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Author(s): Tom Berglund and Eva Liljeblom
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Market Serial Correlation on a Small Security Market: A Note

TOM BERGLUND and EVA LILJEBLOM*

THIS NOTE REPORTS ON an empirical investigation into the relative importance of different explanations of market serial correlation. Market serial correlation taken as the first-order serial correlation in the logarithmic differences of a market index may apparently be explained by the serial correlation of individual stock returns. The other, less apparent, explanation advanced in the literature concerns nonsynchronous trading in individual stocks. Recently, Perry [9] and Atchinson, Butler, and Simonds [1][1] have shown that there seems to be yet an additional unexplained component present that tends to induce serial correlation in portfolio returns, at least in U.S. data.

In this paper, the actual contribution of these explanations to the first-order autocorrelation of changes in the value-weighted market index on a markedly thin security market, the Helsinki Stock Exchange (HeSE)[2] in Finland, will be examined. The HeSE is a specific case in the sense that its trading procedure may create additional first-order market serial correlation. We will show that the rules of the exchange produce additional intraday nonsynchroneity in stock returns and thus aggravate the problem of market serial correlation. An attempt to assess the importance of this additional cause of market serial correlation will also be made.

In 1966, Lawrence Fisher [7] observed that an index return calculated on the basis of the latest recorded trading prices will tend to be serially correlated if share prices tend to react similarly to certain types of news. This will be the case when some share prices react almost immediately whereas others, simply because of an absence of trading, will experience a reaction delay.

If nonsynchronous trading is taken to be the first cause of market serial correlation, the second one is the serial correlation of individual stock returns. Cohen, Hawawini, Maier, Schwartz, and Whitcomb [6] review the literature on why individual stock returns, especially in thin markets, may be serially corre-

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[1] Atchinson, Butler, and Simonds [1], p. 117, conclude, "We are led to the conclusion that at present the high observed autocorrelation of the indices examined is not well explained by the nonsynchronous trading model. Other factors appear to be playing the major role in generating the autocorrelations."

[2] The total value of share turnover in billions of U.S. dollars on the HeSE in 1982 was 0.14. Compare this with other European stock exchanges, e.g., London 32.3, Stockholm 4.3, Brussels 1.8, Copenhagen 0.2, and Vienna 0.1 (Stockholm Stock Exchange: "Report on the Activities of the Stockholm Stock Exchange in 1982").

lated. Evidence of the nature of the serial correlation of stock return on Scandinavian stock exchanges is summarized by Berglund, Wahlroos, and Örnmark [3].

Whereas these explanations were extensively discussed in a previous note by Berglund, Liljeblom, and Wahlroos [4], this paper is mainly devoted to an analysis of that part of index autocorrelation on the HeSE that may be induced by trading practices on the exchange.

The institutional settings that are believed to cause first-order serial correlation are the following. Each day, trading in stocks listed on the HeSE begins with a round of auctions in which a trading price interval, an official "bid-ask interval," is established for all stocks. The stocks are auctioned one by one in the same order each day. Serial correlation may arise when there is a change in the market not discernible during trading for the first stocks on the list but clearly apparent when a majority of the stocks have already been auctioned. When this happens, stocks at the beginning of the list may be effectively hindered from an appropriate price reaction during that same day. The reason is that the trading price interval established during the auction may not include the equilibrium price that corresponds to the new information revealed in the trading of stocks lower on the list. Thus, the reaction will not materialize in some stocks until a new round starts the following trading day, and the change in the market will be carried over to the next day, creating serial correlation in the market index. For simplicity, this hypothesis will henceforce be called the "trading-order" hypothesis.

I. The Data

The analysis is based on daily stock returns measured by logarithmic first differences[3] for stocks listed on the HeSE between January 1, 1977 and December 31, 1982. The stock prices from which returns are computed consist of the daily trading prices[4] corrected for cash and stock dividends and new issues. The corrections are based on the assumption that all proceeds are reinvested without transaction costs in the stock from which they derive. A detailed description of these corrections is given in Berglund, Wahlroos, and Grandell [2].

II. Results

The first column in Table I gives the average trading freuqency for the stocks included in each average return, and the second column gives the estimated first-order serial correlation on this average return. Thus, item 1 in Table I shows the value-weighted trading frequency and the first-order serial-correlation coefficient

[3] See Hawawini and Vora [8] for a detailed analysis of the differences between proportional and logarithmic returns.

