needs special attention in the period after a crisis.

We find that the three most informativeliquidity indicators are relative spreads, turnover, and the illiquidity measure suggested by Amihud (2002). Together these three measures captures the cost, quantity, and price impact dimensions of liquidity. In addition, the measures captures both trade based and order based liquidity.[40]

[40]The compound measure of Liu (2006) works quite well in asset pricing tests, i.e. it is informative with respect to variations in liquidity in the cross-section of firms. However, the measure does not seem to be very informative for the purpose of predicting business cycles or detecting financial distress.

Appendix

A Defining liquidity measures

In this appendix we define the various liquidity measures that has been used in the analysis of this paper. Surveys of various empirical liquidity measures are in found in Baker (1996), Aitken and Comerton-Forde and Hasbrouck (2008), and these sources should be referenced for further explanations.

A.1 The bid ask spread

This is one of the most common measures of the cost of trading. At any time t there is a *best bid* P_t^B, a maximal price a trader is willing to buy the stock at. Similarly, there exists a *best ask*, P_t^A, the lowest price a trader is willing to sell the stock for. If $P_t^A < P_t^B$, no trade is possible. The bid-ask spread (at time t), is the difference between these two prices

$$\text{BA Spread}_t = P_t^B - P_t^A$$

The bid ask spread is a measure of the cost of trading, because it is the amount by which one of these two traders must change the price to get execution.

Often, we will think of a "true", unobservable price that represents the correct price somewhere between the bid and ask price. One estimate of this price is the average of the bid and ask price

$$\hat{P}_t = \frac{1}{2}(P_t^A + P_t^B)$$

Since either the bid or the ask side must change the price to trade, the use of this as an estimate can be justified by assuming that each side is equally likely to change the price.

Similar thinking can be used to argue for an "effective" bid ask spread, the difference between the "true" price and respectively the bid and the ask prices. This is often called the "half spread," half of the bid ask spread.

The bid ask spread is an absolute measure of costs, but one will often want this measure as a proportional one. This is had by measuring the absolute bid ask spread as a percentage of the "true" price. This is called the relative bid ask spread, or also the percentage spread.

$$\text{Relative BA Spread}_t = \frac{\text{BA Spread}_t}{\hat{P}_t}$$

If we use the above estimate of the true price, this spread is calculated as

$$\text{Relative BA Spread}_t = \frac{P_t^B - P_t^A}{\frac{1}{2}(P_t^A + P_t^B)}$$

For some further discussion on properties of the spread, see (Baker, 1996, page 9)

A.2 Trading volume measures

Another indicator of liquidity is the amount of trading during some given interval of time. This *trading volume* can either be measured in units of currency or number of shares.

To normalize these numbers we typically ask what *fraction* of the outstanding shares was traded during some time interval. The answer to this question is the *turnover* of a stock. We calculate the turnover for a period as

$$\text{Turnover} = \frac{\text{Trading volume (in shares)}}{\text{Number of shares outstanding}}$$

The turnover is typically calculated on a daily basis, and then aggregated by summing to find turnovers for lower frequencies such as monthly, quarterly and annually. The reason for this is that the number of shares outstanding change, although infrequently. It is therefore necessary to correct for this, and the simplest is to just aggregate the daily turnovers, using the correct number of shares each date.

A.3 The number of trading days

For stocks that trade seldom merely calculating the number of days in a year with a trade is a measure of liquidity.

A.4 The amortized spread

The amortized spread attempts to measure an expected cost of trading equity that takes into account the holding period of a position. As such it can be viewed as an attempt to make trading costs across stocks comparable by looking at expected costs over a defined time interval, such as a year. The amortized spread measure was introduced in Chalmers and Kadlec (1998), and is roughly equal to the bid ask spread multiplied with the turnover.

Chalmers and Kadlec used trading data to calculate the amortized spread for date T as

$$AS_T = \frac{\sum_{t=1}^{T} |P_t - M_t| V_t}{P_T \times SharesOut_T}$$

where AS_T is the amortized spread, P_t is the transaction price, M_t the midpoint price, V_t the trade quantity and $SharesOut$ is the number of shares outstanding. Since we do not have transaction data we approximate the daily amortized spread as

$$AS \approx \text{Relative BA Spread} \times \frac{\text{Daily trading amount}}{\text{Current market value of equity}}$$

or

$$AS \approx \text{Relative BA Spread} \times \text{Turnover}$$

Multiplying this with 252 gives a daily estimate of the annualized amortized spread.

A.5 The Lesmond et al. (1999) measure of trading costs.

