An Explorative Investigation of Intraday Trading on the German Stock Market

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Abstract

The paper contains an intraday study of the German stock market. Using descriptive statistics for interval and transaction returns, volatilities, and transaction frequencies we try to identify the impact of market structure, information flow, and the overnight trading halt on the behavior of prices and volumes. A very interesting feature of the German stock market in this context is that there are two parallel trading systems (floor trading and computer trading) for the group of the most liquid stocks.

The results of the analysis for the floor market are consistent with the findings of previous studies for other markets in that we also find a U-shaped pattern for transaction frequency and volatility. Intraday return volatility does not seem to be related to the mechanism of price determination (batch trading or continuous trading). However, there seems to be an effect of the noon auction on the direction of price changes. For the computerized market we do not observe such clear patterns. Furthermore, the findings indicate that volatility around the floor opening is mostly induced by information that has accumulated overnight. Although there is computerized trading for two hours before the floor market opens market participants do not seem to consider prices from the computerized system as informative as prices from the floor. Finally, auction prices from the floor seem to contain valuable information for IBIS traders.

1 Introduction

Empirical investigations of stock markets have shown that there are typical patterns in returns, volatility and trading activity over the trading day. It was found that the volatility of intradaily returns is highest during the first trading hour, declines during the trading day, and rises again at the end of the day.[1] Examinations of stock volume also documented a U-shaped pattern during the trading day (for example Chen, Ellis, and Wood [8] and Jain and Joh [17]). For returns, Jain and Joh [17] showed that the average returns across hours are significantly different and that there exists a day of the week effect with significantly negative returns on Monday morning. This latter effect was also documented by Harris [14]. Furthermore, Harris [15] finds an end-of-the-day effect on the NYSE with a large positive mean price change for the last transaction of the day.

Different explanations for these intraday patterns are offered in the literature. One is that the special behaviour of prices and volume at the beginning and at the end of the trading day is due to the discontinuity in trading possibilities. For example, Brock and Kleidon [6] argue that the accumulation of overnight information in the absence of an oppurtunity to trade means that investors have to reestablish their optimal portfolios at the open. Also

[1] See, for example, McInish and Wood [22], Lockwood and Linn [20] and Chen, Ellis, and Wood [8].

at the end of a day investors have a higher propensity to trade since they may want to adjust their portfolios given that no trading takes place during the overnight period. Thus the desire to trade will in general be stronger and relatively more inelastic at the open and at the close compared to other times during the trading day. We call this the *trading halt hypothesis*.

An alternative explanation for intraday-patterns can be given with models based on information economics. In the context of Kyle [19] the accumulated information of the overnight trading halt would be gradually incorporated into prices over time due to the strategic behavior of informed traders. As trading proceeds one should therefore expect a steady decline in transitory volatility. We call this the *information flow hypothesis*. In the model of Admati and Pfleiderer [1] patterns of high volume and volatility arise endogenuously due to the existence of asymmetric information and the strategic behaviour of informed and uninformed investors. However, this model cannot explain the timing of these patterns.

Another possible reason for systematic intraday patterns is the influence of market mircostructure on security prices. For example, on the NYSE opening prices are determined in a a batch auction, whereas all transactions during the rest of the day are executed sequentially. Stoll and Whaley [27] explain the higher volatility of open-to-open returns with the monopolistic position of the specialist during the opening auction. We call this the *market microstructure hypothesis*.

The main problem of an empirical investigation of intraday patterns is to separate the influences of market structure, overnight trading halt and asymmetric information. For example, although Stoll and Whaley [27] find open-to-open returns to be more volatile than close-to-close returns this does not necessarily imply that batch trading is generally inferior to continuous trading. The opening call auction on the NYSE follows a long period without trading, so that there is also a much greater price uncertainty at the opening than over the rest of the day which may cause higher volatility.

Subsequent papers try to seperate the influence of non-trading periods and trading mechanisms. They investigate stock exchanges with different sequences of batch auctions and continuous trading. For example, on the German stock market there are batch auctions at the open, at noon and at the close with continuous trading for the rest of the day. In a recent study Theissen [28] finds that open-to-open returns are consistently more volatile than both noon-to-noon and close-to-close returns. He concludes from these results the trading mechanism cannot be responsible for the differences in volatility. Similar results were obtained for other stock exchanges.[2] Gerety and Mulherin [13] investigate the volatility of daily returns computed with prices recorded at different hours during the trading day. Since the variances of these steadily declines after the opening rather than to drop sharply right after the open, the authors conclude that trading facilitates the incorporation of information into prices, and that the call auction at the open is not destabilizing.

[2] See Amihud, Mendelson, and Murgia [4] for the Milan stock exchange, and Amihud and Mendelson [3] for the Tokio Stock Exchange.

The aim of this paper is twofold. First, we want to give a thorough description of intraday trading on the German stock market. Here we will focus on the Frankfurt Stock Exchange (FSE) which is by far the most important floor market in Germany, and on the computer trading system IBIS.[3] Although the German market is one of the largest markets in Europe it is nevertheless not very well known. Furthermore, no detailed study on intraday trading in Germany has existed in the literature up to now. We will investigate if there are any systematic patterns in returns, volatilities and trading volumes over the day which are similar to those documented for other markets.

Second, using the results of this analysis we will try to separate the three different possible sources for intraday patterns mentioned above, namely market structure, trading times, and information flow. The German market has some intersting features which are useful for an investigation of these hypotheses. One is that there are two parallel markets for the most liquid stocks, since the trading time on IBIS spans the trading session on the FSE plus two hours before the opening and three hours after the close. The other important characteristic is the fact that there are three batch auctions over the trading on the FSE, at the open, at noon (for odd lots and unfilled round lots), and at the close.

For example, to separate the impact of information flow from the impact of market microstructure one can look at the intraday pattern of volatility. A sharp decline in volatility after the open (or around any other batch auction) would support the microstructure hypothesis, whereas a steady decline after the open with a constant volatility over the rest of the day would indicate that it takes some time after the start of trading before prices fully reflect new information. If we observe similar patterns in returns and volatilities around all three auctions on the FSE this would yield support to the microstructure hypothesis, whereas significant differences between the auctions at the open and the other two auctions would point towards the information flow or trading halt hypotheses. Furthermore, the fact that trading on IBIS starts two hours before the open of the FSE offers another opportunity to check if the price behavior on the FSE is consistent with the information flow hypothesis. If IBIS prices contain useful information for market participants we expect return volatility at the open of the FSE to be smaller than at the open of IBIS. If on the other hand volatility on the FSE is higher around the opening than later during the day this may again indicate an influence of the opening batch auction.

The results of our descpriptive analysis show that the well known U-shaped pattern for trading activity and volatility documented for the NYSE is also found on the FSE whereas around the noon auction there is no increase in volatility. The steady decline of (transaction) return volatility after the opening supports the hypothesis of informationally induced volatility rather than the hypothesis of an impact of market structure on price variability. This result supports the hypothesis that it is not the mechanism of price determination which is responsible for the higher volatility at the open and at the close. This result is consistent with the findings documented by Theissen [28]. For mean returns there is no

[3] Integriertes Börsenhandels- und Informationssystem = Integrated Trading and Informations System.

clear pattern, and there is also no day-end effect like the one found by Harris [15] for NYSE stocks. Although it seems that auctions do not have an influence on return volatility there may nevertheless be some effect on return behavior, since we observe significantly higher reversals around the noon auction than for the rest of the day.

For IBIS we do not find such a clear U-shaped pattern as for the FSE, neither for the number of transactions nor for volatility. Another interesting result in this context is that transaction return volatility is nearly equal at the beginning of trading on IBIS and the FSE. There is a notable decrease in volume and volatility about half an hour before the start of trading on the FSE and a sharp increase after the opening of floor trading. If IBIS and the FSE are considered as integrated markets these results are inconsistent with the trading halt hypothesis which predicts higher volume around the open or the close of the market.

In general, it seems that market participants on IBIS consider the auction prices at the opening of the FSE as more informative than IBIS prices. This may be due to asymmetric information between IBIS traders and the Kursmakler, since the latter has information about both the open order book on IBIS plus the order book on the FSE to which IBIS participants do not have access.

Also there is some indication that floor auctions in general have some influence on IBIS trading. After all the three auctions on the FSE we observe a significantly higher volatility in the IBIS transaction immediately following the auction. When there is a large difference between the auction price and the IBIS price recorded immediately before the auction we find a tendency for runs on IBIS in the same direction, i.e. given a large positive price change the likelihood for sequences of transaction returns with positive sign increases (and vice versa). These findings support the notion that during auction periods, (and here especially at the opening) the FSE plays a dominant role in the price discovery process.

The remainder of the paper is organized as follows. Section 2 describes the structure of the German stock market, especially the two major markets FSE and IBIS. Section 3 contains a description of the data and the methodology used in this study. Section 4 presents the results of the empirical investigations and section 5 provides a summary and an outlook.

2 The Structure of the German Stock Market

2.1 Floor Trading

Floor trading on the German stock market takes place on seven regional stock exchanges plus the Frankfurt Stock Exchange (FSE) which is by far the most important exchange in terms of trading volume and number of firms listed.[4] About 75% of the total DM volume of all German stocks was traded on the FSE in 1994 (see DBAG [10]). There is no

[4] The following description draws heavily on DBAG [10].

consolidated order flow for the eight floor exchanges, since there is no system paralleling the National Market System in the U.S.

The FSE is open five days a week from 10:30 a.m. to 1:30 p.m. Its market structure is different from the other major stock exchanges in the world in that there are three different market segments. The stocks with the highest liquidity and the highest market capitalization are traded in the official market ('Amtlicher Handel'). The stocks in this segment are in turn divided into two groups. For the first group there is a continuous market ('Variabler Handel'), while the stocks in the second group are traded at the single price ('Einheitskurs').

