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INFORMATION ASYMMETRY, LIQUIDITY AND THE DYNAMIC VOLUME-RETURN RELATION IN PANEL DATA ANALYSIS

ASYMETRIA INFORMACYJNA, PŁYNNOŚĆ I ANALIZA PANELOWA DYNAMICZNEJ RELACJI POMIĘDZY WIELKOŚCIĄ OBROTU A STOPAMI ZWROTU

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Abstract: In the paper we investigate the dynamic relation between returns and volume of individual stocks traded on the Warsaw Stock Exchange. Theoretical models suggest that this relation reveals the information asymmetry in the market and the role of private information. Unlike other works, we use dynamic regression to obtain the coefficients for 52 stocks, assuming that coefficients for individual stock can vary from month to month. Then we use panel regression with random effects to test the relationship between coefficient of information asymmetry and liquidity. We find an evidence supporting the compliance of measure of information asymmetry, especially for medium and small capitalization companies.

Keywords: information asymmetry, liquidity, stocks, panel regression.

Streszczenie: W artykule zbadano dynamiczną zależność pomiędzy zwrotami i wolumenem poszczególnych akcji z Giełdy Papierów Wartościowych w Warszawie. Modele teoretyczne sugerują, że relacja ta ujawnia asymetrię informacji na rynku i rolę informacji prywatnej. W przeciwieństwie do innych prac, w artykule użyto regresji dynamicznej do uzyskania współczynników dla 52 akcji, przy założeniu, że współczynniki dla poszczególnych z nich mogą się zmieniać z miesiąca na miesiąc. Zastosowano regresję panelową z efektami losowymi w celu przetestowania zależności między współczynnikiem asymetrii informacji a płynnością. Wyniki badań potwierdzają zgodność miary asymetrii informacji, szczególnie w przypadku spółek o średniej i małej kapitalizacji.

Słowa kluczowe: asymetria informacyjna, płynność, akcje, regresja panelowa.

1. Introduction

Research on asymmetry of information on the capital market plays a significant role in the modern finance. Asymmetry of information is important in the investment decision-making process. The paper by Llorente et al. [2002] presents a dynamic model whose parameter describes information asymmetry. In addition, the authors present a relationship between the proposed measure of asymmetry of information and the approximation of information asymmetry, such as bid-ask spread or capitalization. As the authors note, it is also possible to investigate whether there is a relationship between the proposed measure of asymmetry of information and other measures of asymmetry.

Asymmetric information is inextricably linked to liquidity risk. The work of Bagehot [1971], where liquidity in securities was modelled with a bid-ask spread, was significant. Since this work, a number of proposals have been made in the literature to measure liquidity risk, but no satisfactory consensus has been found. It is considered that the most important liquidity measures are bid-ask spread [Copeland 1979; Amihud, Mendelson 1986; Stoll 1989; Hasbrouck, Seppi 2001] or volume size [Datar et al. 1998; Antoniewicz 1993; Stickel, Verrecchia 1994; Blume et al. 1994]. One of the most popular measures is illiquidity measure of Amihud [2002]. Lesmond, Odgen and Trzcinka [1999] proposed a liquidity measure based on the difference between the cost of buying and selling shares. The LOT measure (from the authors' names) represents the influence of private information on the transaction. As a result of various approaches to measuring liquidity, it is difficult to answer the question of how coherent the measures proposed are and to what extent they reflect unobservable liquidity [Liu 2006].

According to the methodology included in Llorente et al. [2002], the article examined the relationship between the measure of asymmetry of information formulated thereof and liquidity measures such as the bid-ask spread, LOT or Amihud's illiquidity measure. It was noted that as in [Amihud 2002], the information asymmetry is related to the size of the company measured by capitalization. For large capitalization companies there is no correlation between the asymmetry of information and the measures of liquidity, as opposed to the companies with medium and small capitalization. Based on the panel data, however, there are periods in which the surveyed relation was observed for all companies, regardless of the company capitalization. This suggests changes in the dynamics of information asymmetry over time.

The article consists of five sections. The original model was presented in the second section. The third section briefly discusses the liquidity measures used here. The fourth section contains the description of the data. The results of empirical research and the conclusions are presented in the fifth section.

2. The model

To evaluate the degree of information asymmetry for individual stocks we applied theoretical framework used in [Llorente et al. 2002]. It is a simplified version of an equilibrium representative-agent model of financial market developed by Wang

[1994]. Here we present a brief description of their model and its empirical conclusions.

