Intraday Market Liquidity on the Swiss Stock Exchange

Angelo Ranaldo[♦]

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Address:
Dr. Angelo Ranaldo
Policy Analysis & Portfolio Coordination
UBS Asset Management
Gessnerallee 3
8098 Zurich, Switzerland
angelo.ranaldo@ubs.com

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Abstract (English Version)

This study is an empirical analysis of the intraday market liquidity and volume concentration on the Swiss Stock Exchange. The intraday market liquidity on the Swiss market exhibits a triple-U shaped pattern. An intraday pattern of volume concentration also exists. The empirical evidence shows that the US market influences the Swiss trading day to a remarkable extent. The results also suggest the dynamics of an order-driven market. Disequilibrium between demand and supply conditions are associated with an increase in trading volume and a thinner limit order book. In this market condition, trades engender a wider spread and price volatility.

Abstract (German Version)

Diese Studie ist eine empirische Analyse der Marktliquidität und Volumenkonzentration während eines Handelstages an der Schweizerischen Aktienbörse. Die Intraday-Marktliquidität zeigt auf dem Schweizermarkt ein dreifach-U-förmiges Muster. Zusätzlich existiert auch ein Muster einer Intraday-Volumenkonzentration. Die empirische Evidenz zeigt, dass der US-Markt den Schweizerischen Handelstag in beträchtlichem Umfang beeinflusst. Die Resultate deuten auch auf die typischen Bewegungen eines auftragsgesteuerten Marktes hin. Ein Ungleichgewicht zwischen Nachfrage und Angebot geht mit einer Erhöhung des Handelsvolumens und einem dünneren Auftragsbuch einher. Bei dieser Marktverfassung erzeugen Trades einen grösseren Spread und eine höhere Volatilität des Preises.

1. Introduction

This study empirically analyzes the intraday market liquidity and the intraday market concentration on the Swiss Stock Exchange (hereafter) SWX. The SWX is a pure order driven market based on two main features: (1) there are no designated market makers, and (2) the trading and the quoting process is computerized and centralized. Several exchange systems recently applied this specific market architecture and Euronext is one of the most successful examples. Therefore, interest in pure limit-order trading has grown rapidly in recent years. In fact, this market architecture represents an original solution for the fundamental role of the liquidity provision.

This study raises the following main questions: (1) how can we measure intraday market liquidity, (2) do different measures of liquidity provide the same estimation of market liquidity, (3) does an intraday pattern of market concentration exist, and (4) what can we learn from the analysis of intraday market liquidity and concentration.

The measurement of the market liquidity is a tricky exercise. The complexity stems from at least two factors: first, the multidimensional nature of market liquidity, and, second, its close relationship with market efficiency. To see the multidimensional nature of market liquidity, it suffices to evoke its common definition: a liquid market allows trading any *volume* size demanding an *immediate* execution and no *price impacts*. On the other hand, while a liquid market implies the absence of market impacts, market efficiency instead requires continuous and significant price adjustments to market news. These considerations bring to the second aim of this study, namely the separate measurement of each liquidity dimension. To do this, I survey the liquidity proxies used in the literature and I propose some new proxies. The third aim deals with an empirical issue not yet investigated to my knowledge, namely the analysis of intraday market concentration.

This paper is relevant for several reasons. First, this study is based on the statistical analysis of a high-frequency database of the most actively traded Swiss stocks. This information enables us (1) to estimate several cross-sectional and stock-specific intraday liquidity proxies, and (2) to propose new measures of intraday market liquidity and market concentration. Second, most of the microstructure literature copes with price-driven markets and dealer models. Hence the Swiss stock exchange provides a motivating case to examine order-driven markets based on an electronic system without market making[1]. Also, it delivers insightful considerations as regards other market architectures combining a limit order book with dealership mechanism such as the NYSE. Third, a separate analysis of each liquidity dimension may be revealing. While most of the literature broadly refers to a sole concept of liquidity, this study points out that market liquidity has multiple dimensions and, therefore, a unique measure of market liquidity may be elusive.

This study provides the following results. First, it shows that the intraday market liquidity on the SWX follows a triple U-shaped pattern and it therefore significantly differs from the analogue patterns on the US and other European markets. This points out that the US pre-opening and opening broadly affect the afternoon trading on the SWX. Second, the separate analysis of market liquidity components provides insightful considerations. Specifically, it indicates that (1) market depth, price dynamics and the trading time dimension are closely related and, (2) the process of price revision is associated with a wider bid-ask spread and large trades. Third, the nine liquidity proxies I estimate have different relative rankings in the order of liquidity. I discuss the possible reasons and I find that these proxies may be sensitive to the market microstructure, to the company quotation policy and to the institutional trading. Finally, I find that an intraday pattern of market concentration exists and I thereby infer the volume impact due to the institutional trading.

The organization of this paper is as follows. Section 2 describes the main aspects of the databases and the market structure of the SWX. Section 3 presents the analysis of intraday market liquidity. Section 4 examines the intraday market concentration. Section 5 concludes.

2. Description of the Market and Dataset

The Swiss exchange system has undergone a fundamental change in the nineties. Besides Soffex, at the end of 1990 there were seven stock exchanges in Switzerland. In 1992, the Swiss electronic exchange project began. On August 2, 1996 the electronic trading in Swiss equities and derivatives started, followed by bonds on August 16, 1996. This was the world's first fully integrated stock market trading system covering the entire spectrum from trade order through to settlement (SWX 1996a). The Swiss stock market has become a computerized limit order market in which trading occurs continuously from 10 a.m. to 4.30 p.m.[2] This is one of three exchange periods of the "regular trading". The other two are the "pre-opening, from 6 to 10 a.m. and 4.30 to 10 p.m., and the "opening", from 9.30 to 10 a.m. The mechanism for entering an order is as follows: first, investors place their exchange orders with their bank; second, the order is fed into the bank's order processing system by the investment consultant, forwarded to the trader, and from there transmitted to the exchange system; finally, the exchange system acknowledges receipt of the order with a time stamp. All these steps elapse in few seconds and the order validity is checked several times. It is important to underline that there are no market makers as in the NASDAQ nor floor traders with special obligations as the specialist in the NYSE. The SWX also differs from Euronext. In fact, Euronext assures a minimum liquidity provision by means of special members called *Animateurs*[3] (see BIAIS, HILLION, and SPATT, 1995).

Before matching, orders on each side of the order book are organized in price-time priority (SWX 1996b)[4]. Obviously, orders can be placed at the best price (Market Order) or with a limit price (Limit Order). Two other order types are the Hidden Order and the Fill or Kill Order. The former corresponds to an order above 200,000 CHF. The latter is an order that must be completely matched in order to create a trade. Unfortunately, our database does not specify the order type.