The second market segment is the regulated market ('Geregelter Markt'). For the stocks in this segment there is only one price per day as for those in the second group of the official market. Requirements for the admission to the regulated market are less strict than for the official market, and one of the major purposes of the regulated market was to make it easier for companies to go public. There are only very few admission requirements to free market, and for stocks in this market segment there is also only one price per day.

Special characteristics of the trading process on the FSE in the official continuous market are batch auctions at the opening, at noon and at the close with a continuous market for the rest of the trading day.

Furthermore, there are no exchange designated market makers or specialists on the FSE. Instead there is a person called the 'Kursmakler' (appointed by the exchange) who is responsible for setting prices which properly reflect current market conditions.[5] The Kursmakler is furthermore the only person who can see the order book on the FSE. In general the functions of the Kursmakler are more like those of an auctioneer, since he or she usually does not trade on his own account.

The batch auction at the opening is similar to the opening procedure at the NYSE. Still, there is a significant difference between the two exchanges. At the NYSE the specialist can easily step in to absorb order imbalances at the prospective opening price (Stoll and Whaley [27]). Since the specialist knows the size of the order imbalance it is argued that he can earn a monopolist rent at the opening by providing the supply or demand that is needed to clear the market.

The Kursmakler on the FSE does not usually absorb excess demand or supply so that he acts more like a classical auctioneer. If supply does not equal demand during the opening auction the Kursmakler announces the highest bid and the lowest ask price. Only in the case when this outcry does not generate further orders by market participants the Kursmakler can (like the NYSE specialist) trade on his own account to absorb the excess supply or demand.

Three types of orders participate in the noon auction. These are odd lot orders (less than

[5] Besides the Kursmakler there are also the so-called Freimakler who are not involved in the process of setting official prices.

50 shares), the residues of orders exceeding multiples of 50 shares[6], and all round lot orders that have not been executed until the beginning of the noon auction at 12:00 p.m. For the stocks in the second segment of the official market the price set during the noon auction is the only price of the day. The auction at the close works like the auction at the opening.

All the orders that could not be executed at the opening price remain in the order book. With new orders coming in during the period of continuous trading the Kursmakler has to check whether further orders can be matched, resulting in a new transaction (and a new price). However, there are no observable bid-ask spreads on the FSE.

Taken together the market structure of the FSE is similar but not exactly equal to a pure order-book system. It also contains elements of a specalist market like the NYSE.

Trading data for the stocks in the continuous market segment are recorded on the KISS tapes (Kurs-Informations-Service-System = Price Information and Service System). The tapes contain the time (exact to the second) and the price of a transaction. However, volumes for the individual trades are not available.

2.2 Computerized Trading

Besides the eight floor markets there is the computer trading system IBIS.[7] 37 stocks, a number of government bonds and some warrants are traded on IBIS. In 1994 the IBIS trading volume for the 30 stocks in the Deutscher Aktienindex (DAX)[8] accounted for about 34% of the total DM trading volume for these stocks on all German exchanges.

Trading time on IBIS is five days a week from 8:30 a.m. to 5 p.m. All banks as well as all Kursmaklers and Free Maklers can participate in IBIS which is an open order book system. On their trading screens market participants can continuously observe both sides of the book with prices as well as quantities. The minimum size of a transaction on IBIS is either 100 or 500 shares which is why IBIS is considered a trading system designed mainly for institutional investors. Furthermore, traders will remain anonymous on IBIS whereas on the floor of the FSE the Kursmakler can see which trader is buying or selling. Some participants act as 'voluntary market makers' for the securities on IBIS, i.e. they stand ready to buy and sell securities at their quoted prices.[9]

With the options and futures exchange Deutsche Terminbörse (DTB) opening at 9:30 a.m. and closing at 4 p.m. the trading day for stocks (on the FSE and IBIS) and their derivatives in Germany can be divided into the following segments:

[6] If a market participant submits an order for 130 shares 100 of these shares will be traded in the continuous market and the remaining 30 shares will be traded at the noon auction.

[7] For a detailed description of IBIS see DBAG [9].

[8] The stocks in the DAX are weighted according to the nominal value of their equity. A special characteristic of the DAX is that it is a performance index, i.e. the index is computed as if dividends were reinvested into the index portfolio.

[9] There is no obligation, however, to post a quote upon a trader's request.

- before 8:30 a.m.: no trading
- 8:30 a.m. to 9:30 a.m.: trading on IBIS only
- 9:30 a.m. to 10:30 a.m.: trading on IBIS and DTB
- 10:30 a.m. to 1:30 p.m.: trading on IBIS, DTB and FSE
- 1:30 p.m. to 4 p.m.: trading on IBIS and DTB
- 4 p.m. to 5 p.m.: trading on IBIS only
- after 5 p.m.: no trading.

The main focus of this paper is the period from 10:30 a.m. to 1:30 p.m., i.e. the trading session on the floor in Frankfurt. It will also be of interest to investigate if IBIS trading before the opening of the FSE has an impact on the opening period on the FSE.

3 Data and Methodology

Two data sources are used in the course of this study. The first is the KISS tape which contains time stamped transaction prices for the 30 stocks in the DAX[10], but no volumes.[11] The second source is the IBIS tape which also contains time stamped transaction prices, but in addition it also shows the volumes of the individual trades.

The basic sample period for KISS data ranges from January 1990 to December 1994, the IBIS data cover the period from July 1991 to December 1994. To investigate intraday patterns on the German stock market the daily trading time was divided into fifteen minute intervals. This interval length was chosen on the basis of a preliminary analysis of the trading activity on the FSE. The mean time between two consecutive transaction for the 30 DAX stocks on the FSE was 4.68 minutes in 1994 with a median of about 3 minutes. Thus, to avoid a very large percentage of empty intervals fifteen minutes seemed an appropriate choice for the interval length.

With fifteen minute intervals the first IBIS interval is the period from 8:30 a.m. to 8:45 a.m., for KISS the first interval starts at 10:30 a.m. and ends at 10:45 a.m. Since the last price of the day on the FSE is set in the course of a batch auction starting at 1:30 p.m. some time may go by until this price is actually recorded. The last interval (interval 12) starts at 1:15 p.m. and has an open end, i.e. it also contains all the observations recorded after 1:30 p.m. The same procedure is applied to IBIS data with interval 34 containing all observations after 4:45 p.m.

[10] See table A.1 in the appendix for a list of the DAX stocks.

[11] Prices on the German floor markets carry a flag indicating whether there was excess suplly or demand at the given price. In 1994 supply did not exactly equal demand in only 0.12 percent of all the observations in our sample.

The 30 stocks in the DAX are grouped into five classes (equally weighted portfolios) according to their total DM trading volume on the FSE and IBIS in the respective previous year, i.e. the classification for 1994 was done on the basis of 1993 volume data. Table A.2 in the appendix shows some descriptive statistics for the five groups as well as the stocks included in the respective groups in 1994. It is obvious that group 1 contains by far the most liquid stocks. The average annual DM trading volume for these stocks is 105 billion DM which is more than three times the average volume for stocks in group 2. Furthermore, the mean time between two consecutive trades on the FSE is considerably shorter for the stocks in groups 1 and 2 than for the other firms. This effect is even more pronounced for IBIS where the mean time between two trades is around 17 and 18 minutes for the least liquid stocks, respectively.[12] These descriptive statistics are a preliminary indication that the 30 DAX stocks cannot be seen as a homogeneous group but that there are some important differences between them.

For the following empirical analyses the return for stock i in interval j is computed as the difference of the logarithmic stock prices at the end of intervals $j-1$ and j. With S_{ij} denoting the price of stock i in interval j the return r_{ij} is computed as

$$r_{ij} = \ln S_{ij} - \ln S_{i,j-1}. \tag{1}$$

If there are several prices observations for stock i in interval 1 the return for this interval is computed using the first and the last of these two prices. This is the only case when a return possibly contains two prices from the same interval. A problem exists when there is no price observation for a stock in a certain interval. In this paper returns are computed only for those intervals for which a stock price is recorded, they are set to missing when no price obvservation is available for a given interval.

For each interval j the return for the group of stocks g is defined as the equally weighted average of the returns of the component stocks. With $r^g_{1,j}, \ldots, r^g_{6,j}$ denoting the returns for the six stocks (possibly containing missing values) in group g in interval j and n^g_j as the number of non-missing return observations the return for this group r^g_j is given as

$$r^g_j = \frac{1}{n^g_j} \sum_{l=1}^{n^g_j} r^g_{l,j} \quad g = 1, \ldots, 5. \tag{2}$$

For the following analysis mean returns and volatilities of the five groups of stocks in the various intervals of the trading day are the main variables of interest. The mean return for a given group in a given interval is computed as the time series average of the interval returns for this group in 1994. All the returns and absolute returns in the following tables and graphs were multiplied by 100.

[12] This result could be a hint that IBIS is the 'true' underlying market for the derivatives traded on the DTB. Relative to the 'important' stocks the stocks which are not underlyings for stock options on the DTB (and which also do not have much weight in the DAX) are traded much less frequently on IBIS than on the FSE.

Volatility is computed as the time series average of non-missing absolute returns. For a given group the average of absolute returns is used. This eliminates diversification effects, but the aggreagation is only used to simplify the presentation of the empirical results and not to analyse any portfolio effects.

Trading activity is measured by the number of transactions in a given interval. For IBIS the share volume is also available. However, recent empirical research, especially the paper by Jones, Kaul and Lipson [18], demonstrated a closer relationship between the number of transactions and volatility than between share volume and volatility. Given this evidence the lack of an observable trading volume for KISS does not seem to be a severe limitation.

