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Trading Nokia: The Roles of the Helsinki vs. the New York Stock Exchanges*

ABSTRACT

We use the Autoregressive Conditional Duration (ACD) framework of Engle and Russell (1998) to study the effect of trading volume on price duration (ie the time lapse between consecutive price changes) of a stock listed both in the domestic and the foreign market. As a case study we use the example of Nokia's share, which is actively traded both in the Helsinki Stock Exchange and the New York Stock Exchange (NYSE). We find asymmetry in the volume-price duration relationship between the two markets. In the NYSE the negative relationship is much stronger and exists both during and outside common trading hours. Outside common trading hours no such relationship is significant in Helsinki. Based on the theory of Easley and O'Hara (1992), these results could be interpreted in that informed investors in Nokia mainly trade in the US market whereas Helsinki is the more liquidity-oriented trading place.

JEL: G14, G19

Key words: *cross-listing, Autoregressive Conditional Duration, market microstructure*

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1 INTRODUCTION

Cross-listing a firm's stock outside its home market, often in multiple markets, has been an interesting phenomenon in the international capital markets over the past two decades. Although the number of internationally cross-listed companies has come down from its 1997 peak of 4,700 to 2,300 in 2002 (Karolyi, 2004), it still constitutes an important phase in the development of international equity markets. Academic interest in studying the various aspects of cross-listings has also been considerable[1].

The reasons why firms cross-list their shares abroad, especially in the United States, have been actively debated. The traditional view suggests that cross-listings facilitate diversification opportunities for international investors by making it easier to invest in foreign companies' stocks. When a company's stock would consequently become a better-integrated part of the world's market portfolio, the company's cost of equity capital would come down. A stock's liquidity also tends to improve after cross-listing. However, the most recent studies have come to emphasize better investor rights and control of managers' private benefits as a source of value when cross-listing in a leading developed market like the U.S. (see e.g. Karolyi and Stulz, 2002; Doidge et al., 2004; Benos and Weisbach, 2004). By bonding itself to a more disciplined legal environment, the firm would credibly signal its value to investors. Another reason to cross-list may be the improved informational environment, as analyst coverage and accuracy are increased (see e.g. Lang et al., 2003). Related to this, US regulators also require higher disclosure than most other countries.

An interesting question, also dealt with in many of the studies on cross-listings, is in which of the markets, foreign or domestic, does price discovery of the stock take place. That is, where is new information mainly incorporated into the company's stock price? The methodology traditionally used to study price discovery is the error-correction model, like in Harris et al. (1995, 2002). Interestingly, recent studies have found that the home market mainly leads price discovery (see in particular Grammig et al., 2004). However, in general price discovery appears to take place in the market which attracts the biggest share of the stock's total trading volume (see Karolyi, 2004, and the studies surveyed therein).

In this paper we approach the issue of price discovery of a cross-listed stock more indirectly, using an alternative empirical methodology. We focus on the trading volume-price duration relationship which, on the basis of extant microstructure theories, can be interpreted as an indicator of informed trading[2]. We extend the framework of the autoregressive conditional duration

1 Karolyi (2004) lists in his survey about 140 studies related to cross-listings. Moreover, as recently as in 2004 European Finance Association's annual meeting two entire sessions were devoted to papers on cross-listings.
2 Price duration means the time lapse between consecutive price changes exceeding some prespecified threshold value.

model (ACD) introduced by Engle and Russell (1998) to the case of two markets. Unlike studies on price discovery using equidistant intra-day data, the ACD model allows for effective use of all irregularly spaced transaction data and modeling of the well-known feature of price duration clustering. Explanatory variables expected to affect the stock's price duration, such as trading volume both in the home and the foreign market, can be flexibly incorporated into the model. Moreover, unlike in the standard price discovery studies of cross-listed stocks, by focusing on price duration we can analyze both the over-lapping trading hours of the two markets as well as the hours when only one market is open.

Theoretical studies of Easley and O'Hara (1992) and Admati and Pfleiderer (1988, 1989) provide empirical implications regarding the volume-price duration relationship, based on the behavior of informed and liquidity traders in the market. In particular, Easley and O'Hara (1992) argue that information based trades tend to cluster. Hence increased volume implies more informed trades which have greater price impacts than trades motivated by pure liquidity needs. Engle and Russell (1998) find evidence supporting Easley and O'Hara (1992) in that price duration tends to shorten when volume increases. We make use of these results as well as other microstructure theories when interpreting our empirical results.