The database[5] contains the history of trades and orders of 15 Swiss stocks[6] for March and April 1997. It reports tick-by-tick data concerning trades: price, execution time (to a hundredth of a second) and the quantity exchanged in number of shares, and orders:

the best bid and ask quotes, the pending volume in number of shares at the best buy and sell quotes, and order book insertion time of each order. The sample period is of 41 trading days including approximately 500,000 observations. All the information in the data set is available to market participants in real time. When a trade results in two or more transaction prices or contracts, the cumulated trading volume and average price are calculated. I subdivide the trading day into 39 periods of 10 minutes for the first part of this study, and into 13 periods of a half-hour, for the second part.

3. Intraday Market Liquidity

3.1. Measures of Intraday Market Liquidity

Several authors have tried to define market liquidity, but its interpretation still causes some problems. The root of the problem lies in the multidimensional nature of liquidity, as emphasized in AMIHUD and MENDELSON (1986), GROSSMAN and MILLER (1988) and KUGLER and STEPHAN (1997). A usual approach consists in breaking up liquidity into three components: tightness, depth and resiliency (KYLE, 1985; BERNSTEIN, 1987; HASBROUCK and SCHWARTZ, 1988). From another point of view, the complex nature of the market liquidity concept comes from the tension between liquidity - a market in which we can buy and sell promptly with minimal price impact - and efficiency - a market in which prices move significantly and immediately in response to all new information as it flows in the marketplace (BERNSTEIN, 1987).

The multidimensional nature of market liquidity encourages analyzing the intraday liquidity behaviors by means of several liquidity proxies, each of them emphasizing one dimension. The literature suggests identifying market liquidity in terms of depth, tightness, resiliency and trading time. Accordingly, I investigate (1) market depth using the *order ratio*, the *trading volume* and the *flow ratio*, (2) tightness through the actual *spread size* and, (3) trading time via the *waiting time* between subsequent trades. Since resiliency is a measure of the price elasticity, it is difficult to define a straightforward indicator to gauge it. In this line of reasoning, I attempt to capture market resiliency by calculating intraday *returns*, the *variance ratio* and the *liquidity ratio*.

Figure 1 provides a graphical representation of the different components of market liquidity. In this Graph, one can observe that market liquidity has four main dimensions: (1) the quantity dimension on the horizontal axis defines the market depth, (2) the price dimension on the vertical axis reveals the market tightness, (3) the elasticity through the price schedules indicates the market resiliency, and (4) the limit order book changes across time identify the time dimension. Appendix 1 reports the mathematical expressions for all the liquidity measures I present in this Section.

Let us discuss these liquidity proxies in more details. Trading volume[7] is a standard measure for estimating the depth dimension of market liquidity (e.g. ADMATI and PFLEIDERER, 1988). More precisely, the cumulated volume is interpreted as a proxy of *realized* market depth, in the sense that the total number of shares exchanged in a given trading period signals the real capacity to being executed. However, one can argue that the trading volume *per se* has at least three limits. First, it is insensitive to the other liquidity dimensions such as market impact or the trading frequency (e.g. JONES et al., 1994). Second, it does not consider the relevance of the trade size since numerous small trades and a large single trade are considered the same. Third, the trading volume differs form the *expected* market depth for an incoming trader. For this reason, I also estimate the market depth as the proportion between order volume imbalances and executed order size over a given trading time. I call this measure *order ratio*. LEE et al. (1993) and ENGLE and LANGE (1997) present a similar liquidity proxy.

The trading time is a more recent topic in intraday financial studies. The *waiting times between subsequent trades* is the time elapsing between two successive transactions (see Appendix 1). LIPPMAN and MCCALL (1986) define liquidity in terms of the time until an asset is exchanged for money. Although this estimator informs on the transaction frequency, it fails to recognize depth, breadth and resiliency of an asset market. In general, we expect that the faster the trading, the more liquid the market. However, the meaning of the trading speed is controversial. For instance, in the model of DIAMOND and VERRECCHIA (1987) no trade means *bad* news whereas in the model of EASLEY and O'HARA (1992) no trades means *no* news[8]. Empirical evidence (e.g. ENGLE, 1999) seems to support the latter model but the issue is still open.

The bid-ask spread is a common liquidity proxy (e.g. AMIHUD and MENDELSON, 1986). However, the bid-ask spread incorporates at least three cost components, namely order processing costs, inventory control costs and adverse selection costs (e.g. STOLL, 1989). This complexity brings to multiple effects. Given our research focus, two main classes of models can be distinguished. On one hand, a class of models emphasizes the role of information asymmetry and the trading strategy of (discretionary) liquidity traders. ADMATI and PFLEIDERER (1988) show that liquidity traders are better off in clustering their trading in specific time of the trading day. The resulting pooling equilibrium leads to (1) a thick market, (2) low transaction costs, and (3) forces informed traders to compete each other[9]. According to this framework, I expect that spread size and market depth be negatively correlated. On the other hand, recent studies such as BIAIS et al. (1995) HANDA et al. (2000) illustrates that the viability of an order-driven market lies in the profitability of liquidity trading. In fact, even though the liquidity traders lose in case of information-motivated price changes, they profit from mean-reversion price fluctuations. According to these models, temporary liquidity shocks produce a short-run volatility associated with a larger spread size that encourages liquidity traders to fill the book. Consequently, I expect that spread size is (1) positively related to market resiliency proxies such as *variance ratio*, *liquidity ratio* and *returns*, (2) positively related to *realized* market depth, i.e. *trading volumes*, but, meantime, (3) negatively related to the thickness of the limit order book or the *expected* market depth, i.e. the *order ratio*.

Liquidity ratio, LR, is another common liquidity proxy (e.g. COOPER et al., 1985; KLUGER and STEPHAN, 1997). This measure, which relates the number of shares traded during a brief time interval to the absolute value of the percentage price change over that interval, is based on the idea that more liquid stocks can absorb more trading volume without large changes in price. The major limit of LR is its lack of time dimension, i.e. the length of time necessary to trade. Another problem may be the ambiguous reaction of the LR when news causes changes in prices and volumes. Overall, I expect to observe (1) a high correlation between the *liquidity ratio* and the other resiliency proxies, namely *returns* and *variance ratio* and, (2) since trading activity essentially leads price dynamics, a positive linkage among *liquidity ratio*, *trading volume* and *trade frequency*.

The *variance ratio* (VR) may be interpreted as a resiliency proxy. It corresponds to the difference between the volatility over a very short period of 10 minutes, σ^2_{BP}, and the volatility over a longer period of 1 day, σ^2_{LP} (see Appendix 1). HASBROUCK and SCHWARTZ (1988) initially proposed this measure as a daily liquidity proxy. Here, the VR is proposed as an *intraday* liquidity proxy.

The last liquidity proxy is the *flow ratio* (FR). It is based on the flow of volume in Swiss francs traded each second, and, by construction, it combines the quantity and the time dimensions of market liquidity. I expect that the trading flow decreases as the spread size widens and the price fluctuations increase.