The trading activity for a given stock is measured as the annual average of the number of trades per day in a given interval. The variable of interest in section 4 is the group average of this trading activity measure. This variable will be denoted by NT. Thus, $NT^g_{l,j}$ is the annual average of the number of transactions per day for stock l of group g in interval j. The value for group g is then computed as the average over the component stocks, i.e.

$$NT^g_j = \frac{1}{6}\sum_{l=1}^{6} NT^g_{l,j} \quad g = 1, \ldots, 5. \tag{3}$$

Besides interval returns transaction returns are also investigated in this paper. A transaction return is simply the change in the logarithmic stock price. The transaction returns for a given group of stocks is computed as the average transaction returns of the individual stocks. For the opening period transaction return 1 involves the opening price and the first following price from the continuous market. Return 2 is computed using the first and the second price, and so on. For the noon auction the two prices in return 0 are the last price before the noon auction and the auction price. All the other transaction returns are numbered in an analogous way.

Non-parametric tests are used in this paper to avoid potential problems caused by distributional assumptions for the underlying variables. Some of the hypotheses tested in this paper build upon explicit rankings of certain variables over different times of the day. For example, the null hypothesis of no information effect on volatility implies that mean absolute returns are constant from immediately after the opening until, e.g., the noon auction. To test this null hypothesis of equal volatility in all intervals against the alternative that volatility decreases monotonically over the day (information flow hypothesis) the nonparametric test developed by Page [23] will be used. The main advantage of the Page test over the classical F-test is that the former allows for an explicitly formulated monotonicity alternative.[13]

With X_{kl} as the observed rank of the underlying variable for group l in interval k and Y_k

[13] The F-test furthermore assumes normality of the underlying variable. Since absolute returns are by definition always non-negative this assumption is automatically violated. The Levene test which is the k-sample analogue of the nonparametric Kruskal-Wallis test does not rely on distributional assumptions but is also not able to test against a specific monotonicity alternative.

as the hypothetical rank for this interval the test statistic L is computed as

$$L = \sum_{k=1}^{n} (Y_k \sum_{l=1}^{m} X_{kl}). \tag{4}$$

In this paper m equals five, since the stocks are group into five categories. Depending on the hypotheses tested n, the number of intervals, may vary. If we wanted to test, for example, that volatility decreases monotonically from the open to the interval immediately preceding the noon auction we would choose n equal to 6, since the noon auction usually takes place in interval 7. In this case the alternative hypothesis of a monotonically decreasing pattern in volatility would lead to the hypothetical ranking $Y_k = 7 - k$ which means that the earlier intervals show higher volatility. Critical values for the test statistic L are tabulated in Page [23] for a certain range of values for m and n. Page has also suggested an approximation based on the standard normal distribution which will be used in this paper.[14]

4 Empirical Results

In this section the empirical results of the analysis are presented in two parts, one for the FSE and one for IBIS. The emphasis of the analysis will be on the year 1994, but the stability of the results was checked comparing them to the period from 1990 to 1993 (FSE) and 1992 to 1993 (IBIS). If significant differences between 1994 and other years exist they will be described in more detail.

4.1 Floor Trading on the Frankfurt Stock Exchange

4.1.1 Analysis of Interval Returns

Transaction frequency Figure 1 shows the average number of transactions per stock for the five groups on the FSE and the 12 intervals in 1994.[15] In general there is a tendency for trading activity of the most liquid stocks in groups 1 and 2 to decrease over the day (except around the auction at the close). For the other stocks we find a slight peak of transaction frequency around the noon auction in interval 7. The general tendency, however, is the same as for groups 1 and 2. Overall, the decrease is more pronounced from open to noon than during the afternoon. For groups 3, 4, and 5 the average number of transactions is almost constant during the afternoon whereas a slight decline is observable for groups 1 and 2.

[14] See Page [23], p. 227.

[15] The number of transactions is used as a proxy measure for trading volume. This necessitates the assumption that the volume per trade is constant. For the three auctions this may be questionable, since Schmidt, Oesterhelweg and Treske [25] find that they account for 9, 7, and 13% of the daily trading volume, repsectively.

Mean returns Figure 2 shows the mean interval returns for the five groups and the twelve intervals.

For each individual interval and each individual group a Wilcoxon sign test was performed to test the null hypothesis of a zero mean return. At the 5% level six out of sixty test statistics were significant. Significant mean returns were found only around the three daily auctions.[16] Groups 1 and 4 exhibit significantly negative average returns in interval 1, and the same is observed in interval 2 for group 5.[17] In interval 7 mean returns are significantly positive for group 3, and towards the end of the day we again find significantly negative returns for group 5 in intervals 11 and 12. However, there is no evidence for a systematic effect over a longer period of time. In the years before 1994 significant means were also found only in auction intervals, but with varying signs.

Furthermore, the results indicate that (in contrast to the findings documented by Harris [15] and Wood, McInish and Ord [29] for U.S. markets) returns around the close of the FSE are not on average positive.[18] Thus there is no evidence for an end-of-the-day anomaly on the FSE, since returns in interval 12 are positive for two and negative for three groups. The fact that the mean return for group 5 is so low in this interval is mostly due to the large negative average return for MET. Taking this firm out of the sample reduces the differences between group 5 and the other classes without changing the general result.

Usually it is also investigated if returns show a systematic behavior with respect to the day of the week. Harris [14] and Jain and Joh [17] document a Monday effect on the U.S. market with significantly negative returns for the first hour of trading. Additional analyses have shown, however, that such an effect does not exist for the German market. Average intradaily returns do not vary systematically with the day of the week.

Volatility Figure 3 shows the mean absolute interval returns for the five groups in 1994.

There is a clear pattern in the graphs for the five groups. Volatility is high at the open (intervals 1 and 2), afterwards it decreases over the morning until interval 6 (groups 1 and 2) and interval 7 (groups 3, 4, and 5), respectively. In the afternoon mean absolute returns remain almost constant for the indivdual groups over the intervals 8 to 11. At the close (interval 12) volatility moves up again, with a very sharp movement for group 5 (which is partly, but not completely due to MET). In general the stocks in group 5 seem to exhibit a significantly higher intraday volatility than the stocks in the other groups. Again, however,

[16] Even an increase in the significance level of the tests did not change this result.

[17] The fact that a significantly negative return for group 5 is found in interval 2 is mainly due to the lower liquidity for these stocks. The second transaction of the day mostly occurs in interval 2, so that the opening return is attributed to this period.

[18] This may be a consequence of the different procedures for determining the closing price on the NYSE and the FSE. Whereas Harris [15] finds that the NYSE (which is a market with specialists) closing price is more often an ask price than a bid price there is no such distinction on the FSE, since the closing price is determined through a batch auction. The flags of the closing prices indicate an imbalance between suply and demand occured in only 2.44 percent of the cases.

a large portion of the difference between group 5 and the other stocks is due to the return behavior of MET. Taking this firm out of the sample yields much smaller differences in volatility, but the qualitative results still remain the same.

Of course, the shape of the graph alone does not allow the conclusion of a decreasing pattern in volatility. To test the hypothesis of decreasing mean absolute returns the Page test was applied to the mean absolute returns for the five groups in intervals 1 through 6. The resulting test statistic was far beyond the critical value for the 1% level so that the null hypothesis of constant mean absolute returns has to be rejected. Furthermore, a Wilcoxon sign test was used to test the hypothesis of equal mean absolute returns in intervals 11 and 12 for the five individual groups. The test statistic was significant at the 1% level for all five groups.

The relationship between volatility and transaction frequency is investigated in two ways. Cross-sectionally volatility is inversely related to liquidity, since mean absolute returns are in most intervals higher for stocks with lower liquidity. The ranking of the five groups with respect to their mean absolute returns in the twelve intervals is almost perfectly inverted compared to the ranking with respect to transaction frequency.

For each individual group there is a positive relationship between volatility and the number of transactions over time. The rank correlation coefficients between the two variables are always positive and highly significant. It is interesting to note that the size of the coefficient is monotonically decreasing from group 1 (0.4436) to group 5 (0.3196).

It is interesting to compare these results to findings for other markets like the NYSE provided by Harris [14], Jain and Joh [17], and Wood and McInish [29]. These authors also find a U-shape for volatility over the trading day with a higher return variability around the open and the close. This pattern is also evident from the graph in figure 3.

4.1.2 Analysis of Transaction Returns

The analysis of interval returns presented above indicates that returns show a different behavior around auctions. Interval returns alone, however, do not allow the conclusion that it is indeed the auction price which is causing the large (absolute) returns. This question has to be investigated on the basis of transaction returns. These returns are independent of the given interval length, but using transaction returns it is impossible to distinguish between stocks of different liquidity since there is no time dimension.

Open Mean transaction returns do not exhibit a systematic structure so that they are not investigated in more detail. Table 1 shows the mean absolute transaction returns for the first five price changes of the day. Return 1 marks the log of the first price change after the open including the opening price and the first price from the continuous market.

Absolute transaction returns mirror the behavior of interval returns as shown in figure 3

very closely. It is evident from the table that the return from the opening price to the first price of the continuous market is the largest in absolute value for all five groups. Absolute transaction returns then decrease monotonically over time. This result also shows that the increase in mean absolute *interval returns* for groups 4 and 5 in figure 3 is a consequence of the lower liquidity of the stocks in this group. The first price from the continuous market is often not recorded before the beginning of interval 2 so that the first transaction return is attributed to this period. As in the case of interval returns the Page test was used to test the null hypothesis of equal mean absolute returns against the alternative of a monotonically decreasing pattern. The resulting test statistic was highly significant at the 1% level.