The empirical analysis in this paper is based on a case study of Nokia's stock traded in the Helsinki Stock Exchange (HSE) and the New York Stock Exchange (NYSE)[3]. The Finnish Nokia provides an interesting example to focus on because still years after its cross-listing a considerable part of its total trading volume takes place in the foreign market, NYSE. This is not typical of cross-listed stocks (see Halling et al., 2004). Although our analysis is limited in that we only consider one stock, we nonetheless believe that we are able to raise some interesting questions related to the liquidity and price discovery of cross-listed stocks that might be worth further study.

We find considerable asymmetry in the effect of volume on price duration in the two markets. Based in particular on Easley and O'Hara (1992), our results could be interpreted in that the NYSE and the HSE have in part specialized roles. While the NYSE would mainly accommodate large informed trades, smaller liquidity oriented trades would be more typical in the HSE. This would suggest that the NYSE leads Nokia's price discovery. Interestingly, this would be in contrast with the earlier consensus view that price discovery is led by the market where most of the trading volume takes place (see Karolyi, 2004). Therefore we suggest that the average trader and trade size may be a more important factor in explaining price discovery. Moreover, we find that the joint opening hours of the NYSE and HSE are by far the most active time for informed trading of

3 Nokia is also listed in a number of other foreign markets (see figure 1), but here we focus on the two main markets, Helsinki and NYSE.

Nokia. This might be interpreted in that local factors such as analyst coverage provided in Helsinki may nevertheless be important for Nokia's international price discovery process.[4]

The paper is organized as follows. Section 2 introduces the ACD model, and section 3 discusses the data and the results. The final section concludes.

2 METHODOLOGY

The basic ACD model gives the conditional expectation ψ_i of the ith price duration, i.e. the time betw een the ith and (i–1)th price change,x_i, conditional on past price changes as

$$(1) \qquad \psi_i = \omega + \sum_{j=1}^{p} \alpha_j x_{i-j} + \sum_{j=1}^{q} \beta_j \psi_{i-j}.$$

In other words the expected conditional duration in this ACD (p, q) model depends on p lags of past observed durations and q own lags. The actual observed duration is assumed to be generated by

$$(2) \qquad x_i = \psi_i \varepsilon_i,$$

where ε_i is an independently and identically distributed non-negative random variable with mean unity. To complete the model, the distribution of ε_i must be specified. The alternatives suggested in the previous literature include the exponential and Weibull distributions (Engle and Russell, 1998) and the generalized Gamma distribution (Zhang et al., 2001), among others. In this paper we leave the distribution of ε_i unspecified and act as if it were exponential. As discussed by Engle and Russell (1998), the ensuing quasi maximum likelihood estimator (QMLE) of the parameters is consistent and asymptotically normal (under mild regularity conditions).[5] Thus inference on the parameters can be conducted in the usual way, relying on standard tests, once the (robust) QMLE estimator of the covariance matrix of the parameters is employed.

The basic ACD model can easily be augmented with extra explanatory variables in equation (1) as demonstrated by Engle and Russell (1998). Furthermore, it is straightforward to allow for shifts in the parameters at prespecified points in time. In our empirical application the main interest lies with examining the differences in the parameter values between common and separate

4 One should bear in mind that our results may be specific to the sample period, November 2000. Since then the market shares of the HSE and the NYSE of Nokia's total trading volume have further changed in favour of HSE. This could have affected the results found in this paper.

5 In the empirical analysis we also experimented with the Weibull distribution, but the conclusions remained virtually unchanged.

opening hours of the two stock exchanges. A generalization of the ACD(1, 1) model, allowing for such differences and including the lagged own volume z_{i-1} as an extra explanatory variable is given by

$$\psi_i = (1 - D_i^c)(\omega + \alpha_1 x_{i-1} + \beta_1 \psi_{i-1} + \gamma z_{i-1}) + D_i^c(\omega^c + \alpha^c{}_1 x_{i-1} + \beta_1{}^c \psi_{i-1} + \gamma^c z_{i-1}) \tag{3}$$

where D_i^c is a dummy variable taking value 1 when both exchanges are simultaneously open and value 0 otherwise. Hence, the superscripted parameters describe the process of price durations during the common opening hours.