3.2. Patterns of Intraday Market Liquidity

Over the last decade several studies on the intraday trading patterns have been carried out. Typically the empirical findings identified the U-shaped pattern. ADMATI and PFLEIDERER (1988, p.3) wrote, for instance, that "the U-shaped pattern of average volume of shares, namely, the heavy trading in the beginning and the end of the day and the relatively light trading in the middle of the day, is very typical and has been documented in a number of studies". The first goal is to verify whether the Swiss stock exchange also follows a U-shaped pattern.

To this end, I first calculate the liquidity proxies for each stock and then the average sample value. Figure 2 shows the graphical representations of the 8 of these proxies. All liquidity measures show:

- A strong liquidity level at the beginning of the trading day, reaching the absolute morning maximum between 10.10 and 10.30 a.m.;
- A decreasing liquidity pattern during the morning (10.30 until 12.10 a.m.), except the brief period beginning at 11.40 until 11.50 a.m. probably due to the opening in the UK markets;
- A deep and long liquidity fall during the midday break (12.10 a.m. until 2.20 p.m.), however proxies more sensitive to the difference between bid and ask quotes show a persistent activity (see Return, OR, VR and Spread during 12.40-50 a.m. and 1.40-50 p.m.);
- A sharp resumption of liquidity after the midday break (2.20 p.m.);
- An evident liquidity slow down around 3.30 p.m., followed by an immediate resumption 10 minutes later;

- An intense increase of market liquidity around the closing time reaching the absolute afternoon maximum in the last 10 minutes of the trading day (4.30 p.m.).

All liquidity proxies reveal that Swiss intraday liquidity patterns do *not* precisely follow a U-shape (as, among others, in JAIN and JOH, 1988; MCINISH and WOOD, 1990) nor am M-shape (as for the Paris Bourse in GOURIÉROUX et al., 1997). The intraday liquidity pattern on the Swiss stock exchange seems to follows *a triple-U-shape*.

The most characteristic feature of the Swiss trading day is the three peaks during the afternoon, namely around 2.20 p.m., 3.30 p.m. and before the SWX closing time. The first one is a peculiar feature found only in the Swiss and the German markets (for the German market, see RÖDER (1996), RÖDER and BAMBERG (1996) and KIRCHNER and SCHLAG (1998)). This can be explained by three major facts. First, the lunch break ends. Second, the US markets pre-opening gives the earliest indication on the daily movements on the US markets. According to BECKER et al. (1995), this is also the moment when the main US macro news are released. Third, there is an important connection between the Swiss and the German markets. The large number of dually listed securities on the Swiss and the German markets corroborates this explanation[10]. The second peak depends on the US opening and corresponds to the analogous afternoon peak in the Paris Bourse (GOURIÉROUX et al., 1997) and the German market (RÖDER, 1996; KIRCHNER and SCHLAG, 1998).

As far as the correlations among different proxies are considered, one can observe the following major points (Table 1):

1. A thick market implies a fast market.
2. An intense trading activity entails price fluctuations. Thus we note that a high rate of trade arrivals is associated with price revisions and volatility.
3. A large spread size involves high demand or supply of liquidity both in terms of trading volume and trading frequency.
4. Transient volatility increases when the spread size widens.
5. Realized (expected) market depth is positively (negatively) related to the other liquidity dimensions.

The first two points result in a positive correlation among trading volumes, trading frequency and the three proxies related to the price dynamic, i.e. returns, variance ratio and liquidity ratio. Thus, the proxies of depth, resiliency and time dimension of market liquidity show that the time, the quantity and the price dimensions of the limit order book are closely related. In a continuous exchange system as in the SWX, the trading volume conveys the flow of new information and thereby the price movements[11]. By virtue of this mechanism, we can identify at least four reasons explaining the interaction among quantity, prices and trading time. First, the release of new information and the consequent review of beliefs typically occur in deterministic moments of the trading day. The results illustrate that the main deterministic moments for the SWX are the opening and the closing of the SWX, and the opening and pre-opening of the US markets. Second, traders can react similarly to the same event, but not necessarily simultaneously. This hypothesis is consistent with the argument that a large number of heterogeneous traders monitor the performance of the economy or firm-specific announcements and successively react in lagged moments. Third, the correlation between cumulated volume and trade frequency could reflect strategic order splitting. A trader is inclined to follow the order splitting strategy either to disguise private information or to avoid market impacts. Fourth, as suggested by BIAIS et al. (1995), different traders could be imitating each other. For example, a broker can imitate a client's order assuming an informative content of that order. This drives to similar consequences of the order splitting.

Correlations in point 3 and 4 above refer to the bid-ask spread. There are two models explaining the intraday patterns. The former refers to the Admati and Pfleiderer's framework (1988) and is supported by the results in MCINISH and WOOD (1992) who find that "there is an inverse relationship between spreads and trading activity" (MCINISH and WOOD, 1992 p. 754). The latter is based on the recent literature on the limit order book market (e.g. HANDA et al., 2000) and provides an explanation why intraday periods of price fluctuation are associated with a disequilibrium between asset demand and liquidity supply and thin book. The negative correlation between the *realized* and the *expected* market depth (trading volumes and order ratio, respectively) confirms this argument. BROCK and KLEIDON (1992) and CHAN et al. (1995)[12] provide further evidence to these models.

Figure 1 provides a graphical representation of the HANDA et al. (2000) argument. The positive intraday correlation between spread size and the other liquidity proxies may depend on the linkage between transient lower elasticity in demand or liquidity supply leading to intense trading activity. Intuitively, Figure 1 shows why an order book can accommodate a large spread size and thin liquidity provision. In fact, the Graph shows that a rotation of the demand curve from D0 to D1 enlarges the spread size and, meantime, reduces the liquidity available on the buy side of the book. In line with this reasoning, a steeper demand entails that some traders are trading more aggressively trading and, therefore, the total amount of traded volume increases. Figure 2 suggests that this phenomenon recurrently occurs after deterministic moments of uncertainty such as the SWX opening and the US opening.

The final considerations of this section concern the liquidity stock ranks according to the different liquidity proxies, see Table 2. The empirical findings reveal that the liquidity ranks vary according to the liquidity proxy we use. For instance, the Roche stock is the least liquid in terms of cumulated trading volume and the most liquid in terms of the variance ratio. Nevertheless some similarity is also evident. For example, Novartis, Roche, Nestlé and UBS N are ranked in the six first most liquid stocks according to LR1, spread, FR and WT criteria, and Ciba is present in the six most liquid positions according to 6 out of the 9 criteria. It is also interesting to note that the two versions of liquidity ratios in Table 2 present very different results. This suggests that a measure of market liquidity neglecting the actual free-floating volume may be misleading.

Liquidity proxies provide different ranks for at least three reasons. First, the market microstructure implies trading rules that may differently affect the intraday stock dynamics. Among those rules, I point out the tick size and the round lot system. The former defines the price grid of a stock price that characterizes price discreteness and transaction costs. In this sense, it may be not surprisingly that a liquidity proxy based on price fluctuations such as the *variance ratio* may be significantly affected. According to the stock price, the round lot defines the minimum order size for a limit order. Thus, the round lot may determine a higher minimum order size *in value* and, hence, a disadvantage for the retail investors.