Typical estimates of actual transaction costs of trading are calculated from microstructure data on actual trades. The goal of Lesmond et al. (1999) (LOT) is to find a measure of transaction costs that can be calculated using lower frequency data, such as daily returns. The idea of the model is to estimate the *threshold* where transaction costs are lower than the cost of *not* updating the price (by trading).

If there is no transaction costs, consider the usual "market model"

$$R_{jt} = a_j + b_j R_{mt} + e_{jt}$$

where R_{jt} is the return on stock j at time t, R_{mt} is the corresponding return on the market portfolio, a_j and b_j are (stock specific) constants, and e_{jt} an error term.

For any change in the market return R_{mt} we should expect a corresponding change in the return $\tilde{R}_{jt}$ of stock j. If we now posit a transaction cost we would only expect a change in R_{jt} when the change in R_{mt} is large enough to outweigh the transaction cost. Lesmond et al. (1999) propose a limited dependent variable model where observed returns R^*_{jt} are related to the "true" returns R_{jt} as follows

$$R^*_{jt} = \beta_j R_{mt} + \varepsilon_{jt}$$

where

$$\begin{aligned} R_{jt} = R^*_{jt} - \alpha_{1j} \quad & \text{if} \quad R^*_{jt} < \alpha_{1j} \\ R_{jt} = 0 \quad & \text{if} \quad \alpha_{2j} \geq R^*_{jt} \geq \alpha_{1j} \\ R_{jt} = R^*_{jt} - \alpha_{2j} \quad & \text{if} \quad R^*_{jt} > \alpha_{2j} \end{aligned}$$

The LOT measure of trading costs are found by estimating the thresholds α_{1j} and α_{2j}. These are found by a maximum likelihood formulation by assuming Gaussian errors. From this one gets estimates $\widehat{\alpha}_{1j}$ and $\widehat{\alpha}_{2j}$. The difference

$$\text{LOT} = \widehat{\alpha}_{2j} - \widehat{\alpha}_{1j}$$

is the estimate of the round trip transaction costs for this stock.

A.6 The Amihud (2002) measure of illiquidity

Amihud (2002) proposes a measure of *illiquidity*, which is the daily ratio of absolute stock return to its dollar volume, and argues that this can be interpreted as "the daily price response associated with one dollar of trading volume, thus serving as a rough measure of price impact.” This measure only needs daily data on returns and volume to calculate, and can be calculated for longer time periods than we have microstructure data for. Using Amihud’s notation, let D_{iy} be the number of days with available data for stock i in year y, R_{iyd} be the stock return for stock i in day d of year y, and $VOLD_{ivyd}$ be the daily trading volume (in units of currency). Amihud (2002)’s measure is calculated as

$$ILLIQ_y = 10^6 \frac{1}{D_{iy}} \sum_d \frac{|R_{iyd}|}{VOLD_{ivyd}}$$

This calculation is done for a year, but one can take averages at different frequencies, such as quarterly or monthly.

See (Hasbrouck, 2008, pg 93) for further comments.

A.7 The Liquidity, or Amivest, ratio

The Liquidity ratio, often called the Amivest ratio, after a securities firm which used this, relates the trading volume over a period to the return, and is an attempt to ask how much trading volume is necessary to move the stock’s price one percentage point.

Different authors uses different definitions of this ratio.

If we let $VOLD_{it}$ be the daily volume (in dollars) for stock i at date t, and R_{it} the return for the same stock at the same date, the *Amivest* ratio over some time interval is calculated as:

$$Amivest = \frac{\sum_{t=1}^{T} VOLD_t}{\sum_t |R_t|}$$

A typical number is approximately monthly by using $T = 20$ observations. This is the definition suggested by (Baker, 1996, page 12) and used in e.g. Amihud, Mendelson, and Lauterbach (1997).

However, (Hasbrouck, 2008, page 93) suggest calculating this ratio as

$$Amivest = \frac{1}{T} \sum_{t=1}^{T} \frac{VOLD_t}{|R_t|}$$

using only days in which the return R_{it} is nonzero, i.e. calculate the ratio on a daily basis and *then* take averages. This does seem like a better way of getting at it, and we implement it this way.