3 DATA AND RESULTS

3.1 Data

The complete data set consists of all the trades in the NYSE[6] and HSE during November 2000[7], extracted from the TAQ and HSE's databases, respectively[8]. Before the empirical analysis some standard modifications were called for. First, the observations of November 23 for the HSE were dropped because the NYSE was closed (due to Thanksgiving). Second, any transaction occurring before the opening time (9.30 a.m. in NYSE and 10.00 a.m. in the HSE) or after the closing time (16.00 in the NYSE and 18.00 in the HSE), were dropped. Third, the trades with the same time stamp were combined and the weighted average, weighted by their relative volumes, was taken as the price of the combined trade. Finally, the price durations were computed from the actual transaction prices. In computing the durations, all the price changes in the NYSE were included, whereas for the HSE price changes less than 1/16 euros were excluded.[9] After these adjustments we were left with the total of 15 313 and 5 539 observations from the NYSE and HSE, respectively.

Although the sample period is relatively short, there are presumably enough observations for meaningful empirical analysis; previous studies using ACD models have also been conducted with data from relatively short periods. As already mentioned above, it is still possible that the sample period is not representative in that the results could be generalized outside this period. However, Ben Sita (2005) has previously estimated ACD models for the price durations of the

6 At NYSE Nokia is listed in the form of American Depositary Receipt (ADR).
7 The data contains a total of 40699 and 88109 observations from the NYSE and HSE, respectively. Due to the large number of observations it is the standard practice in similar market microstructure studies to limit the attention to a relative short time window.
8 Unlike NYSE, HSE is an electronic market. A more detailed description of it is provided by Booth et al. (2002).
9 In HSE the tick size is 0.01 euros, considerably smaller than that in NYSE. This adjustment was employed to make the results comparable across the exchanges.

Nokia stock traded in the HSE in two periods in the spring of 2000, and at least for comparable model specifications our results are similar to his.

It is well known from previous empirical studies on transaction data that price changes as well as volume exhibit a time of the day effect that is not captured by the basic ACD model. Therefore, this intradaily variation must somehow be taken into account, and, following Engle (2000), the adjustment is done before estimating the ACD models. While this is necessary for further analysis, it also gives potentially interesting information on the variation of price durations and volume in the two stock exchanges. The intradaily patterns were calculated nonparametrically: First, averages over certain time intervals were computed[10], and then cubic splines were used to smooth the patterns. Finally ratios were taken to diurnally adjust the price duration and volume series.

The daily patterns of price durations are depicted in the upper panel of Figure 2. The mean duration is longer in the HSE at all hours, i.e., on average, it takes considerably longer for prices to change by a comparable amount in the HSE than in the NYSE. A natural explanation is provided by the different tick sizes; in our sample the total number of price changes in the NYSE was only about two thirds of that in the HSE where typically several small price changes took place between two consecutive price changes in the NYSE during the common opening hours (from 9.30 until 11.00 a.m. in the NYSE corresponding to the period from 4.30 until 6.00 p.m. in the HSE). In both exchanges the typical pattern of shorter durations near the opening and closing of the trading day emerges, but the price duration is shortest during the common opening hours. Also, there seems to be much more variation in the price duration in the HSE.

The intradaily patterns of volume divided by the number of transactions[11] depicted in the lower panel of Figure 2 exhibit clear differences between the common and separate opening hours with the average volume tending to be higher when both exchanges are open. In the HSE this pattern is more pronounced, whereas in the NYSE the average volume also tends to increase towards the close of the trading day. This kind of U-shaped pattern is commonly observed (see, e.g. Gourieroux and Jasiak, 2001, Chapter 14). The figure also clearly demonstrates the fact that the average transaction size is markedly larger in the NYSE at all hours. In our entire sample the mean transaction size in the HSE was about 3 385 shares, while that in the NYSE was about 4 477 shares. Moreover, the proportion of very large trades was considerably bigger in the NYSE.[12] Still,

10 For the NYSE data the cutoff points were 10.00, 11.00, 12.00, 13.00 14.00, 15.00, and 15.30, whereas for the HSE data they were 11.00, 12.00, 13.00, 14.00, 15.00, 16.00, 17.00, and 17.30.

11 Consistent with Jones et al. (1994), we find that the results are robust with respect to whether volume is measured by total or average volume or the number of transactions. Hence, results using the average volume are reported throughout, as they tend to give more accurate estimates.

12 For instance, in our sample 10.1% of all transactions involved more than 10 000 shares in NYSE, whereas the corresponding proportion was only 3.8% in HSE.