Second, decisions on corporate quotation policy such as the multiple listing have a remarkable relevance. For instance, Novartis has a multiple listing. Thus it is more sensitive to the performances of international markets. It also profits from a larger population of traders who continually monitor the markets. Thus, information is embodied in the price over a longer trading time and/or with a faster adjustment process.

Third, institutional traders may significantly affect the stock trading dynamics. CHAN and LAKONISHOK (1993) analyze the institutional trading and show that block trading has a higher permanent price impact than non-institutional trading. CHAN and LAKONISHOK (1995) illustrate how a sequence of “package” determines the market dynamic for several days.

4. Intraday Market Concentration

The analysis of market concentration may be revealing for a better understanding of market liquidity. As emphasized by SPIEGEL and SUBRAHMANYAM (1995, p. 336), "a (liquidity) measure depends not only on contemporaneous inventory and volume, but also on the distribution of volume that is expected to arrive in the future".

For these reasons, I estimate the intraday volume concentration with a proxy based on the Gini Index (see Appendix 2 for the mathematical expression and further details). This proxy allows us to estimate to what extent an intraday trading period is characterized by a small number of large size trades or rather by the predominance of trades with a homogenous size. In Table 3 and Figure 3, the volume concentration for the Novartis stock is investigated. We can see the difference between the two extreme Lorenz curves of the trading day, i.e. the less concentrated Lorenz curve corresponding to 4.10 until 4.20 p.m., the nearest to the bisector, and the most concentrated one occurring between 3.50 and 4.00 p.m.

The estimates of the concentration proxy for each trading period of 10 minutes show some interesting features (see Table 3). The mean of the concentration level is 0.662. We have to wait 30-40 minutes after the opening before seeing a higher concentration than the average value. The same length of time occurs after the NYSE opening time (3.30 p.m.). The volume concentration can be interpreted as evidence of institutional trading. We then infer that institutional and/or discretionary liquidity traders delay their trading in order to go beyond the two moments of uncertainty. The most intriguing result is the enormous concentration between 3.50 and 4.00 p.m. This confirms the previous interpretation regarding the substantial dependence of the Swiss stock exchange on the US markets, according to which Swiss investors attempt to learn from the behavior of US markets before deciding on institutional investments. Hence we can argue that, soon after a crucial moment of uncertainty, traders on the Swiss market take rather speculative positions and only afterwards liquidity follows.

The empirical findings show a considerable concentration level during the lunch period, particularly at 12.30 until 12.50 a.m. and at 1.10 until 2.00 p.m. As before, this evidence seems to contradict the ADMATI and PFLEIDERER (1988) model in which discretionary liquidity traders prefer to trade when the market is thick. These findings clearly show traders submit large-sized market orders even during less liquid periods such as the midday trading day. This suggests that traders strategically use volumes to obtain market impact.

Overall, the study of intraday market concentration hints at the relevance of institutional trading and provides a new empirical tool to investigate this issue. The literature devoted to this argument normally assesses the consequences due to institutional trading through measures of market impacts (e.g. CHAN and LAKONISHOK, 1993 and 1995). Market concentration provides a further measure. The limit of our analysis on intraday market concentration is that it is based only on Novartis stock and over a short sample period. Further studies should reveal (1) to what extent these results hold for a larger sample size and longer sample period, and (2) if these results are sensitive to issues related to the market architecture. More specifically, if the complete market transparency of the SWX forces aggressive traders to reveal their urgent trading schedule while a market making system such the London Stock Exchange allows intraday times of high concentration to be avoided[13].

5. Conclusion

This study deals with the question of how to measure intraday market liquidity. The microstructure literature points out 4 major dimensions of market liquidity, namely depth, tightness, resiliency and trading time. Accordingly, several proxies for depth, tightness, resiliency and time dimension are investigated.

The analysis of intraday market liquidity indicates that SWX exhibits a *triple* U-shape. We observe a U-shaped pattern during the morning and the last half-hour of the trading day while three peaks characterize the afternoon trading. The first of these two peaks occurs around the pre-opening of the US markets. The second peak coincides with the US market opening.

By virtue of this approach, I also find that (1) intraday market depth, resiliency and time dimension of market liquidity are positively related and, (2) a large spread size is associated with a less elastic price schedule and intense trading activity both in terms of trading volume and number of trades, and (3) a firm distinction between *realized* and *expected* market depth matters. Overall, the results support the idea that a limit order book market fluctuates continuously between two opposite states. The former is associated with *unbalanced* demand and liquidity supply and a thin book. In this state, slow trading is characterized by a larger spread and transient volatility. The second state is instead associated with the equilibrium between demand and liquidity supply. In this case, fast trading is characterized by a thick book, weak price fluctuations and tight spread.

The nine liquidity proxies we use provide divergent ranks. The main explanations are discussed. First, liquidity proxies may be sensitive to characteristics of the market structure such as the tick size and the round lot systems. Second, the company policies characterizing the stock trading environment matter. Third, institutional trading may broadly affect the trading dynamics. Accordingly, I investigate intraday market concentration as a measure of volume concentration over intraday short periods. The idea is to gauge to what extent an intraday trading period is characterized by a small number of large-sized trades or rather by the predominance of trades with a homogenous size. We observe that the intraday concentration from 3.40 to 3.50 p.m. is very low whereas from 3.50 to 4.00 p.m. the market is extremely concentrated. I argue that institutional traders slow down their intraday trading activity during moments of pervasive uncertainty such as the US and the Swiss opening. The analysis of market concentration suggests that more speculative trades precede the intraday peaks of liquidity. The results on market liquidity and concentration show that the SWX is substantially influenced by the US markets. Swiss investors wait to know the behavior of US markets before deciding on institutional investments.

FIGURE 1: The Representation of the Limit Order Book. This Figure depicts the information content of the limit order book. The vertical and the horizontal axes indicate the price and the quantity dimensions of the limit order book, respectively. On the left (right) side the vertical axis shows the bid-quote (ask-quote). The horizontal axis indicates the cumulated volume available on the bid side (on the left) and on the ask side (on the right). From the horizontal axis one can estimate the market depth and the order volume imbalance. The combination of the price and quantity dimension of the order book expresses the resiliency liquidity dimension and plots the elasticity of the demand curve (on the left) and of the supply curve (on the right). Thus, curves D0 and D1 refer to the demand curve and S0 to the supply schedule. The arrow on the right side of the picture suggests the dynamic of the order flow and, hence, the time dimension of intraday market liquidity.