Llorente et al. [2002] assume that there are two types of investors. The first group consists of informed investors and the second group consists of uninformed ones. Investors from each group try to maximize their expected utility and all have the same constant absolute risk aversion utility function (CARA):

$$u(W) = -e^{-\gamma W}, \tag{1}$$

where W is the investor's wealth and γ is the reciprocal of absolute risk aversion. The fractions of informed and uninformed investors are ω and $1-\omega$, respectively. In the market there are two types of securities: a bond and a stock. Investments in bonds are risk-free and bring constant, nonnegative rate. The stock at each moment t pays a dividend D_t, which consists of two components: forecastable F_{t-1} and unforecastable one, G_{t-1}:

$$D_t = F_{t-1} + G_{t-1}. \tag{2}$$

The F_{t-1} and G_{t-1} are normally distributed with zero mean and variances σ_F^2 and σ_G^2 respectively. Thus, the σ_G^2 can be seen as a measure of information asymmetry in the market. All investors at any moment t can observe current dividends D_t and forecastable part of next-period dividends F_t. Informed investors know also the unforecastable part of dividends in the next period, G_t. The stock is traded in the market and at the moment t its price is P_t. Investments in stock bring profits in form of dividends and due to the changes of its price. The return on one stock (measured in monetary units) in the period from $t-1$ to t is given by:

$$R_t = D_t + P_t - P_{t-1}. \tag{3}$$

The informed investors also have a possibility to invest in a risky production technology. The rights to a flow of income from this technology are a non-tradable asset. At each moment the investors decide how much of their wealth they are willing to allocate to this asset. The return from a monetary unit of investment in the subsequent period is N_{t+1} – a normally distributed random variable with zero mean and variance equal to σ_N^2.

All investors have information about current prices of assets, current dividends and forecastable part of future dividends. Informed investors have also information about unforecastable part of future dividends. Therefore, for them investment in stock and riskless bond are equivalent. Their effective choice is to allocate wealth between stock (or bond) and private investment in the production technology. The uninformed investors allocate their means between the bond and the risky stock.

Since all investors within the same group share the same information and attitude toward risk, trading in stocks is possible only between the informed and uninformed investors.

Investors from different groups have different motives for trading. The uninformed investors react to public information – the predictable part of future dividends, F_{t-1}. They try to adjust their portfolio to preserve optimal risk profile. The trade generated by this motive is called hedging trade. On the other hand, the informed investors react to private information, G_{t-1}. They speculate on news concerning future dividends. Trade generated by informed investors is referred to as speculative trade.

These two kinds of trade differently influence autocorrelation of stock's returns. If there is no information asymmetry ($\sigma_G^2 = 0$) and there are no good or bad news, then stock returns are not serially correlated. In case of hedging trade there is a negative autocorrelation of returns. Let us assume, for example, that good news was revealed about future dividends. Uniformed investors reallocate their portfolios buying more stock and in order to make a transaction they have to offer a higher price. The return in this period is thus higher. Since public signals concerning future dividends are not serially correlated, it is likely that in the next period return will be lower, which decreases autocorrelation of returns.

On the other hand, let us consider the situation in which good news about the future dividends are revealed only to informed investors ($G_{t-1} > 0$). In this case the speculative trade, initiated by the informed group, takes place. Again, to buy the stock they have to propose a higher price, so in this period the return is higher. In the next period the good news is revealed to all investors (the higher dividends are paid), which increases the return in this period. The autocorrelation of returns tends to increase.

As the trade is possible only between the two groups of investors, it can be shown that in equilibrium the volume of trade, V_t, is given by the changes in total stock holdings of either class:

$$V_t = \omega \left| X_t^I - X_{t-1}^I \right| = (1-\omega) \left| X_t^U - X_{t-1}^U \right|, \tag{4}$$

where X_t^I and X_t^U is the number of stocks held by the informed or uninformed investors, respectively.