A.8 The Liu (2006) liquidity measure

Liu (2006) suggests a compound liquidity measure that emphasizes trading speed (or the continuity of trading). The Liu measure is defined as the standardized turnover-adjusted number of zero daily trading volumes over the prior x months,

$$\mathrm{LM}x = \left[\text{No of zero volume days in prior } x \text{ months} + \frac{1/x\text{-month turnover}}{\text{Deflator}}\right] \times \frac{21x}{\mathrm{NoTD}}$$

where x-*month turnover* is the turnover over the prior x months. This is calculated as the *sum of daily turnover* over the prior x months where daily turnover is the ratio of the number of shares traded on a day to the number of shares outstanding at the end of the day, NoTD is the total number of trading days in the market over the prior x months, and *Deflator* is chosen such that

$$0 < \frac{1/x\text{-month turnover}}{\text{Deflator}} < 1$$

for all sample stocks. The Liu measure is mainly intended to capture the intuition that investors dislike stocks with high "lock-in-risk". The turnover adjustment implies that two stocks with the same number of zero trading days can be distinguished. The factor $21x/\mathrm{NoTD}$ standardizes the number of trading days in a month to 21. This standardization is necessary to make the liquidity measure comparable over time.

B Additional descriptive statistics

In this appendix, we present descriptive statistics for the number of trades, the quoted spread, the amortized spread, and the Amivest liquidity ratio.

Table 10 Descriptive statistics for the number of trading days

The table shows descriptive statistics for the number of trading days for all companies, 4 size portfolios (based on firms market capitalizations), and the GICS industry sectors. Means, medians and standard deviations are calculated for the whole sample period as well as for three sub-periods. The number of days that a security is traded is a simple count of days with no trading volume during a year.

No trading days	Whole sample		1980–1989		1990–1999		2000–2007	
	mean	median	mean	median	mean	median	mean	median
All securities	160.5	185.0	147.6	148.0	168.6	196.5	175.1	222.0
Grouped by industry(GICS)								
10 Energy and consumption	196.1	237.5	184.7	226.0	198.6	235.5	217.1	250.0
15 Material/labor	168.7	184.0	162.6	176.2	197.1	240.5	153.9	164.8
20 Industrials	150.8	162.5	142.8	150.5	155.0	163.8	164.0	186.0
25 Consumer Discretionary	139.8	129.0	127.1	121.5	137.5	109.0	148.0	147.5
30 Consumer Staples	159.2	167.5	130.6	123.8	179.0	169.0	211.4	243.5
35 Health Care/liability	196.7	239.5	178.5	198.0	196.5	239.5	200.9	239.0
40 Financials	139.9	148.5	133.9	125.5	159.3	188.0	137.3	151.0
45 Information Technology	184.0	212.2	180.1	197.8	178.2	219.0	203.8	237.0
50 Telecommunication Services	235.5	248.5			228.5	248.5	250.7	250.0
55 Utilities	197.0	242.5			247.5	248.2	193.6	222.0
Grouped by firm size(MCAP)								
1 (small)	117.8	110.5	122.4	112.0	111.3	103.0	116.2	107.0
2	161.7	182.0	134.4	126.0	163.0	190.0	175.4	217.0
3	197.4	238.0	173.8	197.0	206.2	238.0	220.4	248.0
4 (large)	219.7	249.0	223.6	247.0	225.6	249.5	242.2	250.5

Table 11 Descriptive statistics for quoted spread

The table shows descriptive statistics for quoted spreads for all companies, 4 size portfolios (based on firms market capitalizations), and the GICS industry sectors. Means, medians and standard deviations are calculated for the whole sample period as well as for three sub-periods.

Monthly avg BA Spread	Whole sample		1980–1989		1990–1999		2000–2007	
	mean	median	mean	median	mean	median	mean	median
All securities	4.50	1.82	7.48	3.09	5.08	2.12	3.35	1.07
Grouped by industry(GICS)								
10 Energy and consumption	2.37	1.15	4.88	2.04	2.95	1.68	1.68	0.75
15 Material/labor	3.86	2.27	5.37	2.59	3.20	1.74	4.51	2.33
20 Industrials	5.82	2.27	10.02	2.93	6.09	2.44	4.38	1.65
25 Consumer Discretionary	6.92	2.74	7.07	4.62	8.65	4.89	6.23	1.56
30 Consumer Staples	5.64	2.29	11.60	5.94	8.60	4.14	1.00	0.67
35 Health Care/liability	1.59	1.07	3.07	2.00	2.05	1.38	1.10	0.89
40 Financials	6.20	2.97	7.33	4.35	5.30	2.78	6.77	3.20
45 Information Technology	2.20	1.03	3.24	2.12	2.71	1.34	1.48	0.60
50 Telecommunication Services	2.28	1.91	4.27	4.31	1.80	1.73	1.80	1.39
55 Utilities	12.53	1.19			0.78	0.72	12.61	1.33
Grouped by firm size(MCAP)								
1 (small)	6.27	2.61	11.15	4.79	6.12	3.03	5.00	1.44
2	4.93	1.85	8.51	3.95	4.89	2.06	3.38	1.04
3	3.87	1.80	5.22	2.90	4.26	1.86	2.90	1.07
4 (large)	2.61	1.16	2.94	1.84	3.18	1.52	1.05	0.81

Table 12 Descriptive statistics for amortized spread

The table shows descriptive statistics for amortized spreads for all companies, 4 size portfolios (based on firms market capitalizations), and the GICS industry sectors. Means, medians and standard deviations are calculated for the whole sample period as well as for three sub-periods.