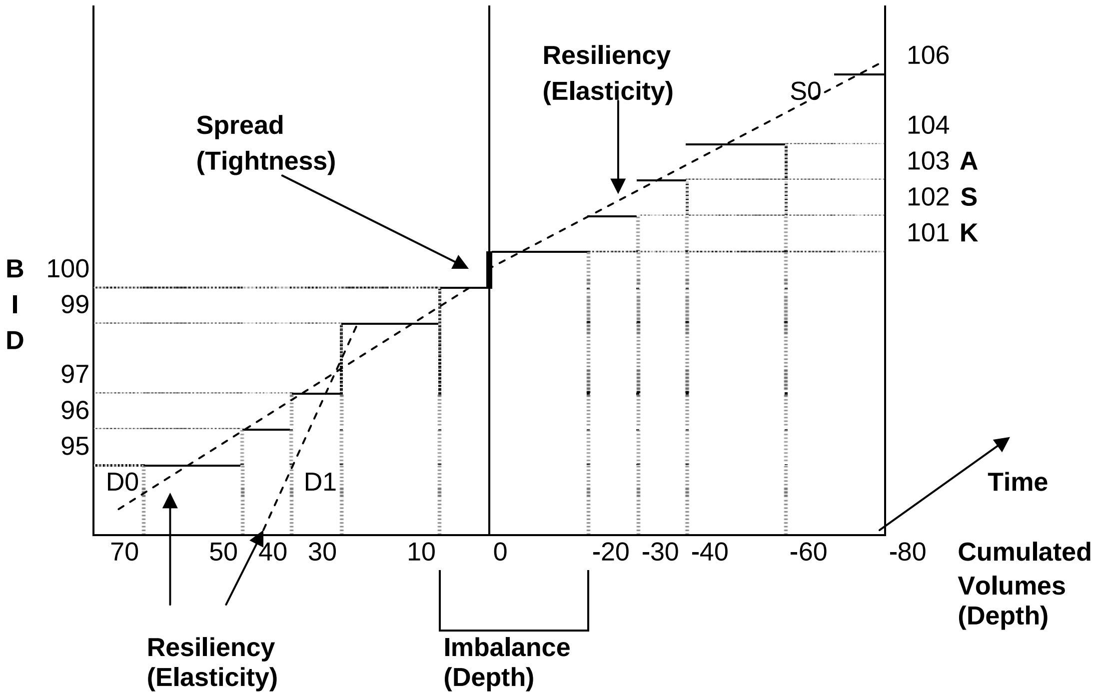

FIGURE 2: The intraday patterns of eight liquidity proxies. This Figure shows the intraday liquidity patterns of the Swiss stock sample. As explained in Appendix 1, each measure has been standardized, i.e. the mean has been subtracted and then divided by its standard deviation. Hence the vertical axis presents the standardized degree of market liquidity. The horizontal axis corresponds to the time axis based on 39 periods of 10 minutes. Figure 2.A shows the intraday pattern of Trading Volume, Price Returns, and Quoted Spread. Figure 2.B shows the intraday pattern of Liquidity Ratio, Variance Ratio and Flow Ratio. Figure 2.C represents the intraday pattern of Order Ratio and Waiting Time between trades. Order Ratio and Waiting Time are negatively related to market liquidity and therefore the patterns in Figure 2.C are opposite.

Figure 2A: Intraday Patterns of Trading Volume, Price Returns and Quoted Spread

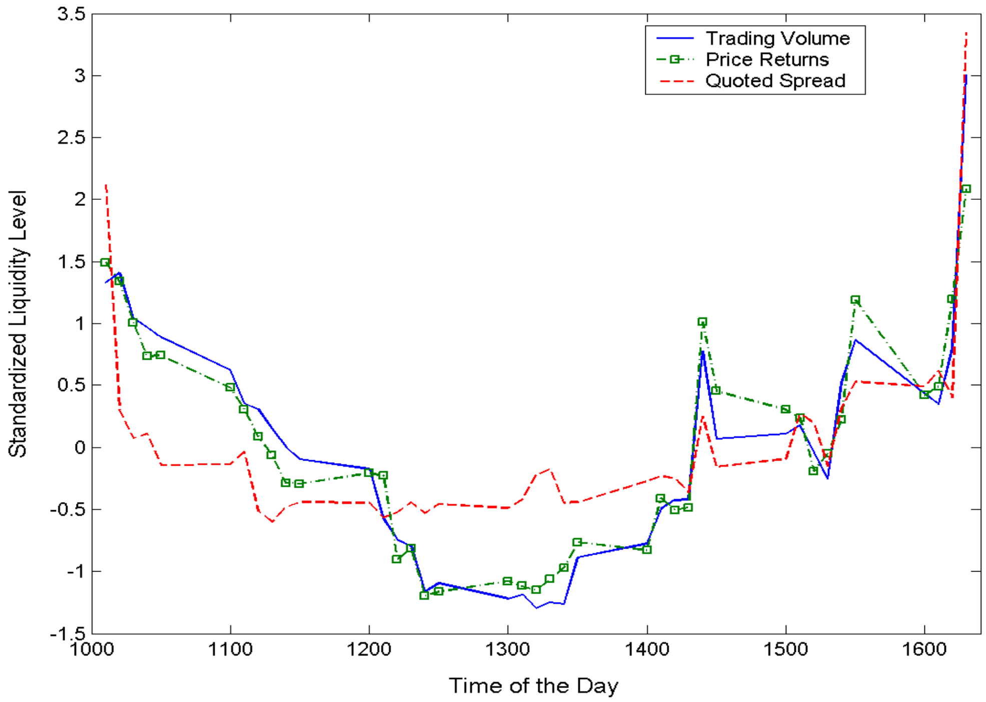

Figure 2B: Intraday Patterns of the Liquidity Ratio, the Variance Ratio and the Flow Ratio

