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An Empirical Analysis of the Trading Structure at the Stockholm Stock Exchange

Jonas Niemeyer and Patrik Sandås

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Jonas Niemeyer**

Stockholm School of Economics

Patrik Sandås

Carnegie Mellon University

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Abstract

This paper describes and analyzes the trading structure at the Stockholm Stock Exchange. In the empirical part, we report stylized facts based on intraday transaction and order book data, focusing on the intraday behavior of returns, trading activity, order placement and bid/ask spread, on the importance of the tick size and finally on some characteristics of the limit order book. Our main empirical conclusions are that a) the intraday U-shape in trading activity found in earlier U.S. studies on the whole also pertains to the Stockholm Stock Exchange, b) the limit order placement also follows an intraday U-shape, c) there is no distinct intraday pattern in returns, d) the volatility and bid/ask spread seems to be higher at the beginning of the trading day, e) the tick size is economically important, and f) the price impact of an order is a non-linear function of its quantity, implying price inelastic demand and supply.

1 Introduction

Standard pricing theories in finance develop the idea that securities prices are determined by variables such as, dividends, earnings per share, riskiness of cash flows and interest rates. However, the actual price formation process has not been studied extensively. How does the market clearing price come about in reality? Furthermore, an implicit assumption in standard pricing theories is that the specific institutional market structure has no effect on the security prices. This assumption is challenged by the growing market microstructure literature, which focuses on the possible effects of the markets' institutional structure on the price formation process.

The technological development in the last decade has enabled stock exchanges to introduce centralized computer based trading systems (i.e., Paris, Toronto, Stockholm). Furthermore, the deregulation of capital markets and the liberalization of capital flows has enhanced the competition between exchanges. The actual trading system has become an increasingly important mean of competition and therefore highly relevant for both market participants and policy-makers.

Recent availability of transaction data from stock exchanges around the world has spurred research of intraday phenomena in the last decade. Several new anomalies have been reported in studies using U.S. data. One of the first studies was Wood, McInish and Ord (1985). Using NYSE[1]-data, they found distinct intraday patterns in the average market return as well as its standard deviation, contrary to all efficient market hypotheses. In another study, also using NYSE-data, Jain and Joh (1988) reported a significant U-shape[2] in trading activity over the trading day. Handa (1992) studied the bid/ask spread and also found a U-shape, using data from both the NYSE and AMEX. The Paris Bourse, with a similar trading structure to the Stockholm Stock Exchange, has been studied by Biais, Hillion and Spatt (1994). One of their findings is that the price impact of an order is a non-linear function of its quantity, and that the supply and demand are price elastic.

The purpose of this paper is twofold. In order to more accurately assess the importance of different market design features, we first describe and analyze the trading structure of the Stockholm Stock Exchange (SSE). Our second objective is to present some stylized facts. The purpose is to investigate whether certain anomalies and stylized facts found in earlier studies are specific to the studied trading structure or also present in a market-by-order trading system. By using data from the SSE, the question of generality can be addressed.

1 Explanation for abbreviations can be found at the end of the reference list.

2 I.e. high trading activity at the beginning and end of the trading day and low trading activity at midday.

The rest of the paper is organized in the following way. Section 2 gives some general information about the size of the SSE. Section 3 describes and analyses the trading system of the SSE. Our data set is presented in section 4. In section 5, we report our empirical results. We focus on 1) the intraday behavior of returns, trading activity, and order placement; 2) the bid/ask spread; and 3) the supply of immediate liquidity through the limit order book. Our empirical results are of two types. First, we report some stylized facts for the SSE. Since detailed data on prices and quotes for continuous limit order driven markets have not yet been analyzed extensively in the empirical literature, stylized facts are of interest per se. Second, we test a few empirical predictions of the existing market microstructure theories. The paper concludes with a summary of our findings in section 6.

2 The Size of the Stockholm Stock Exchange[3]

The SSE is the largest stock exchange in the Nordic countries and one of the 10 largest in Europe (see Table 1).

Table 1

The Size of a Selected Number of Stock Exchanges Around the World.

Exchange	Market Value (Dec. 1992) Billion USD	Turnover (1992) Billion USD*
NYSE + NASDAQ	4 388.5	2 636.6
Tokyo + Osaka	2 397.4	597.9
London	928.4	663.0
Toronto + Montreal	439.7 a)	80.1 b)
Paris	349.6	124.9
Germany (aggregated)	346.9	454.2
Madrid + Barcelona + Bilbao	287.1	42.3
Zürich + Geneva + Basel	189.1	116.5
Amsterdam	134.2	45.7
Italy (aggregated)	129.0	27.2
Stockholm	**76.2**	**27.7**
Brussels	64.1	9.8
Copenhagen	32.5	18.8
Oslo	17.8	10.1
Helsinki	12.2	2.2

Data Source: Fédération Internationale des Bourses de Valeurs Statistics (FIBV) 1992.
* Converted into USD at month-end exchange rates.
a) The market value for Toronto includes convertibles.
b) The turnover for Montreal includes transactions on warrants and rights.

[3] If not otherwise specified, the institutional description in this paper is based on the SSE's "Rules Governing Trading in Stocks and Convertible Participation Notes via the Stockholm Automated Exchange (SAX)" and the Stockholm Stock Exchange Annual Reports 1989 and 1992.

In Dec. 1992, the SSE had 111 companies listed with in total some 220 issues.[4] Furthermore, the OTC-market included 43 companies and there were 44 unofficially registered companies. Trading at the SSE is highly concentrated. In 1992, The 20 most traded companies accounted for 84 per cent of the turnover and 82 per cent of total stock market value. The ownership structure is also extremely concentrated. In Dec. 1991, the 10 largest shareholders/institutions accounted for 32 per cent and the 50 largest shareholders/institutions for 57 per cent of total stock market capitalization.[5]

3 The Trading Structure of the Stockholm Stock Exchange[6]

3.1 The Stockholm Automated Exchange

Since June 30, 1990, all stocks listed at the SSE are traded through a computer based trading system (SAX). The SAX-system is largely inspired by the trading systems in Toronto and Paris (CATS and CAC respectively).

The main features of the SAX system are (i) the continuity; (ii) the limit order book (LOB) aggregating all order placement and trading activity; and (iii) the automatic matching. In order to distinguish between, on one hand the LOB of a specialist at NYSE (including only a part of the order flow and not open to the public), and on the other hand the centralized, consolidated and open limit order book of the SSE, the latter is usually called consolidated open limit order book, or COLOB.

3.1.1 The Dealers

Only officially authorized brokerage firms[7] are eligible for membership at the SSE. Indeed, most brokerage firms are members of the exchange. Only stock exchange members have the right to enter orders directly into the SAX-system. As a consequence, all primary customers are represented by some exchange member in the market. All brokerage firms can act as dealers and brokers in the market, but there are no designated

4 Swedish companies normally have several classes of stocks, i.e. with and without restrictions on foreign ownership and with different voting powers. These are normally called dual-class stocks. As of Jan. 1, 1993, however, all stocks are open to foreign ownership.

5 See Sundqvist (1992).

6 We want to stress that the trading structure at the SSE is under permanent change. For example, the stock exchange monopoly was abolished Jan. 1 1993, (the Stock Exchange Act (1992:543)). In this paper we consider the trading structure as of mid-1992.

7 Brokerage firms can be both firms specialized in securities trading and traditional banks. Only authorized brokerage firms are permitted to trade financial assets as brokers, dealers or market makers. Authorization (according to The Securities Business Act (1991:981)) requires the compliance with certain regulations regarding equity capital and organizational structure. At the end of 1991, 27 companies were recognized as brokerage firms and could act as brokers and dealers. In addition, two firms were allowed to act only as brokers.

market makers.[8] The exchange fees are proportional to their commissions in the preceding year.[9] Brokerage firms are allowed to have significant inventory (i.e. efficiently act as broker or market maker) as long as the risk is hedged or is small compared to the equity capital of the firm.

The function of the dealers at the SSE corresponds to the one of a dual-capacity dealer. The potential conflicts of interest inherent in dual-capacity trading might therefore be of some importance here. The problem of "front-running" (dealers trading on own account before executing a customer order) is relevant in all markets where broker and dealer functions are integrated. Although hard to monitor, it is prohibited on most markets[10] (e.g. NYSE, CME).

3.1.2 Different Types of Orders

Traders have the choice of two different types of orders: market orders and limit orders. A market order is an order to buy or sell a given quantity of a stock at the prevailing market price. A limit order makes the execution conditional on a limit price. It is a firm commitment until withdrawn.

Amihud and Mendelson (1991) note three important differences between market orders and limit orders. First, market orders are executed immediately and with certainty. Second, limit orders do, but market orders do not, provide immediate liquidity to the rest of the market. Third, submitting a limit order implies the release of more information (i.e. the trader's reservation price) to the market, than submitting a market order. They summarize the difference by stating that immediacy is "*supplied* to the market by *limit* orders and *consumed* by *market* orders"[11]. There is therefore a positive externality of submitting a limit order. Since the dealers submitting limit orders get no compensation for the positive externality, the result could be lower immediate liquidity.

There are several aspects to the liquidity of a stock. In the market microstructure literature, four aspects of liquidity are often discussed.[12] Firstly, traders are generally impatient and therefore demand *immediacy*. Secondly, since the spread is a cost, traders prefer to trade stocks with a small spread (or *width*). A third aspect is *depth*, i.e. the volume possible to trade without moving prices. A fourth aspect is the market's *resiliency*, which refers to how quickly a market regains equilibrium after an imbalance

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8 Consequently, we will use the term "dealer" for exchange members since their role in the market is not formally restricted only to broking. On the other hand, the dealer is not a designated market maker as the dealers in the SEAQ International in London or the specialists at the NYSE.