It can be shown that in the equilibrium, the expected return of stock conditioned on current return and volume of trade is given by the following formula:

$$E[R_{t+1} \mid R_t, V_t] = -\beta_1 R_t - \beta_2 \widetilde{V}_t \tanh\left(\eta \widetilde{V}_t R_t\right), \tag{5}$$

where $\widetilde{V}_t = V_t / E[V_t]$ and β_1, β_2, $\eta \geq 0$ are constants. When the volume and return are small, one can use the following approximation:

$$E\left[R_{t+1} \mid R_t, V_t\right] = -\left(\theta_1 + \theta_2 \widetilde{V}_t^2\right) R_t + o(\widetilde{V}_t^2, R_t) , \tag{6}$$

where:

$$\theta_1 = \frac{\omega \sigma_G^2}{2\sigma_D^2} , \qquad \theta_2 = \frac{\sigma_{\widetilde{P}}^2}{\pi \sigma_D^2} \left[1 - \omega \left(\frac{1}{\sigma_D^2} + \frac{3}{\sigma_{\widetilde{P}}^2} \sigma_G^2 \right) \right] + o(\sigma_G^2) . \tag{7}$$

The parameter $\sigma_{\widetilde{P}}^2$ is the variance of stock prices corrected for the forecastable part of dividends ($\widetilde{P}_t = P_t - F_t$) and σ_D^2 is the variance of dividends. In the absence of information asymmetry $\theta_1 = 0$ and $\theta_2 > 0$ – the autocorrelation appears only if the trade motivated by hedging purposes takes place, and the autocorrelation is negative for the reasons specified earlier. If the information asymmetry exists ($\sigma_G^2 > 0$), then θ_1 is positive and increases with σ_G^2 while θ_2 decreases with information asymmetry measured by σ_G^2.

For $\sigma_G^2 > 0$ a positive value of θ_1 means that returns with no volume tend to reverse – in the next period the tendency will be opposite, which is consistent with the rules of risk allocation of representative agent. The parameter θ_2 measures the autocorrelation of returns conditioned on the volume. As it was indicated earlier, the sign of this parameter depends on the motive of trading. Hedge trade involves negative autocorrelation of returns, while speculation trade works in the opposite way.

The equation (6) leads to an empirical equation allowing to test the model and to measure the degree of information asymmetry for different assets (if the model is valid). This is commonly measured by the following linear regression model:

$$R_{it+1} = \alpha_{i0} + \alpha_{i1} R_{it} + \alpha_{i2} R_{it} V_{it} + \varepsilon_{it+1} \tag{8}$$

where R_{it} is the company's i stock return at the moment t, V_{it} is the logarithm of trade volume (empirically, usually trade turnover is used here as an empirical counterpart) of stocks at the moment t, and ε_{it+1} is random error.

The empirical model given by eq. (8) is usually used to measure information asymmetry for individual stocks. In Llorente et al. [2002], Sun et al. [2014] or Su and Huang [2004] the regression equation (8) was estimated for each stock individually, giving the asymmetry measure α_{i2} for individual stock i. In Hasbrouck [1991] the empirical model was developed more intuitively, without developing any theoretical model of trade. In this research we assume that information asymmetry can change dynamically. To measure it we used a dynamic regression. The parameters α_{i0}, α_{i1} and α_{i2} are assumed to change dynamically and the changes can be described by the following state-space model:

$$\alpha_{ijt} = \alpha_{ijt-1} + \eta_{ijt}, \tag{9}$$

where i is the index of considered company, j is the index of parameters in eq. (8) ($j = 0,1,2$). The random variable η_{ijt} describes random changes in the parameters α_{ij}. The model given by eq. (8) and (9) is a state-space model of dynamic regression and the parameters α_{ijt} can be estimated using Kalman filtering and smoothing[1]. In the state-space representation the model (8)-(9) has the following form. The state variable is the vector θ_t of coefficients in the eq. (8): $\theta_t = (\alpha_{0t}, \alpha_{1t}, \alpha_{2t})^T$ (for clarity of notation from here on we omit the index i since the model is estimated for each stock independently). The dynamic of the state variable (unobserved) is given by the system equation:

$$\theta_t = G_t\theta_{t-1} + \eta_t, \tag{10}$$

where the transformation matrices G_t are in our case identity matrices: $G_t = I$. The measurement (observed) variable y is return on asset, $y_t = R_t$, and the measurement equation is given by:

$$y_t = F_t\theta_t + \varepsilon_t, \tag{11}$$

where $H_t = (1, R_{t-1}, V_{t-1}R_{t-1})$. The values of state (unobserved) variables $\theta_t = (\alpha_{0t}, \alpha_{1t}, \alpha_{2t})^T$ in the state-space model (10)-(11) were estimated using Kalman smoothing, i.e. considering all values of observed variables: before and after moment t. The estimators obtained by Kalman smoothing are conditional expectations of state variables provided all values of the measurement variables in the linear state-space model (10)-(11)[2]. For the purpose of this research we are interested only in the parameter α_{2t}, which we take as a measure of information asymmetry for the stock at the moment t.

