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Information Impact on Stock Price Dynamics*

1. Introduction

Although theory of market microstructure has a long history, a rapid development of the empirical investigation in this field could appear only after the technological jump allowing for collecting and analysing a large number of data. One of the most important questions of market microstructure theory concerns the nature of the price formation process. There exist diverse opinions on the mechanism of this process but many researcher point out the impact of information process as a factor triggering the changes of price. Generally speaking, information flow includes very diversified pieces of information from general public announcements to private information available only for insider traders. Direct modeling of information flow is rather difficult and so researchers look for different proxies for it. The most known of them is volume but there is a general agreement that it is too noisy to give a proper picture of the intensity of information flow (Dacorogna *et al.*, 2001). Other possible information substitutes are volatility and price duration, i.e. the length of time interval between two changes of price.

In the paper we investigate the connections between the possible proxies of information process: volume, duration and return, and try to answer the question about the variable which is the most important factor in the process of discovering information by uninformed traders. We are especially interested in how the dynamics of these variables differs when we take into consideration equities of small or large companies.

Our investigation is performed for four selected equities from the Warsaw Stock Exchange (large: Agora and Pekao, and small: ELZAB and Wandalex)

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and based on irregularly spaced high frequency data. We consider the dynamics of the asset returns and the change of volume corresponding to the duration, and ask about the connection between the intensity of information flow and the dynamics of price. Our tools are autoregressive conditional duration model (ACD) (Engle and Russell, 1998), autoregressive conditional volume model (ACV) (Manganelli, 2005), and GARCH models .

2. Theoretical Market Microstructure Models

Market microstructure effects are connected with all the reality of trade. To the most important factors of market microstructure one can count market liquidity, nonsynchronous trade, bid-ask spread, discrete-valued price, irregular time intervals between trades, and the existence of diurnal pattern (Tsay, 2000). Many of the market microstructure models trying to describe a complex reality of trade emphasize the role of access to information.

One of the important questions concerning market microstructure is how information is disclosed by investors and how it affects volume and prices. The impact of the information flow on the market dynamics can be diverse and, according to the market microstructure theories, depends mainly on the behavior of informed and uninformed traders. There exist many papers suggesting theoretical microstructure models allowing for explaining the connection between prices, volume, and information process. The basic framework for such research was suggested by Bagehot (1971) who assumes that there exist two types of traders, informed and uninformed, and that informed traders try to use their informational advantage to obtain an extra profit. In the depiction of Copeland and Galai (1983) or Glosten and Milgram (1985), uninformed traders try to discover unpublic information observing the price process. Later papers (Karpoff, 1987; Easley and O'Hara 1987, 1992 and Blume, Easley and O'Hara, 1994) emphasize the role of volume in the process of hidden information disclosing. Admati and Pfleiderer (1988) point more sources of information which can be used by uninformed traders: volume, bid/ask spread, price duration and volatility.

If informed traders trade only when they obtain new information that affects the asset price, then no trade means no new information (Easley and O'Hara, 1987). Thus, according to their approach, long duration should be associated with low values of returns and low volatility. On the other hand, in a model of Diamand and Varrecchia (1987) no trades means bad news. It is possible, however, that information-based trading will discourage uninformed traders from trading. In such a situation, long duration will be associated with high volatility (Admati and Pfleiderer, 1988).

According to the approach of Admati and Pfleiderer (1988), the analysis of dependencies between returns, changes of volume and durations can cast light on the nature of traders and the way the uninformed traders discover private information exploited by informed traders. For example, a strong positive autocorrelation in volume data indicates the significant role of uninformed traders in the stock market. They observe the behavior of informed traders and imitate their decisions with some delay. It makes the volume data being strongly autocorrelated.

3. Models

In the presented analysis our main tools are the autoregressive conditional duration (ACD) model introduced by Engle and Russell (1998) to describe the dynamics of the conditional expected duration of the stock price, the autoregressive conditional volume (ACV) model suggested by Manganelli (2005), and GARCH models (Bollerslev, 1986).

Let $\theta_1, \theta_2, \ldots, \theta_n, \ldots$ be a sequence of the consecutive moments of price changes and let $d_t = \theta_t - \theta_{t-1}$ denotes the length of interval between two changes which we call duration (waiting time). The expectation of the *t*-th duration under the information about the duration process up to moment θ_{t-1} is given by $\psi_t = E(d_t \mid d_{t-1}, d_{t-2}, \ldots d_1)$.