9 As of 1993, the fee is based on the number of transactions (to 1/3) and on traded volume (to 2/3).

10 See Schwartz (1991).

11 Amihud and Mendelson (1991), page 80.

12 See Harris (1990).

created by large informationless trading. A liquid market would have instant immediacy, negligible width and infinite depth and high resiliency.

In a market-by-order trading system such as at the SEE, the submission of limit orders is of paramount importance since it is the only source of immediate liquidity. Within the market microstructure literature little attention has been paid to the *incentives* of placing limit orders. Handa and Schwartz (1992) develop a model where it, despite the externality problem, is rational for some traders to use limit orders. Temporary order imbalances caused by an influx of traders seeking immediacy "can induce a temporary shift in an asset's current price without there being any change in the expected future payoffs"[13]. The resulting price changes (i.e. additional short-run volatility) can be sufficient to compensate limit order traders. In another model, Glosten (1994) describes the properties of limit orders in equilibrium. He also derives some necessary conditions for the submission of limit orders.

3.1.3 The Consolidated Open Limit Order Book

The central feature of the SAX-system is the electronic COLOB. The COLOB at the SSE is a computer file showing the prices of all limit orders, the aggregate number of stocks offered or demanded at each price and the identification codes of the dealers willing to trade. An incoming market order is automatically matched against the best standing limit order in the COLOB. If an incoming limit order cannot be matched directly, it is added to the COLOB. Table 2 shows what a typical COLOB could look like.

Table 2
The COLOB for TRELLEBORG C at 10.00, December 27, 1991.

Dealers	*Volume*	*Bid-Price*	*Ask-Price*	*Volume*	Dealers
FB	*1000*	*110*	*112*	*1100*	SE
C,HB,C	*900*	*107*	*113*	*400*	SE
HB	*1200*	*106*	*114*	*170*	SW
SW	*700*	*105*	*115*	*500*	SW
FB,SE	*2500*	*104*	*117*	*100*	SW
SW	600	94	127	100	C

3.1.4 Trading in the SAX-system

The Opening Auction

The SAX-system opens trading with a sealed bid call auction. This opening auction can be divided into three stages. At the first stage, from 8.00 a.m. to 10.00 a.m., dealers can

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[13] Handa and Schwartz (1992), page 2.

place sealed orders into the COLOB. The orders are sealed in the sense that the dealers can see neither the orders of other dealers nor any indicative auction prices.

At 10.00 a.m. trading starts. The SAX-system treats the stocks sequentially. For each stock, it computes a single opening price, in order to maximize the number of stocks traded in the auction. The price is computed in the following way:

- If the highest bid quote is equal to the lowest ask quote, this will be the opening price;
- If the highest bid quote is higher than the lowest ask quote, the market opening price will be the price that maximizes trading volume in that stock;
- If the highest bid quote is lower than the lowest ask quote, or if there are no orders on one side of the market, no opening price is set.

Immediately after the completion of the auction for one stock, the continuous trading in that stock starts.

It should be noted that some details of the auction rules in the SAX-system differ from the rules of other exchanges. In Toronto (CATS), all stocks must open through an auction before the continuous trading starts. There is therefore a time gap between the opening auction and the continuous trading. Another difference is that in Toronto and Paris the dealers *can* observe indicative prices. The purpose of the auction is to incorporate as much as possible of the information, accumulated during the non-trading period, into the new equilibrium prices. For this, a certain order volume is necessary. If no indicative prices are available, the individual trader might prefer to postpone his orders since he will have significantly more information about the stock once the auction price is established. The result could be low order volumes in the auction and thereby less informative auction prices. On the other hand if indicative prices are available, order volumes in the auction might increase,[14] resulting in more informative auction prices. However, indicative prices also leave room for manipulation since the orders can be withdrawn without penalty until the auction starts, leaving the prices prior to 10:00 highly unreliable.

The final stage is the dissemination of information on opening prices. Simultaneously, orders which can be executed given the opening prices are matched and trades reported on the screen. First, priority is given to orders "deep in the money". Secondly, there is a pro rata execution on the short side. Limit orders not executed at the opening constitute the COLOB when the continuous trading starts. An example might clarify the process.

Assuming the COLOB in Table 3, the opening price will be 109 and the 500 stocks at the ask price 109 will be matched, first against the 200 stocks at bid price 110 (the

[14] See Harris (1990).

stocks deepest in the money) and second against 300 of the 600 stocks offered at 109. The latter 300 stocks are selected proportionally among the limit orders offered at 109.

Table 3
An Example of a COLOB Before and After the Auction.

Before the Auction				After the Auction			
Bid		Ask		Bid		Ask	
volume	price	price	volume	volume	price	price	volume
200	110	109	500	300	109	110	700
600	109	110	700	1000	108	111	500
1000	108	111	500	.	.	.	.

Continuous Trading

After the opening auction, trading through the COLOB is continuous until the market closes at 2.30 p.m.[15] Market orders, and if possible limit orders, are *automatically* matched against the best existing limit order as soon as they arrive to the market. If there is no matching limit order, the new limit order is added to the COLOB. Limit orders at the end of the day will be deleted unless a duration condition is included in which case the order remains until the desired day.

The definitions of market and limit orders are not uniform for all stock exchanges. At the Paris Bourse, market orders are sometimes converted into limit orders. In contrast to in the SAX-system, a French market buy (sell) order is converted into a limit buy (sell) order at the best ask (bid) quotation rather than "being executed by walking up (down) the limit order book"[16]. In a sense, this creates an insurance against adverse price moves for the submitter of a market order. At the same time, the market order provides additional immediate liquidity to the market. This feature does not exist in the SAX system, i.e. if possible, market orders always clear in the LOB. However, at the SSE, the same insurance against adverse price moves can be obtained by submitting the appropriate limit order.

Small Orders in the SAX-system

Orders of less than one trading unit[17] are submitted to the small order system. In this system, transactions are always executed at the last transaction price in the normal SAX-system.[18] If it is possible to add several orders from the small order book and get a round

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15 April 1, 1993, the stock exchange extended the continuous trading. Trading hours are now between 10.00 a.m. and 4.00 p.m.

16 See Biais, Hillion and Spatt (1994), p 3.

17 A typical trading unit is 100 or 200 stocks (occasionally 50, 500 or 1000 stocks) depending on price. A stock's trading unit is regularly revised. The principle is that a trading unit, measured in SEK, should have an approximately constant value over time and comparable across stocks.

18 Even if there are limit orders with crossing prices in the small order book, a transaction will only take place if it can be executed at the last transaction price in the SAX-system. Furthermore, most small

lot, a transaction with an order in the COLOB might be executed. An order submitted to the COLOB can have an "alternative matching condition" whereby the order will be matched against orders in the small order book if matching across the two order books is possible.

3.1.5 The Information Structure

The dealers' information set in the COLOB includes the total quantity offered or demanded at each price level. Thus, dealers have no direct information on the size of each individual order, but only of the consolidated volume at each price level. Furthermore, the dealers can see the dealer identification codes, which appear in order of priority at each price level.

Information available to financial information firms (e.g. Reuters, Telerate), and thereby in principle to the public, is limited to the five best prices and consolidated volumes at each side of the market. The identification codes of the dealers in the COLOB are available only to member firms. In Table 2 above, only numbers printed in italics represent information available to financial information firms.

All information on transaction prices, volumes and dealers involved in a transaction is continuously transmitted to dealers as well as to financial information firms. Yet, a dealer's trades on his own account cannot be distinguished from his trades on behalf of his customers since all dealers are dual-capacity dealers.

Asymmetric information disclosure through firm quotes is necessary in a computerized order matching system. In contrast to the simultaneous bidding process of a call auction, the SAX-system requires one part of a potential transaction to first disclose his willingness to trade by placing a limit order with a specified and binding price, i.e. to supply immediate liquidity to the market. Furthermore, suppliers of liquidity sometimes trade with liquidity demanders who are better informed than themselves. This is a special case of the asymmetric information problem, extensively discussed in the market microstructure literature (e.g. Kyle (1985), Glosten and Milgrom (1985) and Admati and Pfleiderer (1988)). Amihud and Mendelson (1991) compare the dealer submitting a limit order to a "sitting duck", risking to be hit by a better-informed trader. Stoll (1992) also discusses this problem and describes a limit order as a free trading option.[19]

Limited Visibility of Order Volume

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orders include a condition of "all or nothing". A trade will then take place only if all the stocks in that order can be executed simultaneously. Thus, despite the fact that small orders are often market orders, they are not always matched directly.

[19] Submitting a bid (ask) limit order can be regarded as writing an option to the rest of the market. The option is in the money if new bad (good) information arrives while the limit order is outstanding.