3. Liquidity measures

As mentioned earlier, the article examines the relationship between the asymmetric measure of information represented by the α_{i2t} parameter and the liquidity measures of the stock. We hypothesized, according to Proposition 3 in Llorente et al. [2002], that between the measures of liquidity and α_{i2t} there should be a relation given by the formula:

$$\alpha_{i2t} = f(A_{it}), \tag{12}$$

where A_{it} is a measure of liquidity. We choose bid-ask spread, LOT and Amihud's measure of illiquidity.

[1] See for example Petris et al. [2009] Chapter 2 or Cowpertwait and Metcalfe [2009], Chapter 12.
[2] See Lütkepohl [2005, p. 630].

The size of the daily bid-ask spread was calculated according to the Warsaw Stock Exchange methodology with the formula:

$$S(t)_i = \left|\frac{p_{ti} - m_{ti}}{m_i}\right|, \tag{13}$$

$$m_{ti} = \frac{bid_{ti} + ask_{ti}}{2} \tag{14}$$

and

$$S_i = \frac{\sum_{t=1}^{n}\left(V_{ti} \cdot S_i(t)\right)}{V}, \tag{15}$$

where p_i is the price of stock *i*, m_{ti} is midpoint of *bid* and *ask* price, $S_i(t)$ is temporary spread at time *t*, V_{ti} is the volume turnover of transaction at time *t*, V is total daily turnover for the instrument and S_i is daily bid-ask spread. To study the relation with the asymmetry of information we used the monthly average of the daily value of the spread as an independent variable.

The second measure of liquidity is the spread between the transaction costs incurred by the buyer and the transaction costs incurred by the seller:

$$LOT = a_{2,k} - a_{1,k}. \tag{16}$$

In the LOT model, an investor with additional information will make a transaction as long as the expected profit exceeds transaction costs. Investors who have additional information make a sale after the appearance of negative information, and purchase transactions upon the appearance of good information. Model LOT is therefore defined by a set of conditions:

$$R^*_{k,t} = \beta_k R_{M\,t} + \varepsilon_{k,t}, \tag{17}$$

where $R_{M\,t}$ is market return at time *t*:

$$R_{k,t} = \begin{cases} R^*_{k,t} - a_{1,k} & \text{if} \quad R^*_{k,t} < a_{1,k}, \\ 0 & \text{if} \quad a_{1,k} \le R^*_{k,t} \le a_{2,k}, \\ R^*_{k,t} - a_{2,k} & \text{if} \quad R^*_{k,t} > a_{2,k}, \end{cases} \tag{18}$$

(with $\alpha_{1,k} < 0 < \alpha_{2,k}$) the parameters of which can be estimated based on the likelihood function.

Third measure of liquidity is the illiquidity of shares based on the daily quotation, calculated according to the formula:

$$ILLIQ_{iy} = \frac{1}{D_{iy}} \cdot \sum_{d=1}^{D_{iy}} \frac{|R_{iyd}|}{DVOL_{iyd}}, \tag{19}$$

where D_{iy} is a number of days at period y, for which we have quotation for stock *i*, R_{iyd} is the daily return of stock *i*, $DVOL_{iyd}$ is the daily volume turnover of transaction of stock *i*, at day *d* of period *y*.

4. Data

The sample consists of the stocks traded on the Warsaw Stock Exchange. We obtained data on daily returns, prices, volumes, turnover and intraday (tick-by-tick) data on prices and volumes. The sample period is 02-01-2006 to 29-12-2016. During the sample period all data was available for the selected 52 stocks. The main