[4] When several trading prices are recorded for the same stock on the same day, the arithmetic average for these prices is used. Note, however, that all prices for the same stock are recorded within a few hours, due to the trading procedure adopted on the HeSE.

Table I
Autocorrelation Coefficients and Standard Deviations for Different Stock Samples[a]

	Trading Frequency	Estimated Autocorrelation (All Days)
1. Value-Weighted Index, 66 Stocks	87.8%	0.4919
		(0.0267)
2. Average Trade-to-Trade Returns, 66 Stocks	53.2%	0.5085
		(0.0263)
3. Average Trade-to-Trade Returns, 36 Most Traded Stocks	82.5%	0.5407
		(0.0259)
4. Stock-Specific Returns: Average of 36 Most Traded Stocks	82.5%	0.3167
		(0.1045)
		(0.0332)
–Stocks 1–12 (Most Traded)	97.3%	0.3664
		(0.0803)
		(0.0286)
–Stocks 13–24	86.9%	0.3117
		(0.0786)
		(0.0322)
–Stocks 25–36 (Least Traded)	63.4%	0.2719
		(0.1312)
		(0.0387)

[a] Where multiple standard deviations are reported, the first number is the cross-sectional and the second the average time-series standard deviation. Since the exchange is closed on summer Mondays, all summer (June through August) returns have been omitted to guard against possible distortion produced by the shorter trading week during the summer.

for returns computed from a value-weighted index[5] of all listed issues.[6] This reveals that at least the value-weighted index produces a highly significant serial correlation in market returns.

A. Nonsynchronous Trading

The first step in the analysis is to remove the interday Fisher [7] effect. This is done by omitting all returns save those over adjacent trading days with trades recorded in a given stock.[7] Item 2 in Table I shows the coefficient of first-order serial correlation computed from the arithmetic averages of these returns. A comparison of this coefficient with that computed from the value-weighted index yields the surprising result that almost nothing has been gained by the elimination of the interday Fisher effect.

[5] In this index, the no-trading problem is handled by inserting the bid for each absent closing price.

[6] When serial-correlation coefficients were computed separately for each day of the week to check for a potential weekday pattern, the coefficients turned out to be roughly of the same magnitude. For a more extensive discussion on the effects of the Monday returns on share price behavior, see Berglund, Liljeblom, and Wahlroos [5].

[7] Holiday returns were omitted as well.

This unexpected outcome may, however, be the result of several problems associated with thin trading. First, the original value-weighted index is partially based on bid prices, which causes the coefficients of serial correlation for that index to be downward biased.[8] Second, it is possible that weighting based on stock capitalization may be smaller for stocks exhibiting a higher degree of first-order serial correlation. To assess the magnitude of the effect produced by the weighting scheme, the first-order serial-correlation coefficient was computed for a sample consisting of only the thirty-six most frequently traded stocks. This coefficient is reported as the third item in Table I. A comparison of this with the previous items reveals that the exclusion of infrequently traded stocks produces no appreciable change in the serial-correlation coefficient. Evidently the magnitude of the serial correlation in the second item is not attributable to the least traded stocks.

Apparently we can conclude that the Fisher effect, which is due to a lack of trading in a non-negligible number of stocks almost every day, will not contribute much to observed market serial correlation.

B. Serial Correlation in Individual Stock Returns

Next, attention is focused on the second explanation of the serial correlation of index returns, i.e., the serial correlation of individual stock returns. The average of the serial-correlation coefficients estimated separately for each of the thirty-six major stocks is indicated in item 4 of Table I. As before, all returns save those for adjacent trading days with recorded actual trades are omitted.