The SAX-system also gives the possibility to submit orders with partly hidden volume. In this case, only a part of the order volume will appear in the COLOB. Only when the open part of the order has been executed, will the hidden part of the order become open. In this way, dealers can submit large orders without releasing information about their entire order volume to the market. On the other hand, the dealer gets lower priority, since the hidden part of the order is treated as a new order when it is transformed to an open order. This feature alleviates the asymmetric information problem discussed above. Thus, the possibility to submit hidden orders can be seen as a sacrifice of full market transparency in order to induce the submission of large orders and thereby enhance market liquidity. Without this possibility, there is a risk that large trades would be executed off-the-exchange (see below), where the asymmetric information problem is different due to the possibility of bilateral bargaining and lower transparency. The transparent structure of the SAX system is especially desirable for small and uninformed traders. Large and informed traders often prefer other, less transparent, trading structures.[20]

3.1.6 Tick Size

One important aspect of a trading structure is the minimum price difference allowed between limit orders, normally referred to as the tick size. Harris (1991, 1992, 1994) finds that the tick size used at the NYSE and the AMEX has an economically significant impact on market liquidity. Table 4 reports the tick sizes for both the SSE, the NYSE, the Paris Bourse, and the Helsinki Stock Exchange.[21]

In the most relevant price range, tick sizes at the Paris Bourse are roughly a tenth of the ones at the SSE. Even the tick sizes at the less liquid Helsinki Stock Exchange are smaller than at the SSE. Tick sizes are of similar importance on the SSE and on the NYSE.[22] Clearly the tick sizes at the SSE imply minimum spreads of between 0.2 per cent and one per cent for normally priced shares and a spread as high as five per cent for shares priced just above SEK 10.00 (an unusually low price level). We will return to the importance of the tick size in section 5.5.

[20] See Pagano and Röell (1990 and 1993).

[21] The tick size at the SSE has been reduced in two steps during 1994, (on March 4, and September 30). Presently, the tick size is 0.01 between 0.01 and 5.00, 0.05 between 5.00 and 10.00, 0.10 between 10.00 and 50.00, 0.50 between 50.00 and 500.00 and 1.00 above 500.00.

[22] Most NYSE stocks trade at prices between USD 5 and USD 50 (see Harris 1991), implying a minimum relative spread of between 0.25 and 2.5 per cent. Most Swedish stocks trade at prices between SEK 20 and SEK 500, implying a minimum relative spread of between 0.2 and 2.5 per cent.

Table 4

Tick Size at Different Stock Exchanges

Stock Price*			SSE	NYSE	Paris Bourse	Helsinki SE
0.00	-	0.10	0.01	0.03125	0.01	0.01
0.10	-	0.25	0.05	0.03125	0.01	0.01
0.25	-	1.00	0.05	0.0625	0.01	0.01
1.00	-	5.00	0.05	0.125	0.01	0.01
5.00	-	10.00	0.10	0.125	0.05	0.01
10.00	-	100.00	0.50	0.125	0.05	0.10
100.00	-	500.00	1.00	0.125	0.10	1.00
500.00	-	1000.00	1.00	0.125	1.00	1.00
1000.00	-		1.00	0.125	1.00	10.00

(Data sources: Stockholm Stock Exchange (1991), NYSE Rule 62, Biais, Hillion, and Spatt (1994), and Helsinki Stock Exchange (1991)).

* Stock prices are given in respective currency. SEK 1 is approximately equal to USD 0.14, FRF 0.72, and FIM 0.65 respectively.

3.1.7 Priority Rules in the COLOB

The first basis of priority is naturally the price. At a given price level, displayed orders have priority over hidden orders. Within price and display precedence, orders are given priority according to time of entry. Furthermore, equally priced unmatched orders from the opening call auction are given random priority.

In general, the importance of secondary priority rules (such as display and time) is more considerable when the tick size is economically significant.[23] Otherwise, traders can cheaply obtain priority by slightly improving the limit price. Amihud and Mendelson also argue that since limit orders provide immediate liquidity as a positive externality, traders supplying limit orders should be compensated in order to enhance the market's immediate liquidity. Properly designed priority rules might be one way to achieve this compensation. Direct payment for order flow might be another solution. Since submitting a displayed order at an early stage implies a commitment, Harris (1990) argues that the greatest precedence should be given to "those traders who make the strongest commitment to providing liquidity"[24]. Secondary priority rules are likely to be important in the SAX-system due to the comparatively large tick size.

In the previous subsection, we reported the importance of the tick size at the SSE. Naturally, the large tick size implies comparatively large bid/ask spreads and consequently a negative effect on liquidity. Harris (1992, 1994) argues that a large tick size would make the provision of liquidity highly profitable. Strict adherence to the time priority rule in conjunction with a large tick size protects traders who expose their quotes and limit orders. Their willingness to submit limit orders is therefore enhanced

23 See Amihud and Mendelson (1991).

24 Harris (1990), page 17.

and immediate liquidity increased. The consequence of a high tick size is therefore likely to be large spreads but with considerable depth at each price level. Harris (1994) tests these hypotheses and finds that the depth indeed increases with tick size.[25]

3.2 Off-Exchange Trading

In principle, there are at least three different types of off-exchange trading. The first possibility is to trade after exchange hours. All after hours trades have to be reported to the exchange no less than thirty minutes before trading resumes the following day. Apart from this rule, few restrictions are imposed on this type of off-exchange trading. More specifically, prices during after hours may deviate substantially from those during the day.

Secondly, off-the-exchange trades can also take place during normal trading hours. The rules governing these trades are stock specific. Stocks are classified in two categories according to trading volume. For the most traded stocks, all trades below 100 trading units[26] have to be executed in the SAX-system and within the bid/ask spread. Trades between 100 and 500 trading units may be settled outside the SAX-system but only within the prevailing bid/ask spread. Only large deals, of more than 500 trading units, may be struck outside the SAX-system and outside the bid/ask spread. For other stocks, the same rules apply but the limits are 50 and 250 trading units respectively. It should be noted that if a transaction is executed outside the existing bid/ask spread, the parties to the transaction have no obligation to clear the limit orders in between. In contrast, in Paris a block trade outside the existing spread has to be included in the electronic system CAC and all limit orders better than the block price must be executed. They are then executed at their respective limit prices. At the NYSE, the limit orders in the specialist's order book also have to be executed but at the same price as the block trade (i.e. better than in Paris).

Information on in-house clearing[27] and trading outside the COLOB - during trading hours has to be disclosed within 5 minutes. The restrictions concerning in-house clearing and other types of trading outside the electronic system are much stricter on some other automated exchanges, e.g. Paris.[28] The potential deterioration of price informativeness and liquidity caused by fragmented markets is usually the motive for restrictions limiting trading outside the main electronic system. In practice, the possibility to trade the same stock in other markets makes this kind of restrictions inoperative.

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[25] Niemeyer and Sandås (1994) reach a similar conclusion for the most liquid stocks at the SSE.

[26] See footnote 17.

[27] Dealers may match two customers' orders within the inside spread without placing any orders in the COLOB.

[28] See Biais and Crouhy (1990).

The third type of off-exchange trading occurs on foreign stock markets. A large part of the trading of major Swedish stocks is channelled through SEAQ-International in London, which is a market maker based trading system. Although we lack data from London, it appears that mainly the larger trades take place in London, while smaller trades are captured in the SAX-system. In 1992, the total turnover of Swedish stocks in the SEAQ-system amounted to SEK 131 billion (41 per cent) compared to SEK 166 billion (52 per cent) for the domestic market. Trading in Swedish stocks at other international exchanges, principally NASDAQ, is limited, SEK 23 billion (7 per cent).

Compared to trading in the SAX-system, all three mechanisms for off-exchange trading have a common feature; lower transparency. One of the reasons for the success of these markets seems to be based on the asymmetric information problem mentioned above. Many large investors as well as informed ones prefer to trade on a less transparent market. As a result, we get a market segmentation.[29] Harris (1992) and Pagano and Röell (1990) discuss the importance of transparency as a determinant of market segmentation.
There is an inherent conflict between concentration and segmentation of trading. On one hand, liquidity is enhanced and the price formation process better if everyone trades in the same market place. On the other hand, different traders have different motives for trading and a specific trading structure is not necessarily optimal for all traders. It is also possible that certain trades would not take place at all if all trading was forced into the same form. It might not be feasible or even desirable to design a market structure which integrates all trading in one system. Segmentation is only a problem when it results in low price informativeness and/or low liquidity.

4 The Data Set

In the rest of this paper, we will present some stylized facts from SSE, compare these with international data and perform some tests to see if the presented stylized facts are significant.

The data used in this study come from two sources. First, the Stockholm Stock Exchange has provided transaction and order book data for the thirty stocks included in the OMX index. Second, Dextel Findata AB, the company actually calculating the OMX index, has provided minute by minute data of the index itself. The OMX index data file includes the minute by minute index values computed on transaction prices as well as on

[29] We use the term segmentation for the division of trading between different markets. Harris (1992) makes the distinction between a fragmented market and a segmented market by noting that in a segmented market at least some traders can trade in more than one segment.

the best bid and ask prices available for each stock. The studied period is from December 3, 1991, through March 2, 1992, totalling 59 trading days.

The set of stock transaction data contains the time, price and the number of stocks traded, in total 85 610 observations. The data set from the electronic limit order book consists of the five best bid and ask prices, the associated quantities, and the number of orders at each bid and ask level in the COLOB, in total 157 252 observations.

The OMX index is a value weighted stock market index based on the thirty most traded stocks at the SSE. It should be noted that the stocks included in the OMX index (and thus in our sample) sometimes consist of more than one class of stocks of the same company.[30] Since the composition of the index is revised every six months (January and July) our sample before and after January 1, 1992 is not exactly the same.[31] However, we do not think this is likely to influence our results significantly.

5 Empirical Results

5.1 Descriptive Statistics

In this section, we report some general descriptive statistics from our sample. Summary statistics on trading frequency, daily trading volume and average and median transaction size are given in Table 5. The stocks are divided into three groups according to non-trading probabilities. The ten most frequently traded stocks have average non-trading probabilities of 28 per cent and 6 per cent for ten minute and thirty minute intervals respectively.