Table 1. Summary statistics of the data

Entire sample	Returns	Monthly volume (1000)	Monthly turnover (million PLN)	Capitalization (million PLN)
Mean	0.0041	6178.66	146.05	1014
Median	0.0012	671.96	10.41	288
Std. Dev.	0.1288	16832.61	433.35	1924
Min	–1.0251	0.3790	0.01	3
Max	1.3077	213341.99	4801.16	8247
N	6864	6864	6864	52
Big cap				
Mean	0.0078	13062.66	435.66	2926
Median	0.0058	1725.70	98.09	1529
Std. Dev.	0.1057	26380.55	696.56	2626
Min	–0.5681	0.3790	0.16	662
Max	0.6333	213341.99	4801.16	8247
N	2112	2112	2112	16
Medium cap				
Mean	0.0072	4306.17	23.54	265
Median	0.0049	524.83	9.11	274
Std. Dev.	0.1189	10450.49	51.61	116
Min	–0.8665	1.1410	0.14	114
Max	0.8536	162701.83	878.62	485
N	2772	2772	2772	21
Small cap				
Mean	–0.0043	1457.19	8.65	21
Median	–0.0113	379.80	2.28	17
Std. Dev.	0.1603	3086.44	23.36	14
Min	–1.0251	0.4380	0.01	3
Max	1.3077	55058.04	345.26	48
N	1980	1980	1980	15

Source: own study.

characteristics of the data in the entire sample and in all three subsamples are presented in Table 1.

To estimate the dynamic linear regression model (8)-(9) we used the data concerning monthly returns (R_{it}) and the logarithms of monthly turnover (V_{it}). The regression was estimated for each stock in the sample separately. Usually, in this kind of research the data on turnover is de-trended to make it stationary. However, in our research, based on monthly data, there was no such necessity. The Phillips--Perron unit root test revealed that only in one case one cannot reject the hypothesis of non-stationarity.

On the basis of the intraday data we calculated all asymmetry information and liquidity measures for separated monthly periods. Finally, data for each variable was a panel of 132 monthly observations grouped in 52 time series. The entire sample was divided into three groups of companies according to the market capitalization.

5. Empirical results

Shares of listed companies may be characterized by a different degree of reaction of the information asymmetry meter due to the degree of liquidity. However, if the proposed information asymmetry measure is correctly defined, the reaction should be similar due to the common group effects. In addition, there are possible differences in the defined dependence (12) due to the changes in capital markets at different time periods. However, we assume the occurrence of common time effects, due to similar changes in time of both liquidity and information asymmetry measures. That is why we decided to test the appropriateness of using a panel model for empirical data.

Table 2 summarizes the results of Breusch and Pagan test, based on which it can be stated that there are panel effects in the data (null hypothesis of the test is that variances across entities are zero). This is true for all three liquidity proxies. The results of the test indicate that using panel approach to the data can improve efficiency of the estimators.

Table 2. Breusch and Pagan Lagrangian multiplier test for random effects

	Bid-ask spread as a proxy for liquidity	LOT as a proxy for liquidity	ILLIQ as a proxy for liquidity
chibar2(01) =	5507.58	5153.03	5061.96
Prob > chibar2 =	0.0000	0.0000	0.0000

Source: own study.

To decide between fixed or random effect we run a Hausman test where the null hypothesis is that the preferred model is random effects vs. the alternative the fixed effects. The results of the test are presented in the Table 3. For all three cases we have no reason to reject the null hypothesis, so for the estimation we choose a model with random effects.

Table 3. Hausman test for random effects vs. fixed effects

	Bid-ask spread as proxy for liquidity	LOT as a proxy for liquidity	ILLIQ as a proxy for liquidity
$chi^2(01) =$ $(b-B)'[(V_b-V_B)^{-1}](b-B)=$	1.76	0.72	0.24
Prob > chi^2 =	0.1845	0.3958	0.6234

Source: own study.

On the basis on the results of Breusch and Pagan test and Hausman test we choose a panel data model with random effects:

$$y_{it} = B_0 + b_A A_{it} + u_{it}$$
$$u_{it} = \varepsilon_{it} + \alpha_i + \lambda_t \quad , i=1,...,N, t = 1,...,T, \tag{20}$$

where α_i – is individual effect and λ_t – is time effect, $\varepsilon_{it} \sim N(0,\sigma^2)$.

Table 4 lists the models for all three liquidity proxies. Only in the case of ILLIQ given by equation (17) we can confirm a significant relation with α_{i2t}. As expected, the increase in the lack of illiquidity measured by the ILLIQ variable results in a decrease in asymmetry of information. Tables 5-7 show the results of model estimation for companies with different capitalization. In the case of large companies failed to confirm the relationship in any case examined. By contrast, for medium and small companies in two out of three cases, the relationship has been confirmed. For statistically significant parameters, asymmetry of information should increase with the increase in liquidity risk – which was confirmed in one case for medium companies and one case for small companies.