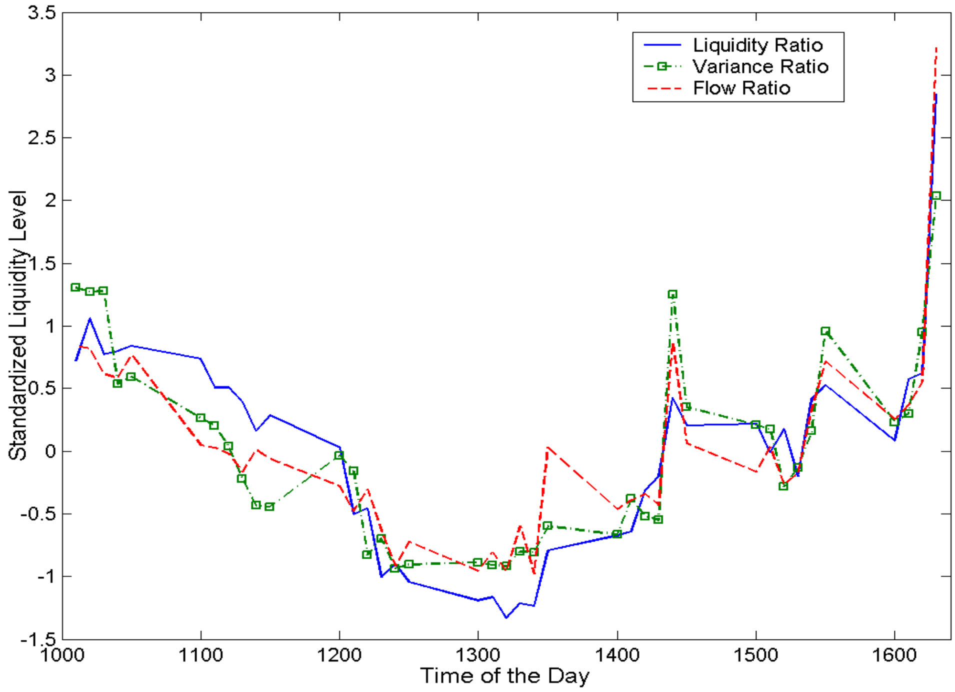

Figure 2C: Intraday Patterns of the Order Ratio and the Waiting Time to Trade

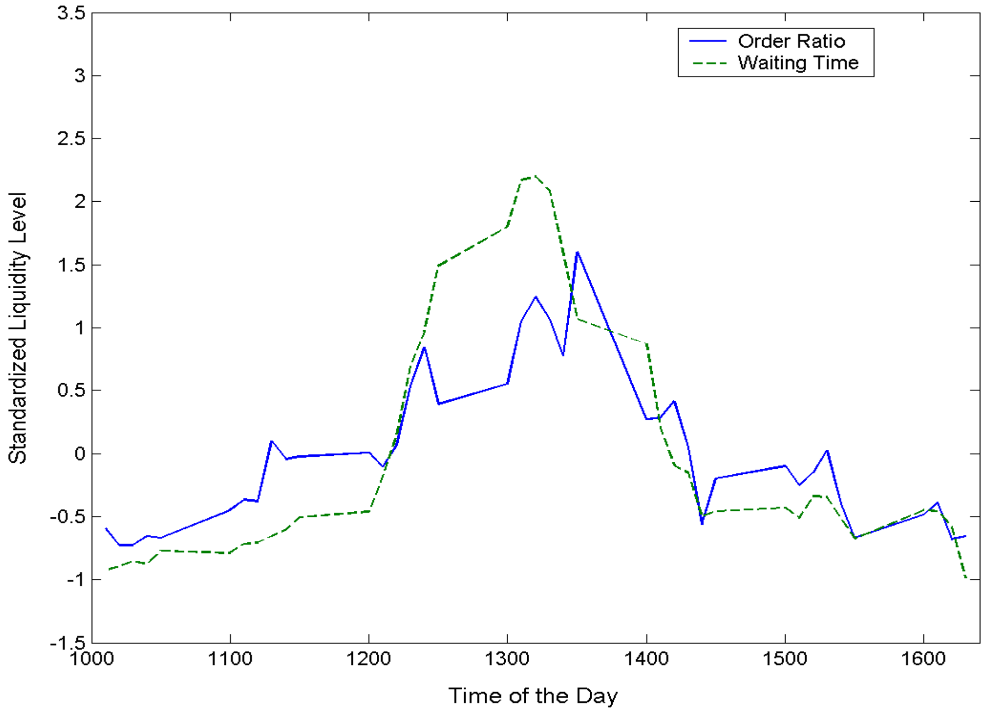

FIGURE 3: intraday Lorenz Curves. The horizontal axis shows the ratio of cumulated number of trades whilst the vertical axis corresponds to the ratio of cumulated traded volume. Before cumulating traded volume, traded volume is ranked from the smallest to the largest size. See Appendix 2 for the mathematical expressions. The nearer the curve is to the horizontal axis, the greater the concentration of volume during an intraday period. The nearest curve to the horizontal axis corresponds to the Lorenz curve for 3.50 until 4.00 p.m. while the nearest curves to the bisector correspond to the periods 4.10 - 20 p.m. and 3.30 – 40 p.m.

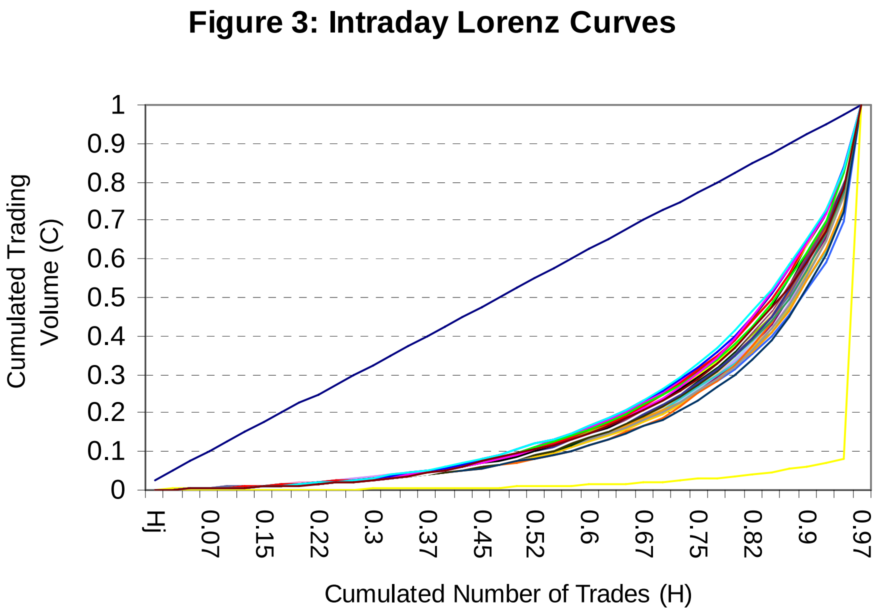

TABLE 1: The Pearson Correlation between eight liquidity proxies. This Table exhibits the correlations among the 8 intraday liquidity proxies defined in Appendix 1. The calculation is based on intraday data of the Swiss stock sample. All correlations are significant at the 0.01 level (two-tailed test). The acronyms indicate: TV the trading volume cumulated within 10 minutes, VR the variance ratio, LR1 the liquidity ratio relating cumulated trading volumes and price changes in absolute value within 10 minutes, FR the flow ratio, OR the order ratio, Return mean of returns, and WT the waiting time between subsequent trades.

	TV	VR	LR1	FR	OR	RETURN	SPREAD	WT
TV	1	0.949	0.973	0.943	-0.849	0.966	0.766	-0.823
VR	0.949	1	0.883	0.9	-0.818	0.984	0.746	-0.745
LR1	0.973	0.883	1	0.916	-0.834	0.914	0.697	-0.856
FR	0.943	0.9	0.916	1	-0.69	0.893	0.835	-0.673
OR	-0.849	-0.818	-0.834	-0.69	1	-0.861	-0.482	0.886
RETURN	0.966	0.984	0.914	0.893	-0.861	1	0.734	-0.811
SPREAD	0.766	0.746	0.697	0.835	-0.482	0.734	1	-0.399
WT	-0.823	-0.745	-0.856	-0.673	0.886	-0.811	-0.399	1

TABLE 2: Fifteen Swiss stocks as ranked by different liquidity proxies. The acronyms indicate: TV the trading volume cumulated within 10 minutes, VR the variance ratio, LR1 the liquidity ratio relating cumulated trading volumes and price changes in absolute value within 10 minutes, LR2 is like LR1 but it takes into account the stock's capitalization and the number of equities owned by the firm, FR the flow ratio, OR the order ratio, Return mean of returns, and WT the waiting time between subsequent trades. See Appendix 1 for the mathematical expressions.