Although significant first-order serial correlation is observed in most of the thirty-six stocks, the average of these coefficients indicates that serial correlation of individual stock returns cannot account for all of the index autocorrelation appearing in items 1 and 2 of Table I. The three entries below item 4 in the table reveal that a partitioning of the thirty-six most frequently traded stocks into three subsets in decreasing order of trading frequency produces coefficients that are almost equal in magnitude, perhaps with a slight tendency for the coefficient to increase with trading frequency.[9]

Since the serial-correlation coefficients in item 4 are substantially lower than those in the previous item, it seems that serial correlation in individual stock returns cannot account for all market serial correlation. However, the figures in Table I are not sufficient to reveal whether the serial correlation that remains after controlling for idiosyncratic serial correlation is statistically significant. Fortunately, such evidence can easily be obtained. If it is true that the serial correlation of index returns is caused by the first-order autocorrelation of

[8] If trading is very infrequent, we will typically observe a sequence of bid quotations occasionally interrupted by a trading price. Since this trading price usually exceeds the preceding bid, we will typically record positive returns for a trading day, followed by a negative return for the following day when only a bid price is recorded. A time series of such returns is likely to exhibit negative serial correlation. This turns out to be the case. When serial correlations for all HeSE stocks were computed form a price series, with bid quotations inserted for days with no trade in 1977 to 1981, the average coefficient of first-order serial correlation was −0.025.

[9] This closely corresponds to observations made in other markets as reported by Cohen, Hawawini, Maier, Schwartz, and Whitcomb [6].

individual stock returns, then an index computed from individual trade-to-trade stock returns from which first-order serial correlation has been eliminated ought to produce a serially uncorrelated market return.

First-order serial correlation was therefore eliminated from the adjacent-day trade-to-trade returns of the thirty-six most traded stocks. This was done using data for September through May for the time period 1977 to 1982. The independent increments thus obtained were then averaged over the thirty-six stocks. The coefficient of first-order serial correlation for this series was 0.25, with a t-ratio of 8.48. It seems extremely unlikely that this autocorrelation coefficient could have been produced by chance alone.

C. Trading Order and Other Causes of Market Serial Correlation

The trading price interval on the HeSE was, during our period of study, determined stock by stock during so-called "calling out," which is completed during the first half of the trading day. If information is revealed through the trading process itself, when the last stocks on the list are called out, prices for the first stocks on the list may well be "out of date" in an informational sense. Since trading prices not included in the official spread will not be allowed, the prices of stocks at the beginning of the list cannot adjust in response to the new information until the next morning. The rules on the HeSE would thus lead us to expect a significant effect from intraday nonsynchroneity in market returns on the exchange. Thus, to put it simply, the institutional rules for the HeSE may lead to a correlation between present returns for stocks at the beginning of the list and lagged returns for stocks at the end of the list, which would constitute a partial explanation of the observed serial correlation in the market index.

In order to run a preliminary test of this explanation, we measured the correlation between the market index[10] and the lagged returns for each of the thirty-six stocks. If the institutional rules for the HeSE are responsible for the index autocorrelation in the sense described above, we should observe an increase in correlation between the market index and lagged individual returns as we move down the list. In other words, we would expect a significant correlation between the ranking of stocks based on the listing order and a ranking based on the size of the above correlation coefficient. The rank correlation was computed using Kendall's τ. This coefficient turned out to be 0.1873, with a probability of 5.6 percent under H_o, thus indicating significant positive dependence at a ten percent level.

The fact that market serial correlation consists of intertemporal correlation between individual stock returns can be utilized to further analyze the hypothesis that the trading order can explain some of the market serial correlation on the HeSE. Taking an individual stock somewhere in the middle of the list, the hypothesis implies that there may be some correlation between the return on this stock and the previous-day returns on stocks further down the list. On the previous day, the appropriate price reaction in this particular stock to information revealed by trading in the last stocks on the list may simply have been prohibited by the rules of the exchange, creating a forced one-day delay. This forced reaction

[10] This was based on individual stock returns corrected for serial correlation.

delay will occur only with respect to price changes in succeeding stocks on the list, and there is no corresponding reason for a delayed reaction with respect to price changes in preceding stocks on the list. Thus, the trading-order hypothesis implies that a considerable proportion of observed market serial correlation should be due to correlation between an individual stock return and the aggregate previous-day return for all stocks that succeed it on the list, whereas—provided that no serial correlation caused by other factors exists—there should be practically no correlation with the aggregate previous-day return for all stocks that precede it on the list.