Total trading volume in our sample amounted to SEK 30 648 million. Table 6 demonstrates that only a fairly limited proportion of all trades is actually matched within the SAX-system. A large proportion of trades is matched off-the-exchange (either during trading hours or after) and only reported to the exchange. Only 48 per cent of total trading volume in our sample (excluding four major take-overs, which would otherwise distort the statistics) was matched in the fully automatic system. In interpreting Table 6, it should also be noted that only roughly half of all trading in Swedish stocks takes place in Sweden (see section 3.2).

30 See footnote 4.
31 5 old stocks were excluded and 5 new stocks included as of January 1, 1992.

Table 5

Average Trading Frequency, Average Daily Trading Volume, Average Transaction Size and Median Transaction Size.

	Group 1	Group 2	Group 3
NT Prob. [1]	28%	54%	68%
NT Prob. [2]	6%	21%	37%
Average Daily Volume [SEK 1000]	22 014	7 326	3 731
Average Transaction Size [SEK 1000]	228	240	238
Median Transaction Size [SEK 1000]	56	55	40

The stocks are divided into three groups according to non-trading probabilities.
NT Prob [1] and NT Prob [2] denote the average non-trading probabilities, within the groups, computed on ten and thirty minute intervals respectively.
The sample period covers 1590 ten minute intervals and 531 thirty minute intervals.

Table 6

Amount Traded Through Different Systems in Our Sample.

	All Transactions				Excluding 4 Major Block Trades	
	Million SEK		# of Transactions		Million SEK	
SAX	11 438	37%	75 747	88%	11 438	48%
Manual	8 074	26%	8 431	10%	8 074	34%
After hours	11 137	36%	1 432	2%	4 276	18%
Total in Sweden	30 648		85 610		23 787	

SAX refers to fully automated transactions via the COLOB.
Manual refers to manually settled transactions during normal trading hours.
After hours refers to transactions settled off-the-exchange after normal trading hours. These transactions are reported to the SAX-system before 9.30 a.m. the following trading day.

The Paris Bourse has been more successful in retaining trading in French stocks. The turnover of French stocks on the SEAQ-International in London was only 7 per cent of the Paris Bourse turnover in 1988.[32] Even if electronic trading systems, such as SAX and CAC, are designed to handle all trading, they actually capture only a fraction of it. Different groups of traders prefer to trade the same assets in different locations and/or under different trading structure. The consequence is market segmentation.[33]

Due to higher negotiation and settlement costs, we would expect larger transactions at off-exchange hours. This is largely confirmed by Table 7, showing the distribution of trade size[34] within the SAX-system, manually during exchange hours and after trading

32 See Pagano and Röell (1990).
33 See Harris (1992).
34 It should be noted that the practical meaning of a transaction depends on the specific market structure. In the SAX system, one buy order which for example is matched with three sell orders will be recorded as three transactions. In a dealer based system (e.g. London) the same transaction would be recorded as four different transactions because the dealer will normally be the counter part in all transactions.

hours respectively. As expected, the SAX-system attracts the smallest transactions while most large transactions are made outside SAX and during exchange hours. The transactions after exchange hours are primarily larger than SEK 1 million. The average transaction size is SEK 151 000 within the SAX-system, SEK 958 000 off-the-exchange during normal trading hours, and SEK 7.8 million, (3.0 million excluding the four major take-overs) during after hours.

Table 7
Distribution of Stock Trades

Trade Size	Within SAX		Manually		After Hours	
	# of Trades	C-Freq	# of Trades	C-Freq	# of Trades	C-Freq
0 - 0.1	49 628	0.655	3 323	0.394	105	0.073
0.1 - 0.2	10 676	0.796	1 218	0.539	113	0.152
0.2 - 0.3	5 092	0.863	621	0.612	69	0.200
0.3 - 0.4	2 773	0.900	347	0.653	59	0.242
0.4 - 0.5	1 907	0.925	236	0.681	59	0.283
0.5 - 0.6	2 055	0.952	370	0.725	63	0.327
0.6 - 0.7	641	0.961	163	0.745	35	0.351
0.7 - 0.8	538	0.968	116	0.758	29	0.372
0.8 - 0.9	346	0.972	80	0.768	30	0.392
0.9 - 1.0	370	0.977	116	0.782	45	0.424
0 - 1	74 026	0.977	6 590	0.782	607	0.424
1 - 2	1 403	0.996	776	0.874	273	0.615
2 - 3	262	0.999	434	0.925	164	0.729
3 - 4	29	1.000	171	0.945	79	0.784
4 - 5	12	1.000	96	0.957	64	0.829
5 - 6	12	1.000	140	0.973	77	0.883
6 - 7	2	1.000	39	0.978	31	0.904
7 - 8	0	1.000	23	0.981	20	0.918
8 - 9	1	1.000	19	0.983	14	0.928
9 - 10	0	1.000	19	0.985	9	0.934
10 -	0	1.000	124	1.000	94	1.000
Total	75 747		8 431		1 432	

Trading is divided into trading during normal hours (within the SAX-system and manually) and after hours. C-Freq is the cumulative frequency.

5.2 Intraday Patterns in Trading Activity

In this section we document some intraday patterns in trading activity at the SSE. A significant intraday pattern in trading activity could imply that the information contents in prices differ in different periods of the trading day. Since information is incorporated

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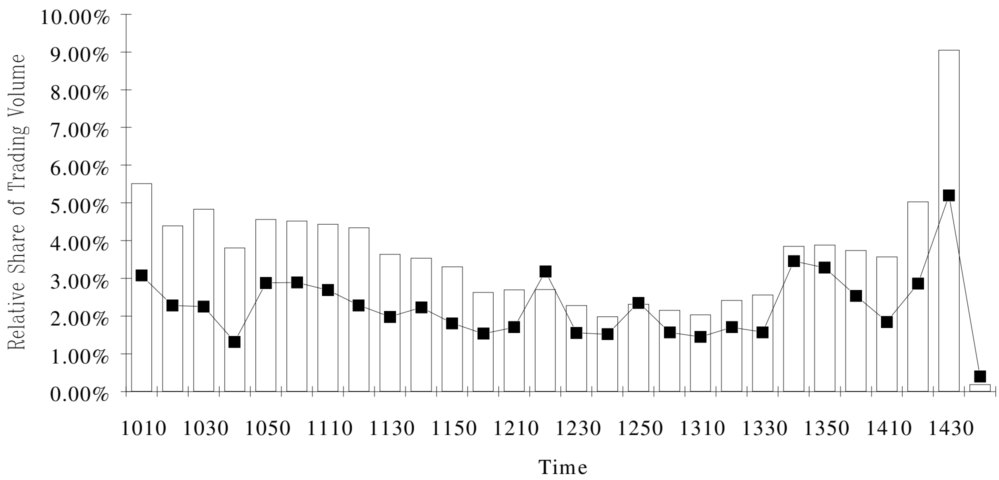
Naturally, these technical differences have an impact on market statistics such as number of transactions and average transaction size.

into prices, at least partly through trading, a period of high trading activity would produce more informative prices than a period of low trading activity.

Jain and Joh (1988) report a statistically significant U-shaped pattern in stock trading volume at the NYSE. The highest volume occurs at the opening. During the trading day, the volume then subsides and near the close it increases again, albeit not to the same level as at the opening. Foster and Viswanathan (1993) test and reject the hypothesis of equal volumes across different hours of the trading day (using data from the NYSE and the AMEX). In Figure 1, we report the average intraday pattern of the trading volume (bars), as per cent of the total daily trading volume, and standard deviation (dotted line) by each ten minute interval[35] excluding after hours trading for the SSE.

Figure 1
Average Intraday Proportion of Daily Trading Volume (in SEK)



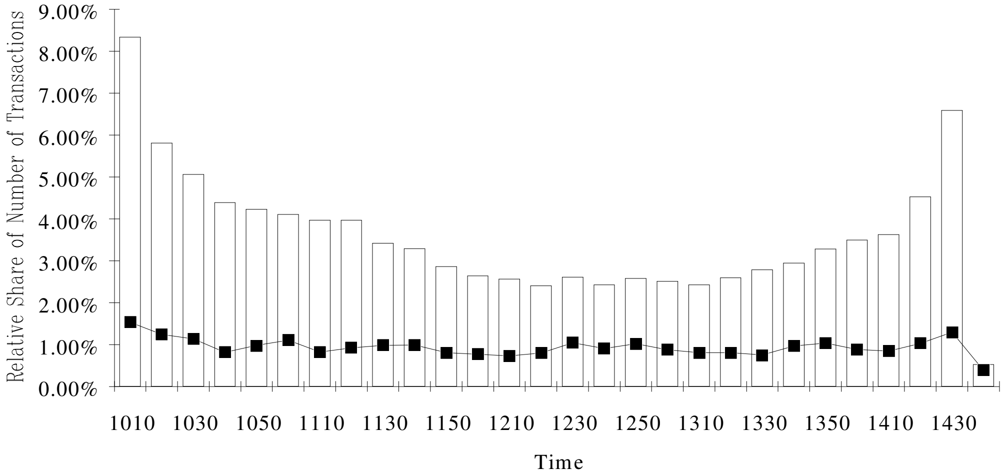
Average proportion is indicated by bars and the standard deviation across days by the dotted line. After hours trading is excluded.