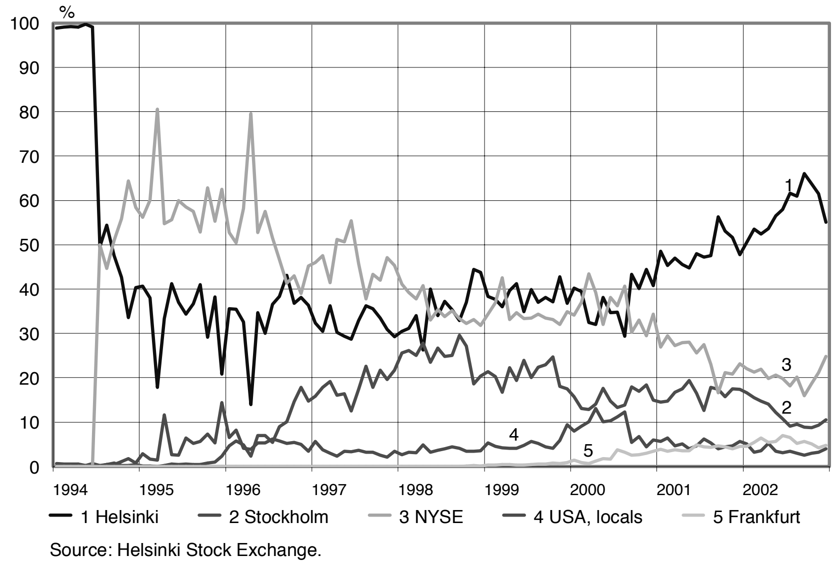

FIGURE 1. Nokia Share Turnover in World Exchanges (% share of total turnover, measured as number of transactions). Source: HEX plc.

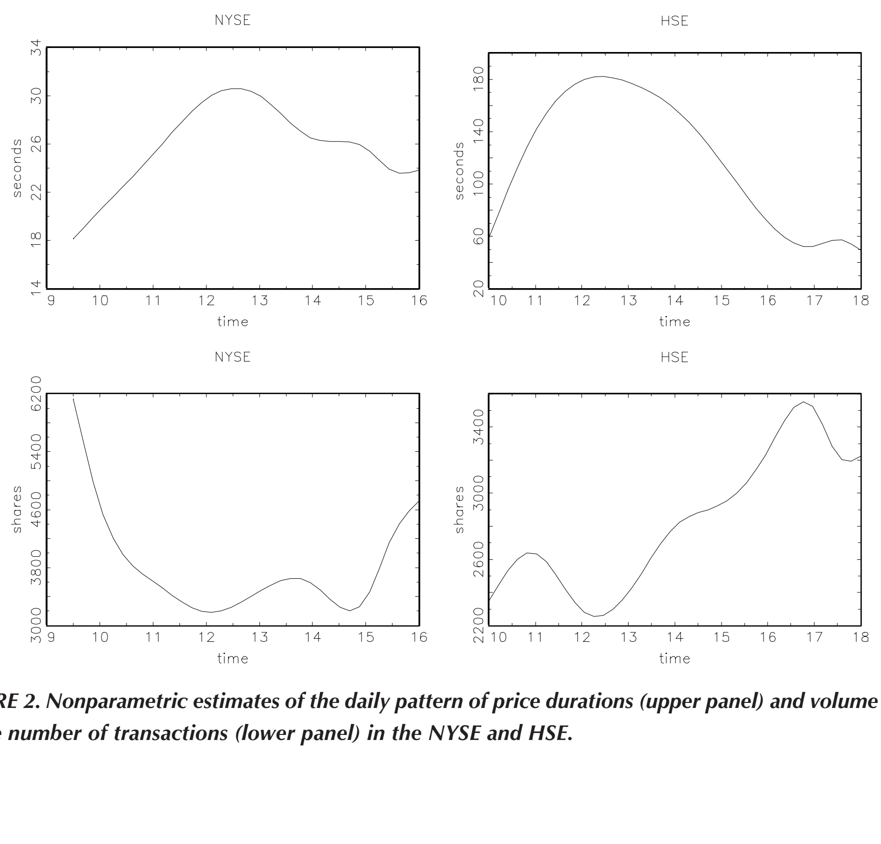

FIGURE 2. Nonparametric estimates of the daily pattern of price durations (upper panel) and volume divided by the number of transactions (lower panel) in the NYSE and HSE.

the total volume in the NYSE in November 2000 was only about two thirds of that in the HSE. Based on the market share development in figure 1, measured in numbers of transactions, the difference in total volumes has most likely continued to increase in favor of the HSE.