The ACD class of models (Engle and Russell, 1998) describe the dynamics of expected duration $\psi_t = \psi_t(d_{t-1}, d_{t-2}, \ldots d_1; \vartheta)$, where ϑ is a parameter vector. The idea of the model specification is based on the observation that the time series of price duration exhibit the same properties as the series of price volatility. They contain the successive clusters of high and low values, and show strong autocorrelation. The specification of the ACD(1,1) model that we use in this paper is based on the assumption that

$$d_t = \psi_t \xi_t \ , \tag{1}$$

where $\xi_t \sim \text{iid}$ with a Weibull distribution with mean equal to 1, and the dynamics of the conditional expected duration ψ_t is described by the formula

$$\psi_t = \omega + \alpha d_{t-1} + \beta \psi_{t-1}, \tag{2}$$

where $\omega > 0$, $\alpha \geq 0$, $\beta \geq 0$. In such situation, under the condition $1 - \alpha - \beta > 0$, the unconditional mean duration exists and it is given by

$$E(d_t) = \frac{\omega}{1 - \alpha - \beta}.$$

It is easy to see that the idea of the ACD model is very similar to the GARCH construction in the sense that ψ_t is modeled in the same way as the conditional variance. This analogy can be justified by the observation that the dynamics of the both mentioned above processes can be considered as a result of the impact of the information flow. The volatility clusters and the clusters of low and high values of duration reflect the changes in the intensity of the information flow. The same statement is true for volume and so the same idea can be used to describe the dynamics of expected volume. The construction of ACV(1,1) model introduced by Manganelli (2005) and given by formulas (3)-(4) is very similar to that of ACD(1,1) model with the observed volume (corresponding to the period of duration) w_t and the expected volume v_t instead of the duration d_t and expected duration ψ_t, respectively. Thus

$$w_t = v_t \eta_t , \tag{3}$$

where $\eta_t \sim$ iid with a Weibull distribution and

$$v_t = \omega + \alpha w_{t-1} + \beta v_{t-1} . \tag{4}$$

Because of similarity to GARCH models, the ACD and ACV models can be estimated with GARCH software after necessary modifications (Engle and Russell, 1998; Manganelli, 2005).

4. The Data

The analysis is based on the tick-by-tick quotations of four companies listed on the WSE. The period under scrutiny is from May 4, 2006 to April 14, 2007. Transaction time is measured exactly to the second. The time between the end of the session and the beginning of the next day session is assumed to be equal to zero. This solution is one of many possible but it is frequently applied. We calculate percentage logarithmic returns corresponding to the durations (length of the period during which the price stays constant). The volumes of transactions made at the same price are summed up. In the case of transactions with different prices and the same time, the price of transaction is calculated as a volume-weighted average. The reduction in number of observations after calculating the duration corresponding returns is shown in Table 1. The differences in the analyzed stocks liquidity can easily be seen. There exists strong hourly seasonality in duration data. Following Engle and Russell (1998), we remove it simply by dividing the duration and volume by the mean corresponding to the trading hour, and the return by hourly mean of its absolute value.

Table 1. Number of observations

Company	AGORA	PEKAO	ELZAB	WANDALEX
Number of the tick-by-tick returns	84817	105945	9882	9126
Number of the duration corresponding returns	28745	25374	3868	3374

5. Empirical Results

The analysis presented in this section follows the ideas presented in (Manganelli, 2005). To obtain the information about the dependencies between the returns, volume, volatility and duration we estimate ACV model, ACD model, AR(1)-GARCH(1,1) model with duration and volume as additional variables (see formulas (5)-(7)), and two regressions given by formulas (8) and (9):

$$r_t = a_0 + a_1 r_{t-1} + b_1 d_{t-1} + b_2 w_{t-1} + c y_{t-1} + y_t , \quad (5)$$

$$y_t = \sigma_t \varepsilon_t , \quad (6)$$

$$\sigma_t^2 = \omega + \alpha_1 y_{t-1}^2 + \beta_1 \sigma_{t-1}^2 + \rho_1 d_{t-1} + \rho_2 w_{t-1} , \quad (7)$$

$$\psi_t = p_0 + p_1 \psi_{t-1} + p_2 d_{t-1} + p_3 w_{t-1} + p_4 y_{t-1}^2 + \varepsilon_t^{\psi} , \quad (8)$$

$$v_t = q_0 + q_1 v_{t-1} + q_2 d_{t-1} + q_3 w_{t-1} + q_4 y_{t-1}^2 + \varepsilon_t^{v} . \quad (9)$$

There are quite strong assumptions needed to justify such approach. We do not present them because of the lack of space, but the details can be found in (Manganelli, 2005).