To test this implication, the returns[11] for each of the thirty-five stocks in our sample of thirty-six stocks that are preceded on the list by at least one stock were first correlated with the average previous-day return for all preceding stocks on the list, producing thirty-five "predecessor" correlation coefficients. Next, the returns for all thirty-five stocks in our sample that are succeeded on the list by at least one stock were correlated with the average previous-day return for all stocks that succeed this stock on the list, in this case producing thirty-five "successor" correlation coefficients. The trading-order hypothesis implies that the coefficients for succeeding stocks should be higher than for preceding stocks. Furthermore, if the trading order is the sole cause of the remaining market serial correlation, the coefficients for the preceding stocks should not be significantly different from zero.

Table II reveals that none of the coefficients for the preceding stocks is zero or negative. If the true underlying coefficients were zero and independent,[12] this outcome would be extremely unlikely.[13] The coefficients reported in the table thus indicate that the institutional settings describe above cannot be regarded as the sole cause of the remaining market serial correlation on the HeSE.

However, the fourth column reported in Table II in particular reveals that there is also some explanatory power in the trading-order hypothesis. A total of twenty-nine out of thirty-four differences in the column are positive. Under the null hypothesis of equality and independence between the differences, the probability of a positive sign should be 0.5. Thus, the null hypothesis implies that the number of positive signs should be a binomially distributed variable with $p = 0.5$ and $n = 34$. The probability of observing twenty-nine or more positive signs would thus be less than 0.01 percent. In other words, the null hypothesis can be rejected. The same conclusion is obtained if a more restrictive parametric method is applied instead. Assuming a normally distributed difference, the standard deviation of the sample mean is 0.00615, producing a t-ratio of approximately 4.25 under the null hypothesis of a zero true difference.

[11] Returns corrected for first-order serial correlation were used in this experiment.

[12] The independence assumption is somewhat at odds with our trading-order hypothesis. According to that hypothesis, the coefficients are probably sequentially dependent. However, the conclusion is also supported by the fact that the serial-correlation coefficient, reported below for the aggregate return from which the influence of the previous-day returns of the succeeding stocks is eliminated, remains statistically significant.

[13] Assuming that the coefficients are randomly drawn from a normally distributed population, the average for the preceding stocks' coefficient is naturally also significantly larger than zero. The standard deviation for the sample mean is $0.0258/\sqrt{35} = 0.0044$, producing a t-ratio of approximately 7, under a null hypothesis of a zero underlying mean.

Table II

Correlation Coefficients between Stock-Specific Returns and Lagged Values of Average Returns Computed on Preceding and Succeeding Stocks on the HeSE List

Stock No.	(1) Preceding Stocks	(2) Succeeding Stocks	Difference (2) − (1)
1	—	0.0838	—
2	0.0036	0.0528	0.0492
3	0.0045	0.0682	0.0638
4	0.0172	0.0387	0.0214
5	0.0085	0.0226	0.0141
6	0.0105	0.0135	0.0030
7	0.1036	0.0289	−0.0747
8	0.0221	0.0030	−0.0191
9	0.0108	0.0348	0.0240
10	0.0101	0.0250	0.0149
11	0.0139	0.0703	0.0564
12	0.0301	0.0591	0.0290
13	0.0165	0.0383	0.0218
14	0.0440	0.0962	0.0521
15	0.0312	0.1161	0.0849
16	0.0438	0.0673	0.0235
17	0.0203	0.0487	0.0284
18	0.0284	0.0812	0.0528
19	0.0750	0.1060	0.0310
20	0.0253	0.0284	0.0030
21	0.0067	0.0166	0.0099
22	0.0996	0.0517	−0.0480
23	0.0607	0.0922	0.0315
24	0.0162	0.0149	−0.0013
25	0.0655	0.0960	0.0305
26	0.0262	0.0814	0.0551
27	0.0665	0.0474	−0.0191
28	0.0401	0.1418	0.1017
29	0.0150	0.0483	0.0333
30	0.0429	0.0711	0.0281
31	0.0120	0.0439	0.0320
32	0.0192	0.0311	0.0119
33	0.0087	0.0318	0.0231
34	0.0215	0.1226	0.1011
35	0.0108	0.0303	0.0195
36	0.0433	—	—
Average	0.0307	0.0573	0.0261
Standard Deviation	0.0258	0.0342	0.0359

Rejection of the null hypothesis implies that the differences in the fourth column of Table II are significantly different from zero, statistically dependent, or both. Since the correlation coefficients in the second and third columns are sequentially dependent according to the trading-order hypothesis, this may also be the case for the differences reported in the fourth column.[14] To check for sequential dependence between these differences, the Durbin-Watson coefficient for deviations from the average difference was computed. A coefficient value of 1.74 was obtained, implying that first-order sequential correlation is not present in the differences. Thus, we may conclude that the null hypothesis of a zero underlying difference can be rejected.