Taken together this evidence suggests that there is uncertainty in the market at the open, but in the course of trading information is incorporated into prices so that volatility is reduced. The gradual decline in volatility thus supports the hypothesis of informationally induced volatility at the open in contrast to the notion of a microstructural impact.

Noon In contrast to the open the volatility of transaction returns around the noon auction is more or less constant within the groups.[19]

An interesting fact about the transaction returns at noon is depicted in figure 4. The means for return 0 are positive for all five groups whereas the average for return 1 are on average negative.[20] A reversal in consecutive returns is expected on a non-dealer market (as shown theoretically by Ho, Schwartz, and Whitcomb [16] and empirically by Stoll and Haller [26]), but reversals seem to be much more pronounced around the noon auction. To investigate this hypothesis the following regression was run for each individual stock i:

$$r_{i,j} = \alpha_i + \beta_i r_{i,j-1} + \gamma_i D_{j-1} r_{i,j-1} + \epsilon_{i,t}. \tag{5}$$

The dummy variable D_{j-1} was set equal to 1, if transaction return $j-1$ was computed using the price recorded immediately before the noon auction price and the noon auction price itself. Otherwise D_{j-1} was set equal to zero. The first and the last transaction return were excluded for each day in the sample period and each stock to avoid a possible bias in the estimation due to effects around the open or the close. The expected sign of both β_i and γ_i is negative, and the estimate for γ_i measures the additional (negative) autocorrelation of transaction returns around the noon auctions.

The results for the estimation of (5) are presented in table 2. The entries show the averages $\bar{\beta}$ and $\bar{\gamma}$ for the five groups as well as the number of significant t-statistics for the two coefficients. Overall the results are as expected. The autocorrelation coefficient is generally

[19] The Friedman test rejected the null hypothesis of equal mean absolute transaction returns around the noon auction for groups 1 and 2. A detailed investigation of the ranks of the absolute transaction returns showed that the return involving the noon auction price was not the reason for these rejections.

[20] Significantly positive means are found for groups 1, 3, and 5 for return 0, significantly negative means are observable for groups 1 and 3 for return 1.

negative for transaction returns and return reversals are larger around the noon auction than for the rest of the day. A possible interpretation is that there are order imbalances at the noon auction and that the Kursmakler takes the other side of the market to provide additional liquidity. If he charges an implicit fee for this service this could result in larger return reversals. The results in table 2 provide some support for this hypothesis, since the additional autocorrelation is smallest for group 1 containing the most liquid stocks. On the other hand the larger reversals around the noon auction could also indicate that the quality of the noon auction price in terms of its informational content is worse than that of the prices from the continuous market. The auction would then differ to some degree from the true value which is represented by the prices from the continuous market.

Close Table 3 shows the mean absolute returns for the five last transactions of the day. As in the case of the opening transactions the means of these returns do not exhibit systematic patterns so that they are not presented. Looking at the numbers in the table it becomes clear that it is mainly the last price return which causes the volatility shift at the end of the day observed in figure 3. In contrast to the results for the first price changes of the day there is no clear pattern in transaction return volatility. Thus, although there is no systematic tendency in mean transaction returns there is still some kind of a 'day-end' anomaly for the German market, since the volatility of the last return of the day is significantly higher.[21]

The result of an increasing volatility at the close does again not imply a microstructural impact on volatility. Market participants may have special motives inducing trades at the close which could drive up volatility. Further support against the microstructure explanation is provided by the observed increase in volatility around the close on the NYSE which does not have a closing auction (see McInish and Wood [22]).

4.2 Computerized Trading on IBIS

As mentioned in the introduction one special feature of the German stock market is that there are two trading systems for the DAX stocks. Besides the floor there is the electronic screen trading system IBIS with a trading time from 8:30 a.m. to 5 p.m. If the higher volatility in the morning which is documented above is actually caused by new information that has come to the market overnight it should be reflected in the IBIS prices around the start of trading in this market. As information is incorporated into prices the level of volatility should subsequently decrease. When trading starts on the FSE at 10:30 a.m. the volatility around the opening should be (at least roughly) similar to the IBIS volatility. If on the other hand the special price determination mechanism of the opening auction on the FSE is repsonsible for the high volatility at the beginning of the day we expect

[21] The Wilcoxon sign test for equality of mean absolute returns for the last trade compared to the immediately preceding trade yields a significant statistic for all five groups.

a divergence between the two markets, i.e volatility should be temporarily higher on the FSE than on IBIS.

The results of the following analyses are not presented separately for interval and transaction returns, since the use of transaction returns mostly supports the results obtained when interval returns were used.

Transaction frequency Figure 5 shows the average number of transactions per stock over the fifteen minute intervals for all stocks taken together. The grand means of the two markets are presented to facilitate comparisons between the FSE and IBIS. In general the shapes of the graphs for the five groups on IBIS are very similar so that they are not presented individually.

It is evident that during the trading time of the FSE (intervals 8 to 20) the number of transactions is most of the time higher on IBIS than on the FSE, except for the auction at the close. The main reason for this result is that the trading activity for the most liquid stocks is higher on IBIS than on the FSE. For the other groups we obtain the opposite result. This is also reflected in table A.2 in the appendix which shows that for group 1 the mean time between two consecutive transactions is shorter on IBIS than on the FSE whereas it is the other way round for the other stocks. IBIS is thus a system on which mainly large stocks are traded. For the less liquid stocks in the DAX trading on IBIS is not as relevant.[22]

As indicated by the graph in figure 5 there is a clear pattern for the number of transactions on IBIS. The first upward jump occurs in interval 5, i.e. from 9:30 a.m. to 9:45 a.m. when trading in stock options and stock index derivatives starts on the options and futures exchange DTB. After a rather active period of 30 minutes the number of transactions decreases rapidly until the FSE opens at 10:30 a.m. (interval 9). The patterns of trading activity on IBIS and the FSE are then very similar, the two curves are almost parallel. After the close of the FSE the average number of transactions decreases sharply on IBIS reaching the daily minimum in interval 22. This period of low trading activity on IBIS also corresponds to a time with considerably fewer than average trades on the DTB (see Lüdecke [21]). Afterwards trading activity again increases until the close of the DTB at 4:00 p.m. (interval 30). Then the number of transactions declines steadily before a slight increase occurs at the close of the market. Overall it is obvious that the two markets are pretty well integrated since the behavior of trading activity is very similar. Furthermore, it becomes clear that for the level of trading activity on IBIS it is also important if the DTB is open or not.

Mean returns There is no clear pattern in mean interval returns on IBIS so that no extra graph is presented. The Wilcoxon sign test indicated that eleven out of 170 mean

[22] Furthermore, the volume in shares is generally smaller on IBIS. This implies that the average trade size is smaller on IBIS than on the FSE.

interval returns were significantly different from zero. Again there is a clustering of significant means at the beginning (intervals 1 and 2) and at the end of the trading day (intervals 33 and 34). At the open as well as at the close we find significantly positive means for three and four groups, respectively. The hypothesis of an end-of-the-day anomaly on IBIS similar to the one found by Harris [15] on the NYSE is nevertheless not supported by the data very strongly. The last transaction returns of the day are significantly different from zero only for group 2.

Volatility Mean absolute returns on IBIS and the FSE are shown in figure 6. The average absolute return is computed as the equally weighted average of the five group means. This method was chosen since the much larger number of observations for group 1 would have biased the results towards the group 1 averages. During the three hour period of floor trading in Frankfurt the two curves in figure 6 are almost perfectly parallel, again with the exception of the noon and the closing auctions on the FSE. The overall level of volatility is slightly higher on IBIS than on the FSE, but the difference decreases over the day. It is more pronounced for less liquid stocks, whereas for group 1 the volatilities on the two markets are almost undistinguishable.

IBIS volatility is relatively low at the beginning of the day with a jump from interval 1 to interval 2. The fact that there is no clear pattern at the beginning of the day is a consequence of the lower liquidity for some stocks on IBIS, since opening returns are sometimes not recorded until interval 6 or 7. On the other hand a look at mean absolute transaction returns in table 4 shows that they are monotonically decreasing over the first five trades for all five groups which supports the information flow hypothesis.[23] The increase in return volatility in interval 5 is most likely caused by the opening of the DTB at 9:30 a.m. This hypothesis is supported by the observation that the largest upward movement in volatility is found for group 1 containing the stocks with the most actively traded options on the DTB.

The volatility of interval returns decreases in intervals 6 and 7. Around the opening of the FSE (interval 9) we find a sharpe increase in volatility when mean absolute returns almost double compared to interval 7 or 8. It is interesting to note that mean absolute returns in interval 9 are so much higher on IBIS than on the FSE and that this interval is the one with the highest volatlity of the day. If volatility is really caused by new information coming to the market overnight we would expect to find a higher volatility at the open than later during the day. The difference in volatility between IBIS and the FSE is not the same across the five groups, for example it is much smaller for the most liquid stocks in group 1 than for group 5.

After the three hour period when the FSE and IBIS are open simultaneously there is a noteable decrease in IBIS volatility until interval 23. This volatility movement is parallel

[23] The Page test rejects the null hypothesis of equal mean absolute returns against the alternative of a decreasing volatility at the 1% level.

to the decrease in trading activity documented in figure 5. Volatility then does not vary much, with the exception of an increase in intervals 24 and 25. A possible explanation for this movement is that the period of lower trading activity on the DTB is over, and as a consequence there are more trades and higher volatility on IBIS. Like on the FSE there is something like a day-end effect on IBIS, since mean absolute returns go up in interval 34 and are larger than in the preceding intervals. The same pattern can be found for mean absolute transaction returns in table 5.[24]

IBIS around auctions on the FSE As can be seen from a comparison of tables 1 and 4 absolute transaction returns at the open are virtually equal on IBIS and the FSE for all the five groups of stocks. This result may be taken as evidence that market participants do not consider IBIS prices as very informative.