The results of estimation are presented in Tables 2-7. As concerns the ACD models, we can notice significant differences in the duration dynamics depending on liquidity of the stocks. In the case of Agora and Pekao, the unconditional duration is much higher than it is for the two smaller companies. High values of beta indicate strong persistence in duration. The estimation results for Wandalex data are not satisfying.

Table 2. Parameter estimates of the fitted ACD models

Parameter	AGORA	PEKAO	ELZAB	WANDALEX
ω	**0.0149** (0.0040)	**0.0385** (0.0055)	**0.0025** (0.0001)	0.0058 (7.2434)
α	**0.1197** (0.0085)	**0.1247** (0.0095)	**0.0840** (0.0174)	0.1477 (46.0629)
β	**0.8706** (0.0100)	**0.8388** (0.0139)	**0.9060** (0.0168)	0.8323 (11.7405)
γ	**0.7946** (0.0100)	**0.7979** (0.0040)	**0.7617** (0.0099)	0.7551 (7.0205)

Looking at the estimation results of the ACV models (Table 3), we can see high values of beta (apart from Wandalex), which point out the high persistence in volume data and, according to Admati and Pfleiderer (1988), it could indicate high level of activity of uninformed traders. Such behavior is typical for the stocks of rather large companies, so it is rather strange in the case of ELZAB. Low values for the parameter gamma characterizing the Weibull distribution indicate large amount of outliers in the analyzed time series.

Looking at the parameter estimates for AR(1)-GARCH(1,1) model (Table 3 and 4), one can notice significant negative impact of duration on the return, which is in accordance with the “no trade – bad news” relationship (Easley and O’Hara, 1987). Next, in the volatility equation (Table 4) one can observe a significant negative impact of duration and a positive of volume on the volatility for liquid stocks. It is in agreement with known theoretical results. The estimates of the parameter α indicating the importance of the information about new returns are almost equal in all cases. The results we obtained for small companies are different from those for the large and do not fit to the theory.

Table 3. Parameter estimates of the fitted ACV models

Parametr	AGORA	PEKAO	ELZAB	WANDALEX
ω	0.0368 (0.0197)	**0.0317** (0.0146)	**0.0133** (0.0070)	**0.1920** (0.0492)
α	**0.0437** (0.0154)	**0.0482** (0.0163)	**0.0358** (0.0104)	**0.1325** (0.0382)
β	**0.9088** (0.0392)	**0.9193** (0.0304)	**0.9500** (0.0165)	**0.6256** (0.0872)
γ	**0.5788** (0.0050)	**0.5261** (0.0033)	**0.7599** (0.0101)	**0.6094** (0.0086)

Table 4. Parameter estimates of the fitted AR(1)-GARCH(1,1) models (equation 5)

Parameter	a_0	a_1	b_1	b_2	c
AGORA		**-0.4012** (0.0189)	-0.0010 (0.0019)	**0.0080** (0.0009)	**0.0781** (0.0173)
PEKAO		**-0.4583** (0.0111)	-0.0015 (0.0026)	0.0020 (0.0016)	
ELZAB	0.0020 (0.0166)	**-0.1920** (0.0578)	**-0.0388** (0.0104)	**0.0217** (0.0056)	**0.1837** (0.0584)
WANDALEX	0.0246 (0.0157)	**-0.2316** (0.0477)	**-0.0316** (0.0110)	**0.0236** (0.0093)	**0.1717** (0.0473)

Table 5. Parameter estimates of the fitted AR(1)-GARCH(1,1) models (equation 6)