Finally, the correlation coefficients reported in Table II were used to purge the returns corrected for idiosyncratic serial correlation from the information contained in the preceding-day returns. This was done separately for the returns for preceding and succeeding stocks on the list. These two sets of twice-corrected returns were then averaged to produce two new aggregate-return series. The aggregate-return series corrected for influence from preceding stocks on the list produced a first-order serial correlation of 0.203 (standard deviation 0.029). This should be compared with the corresponding coefficient for the aggregate-return series corrected for influence from succeeding stocks on the list, which turned out to be 0.134 (standard deviation 0.030). These figures corroborate the conclusion that, although some serial correlation is accounted for by our trading-order hypothesis,[15] there is a considerable amount that definitely cannot be thus explained.

However, intraday nonsynchroneity may still explain some of the remaining serial correlation. Normally, intraday nonsynchronous trading consists of the random arrival of market orders at discrete points in time within the day. As shown by Scholes and Williams [11], some autocorrelation can be accounted for by this random nonsynchronous trading. In Atchinson, Butler, and Simonds [1], the approximate magnitude of the market-index autocorrelation implied by this nonsynchronous trading was computed. The Scholes and Williams [10][16] model was used to construct an estimator for the implied market serial correlation. To estimate the magnitude of the market-index autocorrelation explained by random nonsynchronous trading for the HeSE, a similar procedure was applied.

In the Scholes and Williams [10] model, it is assumed that trading is continuous. Another way of interpreting this assumption is to suppose that price changes occur only when the exchange is open. If there are implicit changes in the stock price when the exchange is closed as well, the assumption is no longer valid. As an extreme example, we could imagine that the underlying price of a stock would be determined by a continuous stationary process in calendar time and that trading would be restricted to ten minutes in the middle of the day. In that specific case, nonsynchroneity would clearly not constitute a very serious problem, not even in the unlikely event that all stocks were traded only once a day.

In Atchinson, Butler, and Simonds [1], the Scholes and Williams [10] model was applied directly without any adjustment for the fact that the exchange is closed during part of the calendar day. If some of the information reflected in

[14] Note, however, that a dependency that affects the coefficients in the second and third columns in a similar way is likely to be cancelled in the difference between the columns.

[15] The difference between the coefficients is statistically significant.

[16] A detailed description of this model is not given in the Scholes and Williams [11] paper.

daily returns actually arrives during the time the exchange is closed, the procedure implies that the relative nonsynchroneity of trades in some stocks will appear greater than what is really the case. This will introduce an upward bias in the theoretical measures of the magnitude of market-index autocorrelation.

The problem of nonsynchroneity depends on how far apart in informational time[17] the closing prices in different stocks are expected to be. This in turn will depend on the density of transaction arrivals measured in informational time. Since this will be higher if transactions are restricted to occur during a specific part of a day rather than during the whole day, the observed density in the restricted case has to be multiplied by a correction factor larger than one to obtain a corresponding density in the continuous framework.

From a sample of the most traded stocks on the HeSE, the variance of the return defined as the logarithmic price difference between the first trading price and the last trading price during the previous day was observed to be 2.56 times the variance of the return defined as a similar difference between the last and the first trading price within the same day. In an informational sense, this can be taken to indicate that the exchange is open 1/3.56 of the day since approximately 1/3.56 of the total daily fluctuation in price is observed from open to close within the day.

Since the observed number of transactions in a stock in our sample during this period of study was between one and ten, the corresponding transaction-arrival densities in continuous-information time were obtained by multiplying by a factor of 3.56. This would produce a range of three and thirty-six transactions per day. To avoid an exaggeration of the trading frequencies, the transaction frequencies for different stocks were conservatively assumed to be distributed[18] within the range of three and twenty-four transactions per day. The magnitude of the equally-weighted-portfolio serial correlation implied by this input distribution of transaction frequencies was computed using the method of Scholes and Williams [10]. A resulting theoretical serial correlation coefficient of less than 0.05 was obtained.[19] This low theoretical value is far from the magnitude of the serial correlation in the market index that remains after correction for the trading-order hypothesis.