Range	VT	VR	LR1	LR2	Spread	FR	OR	WT	Return
1	CS group	Roche	Novartis	Alusuisse	Novartis	Novartis	Ciba	Novartis	Swiss Re
2	Ciba	ABB	Roche	Winterthur	Roche	Roche	CS group	Roche	Nestlé
3	SBV	Ciba	Nestlé	UBS N	Nestlé	UBS N	SBV	Nestlé	ABB
4	**mean**	Swiss Re	UBS N	ABB	Swiss Re	Nestlé	Zürich	Ciba	Novartis
5	Novartis	Novartis	**mean**	Swiss Re	ABB	CS group	Winterthur	UBS N	Alusuisse
6	UBS N	Alusuisse	CS group	**mean**	UBS N	Ciba	**mean**	CS group	UBS N
7	Nestlé	CS group	Swiss Re	Ciba	Alusuisse	**mean**	UBS N	Swiss Re	Roche
8	Zürich	SBV	ABB	Nestlé	Zürich	Winterthur	SMH	SBV	Zürich
9	Winterthur	Nestlé	Winterthur	Roche	**mean**	Swiss Re	Clariant	ABB	**mean**
10	Swiss Re	**mean**	Zürich	CS group	Winterthur	ABB	Alusuisse	Zürich	SMH
11	SMH	Zürich	SBV	Novartis	CS group	SBV	UBS B	**mean**	Winterthur
12	ABB	UBS N	Alusuisse	Clariant	SBV	Zürich	ABB	Winterthur	UBS B
13	Alusuisse	Clariant	Ciba	SMH	UBS B	Alusuisse	Novartis	Clariant	SBV
14	Clariant	UBS B	UBS B	Zürich	Ciba	Clariant	Swiss Re	Alusuisse	CS group
15	UBS B	SMH	Clariant	SBV	Clariant	UBS B	Roche	UBS B	Clariant
16	Roche	Winterthur	SMH	UBS B	SMH	SMH	Nestlé	SMH	Ciba

TABLE 3: An estimation of intraday market concentration. This Table reports the estimation of the Gini Index for all the 39 periods of 10 minutes constituting the trading day of Novartis stock. This Table also exhibits the average traded size ("Average Size"), the average number of trades ("Average # of Trades"), and the total number of trades ("Total # of Trades") for each period of 10 minutes over the sample period of March and April 1997. The highest intraday market concentration occurs 20 minutes after the US markets opening (3.50 -4.00 p.m.). Soon after the opening at the Swiss and US markets (10.00 -10.30 a.m. and 3.30 - 3.50 p.m.) the intraday market concentration falls to relatively low levels. Some moments of high concentration also occur during the lunch period (e.g. 12.30 – 12.40 a.m.). See Appendix 2 for the mathematical expressions and further details.

Intraday Period	Gini Index	Average Size	Average # of Trades	Total # of Trades	Intraday Period	Gini Index	Average Size	Average # of Trades	Total # of Trades
10.00-10.10	0.621	144.28	41.707	1710	1.20-1.30	0.675	129.40	10.439	429
10.10-10.20	0.633	141.62	43.780	1795	1.30-1.40	0.655	120.51	13.146	539
10.20-10.30	0.659	145.39	38.902	1595	1.40-1.50	0.676	144.24	15.317	628
10.30-10.40	0.672	155.12	39.439	1617	1.50-2.00	0.699	131.65	16.829	690
10.40-10.50	0.659	138.01	35.537	1457	2.00-2.10	0.662	123.39	19.025	761
10.50-11.00	0.659	119.87	35.488	1455	2.10-2.20	0.651	134.78	21.100	844
11.00-11.10	0.654	128.77	34.366	1409	2.20-2.30	0.658	143.25	21.925	877
11.10-11.20	0.665	122.86	35.683	1463	2.30-2.40	0.627	169.41	32.150	1286
11.20-11.30	0.660	119.99	31.732	1301	2.40-2.50	0.646	145.56	29.775	1191
11.30-11.40	0.662	133.56	32.024	1313	2.50-3.00	0.655	155.92	30.225	1209
11.40-11.50	0.656	130.70	31.488	1291	3.00-3.10	0.639	152.40	26.675	1067
11.50-12.00	0.668	141.31	26.659	1093	3.10-3.20	0.646	138.06	26.200	1048
12.00-12.10	0.650	120.51	22.756	933	3.20-3.30	0.625	132.09	25.300	1012
12.10-12.20	0.658	121.76	19.707	808	3.30-3.40	0.632	178.70	31.075	1243
12.20-12.30	0.654	128.66	14.732	604	3.40-3.50	0.615	178.09	34.775	1391
12.30-12.40	0.688	160.25	11.829	485	3.50-4.00	0.964	172.35	29.900	1196
12.40-12.50	0.674	134.78	11.537	473	4.00-4.10	0.630	187.28	30.950	1238
12.50-1.00	0.647	149.69	11.780	483	4.10-4.20	0.610	181.01	29.850	1194
1.00-1.10	0.679	123.70	11.250	450	4.20-4.30	0.646	228.88	47.175	1887
1.10-1.20	0.677	145.01	10.415	427	**Mean**	0.662	144.80	26.463	1396

APPENDIX 1: Proxies of Intraday Market Liquidity. I use 9 indicators of market liquidity, namely returns (RETURN), cumulated trading volumes (VT), the mean of waiting time trading between subsequent trades (WT), the mean of bid-ask spread (SPREAD), the first version of liquidity ratio (LR1), the second version of liquidity ratio (LR2), variance ratio (VR), flow ratio (FR) and order ratio (OR). Every proxy is measured on an intraday time of 10 minutes. Trading volume for each transaction is labeled by $tv_{t,i,j}$, price by $p_{t,i,j}$, the bid quote by $Bid_{t,i,j}$, the sell quote by $Ask_{t,i,j}$, the volume related to the best bid by $VBuy_{t,i,j}$, the volume related to the best ask by $VSell_{t,i,j}$, the intraday period of 10 minutes by i = 1, ..., 39, the day is indexed by j = 1, ..., J, and the trade time during the j-10 minutes period by t = 1, ..., n while the trade time during the day by t = 1, ..., T.