Parametr	ω	α_1	β_1	ρ_1	ρ_2	DF
AGORA	**0.0331** (0.0039)	**0.2546** (0.0151)	**0.7127** (0.0118)	**-0.0026** (0.0014)	**0.0110** (0.0014)	**6.5**
PEKAO	**0.0238** (0.0038)	**0.2747** (0.0176)	**0.7124** (0.0157)	**-0.0021** (0.0003)	**0.0123** (0.0036)	**8.2**
ELZAB	**0.2078** (0.0643)	**0.2613** (0.0529)	**0.6368** (0.0789)	0.0225 (0.0128)	**-0.0305** (0.0046)	**5.4**
WANDALEX	**0.2314** (0.0909)	**0.2473** (0.0365)	**0.7348** (0.0357)	**0.0505** (0.0148)	0.0104 (0.0089)	**7**

The results obtained for the expected duration equation are not in agreement with the market microstructure theory (apart from Agora). The volumes impact on expected duration is insignificant for Pekao, ELZAB and Wandalex. In the case of Agora, one can notice a negative impact of volume on expected duration, which stays in accordance with the theoretical results. The almost equal values of the parameter p_1 estimates show that the expectations concerning duration are independent on the size and liquidity of company. The results for expected volume (Table 7) show the similar level of the expectations persistency in each case. The impact of volatility on volume is not observed. This indicates the high number of informed traders in the market.

Table 6. Parameter estimates of the fitted models (equation 8)

Parametr	p_0	p_1	p_2	p_3	p_4
AGORA	**0.4909** (0.0040)	**0.3039** (0.0033)	**0.1920** (0.0018)	0.0001 (0.0002)	**-0.0045** (0.0008)
PEKAO	**0.5336** (0.0044)	**0.3039** (0.0034)	**0.1708** (0.0029)	0.0007 (0.005)	0
ELZAB	**0.4337** (0.0164)	**0.3019** (0.0097)	**0.2274** (0.0074)	0.0004 (0.0032)	**-0.0065** (0.0017)
WANDALEX	**0.4522** (0.0137)	**0.3018** (0.0095)	**0.2454** (0.0090)	0.0013 (0.0035)	**0.0159** (0.0031)

Table 7. Parameter estimates of the fitted models (equation 9)

Parametr	q_0	q_1	q_2	q_3	q_4
AGORA	**0.5609** (0.0047)	**0.3039** (0.0036)	**0.0063** (0.0019)	**0.0484** (0.0022)	-0.0004 (0.0003)
PEKAO	**0.6243** (0.0050)	**0.3037** (0.0039)	**0.0123** (0.0015)	**0.0534** (0.0024)	0
ELZAB	**0.5826** (0.0100)	**0.3018** (0.0105)	**0.0037** (0.0017)	**0.0600** (0.0024)	**-0.0034** (0.0010)
WANDALEX	**0.4470** (0.0051)	**0.3023** (0.0056)	**0.0037** (0.0016)	**0.1358** (0.0010)	0.0002 (0.0006)

6. Conclusions

One of the most important questions of market microstructure theory is about the way in which information is disclosed and how it affects volume and prices. The impact of the information flow on the market dynamics can be diverse and, according to different market microstructure theories, depends mainly on the behavior of informed and uninformed traders. Direct modeling of information flow is very laborious, so different proxies for it are used in empirical investigations. The most popular are volume, volatility, and duration, i.e. length of the period during which the price stays constant.

In the paper we analyze the interdependencies between the possible proxies of information process: volume, duration and return, and try to answer the questions how uninformed traders discover hidden private information by observing the market behavior, and how significant are impacts of informed and uninformed traders on market dynamics. Moreover, we ask about the differences in the rules of discovering information when large or small companies are taken into account. We consider the dynamics of the return and the volume corresponding to the duration and ask about the connection between the intensity of information flow and the dynamics of price. Our investigation is performed for four selected equities from the Warsaw Stock Exchange, two large and liquid: Agora and Pekao, and two small and illiquid: ELZAB and Wandalex, and based on irregularly spaced high frequency data.

Our results point out that, at the WSE, volume does not influence significantly future returns and its impact on duration is ambiguous. For liquid stocks of large companies one can observe a significant negative impact of duration and a positive impact of volume on volatility. The dynamics of duration depends first of all on the size of the company. Moreover, duration turns out to be not important in process of discovering information by market. The traders do not draw conclusions from the changes of duration. It is likely to be connected with still low liquidity at the WSE. Our results show that the uninformed traders trade actively only on liquid companies and that impact of the informed traders on the trade at the WSE remains dominant.

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