The serial correlation that remains unexplained leads us to conclude that our results agree with those reported by Perry [9] and Atchinson, Butler, and Simonds [1] on U.S. data; i.e., market returns seem to be subject to some serial correlation, which indicates that new information is not absorbed simultaneously in trading prices for different stocks. In this respect, the results contradict the prediction of the efficient-market hypothesis.

[17] One unit of informational time could be taken as the expected time it takes between successive pieces of significant information that will reach the market. The corresponding calendar time will thus be longer during the night than during daytime.

[18] The distribution was assumed to be approximately normal, with a mean of 13.5.

[19] This value was only slightly higher than the value of 0.0408 of Atchinson, Butler, and Simonds [1] for an equally weighted portfolio. The small difference is due to the fact that the theoretical portfolio autocorrelation is especially sensitive to very small transaction frequencies. In our experiment, the smallest daily transaction frequency was three, whereas, in Atchinson, Butler, and Simonds [1], it was 1.88.

III. Conclusion

This note addresses the question of the relative importance of the different causes of the serial correlation of market-index returns on a thin market. The analysis is based on daily price and volume data from a small European exchange, the Helsinki Stock Exchange in Finland. The results clearly indicate that the Fisher effect by itself and in conjunction with the autocorrelation of individual stock returns cannot account for all of the serial correlation found in market returns. Although some of the serial correlation that remained after controlling for these explanations was shown to be attributable to the trading practices of the exchange, some serial correlation seems to remain even after allowance for that additional effect has been made.

The general implication of our results is that, in the estimation of market or nondiversifiable risk, especially on small exchanges, the use of trade-to-trade returns eliminates only relatively few of the problems caused by nonsynchronous price behavior. Apparently there are cases where the use of trade-to-trade returns is not sufficient to eliminate all the biases in estimated betas caused by stock price behavior that deviates from what is expected under informational efficiency.

REFERENCES

1. M. Atchinson, K. Butler, and R. Simonds. "Nonsynchronous Security Trading and Market Index Autocorrelation." *Journal of Finance* 42 (March 1987), 111–18.
2. T. Berglund, B. Wahlroos, and L. Grandell. "The KOP and the UNITAS Indexes for the Helsinki Stock Exchange in Light of a New Value Weighted Index." *Finnish Journal of Business Economics* 32 (No. 1, 1983), 30–41.
3. T. Berglund, B. Wahlroos, and A. Örnmark. "The Weak Form Efficiency of the Finnish and the Scandinavian Stock Exchanges: A Comparative Note on Thin Trading." *Scandinavian Journal of Economics* 85 (No. 4, 1983), 521–30.
4. T. Berglund, E. Liljeblom, and B. Wahlroos. "On the Use of Trade-to-Trade Returns for Risk Estimation in Thin Security Markets: A Note." Working Paper No. 126, Swedish School of Economics and Business Administration, 1984.
5. ———. "Day-of-the-Week Effects on a Thin Security Market." CMSEMS Discussion Paper No. 599, Northwestern University, 1984.
6. K. J. Cohen, G. A. Hawawini, S. F. Maier, R. A. Schwartz, and D. K. Whitcomb. "Implications of Microstructure Theory for Empirical Research on Stock Price Behavior." *Journal of Finance* 35 (May 1980), 249–57.
7. J. L. Fisher. "Some New Stock Market Indexes." *Journal of Business* 38 (January 1966), 191–225.
8. G. Hawawini and A. Vora. "Proportional vs. Logarithmic Models of Asset Pricing." *Research in Finance* 5 (1985), 1–24.
9. P. R. Perry. "Portfolio Serial Correlation and Nonsynchronous Trading." *Journal of Financial and Quantitative Analysis* 20 (December 1985), 517–23.
10. M. Scholes and J. Williams. "Estimating Betas from Daily Data." Working paper, University of Chicago, 1976.
11. ———. "Estimating Betas from Non-Synchronous Data." *Journal of Financial Economics* 5 (December 1977), 309–27.