$$\mathrm{RETURN}_{i,j} = \ln(p_{n,i,j}) - \ln(p_{1,i,j}) \quad \text{(A.1.1)}$$

$$\mathrm{VT}_{i,j} = \sum_{t=1}^{n} \mathrm{tv}_{t,i,j} \quad \text{(A.1.2)}$$

$$\mathrm{WT}_{i,j} = \frac{1}{n}\sum_{t=1}^{n} (\mathrm{tr}_{t,i,j} - \mathrm{tr}_{t-1,i,j}) \quad \text{(A.1.3)}$$

$$\mathrm{SPREAD}_{i,j} = \frac{1}{n}\sum_{t=1}^{n} (\mathrm{Bid}_{t,i,j} - \mathrm{Ask}_{t,i,j}) \quad \text{(A.1.4)}$$

$$LR1_{i,j} = \frac{\sum_{t=1}^{n}(tv_{t,i,j}.p_{t,i,j})}{\left|\left\{\frac{p_{n,i,j} - p_{1,i,j}}{p_{1,i,j}}\right\}.100\right|} \quad \text{(A.1.5)}$$

$$LR2_{i,j} = \frac{\left(\sum_{i=1}^{n}(tv_{t,i,j}.p_{t,i,j})\right) \div (Ne - No)}{\left|\left\{\frac{p_{n,i,j} - p_{1,i,j}}{p_{1,i,j}}\right\}.100\right|} \quad \text{(A.1.6)}$$

$$VR_{i,j} = \frac{\sigma_{BP}^2}{\sigma_{LP}^2} = \frac{\underset{j}{E}\left[\left\{\ln\frac{p_t}{p_1} - \underset{i}{E}\left[\ln\frac{p_t}{p_1}\right]\right\}^2\right]}{\underset{i}{E}\left[\left\{\ln\frac{p_T}{p_1} - \underset{j}{E}\left[\ln\frac{p_T}{p_1}\right]\right\}^2\right]} \quad \text{(A.1.7)}$$

$$FR_{i,j} = \frac{1}{n}\sum_{i=1}^{n}\frac{(tv_{t,i,j}.p_{t,i,j})}{(tr_{t,i,j} - tr_{t-1,i,j})} \tag{A.1.8}$$

$$OR_{i,j} = \frac{\frac{1}{n}\left\{\left|\sum_{i=1}^{n}(VBuy_{t,i,j}) - \sum_{i=1}^{n}(VSell_{t,i,j})\right|\right\}}{\frac{1}{n}\sum_{i=1}^{n}(tv_{t,i,j})} \tag{A.1.9}$$

The standardization of each time series was based on the daily mean and the daily variance of each individual stock. Let the stock be s=1,…,S and, as before, the intraday period of 10 minutes i = 1, ..., 39 while the day is indexed by j = 1, ..., J. So, for instance, standardized cumulated trading volume, say SVT, for the stock s and the day j is:

$$SVT_{i,j}^{s} = \frac{VT_{i,j}^{s} - \frac{1}{39}\sum_{i=1}^{39}VT_{i,j}^{s}}{\left[\frac{\sum_{i=1}^{39}\left(VT_{i,j}^{s} - \frac{1}{39}\sum_{i=1}^{39}VT_{i,j}^{s}\right)^{2}}{n-1}\right]^{1/2}} \tag{A.1.10}$$

The standardized market liquidity (here called MVT) in terms of cumulated trading volume for the intraday time i and the trading day j is:

$$MVT_{i,j} = \frac{1}{S}\sum_{s=1}^{S}SVT_{i,j}^{s} \tag{A.1.11}$$

The other 8 standardized proxies of intraday market liquidity are calculated following the same process.

APPENDIX 2: the proxy of intraday market concentration. To calculate this proxy, I begin by ordering trades within a given period according to the increasing size volume criterion. In Section 3 I decompose the trading day into 39 ten-minute intervals. Trading volume size of each transaction is labeled by $tv_{t,i,j}$, the intraday period of 10 minutes by i = 1, ..., 39, the day is indexed by j = 1, ..., J, and the trade time during the j-10 minutes period by t = 1, ..., n. Hence the total number of trades exchanged in a 10-minute intraday period is:

$$n = \sum_{t=1}^{n} t_{t,i,j} \qquad \text{(A.2.1)}$$

The cumulated volume size at the end of a 10-minutes intraday period is:

$$\sum_{t=1}^{n} tv_{t,i,j} \qquad \text{(A.2.2)}$$

We indicate with $H_{t,i,j}$ the trade ratio:

$$H_{t,i,j} = \frac{\sum_{t} t_{t,i,j}}{\sum_{t=1}^{n} t_{t,i,j}} \qquad \text{(A.2.3)}$$

and we name C the volume ratio:

$$C_{t,i,j} = \frac{\sum_{t} tv_{t,i,j}}{\sum_{t=1}^{n} tv_{t,i,j}} \qquad \text{(A.2.4)}$$

So, the level of intraday market concentration, IMC, is:

$$IMC_{i,j} = 1 - \sum_{t=1}^{n} (H_{t,i,j} - H_{t-1,i,j})(C_{t,i,j} + C_{t-1,i,j}) \qquad \text{(A.2.5)}$$

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End Notes

[1] One of the rare examples of intraday studies on Swiss markets is ZOGG and ZIMMERMANN (1996). However, this paper focuses on SMI stock index futures.
[2] In 1998 the regular trading was set from 9 a.m. to 5 p.m.
[3] In case of lack of liquidity, *Animateurs* undertake to provide a minimum volume size and a maximum spread size.
[4] The price-time priority rule consists in ordering the order book as follows: best price to worst price (where Market Orders are followed by Limit Order); then, within price, first in to last in.
[5] This data set was graciously provided by the Swiss Stock Exchange in Zurich.
[6] None of the 15 firms has undergone an extraordinary change or transformation during the sample period (NZZ archives March and April 1997).
[7] Intraday volumes and returns pattern were originally studied by HARRIS (1986), who found that there are systematic intraday return patterns. JAIN and JOH (1988) showed significant differences across trading hours of the day.
[8] In DIAMOND and VERRECCHIA (1987) non-trading time means that news may be bad so the specialist learns from the waiting time to trade and lowers his trading activity by widening the spread. Notice that in this framework the assumption that sellers who do not own the stock must short sell is crucial. In EASLEY and O'HARA (1992) the frequency of trades depends of information asymmetry. Therefore, the specialist interprets the decrease of trading speed as a decrease in information asymmetry.
[9] In fact, informed traders can hide their private information trading when the market is thick. However, this induces informed traders to compete among each other.
[10] This remark is also noteworthy for the French and UK markets.
[11] STOLL and WHALEY (1990) show that returns and trading volume in the last part of the trading day are substantially higher than normal. LOCKWOOD and LINN (1990) observe that return volatility falls from the opening hour until early afternoon and rises thereafter, and is significantly greater for intraday versus overnight periods. Similar results are found for the option markets (among the others, SKEIKH and RONN, 1994; SUSMEL and ENGLE, 1994).
[12] BROCK and KLEIDON (1992) clearly show wider spreads at the beginning and at the end of the day. The authors show that transaction demand at the opening and closing times is greater and less elastic than at other times of the trading day. As a result, a market maker such as a NYSE specialist may effectively use discriminate pricing by charging higher prices at these periods of peak demand. Their predictions of periodic demand with high volume and wide spreads are consistent with our empirical evidence.
[13] In a dealer or upstairs market, a client can negotiate a personalised treatment of an order or a "package" of orders. The consequent splitting strategy provided by the market maker engenders different patterns of intraday market concentration.