3.2 Results

The relationship between Nokia's price duration and trading volume is investigated in both markets (see tables 1 and 2). First we estimate the basic ACD(1,1) models (specification (1)), and then proceed to augmenting the models with explanatory variables. Specification (2) includes the lagged own volume divided by the number of transactions (i.e., it is model (3) in section 2) and specification (3), in addition, the cross trading volume (i.e., the volume divided by the number of transactions in the other market between two consecutive price changes in the market being studied). Within each specification we allow the parameters to take different values conditional

TABLE 1. Estimation results for the price duration models for NYSE.

	(1)	(2)	(3)
ω	**0.115**	**0.256**	**0.271**
	(3.95)	**(3.76)**	**(0.79)**
α_1	**0.115**	**0.115**	**0.114**
	(6.39)	**(6.20)**	**(5.97)**
β_1	**0.665**	**0.681**	**0.672**
	(9.57)	**(9.64)**	**(9.26)**
ω^c	**0.327**	**0.372**	**0.366**
	(1.30)	**(2.70)**	**(1.85)**
α_1^c	**0.137**	**0.145**	**0.138**
	(2.94)	**(4.51)**	**(4.42)**
β_1^c	**0.561**	**0.535**	**0.512**
	(2.02)	**(3.55)**	**(2.36)**
volume/#transactions		**–0.475**	**–0.481**
		(–4.15)	**(–4.10)**
(volume/#transactions)		**–3.416**	**–2.555**
		(–4.97)	**(–3.39)**
volume/#transactions at HSE			**0.097**
			(1.91)
L-B(10)	**13.08**		
L-B^2(10)	**0.77**		

Robust *t*-statistics in parentheses.
L-B and L-B^2 are Ljung-Box test statistics for serial correlation in the standardized residuals and their squares, respectively. With 10 lags, the 5 and 10 percent critical values are 18.31 and 15.99, respectively.

TABLE 2. Estimation results for the price duration models for HSE.

	(1)	(2)	(3)
ω	**0.034**	**0.040**	**0.040**
	(3.82)	**(3.45)**	**(3.45)**
α_1	**0.182**	**0.180**	**0.180**
	(7.21)	**(5.93)**	**(5.93)**
β_1	**0.804**	**0.803**	**0.802**
	(30.67)	**(24.25)**	**(24.24)**
ω^c	**0.078**	**0.025**	**0.023**
	(2.70)	**(2.57)**	**(2.19)**
α_1^c	**0.209**	**0.100**	**0.095**
	(5.68)	**(3.74)**	**(3.38)**
β_1^c	**0.547**	**0.890**	**0.833**
	(4.81)	**(15.84)**	**(16.08)**
volume/#transactions		**–0.057**	**–0.057**
		(–1.40)	**(–1.40)**
(volume/#transactions)		**–0.227**	**–0.227**
		(–12.32)	**(–12.19)**
volume/#transactions at NYSE			**0.003**
			(0.51)
L-B(10	**13.16**		
L-B^2(10)	**9.14**		

See notes to Table 1.

on only one market being open and on both markets being open simultaneously, as explained above in section 2.

To examine the dynamic sufficiency of the ACD specification, Ljung-Box statistics with ten lags of the "standardized" durations $\hat{\varepsilon}_i = xi/\hat{\psi}_i$ and their squares were computed. The estimate of the conditional expectation of the duration, $\hat{\psi}_i$, is obtained by plugging in the estimates of the parameters into equation (1). Under the adequacy of the model, no significant autocorrelation should be present. For both markets the basic ACD model seems to capture the dynamics of the price duration process adequately. Hence, this simple lag structure is employed also in the models with additional explanatory variables. According to the robust t-statistics, the parameters of all the specifications are, in general, accurately estimated. It is also noteworthy that the price duration processes differ considerably in both markets between the common and separate opening hours. A Wald test for equality of all the coefficients across the regimes rejects at the 1% level of significance for each specification. There are differences in all the parameters, but, in particular, the sum $\alpha_1 + \beta_1$ that measures the persistence in the price duration is clearly smaller during the common opening hours in all the model specifications. The price durations also seem to be considerably more persistent in the HSE than in the NYSE.[13]