This view is further supported by the jump in the volatility of transaction returns on IBIS around the opening of the FSE (see figure 7).[25] The mean absolute transaction return from the last IBIS price before the opening of the FSE to the first price after this event (transaction return 0 in figure 7) is considerably larger than all the earlier or later transaction returns in the morning. The statistic of the Wilcoxon sign test is highly significant for all five groups. Furthermore the mean absolute return from the last IBIS price before the opening of the FSE to the Frankfurt opening price is much larger than the average absolute return from the opening price to the next IBIS price. Again the test rejects the null hypothesis of equal means at low levels of significance.[26] This special behavior of IBIS prices is observable during all three auctions of the day, but with a decreasing tendency. The same tests as above were conducted for the noon and the afternoon auctions, and the statistics were in general significant for the noon auction but no longer for the auction at the close.

Another interesting observation is that the signs of the IBIS transaction returns following the opening auction on the FSE seem to depend on the amount of the 'price correction' from the last IBIS price to the opening price on the FSE. A sequence of transaction returns with equal signs is called a run.[27] The daily observations of this price correction for the individual stocks were grouped into three categories: the highest and the lowest decile and the remaining group which contained 80% of the observations. Afterwards the number of positive and negative runs of length k ($k = 3, 4, 5$) were counted for these three groups. The results are qualitatively similar for all five groups of stocks so that they are only presented for group 1. If the occurence of a run was indeed independent of the amount of the price

[24] In the case of interval returns the statistics for the Wilcoxon sign test are significant for groups 1, 2, 3, and 5. For transaction returns we obtain significance for groups 1 to 3.

[25] A further indicator for the higher informational content of the FSE opening price is the fact that spreads quoted by dealers on IBIS widen considerably before the FSE opens as documented by Schmidt and Iversen [24].

[26] All these results are consistent with the sharp decrease in number of trades on IBIS immediately before the opening of the FSE.

[27] See Fama [11] for a first analysis of runs in stock returns and their implications for market efficiency.

correction we would expect to find 10% of the positive and the negative runs as well as 10% of all the other observations in the decile with the largest positive observations. However, the results indicate that this is not the case. For group 1 the upper decile contains about 27% of all positive runs of length 3, 23% of those of length 4 and 15% of the positive runs of length 5. On the other we observe only 1% of the negative runs of length 3 and none of length 4 or 5, respectively, in this decile. The findings for negative runs are almost symmetric. The decile with the 10% lowest price corrections contains 25, 30, and 18% of the negative runs of length 3, 4, and 5, and only 1, 3, and 1% of the positive runs, respectively.[28]

It is not clear how the results concerning the integration of IBIS and the FSE should be explained in the light of the existing theory. While it seems reasonable to conclude from the results at the open that market participants consider the FSE as the leading market this argument cannot be used for the noon and afternoon auctions. One possibility is to assume that auction prices generally contain more information than prices set in the continuous market. In this case we could expect a repetition of the pattern at the open also later during the day.

5 Summary and Conclusions

This study has investigated intraday trading on the FSE and on IBIS. The results for the floor market on the FSE are mostly consistent with the findings for other markets. We observe U-shaped patterns for both the frequency of transactions and the volatility of returns. Transaction returns around the noon auction are not significantly more volatile than other returns. However, there is some return effect in that return reversals are more pronounced here than for the rest of the trading day. Furthermore we find a continuous decline in volatility on the FSE after the opening. This finding provides strong support for the hypothesis that return volatility is primarily induced by the information flow rather than by market structure.

For the computer trading system IBIS we do not observe similar patterns in volatility or transaction frequency. Furthermore, although there is a quite long period of IBIS trading before the floor market opens on the FSE, the informative content of the prices generated during this period seems to be low. This can be seen from the fact that transaction return volatility at the open on the FSE is just as high as the opening volatility on IBIS. IBIS prices seem to be influenced especially by auction prices from the floor in Frankfurt. Price movements on IBIS after an auction on the FSE tend to have the same direction as the price difference between the two markets at the time of the auction. In general the IBIS results together with the findings for the FSE seem to contradict the hypothesis of Brock

[28] In general the directions of the last IBIS price change before the opening on the FSE and the first IBIS price change afterwards have the same sign as the difference between the last IBIS price before the FSE open and the FSE opening price.

and Kleidon [6] that it is mainly the trading halt between the close on the previous day and the following opening that causes higher volume and higher volatility at the open. Overall, it seems safe to conclude that the FSE is the leading market in Germany. This is also consistent with the findings of Bühler, Grünbichler, and Schmidt [7], who find by means of a VAR model that for three of the four most liquid German stocks the floor market leads the computer market.

A possible direction for further research is to focus on the stationarity of the price discovery process over the trading day. Given the results of this study it seems likely that some events on one market have a higher impact on a second market than others. An example for this hypothesis is given by the finding that especially the opening auction price from the FSE seems to be important for the behavior of prices on IBIS.

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Appendix

Table A.1:

Stocks in the DAX index (1994)

Firm Name	Symbol	Firm Name	Symbol	Firm Name	Symbol
Allianz	ALV	Deutsche Babcock	DBC	Mannesmann	MMW
BASF	BAS	Deutsche Bank	DBK	Metallgesellschaft	MET
Bayer	BAY	Dresdner Bank	DRB	Preussag	PRS
Bayerische Hypo	BHW	Henkel	HEN3	RWE	RWE
Bayerische Vereinsbank	BVM	Hoechst	HFA	Schering	SCH
BMW	BMW	Karstadt	KAR	Siemens	SIE
Commerzbank	CBK	Kaufhof	KFH	Thyssen	THY
Continental	CON	Linde	LIN	VEBA	VEB
Daimler-Benz	DAI	Lufthansa	LHA	VIAG	VIA
Degussa	DGS	MAN	MAN	Volkswagen	VOW

Table A.2:

Classification of DAX stocks in 1994 according to DM trading volume on the FSE

Class	Volume*	$TBTK^{\dagger}$	$TBTI_1^{\#}$	$TBTI_2^{\ddagger}$	Stocks
1	105.866	2:49	1:45	2:19	ALV, BAY, DAI, DBK, SIE, VOW
2	32.025	3:37	3:46	4:54	BAS, CBK, DRB, HFA, MMW, VEB
3	19.844	5:51	6:34	8:44	BHW, BMW, BVM, RWE, SCH, THY
4	11.572	7:15	14:35	19:46	KAR, KFH, LIN, MAN, PRS, VIA
5	6.408	7:48	15:10	19:24	CON, DBC, DGS, HEN3, LHA, MET

*: Average annual trading volume in billions of DM.
†: Mean time in minutes between two consecutive transactions on the FSE.
#: Mean time in minutes between two consecutive transactions on IBIS during trading time of the FSE.
‡: Mean time in minutes between two consecutive transactions on IBIS when FSE is closed.

Table 1:

Mean absolute transaction returns after the open on the FSE

	Group				
Transaction return	1	2	3	4	5
1	0.1053	0.1273	0.1812	0.2262	0.3234
2	0.0966	0.1150	0.1699	0.1990	0.2882
3	0.0931	0.1064	0.1620	0.1870	0.2576
4	0.0934	0.1063	0.1532	0.1744	0.2485
5	0.0908	0.1084	0.1433	0.1687	0.2407

Transaction return 1 denotes the return computed from the opening price and the first price from the continuous market each day. Analogously, transaction return 2 is computed using the first and the second price from the continuous market, and so on. The numbers in the table are the 1994 grand mean of the absolute transaction returns of the stocks within a given group.

Table 2:

Estimation results for the model

$$r_{i,j} = \alpha_i + \beta_i r_{i,j-1} + \gamma_i D_{j-1} r_{i,j-1} + \epsilon_{i,t}$$

Group	$\bar{\beta}$	$\bar{\gamma}$
1	-0.1235 (6)	-0.0491 (1)
2	-0.1245 (6)	-0.1909 (4)
3	-0.0841 (4)	-0.1639 (4)
4	-0.0740 (5)	-0.1120 (4)
5	-0.0791 (6)	-0.1120 (2)

The variables in the regression are defined as follows: $r_{i,j}$ is the jth transaction return for stock i and D_{j-1} is dummy variable which is set to one if return $j-1$ is computed using the last price from the continuous market and the noon auction price, and to zero otherwise. The numbers in parentheses denote the number of significant t-statistics for the given coefficient in the respective group.

Table 3:

Mean absolute transaction returns before the close

	Group				
Transaction return	1	2	3	4	5
−4	0.0831	0.0903	0.1253	0.1381	0.2113
−3	0.0820	0.0910	0.1287	0.1454	0.2178
−2	0.0835	0.0923	0.1296	0.1337	0.2048
−1	0.0793	0.0930	0.1274	0.1298	0.2049
0	0.0961	0.1135	0.1474	0.1483	0.2622

Transaction return 0 denotes the return computed from the last price from the continuous market and the closing price. Analogously, transaction return −1 is computed using the last but one and the last price from the continuous market, and so on. The numbers in the table are the 1994 grand mean of the absolute transaction returns of the stocks within a given group.

Table 4:

Mean absolute transaction returns after the open on IBIS

	Group				
Transaction return	1	2	3	4	5
1	0.0980	0.1225	0.1737	0.2218	0.3257
2	0.0807	0.1107	0.1453	0.2001	0.2825
3	0.0719	0.0976	0.1374	0.1841	0.2743
4	0.0714	0.0909	0.1332	0.1723	0.2576
5	0.0719	0.0934	0.1244	0.1582	0.2479

Transaction return 1 denotes the return computed from the first price and the second price recorded on IBIS each day. Analogously, transaction return 2 is computed using the and the second and the third price from the continuous market, and so on. The numbers in the table are the 1994 grand mean of the absolute transaction returns of the stocks within a given group.