Figure 2 gives the SSE intraday pattern of the number of transactions[36] (bars) as proportions of the total daily number of transactions and standard deviation (dotted line) by each ten minute interval. The pattern in the numbers of transactions is clearly U-shaped. The intraday pattern of volume exhibits a somewhat U-shaped pattern but not as clearly as for number of transactions. If we aggregate trading volume during thirty minute intervals (not shown) the U-shaped pattern will be more pronounced.

[35] Due to technicalities in the reporting system, there might arise a lag of a few seconds between the trading and the reporting system during intensive trading. This explains why we observe some trades after 2.30 p.m. (14.30), the official closing hour of the exchange.

[36] See footnote 35.

Figure 2
Average Intraday Proportion of Number of Transactions



Average proportion is indicated by bars and the standard deviation across days by the dotted line. After hours trading is excluded.

In order to test if the U-shapes suggested by Figure 1 and 2 are significant, we need the observations to be statistically independent. This is not the case in Figure 1 and 2 since the proportions always add up to unity every day. Therefore, we compute related statistics which are independent. For each stock, we take the number of stocks traded per thirty minute interval at different days, divided by the number of outstanding stocks. Taking the unweighted average across stocks for every time interval and day yields a series of 59 observations of the trading activity across days for each interval. Similarly, we take the number of transactions per stock, divide with the number of outstanding stocks, take the unweighted average across stocks to get a series of 59 observations across days for each interval. Table 8 lists the two means for each time interval. The null hypotheses of equal means are rejected at a one per cent significance level in both cases (F-value = 12.60 for the number of stocks and F-value = 66.72 for the number of transactions; critical $F(8,522) = 2.51$). Table 8 also lists the successive t-values when testing two adjacent means against each other.[37]

[37] Strictly statistically speaking, we cannot draw any overall conclusion from the t-tests. We cannot control for the aggregated significance level since we do not perform a joint test but several individual tests. Still, in this case the t-tests may add something to the inference.

Table 8

Significance of U-Shape in Trading Activity (Thirty Minute Intervals).

Time	10.00-10.30		10.30-11.00		11.00-11.30		11.30-12.00		12.00-12.30		12.30-13.00		13.00-13.30		13.30-14.00		14.00-14.30
Average Number of Traded Stocks (x 100) as % of Outstanding	1.956		1.894		1.969		1.664		1.355		1.093		1.252		1.943		2.677
t-value of Diff.		-0.32		0.40		-1.78		-1.89		-1.80		1.25		3.16**		2.84**	
Average Number of Transactions (x 100,000) as % of Outstanding	2.465		1.742		1.591		1.311		1.196		1.117		1.239		1.352		1.883
t-value of Diff.		-7.46**		-1.93		-3.87**		-1.71		-1.42		2.15*		1.76		7.23**	

We report average intraday proportions and t-statistics for the difference between intraday successive averages.
Significance is reported at the 1 per cent level with ** and at the 5 per cent level with *.

On the whole, our tests support the hypothesis of a U-shape in trading activity and are thus in conformity with the findings of both Jain and Joh (1988) and Foster and Viswanathan (1993). One difference from the American studies is that the increased volume during the last ten minutes is more pronounced at the SSE. The relative share of the last interval during the day (i.e. trading between 14.20 and 14.30) is considerably higher than in any other interval. Increased trading activity prior to the close of the market may reflect investors closing open positions, they do not desire to hold overnight. However, it is still an unresolved question why this effect would be more pronounced at the SSE than in the U.S. Furthermore, an analysis of the average transaction size (not shown) indicates on average smaller transactions during the first ten minutes of the trading day and larger transactions during the last ten minutes.

There are only a few theoretical models trying to explain the concentration of trading volume. In the Admati and Pfleiderer (1988) model, concentrated trading patterns arise endogenously as a result of strategic behavior of liquidity traders and informed traders. However, their model does not explain when, during the trading day, the concentration of trading will occur. The Brock and Kleidon (1992) model extends the Admati and Pfleiderer model and tries to relate the trading patterns to the opening hours of the exchange. Their model argues that optimal portfolios are different when the exchange is open and closed. Trading to rebalance portfolios would induce U-shaped volume over the trading day, consistent with our data.

5.3 Intraday Patterns in the Placement of New Limit Orders

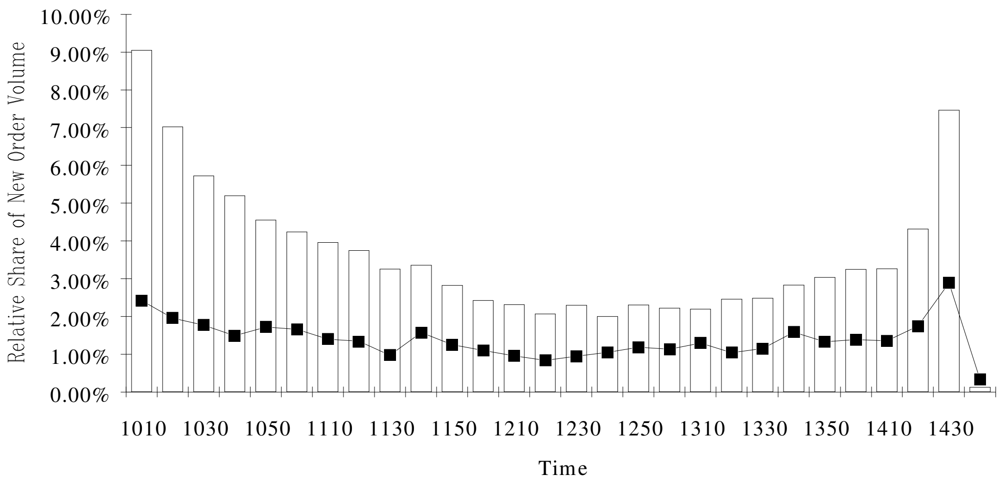
Another way to measure trading activity in an order book driven system such as at the SSE is to focus on the submission of new limit orders. Regardless of whether a new limit order immediately results in a transaction or not, it will bring new information to the market. The information content of the bid and ask prices is therefore, ceteris paribus, likely to be larger when the submission rate of new limit orders is high. Until recently there are few studies focusing on the submission rate of new limit orders.

The intraday pattern in the average proportions of the placement of new limit orders (bars) and the standard deviation over days (dotted line) (excluding orders executed in the auction) are shown in Figure 3 and Figure 4. The pattern is U-shaped both in terms of volume (Figure 3) and in terms of number of orders (Figure 4).

The high level of new limit orders at the very end of the trading day is a bit surprising. Our findings are likely to at least partly be a result of the reporting system. If the price of an outstanding limit order is changed, it will be recorded as a new limit order. As a consequence, investors, with an outstanding unmatched limit order who are forced to trade a specific day, will have to worsen their price in order to trade. Since the tendency is to wait with the necessary change as long as possible, the system produces a large reported influx of new orders during the last minutes. However, it is still somewhat of a puzzle that so many investors choose to submit a new *limit* order when forced to trade. Investors wanting to close open positions would presumably use market orders rather than limit orders during the last minutes. Is there possibly another explanation? The puzzle is left for future research.

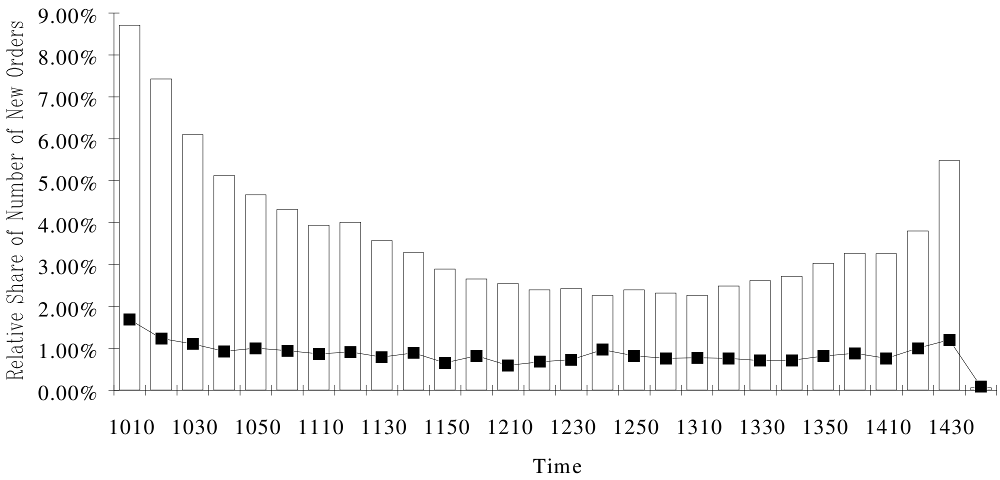
Figure 3

Average Intraday Proportion of Daily Volume of New Limit Orders



Average proportion is indicated by bars and the standard deviation across days by the dotted line.

Figure 4
Average Intraday Proportion of Daily Number of New Limit Orders



Average proportion is indicated by bars and the standard deviation across days by the dotted line.

In Table 9 we test, on half hour basis in a way parallel to the one in Table 8, whether the apparent U-shapes in Figure 3 and 4 are significant. For each stock, we take the sum of the number of stocks of all limit orders submitted during a specific interval and day, and divide by the total number of outstanding stocks. Repeating for every thirty minute interval and day, and then taking the unweighted average across stocks for every time interval and day yields a series of 59 observations of the submission rate across days for each interval. Similarly, we take the number of new limit order per stock, divide with the number of outstanding stocks, take the unweighted average across stocks to get a series of 59 observations across days for each interval. Table 9 lists the two means for each time interval.