Table 4. Panel data random effects model, all companies

		Bid-ask spread as a proxy for liquidity	LOT as a proxy for liquidity	ILLIQ as a proxy for liquidity
Coefficients (p value)	b_A	0.1274569 (0.898)	–0.1453299 (0.375)	–0.0014264 (0.019)
	B_0	–0.0612758 (0.072)	–0.0634183 (0.046)	–0.0632445 (0.045)
R^2 within =		0.0000	0.0001	0.0007
R^2 between =		0.0340	0.0120	0.0130
R^2 overall =		0.0016	0.0000	0.0017
rho (fraction of variance due to u_i)		0.11863759	0.1098748	0.1098361

Note: b_0 is constant and b_A is the coefficient of the proxy for liquidity; u_i is between entity error.

Source: own study.

Table 5. Panel data random effects model, big companies (capitalization > 500 million euro)

		Bid-ask spread as a proxy for liquidity	LOT as a proxy for liquidity	ILLIQ as a proxy for liquidity
Coefficients (p value)	b_A	–0.4959594 (0.943)	–0.792793 (0.566)	0.0780211 (0.363)
	B_0	0.0366397 (0.670)	0.015783 (0.833)	–0.0072199 (0.922)
R^2 within =		0.0000	0.0004	0.0005
R^2 between =		0.0522	0.1028	0.0112
R^2 overall =		0.0015	0.0012	0.0000
rho (fraction of variance due to u_i)		0.07059424	0.06560153	0.07250222

Note: b_0 is constant and b_A is the coefficient of the proxy for liquidity; u_i is between entity error.

Source: own study.

Table 6. Panel data random effects model, medium companies (capitalization > 100 million euro)

		Bid-ask spread as a proxy for liquidity	LOT as a proxy for liquidity	ILLIQ as a proxy for liquidity
Coefficients (p value)	b_A	5.972768 (0.000)	–0.2955372 (0.015)	0.0020095 (0.150)
	B_0	–0.1124887 (0.027)	–0.0480315 (0.295)	–0.0568708 (0.248)
R^2 within =		0.0056	0.0023	0.0007
R^2 between =		0.0337	0.1454	0.0099
R^2 overall =		0.0109	0.0000	0.0012
rho (fraction of variance due to u_i)		0.24477996	0.22166141	0.24846779

Note: b_0 is constant and b_A is the coefficient of the proxy for liquidity; u_i is between entity error.

Source: own study.

Table 7. Panel data random effects model, small companies (capitalization < 100 million euro)

		Bid-ask spread as a proxy for liquidity	LOT as a proxy for liquidity	ILLIQ as a proxy for liquidity
Coefficients (p value)	b_A	–0.9958544 (0.086)	0.3392341 (0.025)	–0.0016495 (0.000)
	B_0	–0.1360963 (0.000)	–0.1648574 (0.000)	–0.1422925 (0.000)
R^2 within =		0.0018	0.0028	0.0007
R^2 between =		0.1127	0.0809	0.0130
R^2 overall =		0.0006	0.0000	0.0017
rho (fraction of variance due to u_i)		0.16286741	0.14869221	0.1098361

Note: b_0 is constant and b_A is the coefficient of the proxy for liquidity; u_i is between entity error.

Source: own study.

6. Conclusion

In conclusion, the relationship between the degree of asymmetry of information and the liquidity measures cannot be confirmed for all the companies in the study. According to the results, large capitalization companies do not show the relationship between information asymmetry and liquidity measures. Therefore, it can be stated that the model presented in [Llorente et al. 2002] is not appropriate for these companies. The reason probably lies in the small degree of information asymmetry caused by better access to information concerning these companies. In the case of companies with lower capitalization, the correlation was confirmed. Thus, on the Warsaw Stock Exchange there is a correlation between liquidity measures and asymmetry of information defined in [Llorente et al. 2002].

For models estimated for medium and small capitalization companies, not all cases have been able to achieve full compliance with the liquidity proxies used. The reason for this may be the fact that Polish stock market is not fully developed, which may result in difficulty in estimating liquidity risk. The Warsaw Stock Exchange continues to be included in emerging markets despite the fact that a significant part of the requirements for developed markets have been met.

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