Table 5:

Mean absolute transaction returns before the close on IBIS

	Group				
Transaction return	1	2	3	4	5
−4	0.0541	0.0742	0.1065	0.1644	0.2342
−3	0.0551	0.0764	0.1091	0.1549	0.2204
−2	0.0596	0.0840	0.1104	0.1600	0.2239
−1	0.0583	0.0851	0.1182	0.1535	0.2148
0	0.0645	0.0978	0.1383	0.1603	0.2375

Transaction return 0 denotes the return computed from the last but one and the last price of each day recorded on IBIS. Analogously, transaction return −1 is computed using the last but two and the last but one price, and so on. The numbers in the table are the 1994 grand mean of the absolute transaction returns of the stocks within a given group.

Table 6:

Mean absolute transaction returns on IBIS around the open of the FSE

	Group				
Transaction return	1	2	3	4	5
−2	0.0586	0.0814	0.1213	0.1587	0.2358
−1	0.0611	0.0872	0.1279	0.1683	0.2597
0	0.0891	0.1338	0.2175	0.2998	0.4362
1	0.0605	0.0885	0.1223	0.1783	0.2417
2	0.0596	0.0895	0.1184	0.1641	0.2494

Transaction return 0 denotes the return computed each day from the last IBIS price before the opening price on the FSE is set and the first price thereafter. Transaction return −1 is computed using the last but one and the last IBIS price before the opening of the FSE. Analogously, transaction return 1 is computed from the first and the second IBIS price following the opening on the FSE. The numbers in the table are the 1994 grand mean of the absolute transaction returns of the stocks within a given group.

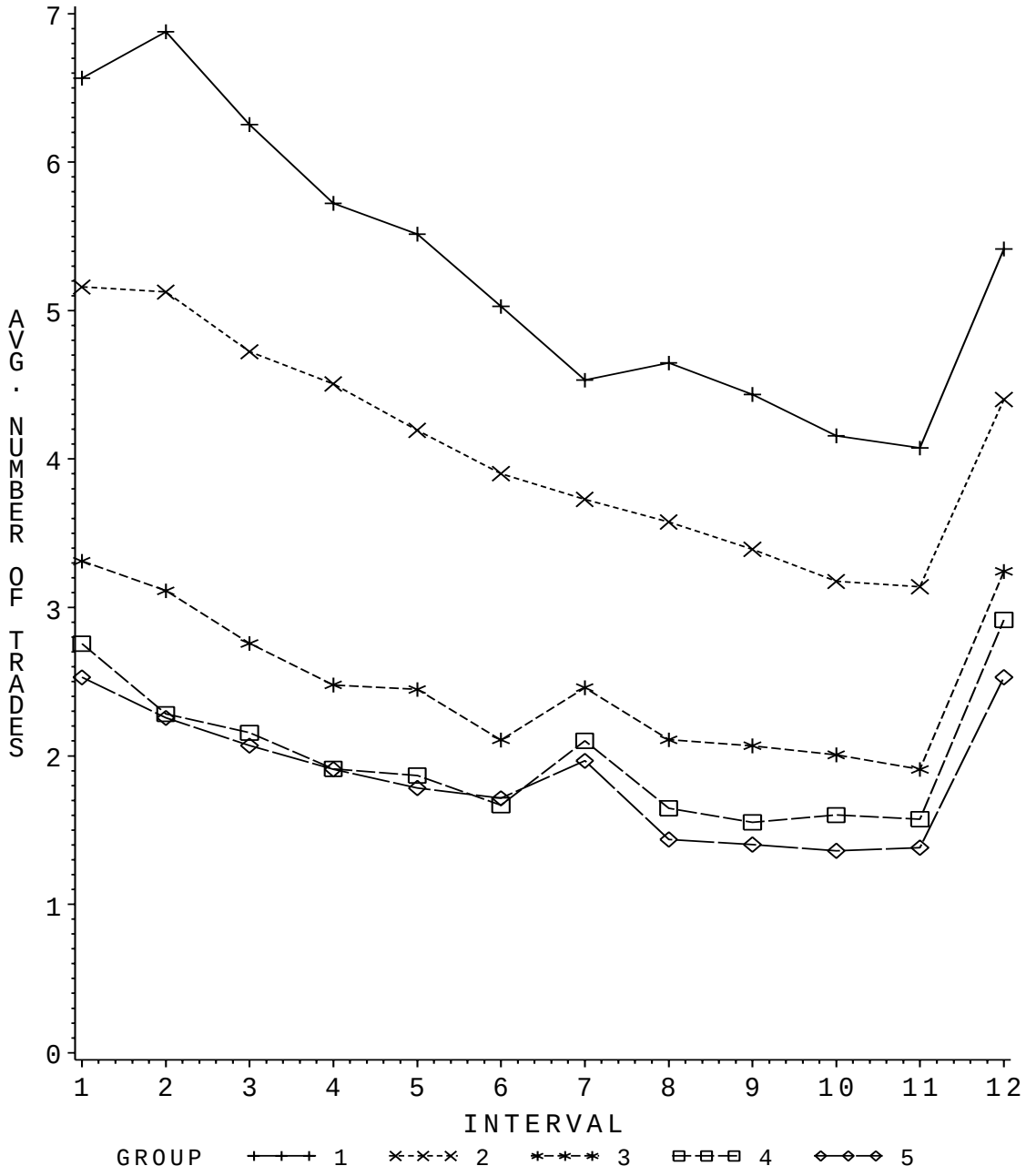

Figure 1: Average number of transactions on the FSE 1994 (groups of stocks)