The null hypotheses of equal means in Table 9 are rejected at a one per cent significance level in both cases (F-value = 47.91 for the number of stocks and F-value = 66.10 for the number of new limit orders; critical F(8,522) = 2.51). Table 9 also lists the successive t-values when testing two adjacent means against each other.[38] The statistics all strongly indicate clear U-shapes.

[38] See footnote 37.

Table 9

Significance of U-Shape in Submission of New Limit Orders (Thirty Minute Intervals).

Time	10.00-10.30	10.30-11.00	11.00-11.30	11.30-12.00	12.00-12.30	12.30-13.00	13.00-13.30	13.30-14.00	14.00-14.30
Average Order Volume; Number of Stocks (x 100) as % of Outstanding Stocks	4.958	3.465	2.921	2.442	2.102	1.910	2.265	2.562	4.391
t-value of Diff.		-5.70**	-2.86**	-2.80**	-2.28*	-1.43	1.79	1.29	7.15**
Average Number of Orders (x 100,000) as % of Outstanding Stocks	4.098	3.138	2.722	2.244	2.039	1.842	2.035	3.460	4.147
t-value of Diff.		-5.65**	-2.94**	-3.74**	-1.76	-1.95	2.05*	2.77**	8.13**

We report average intraday proportions and t-statistics for the difference between intraday successive averages. Significance is reported at the 1 per cent level with ** and at the 5 per cent level with *.

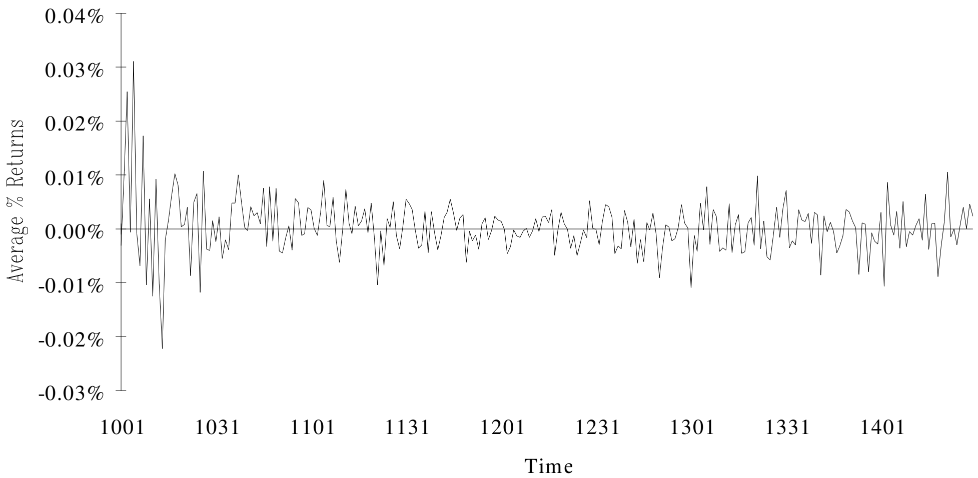
5.4 Intraday Patterns of Returns and Volatility

In this section we document some intraday patterns in returns and return volatility at the SSE. The economic significance of an intraday pattern in returns is obvious. Patterns in returns and/or volatilities would indicate profit opportunities, at least for traders with small transaction costs (i.e., dealers). Furthermore, intraday patterns in volatilities would have obvious consequences for option pricing and could also affect the profitability of submitting limit orders (a short term volatility could imply a certain compensation for submitting limit orders (see section 3.1.2)).

The results of several earlier studies (Wood, McInish, and Ord (1985), Harris (1986), Jain and Joh (1988) and Foster and Viswanathan (1993)) suggest that mean returns and volatilities exhibit distinct intraday patterns, with overall high returns at the beginning and end of the trading day. Our data enable us to compare these results with the ones for the SSE.

Figure 5 shows the average minute by minute return on the OMX-index, based on transaction prices. Figures based on ask or bid prices (not shown) are very similar.

Figure 5
The Average Minute by Minute Returns on the OMX Index.



Returns are calculated as $ln(I_t) - ln(I_{t-1})$, where I_t denotes the index value at time t. Overnight returns are excluded.

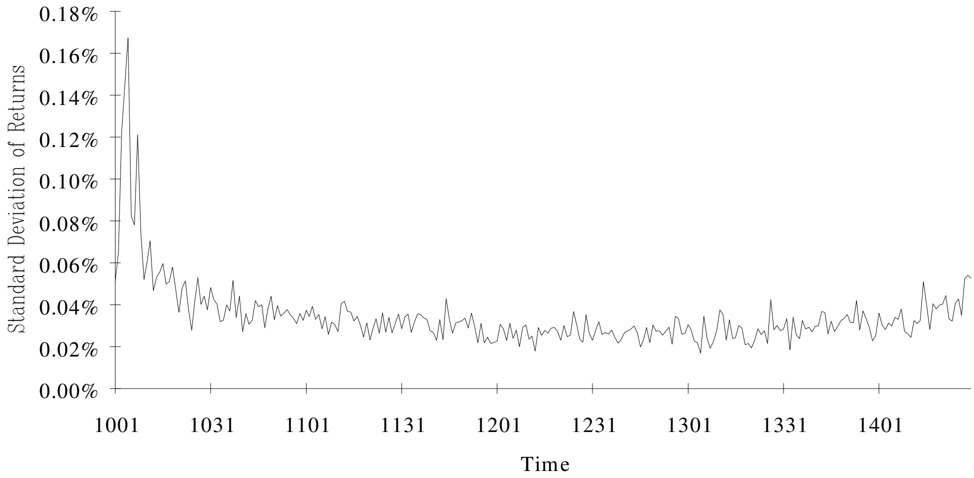
In contrast to the results of the American studies, there is no clear pattern. Wood, McInish and Ord report weak evidence of positive returns during the first trading minutes. Harris, using data from 287 trading days and a portfolio of 1616 equally weighted NYSE stocks, reports significant positive returns both during the first 45 minutes (except Mondays) and during the last 15 minutes of the trading day. Jain and Joh, using 1263 trading days of data, find a higher return on the S&P500 index during the first trading hour (except Mondays) than during the rest of the day.

Wood, McInish and Ord (1985) as well as Foster and Viswanathan (1993) report a U-shape in volatility for the NYSE stocks during the trading day. The volatility is typically high at the opening, falls during the first hour, only to rise slowly during the last hour of trading.

For the SSE-data, Figure 6 clearly demonstrates the higher volatility in the first 15 minutes of trading than during the rest of the day. Compared to the U.S. studies, the fall in volatility seems to be quicker at the SSE. Furthermore, is there no evidence of an increased volatility at the end of the day as in the U.S. studies.

The higher volatility at the beginning of the trading day could be due to be the greater uncertainty following the non-trading period. However, a specific trading feature might also be important. The opening call auction at the SSE is a sequential procedure and this affects the behavior of the returns during the first few minutes. During that period, the index is calculated with some stock prices from the current trading day and some prices from the end of the previous trading day. The "true" volatility of the opening prices is thus spread out over several minutes after the opening.

Figure 6
The Standard Deviation of the Minute by Minute Returns on the OMX Index.



Returns are calculated as $ln(I_t) - ln(I_{t-1})$, where I_t denotes the index value at time t. Overnight returns are excluded.

A higher price variability in periods of concentrated trading is consistent with the Admati and Pfleiderer (1988) model. Our data with high volume and high volatility at the beginning of the trading day is therefore consistent with their model. However, it can also be noted that the volatility does not increase significantly during the last ten minutes of trading despite a sharp increase in trading volume.

5.5 The Importance of the Tick Size

The price discreteness imposed by the tick size forms a lower bound for the difference between levels in the COLOB. No difference between two adjacent levels in the order book can be less than one tick, since traders can submit orders only at prespecified prices separated by one tick. The cross-sectional statistics of the average bid/ask spread measured in number of ticks across stocks in our sample are reported below:

	average	min	25%	median	75%	max
Inside Spread[39] [# of ticks]	2.58	1.11	1.73	2.27	3.48	5.40

The average inside spread is considerable larger than one tick, suggesting that the tick size is not an important factor in determining the inside spread. However, Table 10 demonstrates that for some stocks at least, the tick size is important. For one of the most

39 In principle, the differences between different levels in the limit order book (e.g. between the fourth and third best ask prices) can all be termed spreads. When we want to discuss the specific spread between the best ask and best bid price, we will use the term inside spread.

liquid stocks LM Ericsson BF, the tick size is binding in 90 per cent of the observations in the COLOB. For ten stocks, the tick size is binding in at least half of the observations of the inside spread.