In both markets, during the joint opening hours, there is a negative relationship between price duration and the trading volume, indicating that increased volume results in higher price volatility. In the NYSE there is significant, although much weaker, negative relationship between price duration and volume also outside the joint opening hours. In the HSE no significant relationship between price duration and volume exists outside the joint opening hours. It also appears that the negative duration – volume relationship observed in the NYSE is not driven by the peak volume per transactions and the shortest price durations right at the opening of the market, which are shown in figure 2[14]. The direct impact of trading volume from one market to the other is weak: the NYSE volume has no significant impact on price duration in the HSE, and the HSE volume has a marginally significant positive impact on price duration in the NYSE (p-value 5.5%).

To summarize, there is a marked asymmetry in the results concerning the NYSE and HSE price durations. Although during the joint opening hours both markets exhibit a negative duration – volume relationship, this relationship reliably extends outside the joint hours only in the case of the NYSE. The overall persistence in price durations is also weaker in the NYSE. Finally, a weak (positive) cross-effect from the one market's volume to the other market's price duration can only be found from the HSE to NYSE. In the following subsection these results are interpreted in light of the existing microstructure theories.

3.3 Discussion of the results

Taken together with descriptive statistics, our results could be interpreted as follows. The HSE and NYSE have in part specialized roles in providing liquidity and aggregating private information into prices. The NYSE is mainly the place for larger, well-informed investors of Nokia, whereas the HSE more typically services relatively smaller, liquidity oriented investors. Nonetheless, the common trading hours of the NYSE and the HSE is the time when most active trading takes place in each market and when also informed trading is most pronounced. One explanation for this could be that much of the information that is important for Nokia's price discovery process, such as analyst coverage, is produced in Helsinki.

13 As a check, we also estimated models with constant parameters across the opening hours (results are not reported in detail, but are available upon request). In those models the persistence is clearly higher (the sum $\alpha_1 + \beta_1$ is almost unity in both markets) and the lagged volume has a significantly negative effect on duration. As far as the HSE is concerned, these results are in line with Ben Sita (2005) who estimated similar models for two periods in the spring of 2002.

14 This came apparent when we also estimated an additional ACD model with the joint trading hours divided into subperiods. We found that during the first 15 minutes there is no relationship between price duration and volume. This suggests that the first big trades reflect liquidity trading demand, accumulated by the opening of the market, without any particular information content.

The first observation that supports the above view is that the average transaction size is significantly larger in the NYSE than in Helsinki, although the total euro amount of trading volume is larger in the HSE (because the number of transactions is larger in the HSE). Moreover, the proportion of very large trades is substantially higher in the NYSE (see footnote 11). This is consistent with Pagano's (1989) theoretical analysis of alternative market places. He predicts that when transaction costs differ, which is clearly the case between the NYSE and the HSE for Nokia's stock during the sample period[15], one market may specialize in the relatively smaller traders and the other in relatively larger traders. Further, it is natural to assume that the larger investors are also the better informed investors. This would also be consistent with Easley and O'Hara's (1992) arguments that informed traders are less responsive to high spreads, as well as with the arguments and findings of Mayhew et al. (1995) that the relative concentration of informed investors in two related markets is greater in the market with higher costs.

Evidence supporting the view that the NYSE is the main site for informed trading with Nokia's stock, whereas trading in the HSE is more liquidity oriented, comes from our ACD regression results[16]. Following Engle and Russell's (1998) interpretation of ACD regressions in the light of the theoretical arguments of Easley and O'Hara (1992), the negative volume-price duration relationship in the NYSE, both during and outside the joint opening hours, is consistent with that informed investors mainly cluster in the NYSE[17]. The result that a similar negative relationship is observed in the HSE only during the joint opening hours, but not outside them, suggests that informed trading in the NYSE partly spills over to the HSE[18] but that no significant informed trading takes place in the HSE outside the joint opening hours.

The view that informed trading, and hence price discovery of Nokia's stock, would mainly take place in the NYSE is consistent with Hedvall et al. (1997)[19]. During their sample period the

15 During our sample period, the average spread in HSE, computed from daily closing transaction prices, is 0.094% against NYSE's 0.263%, based on intra-day bid-ask quotes. According to Koivisto et al. (1998), the spread constitutes the major part of Nokia's transaction costs both in NYSE and in HSE. Comparing with their results, it is apparent that over time, spreads in HSE have dramatically decreased, probably explaining HSE's increasing market share of Nokia trading.