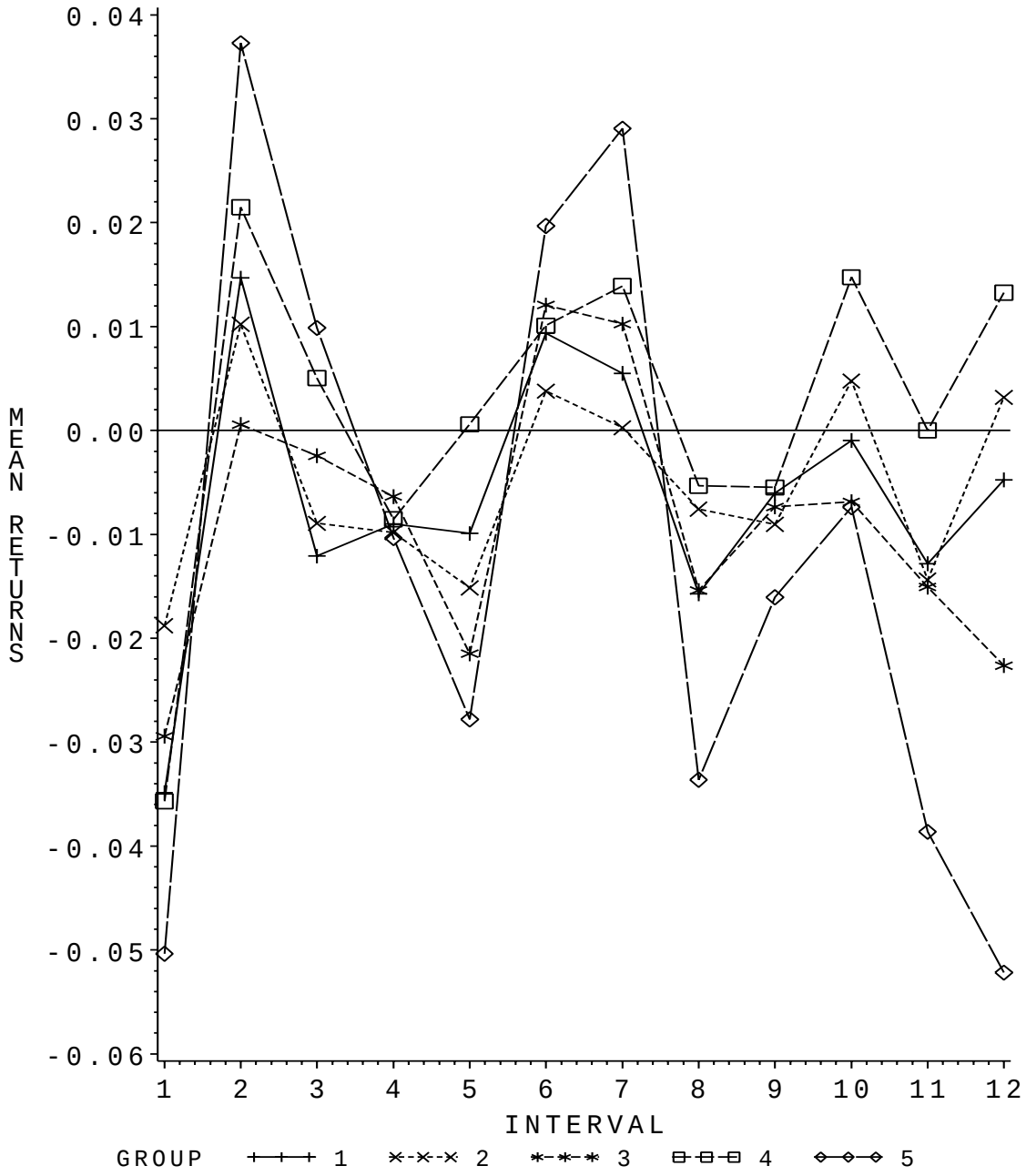

Figure 2: Mean intraday returns for groups of stocks

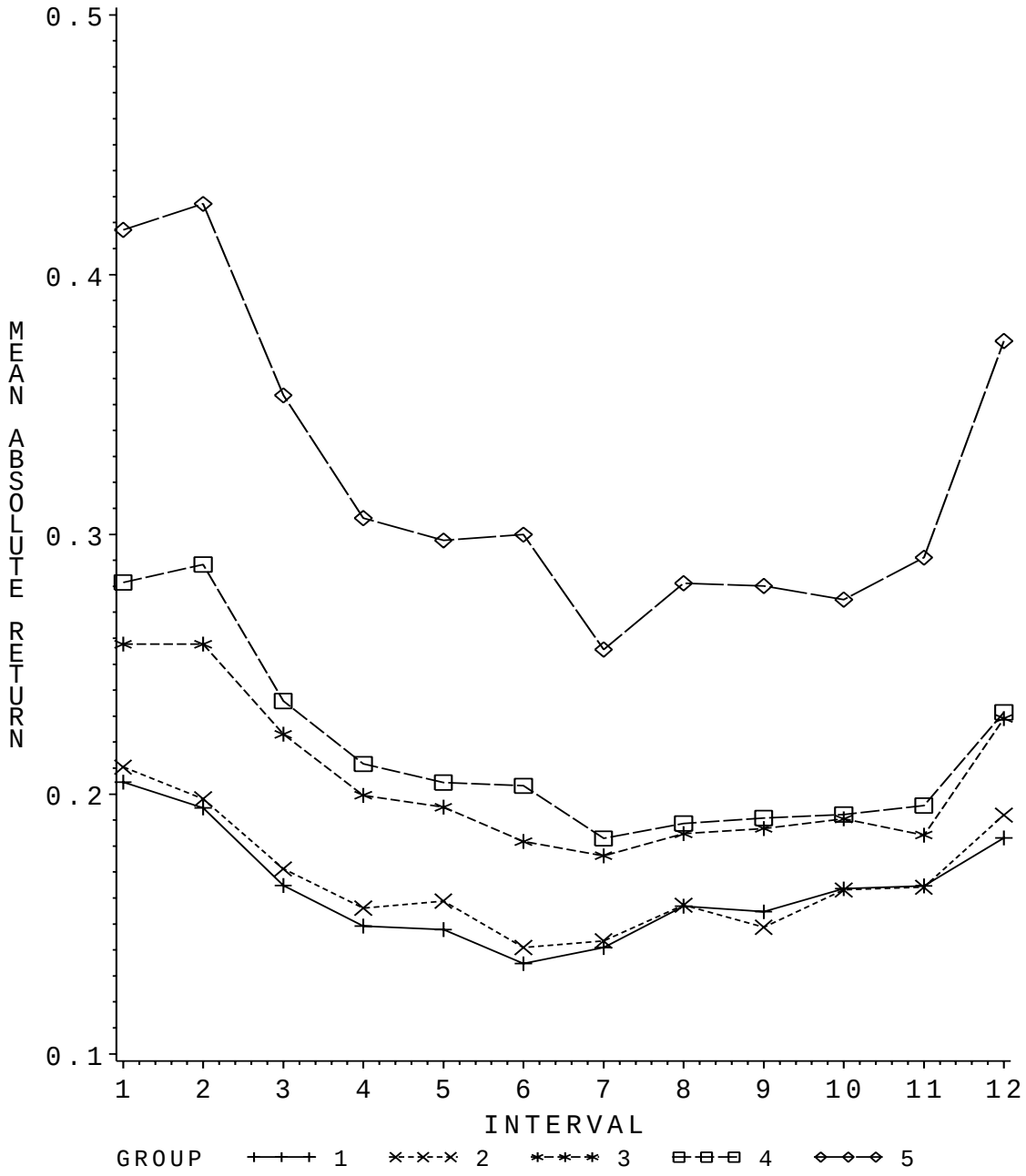

Figure 3: Mean absolute intraday returns on the FSE for groups of stocks 1994

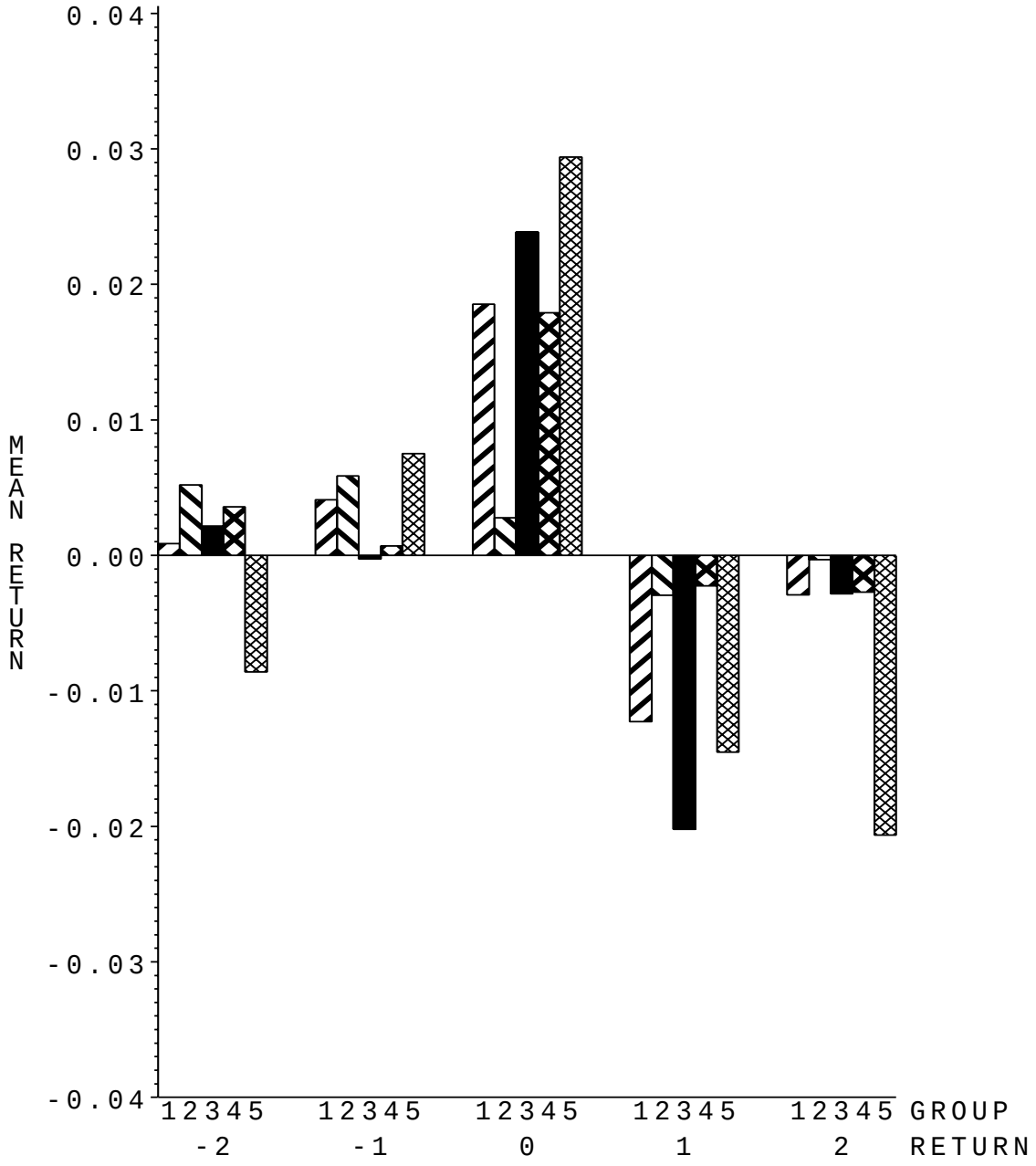

Figure 4: Transaction returns around the noon auction