Table 10
The Importance of the Tick Size

Stock	One Tick Spreads as %	Average Midquote	Average Daily Volume
Ericsson, Tel.-ab. LM, ser. B fr	90	110	51.3
Skandi. Enskilda Banken, ser. A	83	48	10.7
Trelleborg AB, ser. B	76	108	12.4
Sydkraft AB, st ser. C	70	141	4.3
Skanska AB, ser. B	64	124	5.3
SKF, AB, ser. B fr	63	99	9.8
Electrolux, AB, ser. B fr	61	242	22.2
Sv. Cellulosa AB SCA, ser. B	60	105	4.1
Investor, AB, ser. B fr	56	123	4.5
Sv. Cellulosa AB SCA, ser. B fr	51	104	3.4
Astra, AB, ser. A	49	522	50.6
Procordia AB, ser. B	49	198	5.2
Proventus AB, ser. B	49	53	1.6
ASEA AB, ser. B fr	48	306	12.4
Argonaut AB, ser. B	47	45	1

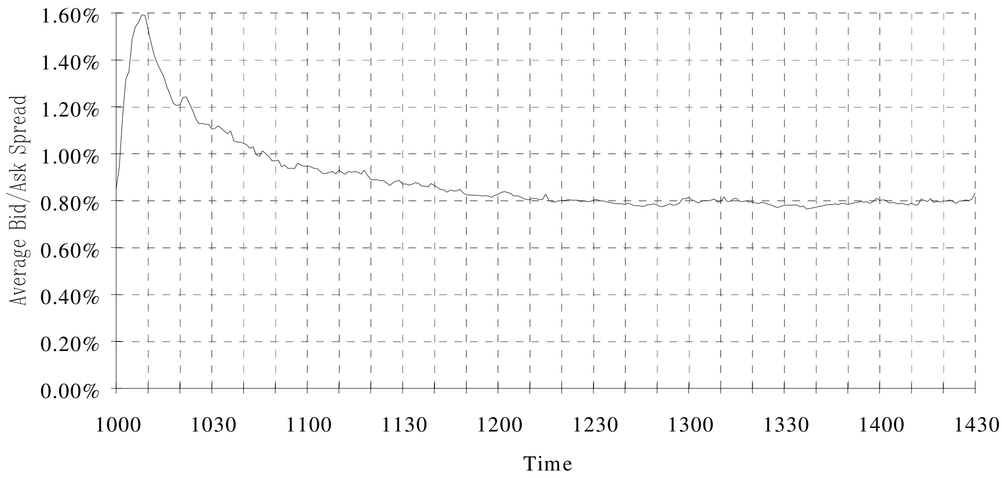
The Proportion of Observations in the COLOB for which the Inside Spread Equals One Tick, Average Midpoint Quote and Average Daily Trading Volume
[In Million SEK] (Excel. After Hours Trading), for Selected Stocks.

Using U.S. data, Harris (1994) finds that a significant reduction in bid/ask spreads would be obtained if smaller tick sizes were introduced at the NYSE. The positive effect on liquidity of reduced bid/ask spreads would on the other hand be countered by a reduction in displayed quotation sizes or market depth. The net effect on overall liquidity is therefore ambiguous. Since the tick size in the SAX-system is comparatively large, it may have an economically significant impact on both market width and market depth. Using data from the SSE, Niemeyer and Sandås (1994) indeed report a significant impact on market width. They find evidence that a lower tick size would imply a lower depth at the SSE, at least for the most liquid stocks.

5.6 Intraday Behavior of the Bid/Ask Spread

Handa (1992) reports largely U-shaped intraday pattern for bid/ask spreads at the NYSE and the AMEX. Market makers post a large spread in the morning and in the afternoon, but lower spreads during midday. Handa finds a significant increase shortly before the close to be followed by a sharp drop at the close.

Figure 7
The Intraday Behavior of the Market Inside Spread



Fictitious bid/ask prices on the OMX-index were calculated by weighting together the best bid and ask prices of the individual stocks with the same weights as the OMX-index. The fictitious index bid/ask prices were then used to calculate the spread as 200*(ask-bid)/(ask+bid). The reported spread is calculated by taking minute-to-minute point estimates and averaging over days.

Our aim is to see whether this overall pattern is present at the SSE. Figure 7 shows the intraday average bid-ask spread, as per cent of the quote midpoint, for the OMX index. Since the OMX index includes the thirty most traded stocks, the spread reported can be seen as the value weighted average spread for the stocks in our sample. The average spread reaches a peak of 1.6% shortly after the opening and falls, remarkably slowly, during the two first hours of trading to a level of 0.8 per cent.

On a thirty minute interval basis, the successive fall until noon of the average inside spread is statistically significant[40] at the one per cent level, as is shown in Table 11. However, the spread does not change significantly prior to the close as in Handa (1992).

Table 11
Average Intraday Percentage Spread for the OMX Index

Time	10.00-10.30	10.30-11.00	11.00-11.30	11.30-12.00	12.00-12.30	12.30-13.00	13.00-13.30	13.30-14.00	14.00-14.30
Avg. Spread	1.27%	1.01%	0.91%	0.84%	0.81%	0.79%	0.79%	0.78%	0.80%
t-value of Diff.		-4.35**	-2.73**	-2.11*	-1.21	-0.83	0.26	-0.37	0.35

We compute the average spread for the OMX-index during different thirty minute periods during the day, using 58 days of data. We also report t-statistics for the difference between intraday successive means. Significance is reported at the 1 per cent level with ** and at the 5 per cent level with *.

40 See footnote 37.

The daily fall in the spread can probably be explained by the market information flow by which the market gets tighter as the dealers learn about the overall market movements from the first trades. The large tick sizes at the SSE, discussed above, are also likely to affect the spreads. The prediction of the Brock and Kleidon (1992) model is that the spread would be U-shaped. However, we do not observe higher spreads at the close.

The level of the bid/ask spread seems to be rather large compared to other stock markets. Pagano and Röell (1990) find an average inside spread for the most traded stocks of 0.80-0.85 per cent of quote midpoint in London and 0.52-0.67 per cent in Paris respectively. Handa (1992) reports average spreads between 0.50 and 0.60 per cent of quote midpoint for the ten per cent largest stocks at the NYSE and AMEX.

5.7 Cross-Sectional Characteristics of the Limit Order Book

With data from an entire order book, it is possible to calculate the immediate price impact of a specific transaction size. This forms an approximation of the slope of the limit order book.[41] Glosten (1994) denotes this marginal price function of the limit order book by $R'(q)$. Most other theoretical models use a stylized specialist model (market-by-quote-system) rather than a limit order model (market-by-order-system). In the latter models, the comparable measure is normally referred to as λ (e.g. Kyle (1985)). Most models assume a constant λ, i.e. a linear slope. One model, Easley and O'Hara (1987), allows for a non-constant λ. Empirically, the slope of the LOB can be decomposed into two different components: the volume at each level in the LOB and the difference between adjacent prices in the LOB. However, existing theories do not provide any predictions about the different components of the slope.

Using data from the Paris Bourse, Biais, Hillion, and Spatt (1994) find that the LOB is non-linear with the steepest slope close to the spread. The inside spread is more than twice as large as the differences between other levels in the LOB. The volumes offered or demanded at the best levels are smaller than the volumes further away from the best levels.

With our SSE data, average relative differences between the levels in the COLOB were computed for each stock in order to measure the slope of the LOB. We report the cross sectional variation in these differences in the upper part of Table 12. For instance, the column B3-B4 refers to the relative difference between the third best bid price (bid price 3) and the fourth best bid price (bid price 4). This difference is then calculated as

[41] We use the term slope of the limit order book to refer to the plot of price changes as a result of trades of different sizes. In other words, the slope of the limit order book is a measure of the price elasticities of demand and supply.

200*(bid price 3 - bid price 4)/(bid price 3 + bid price 4). The A1-B1 column gives the inside spread. The median value of 1.12% indicates that on average, only half of Sweden's thirty "blue chip" stocks have individual spreads below 1.12 per cent. In our opinion this is high.

Table 12
Relative Differences Between Successive Levels in the Limit Order Book.

	B4-B5	B3-B4	B2-B3	B1-B2	A1-B1	A2-A1	A3-A2	A4-A3	A5-A4
Max.	13.79	13.56	15.92	4.99	4.36	5.95	7.92	11.12	18.37
75%	3.26	2.93	2.24	1.41	1.51	1.58	2.13	2.45	2.59
Median	2.53	2.20	1.78	1.17	1.12	1.10	1.41	1.83	1.98
25%	1.56	1.54	1.16	0.85	0.91	0.84	1.05	1.20	1.25
Min.	0.73	0.86	0.56	0.36	0.38	0.31	0.38	0.46	0.54
Avg.	2.74	2.47	2.11	1.31	1.36	1.51	2.07	2.52	2.91
Diff	B45-B34	B34-B23	B23-B12	B12-A1B1	A1B1-A21	A21-A32	A32-A43	A43-A54	
t-value	0.53	0.65	1.81	-0.26	-0.59	-1.51	-0.91	-0.55	
Diff		B45-B23	B34-B12	B23-A1B1		A1B1-A32	A21-A43	A32-A54	
t-value		1.13	3.05**	1.71		-2.17*	-2.24*	-1.26	

Summary statistics across the stocks (35) in the sample. Differences are calculated as follows:
B4-B5 = 200*(bid price 4 - bid price 5) / (bid price 4 + bid price 5).
Differences between the mean of the first differences are tested with t-tests
where B34-B23 refers to the difference between B3-B4 and B2-B3.
Significant t-values are denoted by ** and * for the 1% and 5% level respectively.

It is also clear from Table 12 that the spreads between the levels of the COLOB generally are wider further away from the inside spread. This is likely to be a natural consequence of the focus of interest on the inside spread and nearby spreads. A null hypothesis of equal means of the nine differences is rejected at the one per cent level, (F-value = 2.92; critical value F(8,306) = 2.51). It is also noteworthy that the successive spreads generally are larger on the bid than on the ask side. The reasons for these differences are not fully transparent. One possible explanation is that the same SEK spread automatically will produce a higher spread for lower prices (bids) than for higher prices (asks). With a significant tick size, this *could* possibly be important. Contrary to our findings Biais, Hillion and Spatt (1994) report larger spreads on the ask than on the bid side.