Monthly Amortized Spread	Whole sample		1980–1989		1990–1999		2000–2007	
	mean	median	mean	median	mean	median	mean	median
All securities	0.63	0.41	0.71	0.40	0.70	0.49	0.49	0.36
Grouped by industry(GICS)								
10 Energy and consumption	0.50	0.39	0.70	0.55	0.62	0.49	0.40	0.35
15 Material/labor	0.55	0.40	0.46	0.35	0.73	0.50	0.46	0.27
20 Industrials	0.80	0.44	1.04	0.54	0.77	0.47	0.47	0.30
25 Consumer Discretionary	0.67	0.49	0.69	0.47	0.74	0.56	0.49	0.31
30 Consumer Staples	0.43	0.35	0.42	0.29	0.49	0.30	0.39	0.36
35 Health Care/liability	0.47	0.35	0.30	0.26	0.63	0.31	0.53	0.46
40 Financials	0.57	0.35	0.52	0.31	0.59	0.37	0.57	0.35
45 Information Technology	0.69	0.59	0.70	0.60	0.88	0.70	0.60	0.49
50 Telecommunication Services	0.44	0.37	0.57	0.43	0.39	0.38	0.38	0.34
55 Utilities	0.16	0.07			0.28	0.26	0.13	0.05
Grouped by firm size(MCAP)								
1 (small)	0.99	0.70	1.26	0.90	1.06	0.78	0.72	0.47
2	0.56	0.43	0.61	0.42	0.66	0.52	0.45	0.35
3	0.40	0.32	0.32	0.22	0.48	0.38	0.36	0.32
4 (large)	0.28	0.23	0.23	0.15	0.32	0.28	0.26	0.23

Table 13 Descriptive statistics for the annual Amivest liquidity measure

The table shows descriptive statistics for the Amivest liquidity ratio for all companies, 4 size portfolios (based on firms market capitalizations), and the GICS industry sectors. Means, medians and standard deviations are calculated for the whole sample period as well as for three sub-periods. The Amivest ratio is measured as $\frac{NOKVOL_{i,t}}{|R_{i,t}|}$ where $NOKVOL_{i,t}$ is the daily NOK trading volume in stock i at day t and $|R_{i,t}|$ is the absolute value of the daily return on stock i at day t.

Amivest	Whole sample		1980–1989		1990–1999		2000–2007	
	mean	median	mean	median	mean	median	mean	median
All securities	859.66	61.91	45.19	9.36	338.08	112.35	2127.58	146.66
Grouped by industry(GICS)								
10 Energy and consumption	3721.34	216.45	58.58	17.44	433.29	208.09	6401.64	756.68
15 Material/labor	318.81	41.37	80.19	23.23	336.54	231.22	1660.67	391.85
20 Industrials	496.86	40.09	53.18	6.80	303.45	80.44	1011.48	147.22
25 Consumer Discretionary	240.19	40.19	32.50	7.33	201.06	44.85	577.09	83.67
30 Consumer Staples	536.61	78.00	38.88	10.61	464.59	225.14	3205.77	240.52
35 Health Care/liability	406.12	110.23	110.80	58.34	416.47	211.47	465.28	103.40
40 Financials	402.76	28.33	31.35	6.78	385.09	98.36	810.32	46.65
45 Information Technology	396.43	84.58	22.55	10.07	263.21	88.96	871.37	184.54
50 Telecommunication Services	15181.64	14760.01			737.02	772.95	27423.40	28602.90
55 Utilities	244.71	106.44			664.35	406.68	131.64	66.37
Grouped by firm size(MCAP)								
1 (small)	33.79	8.15	5.23	2.82	37.60	16.20	47.28	15.01
2	168.68	49.95	11.41	7.42	126.92	92.85	297.02	131.34
3	778.24	186.67	71.31	27.93	445.72	296.23	1848.38	683.58
4 (large)	4376.00	582.72	220.81	107.27	1181.81	716.29	26855.24	14272.30

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