16 The mere fact that most HSE price duration observations have been omitted from data because they did not exceed the NYSE tick size threshold already points to the conclusion that the HSE is a more liquidity oriented trading place (see section 3.1).

17 A word of caution is in order here in that testing the significance of the ACD regression coefficients on the volume-price duration relationship and interpreting a negative coefficient as a sign of informed trader clustering is actually a joint hypothesis. Nonetheless, neither the traditional price discovery research settings are free of the joint hypothesis issue (see Karolyi, 2004).

18 The mirror image-like pattern of the monthly volume share series of the HSE and the NYSE in figure 1 suggests that there may be active seeking for the best trade execution place between the two markets also during the day.

19 Hedvall et al. (1997) find that price discovery goes in both directions between the two markets, although most of the time NYSE leads HSE. HSE affects NYSE particularly when days with result reports are included. Since Nokia has typically announced its results during European daytime hours, part of the price discovery has naturally taken place in HSE. The fact that in our sample month, November, no quarterly reports are released may have affected our result that HSE seems to have little role in price discovery compared to NYSE. We thank the referee for these remarks.

NYSE still attracted most of Nokia's total trading volume, so their result is consistent with the view that the market with the largest volume also leads price discovery. The fact that during our sample period Helsinki has captured most of the trading suggests that other factors – average trader and trade size – may be more fundamental to understanding how trading volume is related to price discovery[20].

The result that the HSE volume has a marginally significant positive impact on the NYSE price duration at first appears contradictory but could also be consistent with the overall interpretation of results. When liquidity trades take place in the HSE, the demand for liquidity trades in the NYSE is reduced. This results in longer price durations in the NYSE. The fact that no such cross-effect is detected from the NYSE to the HSE is in line with the view that trading in the NYSE is mainly information based.

Why is it that the most active time for informed trading clustering are the common opening hours of the two markets? Naturally, during these hours informed traders from both Europe and the U.S. have the opportunity to be at the same time in the two markets. However, another reason could be that Nokia is still strongly based in Finland; for instance, its headquarters are in Finland, and its top management is mainly Finnish. The last office hours of the day in Helsinki which coincide with the common trading hours of the two markets might be an important time for processing information, and discussing with local analysts. Local analysts may also have developed expertise that provides an important element to the overall analysis on Nokia.

4 CONCLUSIONS

In this paper we have applied the autoregressive conditional duration (ACD) model of Engle and Russell (1998) to the case of a cross-listed stock. In particular, we have investigated the intra-day price data of Nokia, trading both in New York and Helsinki, during November 2000. The advantage of the ACD model is that it allows for effective use of all irregularly spaced transaction data as well as modeling the well-known feature of price duration clustering and its relationship with trading volume. The framework also allows us to naturally study both the over-lapping trading hours and the hours when only one market is open.

The results on the price duration-volume relationship have been interpreted in the light of microstructure theories relating informed and liquidity trading. This possibly furthers our under-

20 The general caveat concerning our limited sample period, already laid out in footnote 5, should be kept in mind. In November 2000 the market shares of Helsinki and the NYSE of Nokia's total trading volume were above 40% and 30%, respectively. Since then these have continued to drift further apart in favour of Helsinki. By the end of 2002 they had reached roughly 55% for Helsinki and 25% for the NYSE. Such a significant shift could have affected the empirical relationships found, and hence interpretations made, in this study.

standing of the roles of the two markets in Nokia's price discovery. Although our results maybe case specific, some of the findings may suggest ideas worth more general investigation on the trading and price processes of cross-listed stocks.

Drawing from studies such as Easley and O'Hara, 1992, Pagano, 1989, and Mayhew et al. (1995), our empirical results could be interpreted in that Helsinki and New York have in part specialized roles in the supply of liquidity and price discovery. With its apparently lower transaction costs, Helsinki would primarily accommodate more liquidity oriented trading, while New York, in spite of its smaller overall volume, but with larger average trade size, would be the trading venue where private information is mostly incorporated in Nokia's stock price. This challenges the common view that the market with the largest share of total trading volume would also lead price discovery. The most active time of the day for informed trading is clearly the joint opening hours of the two exchanges. This suggests that although most informed trades would take place in the NYSE, an important part of the information and analysis to trade on would be produced in Helsinki. ■

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