In the lower part of Table 12, we also test whether there is a statistically significant change in the differences between the levels of the LOB as we move from the fifth best bid to the fifth best ask level. We take the adjacent average spreads (e.g. between B4-B5 and B3-B4; labelled B45-B34) and test if these are significantly different. We also test if the next-to-adjacent average spreads (e.g. between B4-B5 and B2-B3; labelled B45-B23) are significantly different. In Table 12 we report the simple t-statistics.[42] This test

[42] See footnote 37.

procedure approximates a test of the second derivative of the slope of the LOB. The t-values give weak support for a steeper slope further out from the inside spread, i.e. for non linearity. Our results are different from the ones in Biais, Hillion, and Spatt (1994). Both their study and ours indicate non linearity, but of different sort. In contrast to our results they find that the inside spread is more than twice the average relative spreads further out in the LOB.

Table 13
Average Volume [Thousand SEK] at Different Levels in the COLOB

	BV5	BV4	BV3	BV2	BV1	AV1	AV2	AV3	AV4	AV5
Max.	820	1 097	1 787	2 673	2 102	2 404	2 968	1 895	1 303	924
75%	267	454	541	822	897	660	788	589	370	265
Median	147	233	356	550	566	495	495	315	187	129
25%	68	126	228	330	374	365	320	212	138	71
Min.	0	4	25	135	165	177	131	98	24	4
Avg.	212	325	478	685	679	589	597	422	289	208

Diff.	B5-B4	B4-B3	B3-B2	B2-B1	B1-A1	A1-A2	A2-A3	A3-A4	A4-A5
t-value	-1.90	-1.90	-1.93	0.05	0.95	-0.08	1.74	1.78	1.38

Diff.	B5-B3	B4-B2	B3-B1	A1-A3	A2-A4	A3-A5
t-value	-3.60**	-3.67**	-2.15*	1.89	3.26**	3.10**

BV4 refers to the volume at the fourth best bid price. Sample size: 35 stocks.
Differences between means are tested with t-tests,
where B4-B3 refers to the difference between BV4 and BV3.
Significant t-values are denoted by ** and * for the 1% and 5% level respectively.

In the upper part of Table 13, the cross-sectional variation in the average volume offered or demanded at each level in the COLOB is reported. In this table the column BV4 refers to the total volume offered on the fourth best bid price level. We also test whether the ten averages of Table 13 are significantly different. The null hypothesis of equal means is rejected at the one per cent level of significance, (F-value = 9.01; critical F(9,340) = 2.41). In the lower part of Table 13, we use t-tests to test the mean values of volume offered at different levels of the LOB. T-values for differences between adjacent levels as well as differences between the fifth and the third best bid levels, etc. are reported.

In contrast to the results of Biais, Hillion and Spatt (1994), we find a higher average volume close to the inside spread and lower volumes further out on the bid and the ask side. Our tests[43] indicate that the volumes offered or demanded in the LOB exhibit an inverted U-shape. Thus, our study shows that the liquidity is primarily supplied close to the midquote while it in their study is supplied further out in the COLOB. The interpretation of Biais et al is that the adverse selection problem is more pronounced the

[43] See footnote 37.

closer to the inside spread we get. The difference between the results could be explained by the coarser price grid at the SSE.[44] A large tick size might indirectly make it more profitable to supply liquidity and this could produce our results (see also section 3.1.6 and 3.1.7). Our data does not allow us to discern how volumes would be distributed under a finer price grid regime.[45] Therefore, our results are not necessarily incompatible with the ones of Biais et al. One possible hypothesis is that the asymmetric information effect dominates when the tick size is small, whereas the profits from liquidity supply more than compensate for the risk of being "picked off" when the tick size is large.

From Table 13, it can further be noted that the bid side normally has a somewhat larger depth than the ask side. The overall level of liquidity seems to be considerable. All stocks in our sample have an average depth both at the best bid and ask levels exceeding an average sized transaction, (SEK 151 000 see section 5.1), and 75% of the stocks have an average depth of more than twice that amount. As a consequence, the bid- and ask prices change remarkably seldom.

The overall conclusion of this section is that the slope of the COLOB is non-linear and that the demand and supply are price inelastic. The non linearity can be divided into two parts. Both the average differences between different price levels of the LOB and the average volume at each level contribute to the non linearity. The non-linear relation between price changes in the COLOB and the volumes offered is illustrated in Figure 8, which plots the relation between average price changes and average accumulated volume offered or demanded for the COLOB for a typical stock (Volvo B) in our sample.

The plotted function in Figure 8 is equivalent to the $R'(q)$ function in Glosten (1994). His prediction of the slope of the function is in accordance with our empirical findings. In interpreting the non linearity of Figure 8, it should be noted that as the price of a stock changes, there is a subsequent shift in price focus. The COLOB will probably not include all possible limit orders. When a stock's bid;ask rises from for instance 150;151 to 151;152, the interest will quickly focus on the new inside spread. The likely consequence is an influx of new orders *both* at bid 151 and at ask 152, producing more volume at both levels and possibly a more linear slope of the limit order book. The interpretation regarding the elasticities and slope of the order book should therefore be

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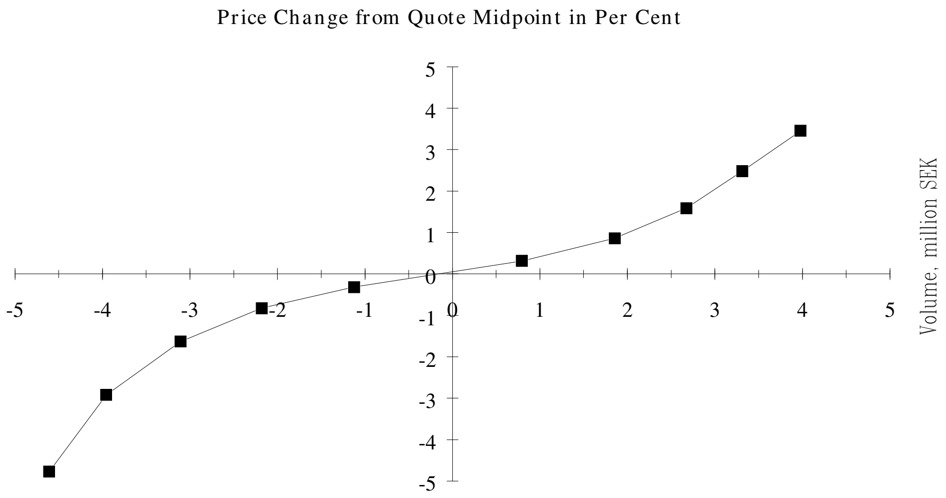
[44] Due to the coarser price grid (i.e. larger tick size), the five best bid and ask price levels in the LOB at the SSE normally covers a wider relative price range around the quote midpoint than the corresponding levels at the Paris Bourse.

[45] A replication of this study might be warranted using data from the period after September 1994 and the reduction of the tick size at the SSE.

made with caution. A more extensive analysis of the inter-temporal aspects of liquidity is beyond the scope of this paper.[46]

Figure 8
The Average LOB of a Typical Stock



The stock in the example is Volvo B. Volumes on the x-axis are in million SEK. Negative volumes represent sell transactions. Price changes on the y-axis are the price change calculated from the midpoint of bid/ask prices.

6 Conclusions

In this paper we analytically describe the market trading structure at the Stockholm Stock Exchange. We point to the conflict between different aspects of the immediate liquidity in terms of immediacy, depth, width and resiliency. We also discuss the asymmetric information problem as it affects the trading structure at the SSE in terms of free trading options, etc. Furthermore, we note the impact of an important tick size and how it is possible to modify the negative effects of the significant tick size by priority rules and other measures. All these issues are important not only for the SSE as means of competition in a deregulated competitive international surrounding, but also for all traders considering the possibility to trade at the SSE.

In our empirical part, we report a number of results related to the market microstructure of the SSE. Our key empirical findings are:

- The intraday pattern in trading activity corresponds on the whole to the American findings (Jain and Joh (1988) and Foster and Viswanathan (1993)) with the exception that the trading volume shortly before trading halts is extraordinary large at the SSE.

[46] For a study of the intertemporal aspects on similar stock exchanges see Biais, Hillion and Spatt (1994) and Hedvall and Niemeyer (1994).

- The intraday pattern in the placement of limit orders follows the pattern of the overall trading activity. A surprisingly high frequency of limit orders placed during the last minutes of the trading day is probably due to the reporting system.
- We find no evidence of intraday pattern in returns, like in the USA.
- There is a higher standard deviation of returns shortly after the opening, but no increase shortly before the close as in U.S. studies (Wood, McInish and Ord (1985) and Jain and Joh (1988)).
- The average inside spread is comparatively large at the SSE. The inside spread of the market index typically falls significantly under the first two hours of trading, but does not increase again shortly before the close such as in the U.S.
- The tick sizes seem to be an important determinant of the spread at least for some stocks.
- The slope of the limit order book is non-linear, both with respect to volumes in the LOB and differences in price. The demand and supply are both price inelastic contrary to the findings in Biais, Hillion and Spatt (1994).

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Abbreviations

AMEX	American Stock Exchange
CAC	Cotation Assistée en Continu
CATS	Computer Assisted Trading System
CME	Chicago Mercantile Exchange
COLOB	Consolidated Open Limit Order Book
ISE	International Stock Exchange
NASDAQ	National Association of Security Dealers' Automated Quote System
NYSE	New York Stock Exchange
LOB	Limit Order Book
SAX	Stockholm Automated Exchange
SEAQ	Stock Exchange Automated Quote system
SSE	Stockholm Stock Exchange