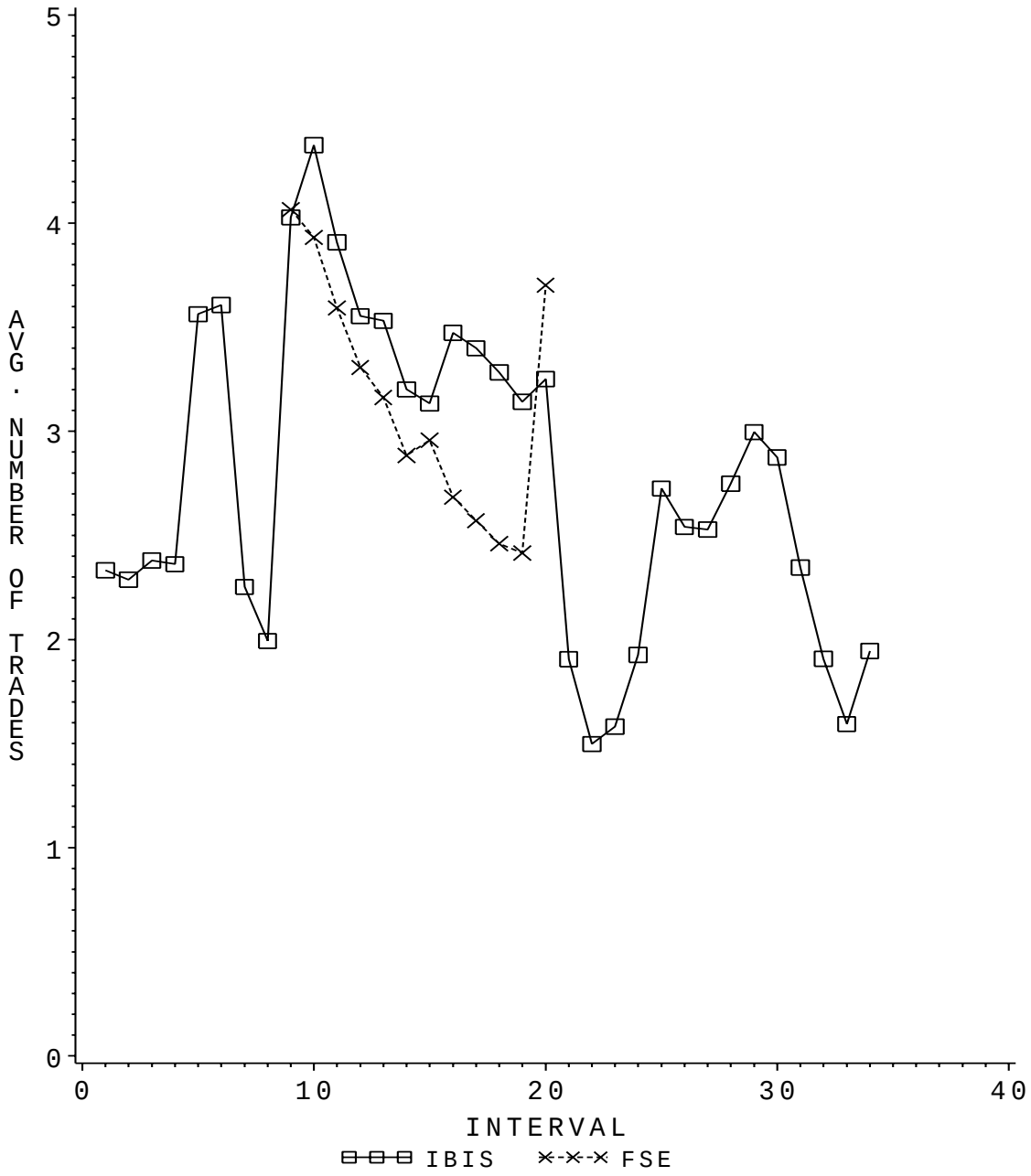

Figure 5: Average number of transactions on IBIS and on the FSE 1994

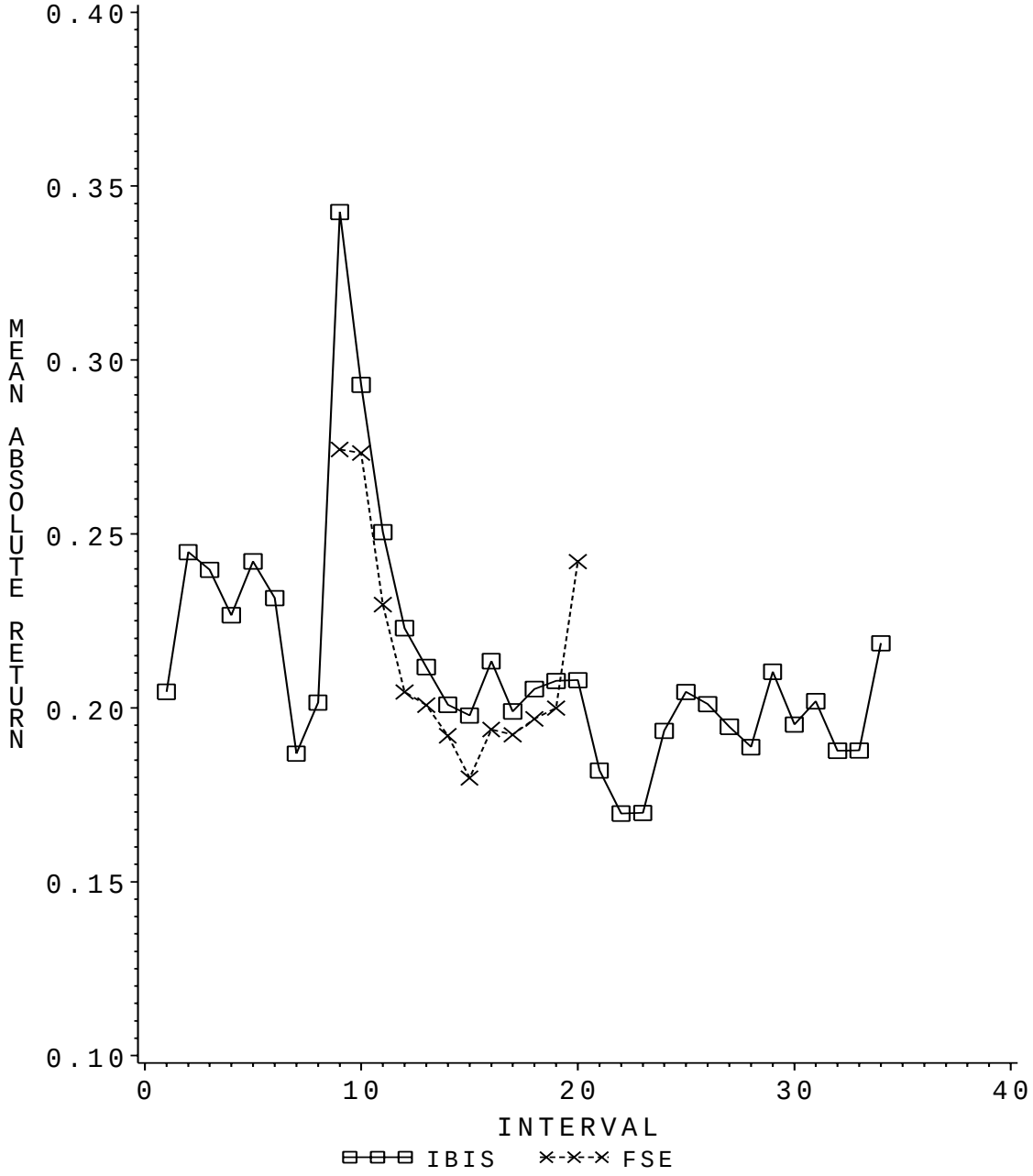

Figure 6: Mean absolute returns on IBIS and on the FSE 1994

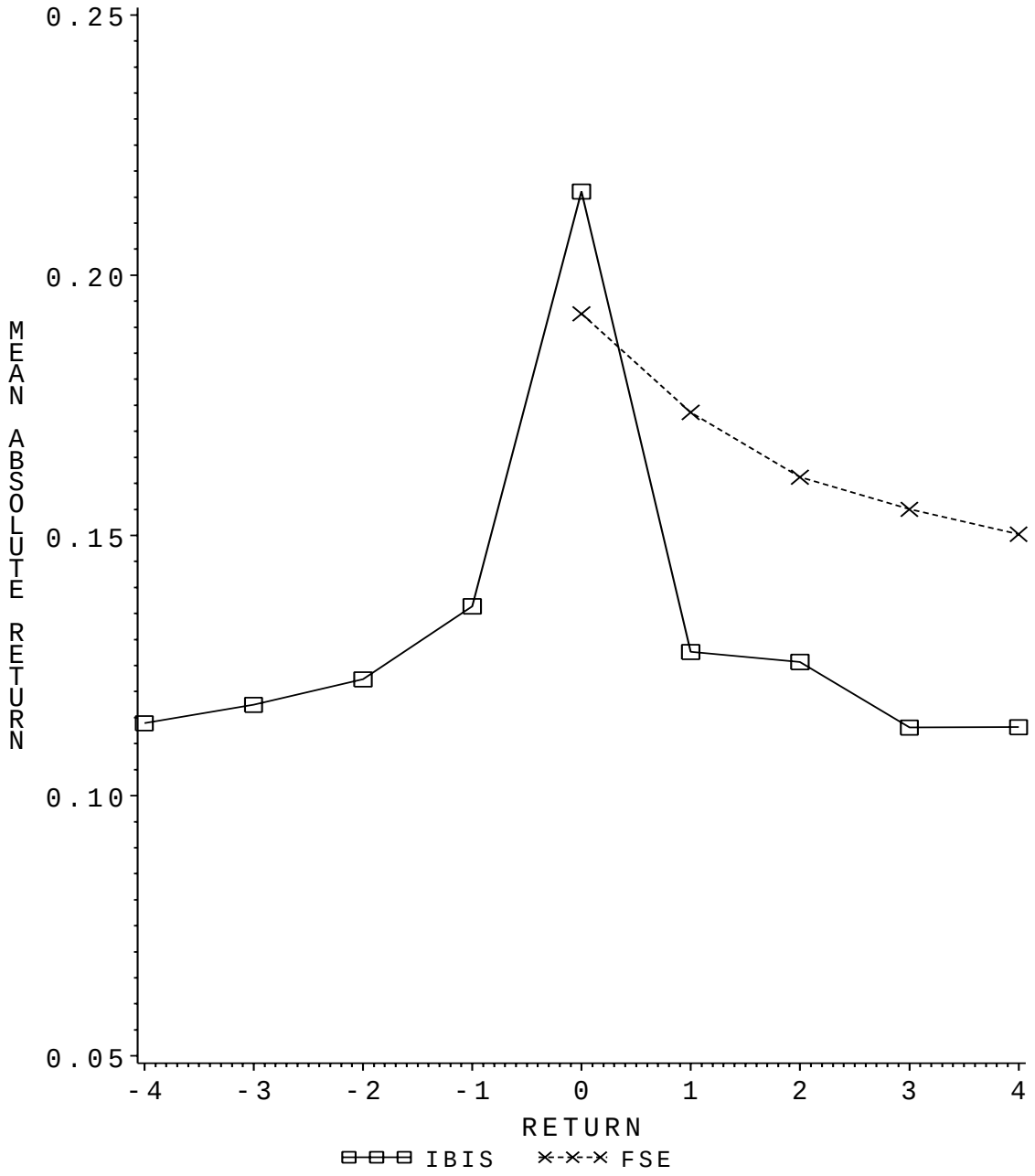

Figure 7: Mean absolute transaction returns on IBIS around the opening on the FSE