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An analysis of the relationships among NASDAQ Baltic stock exchanges: VAR approach

Abstract

The author examines the relationships among three stock exchanges of selected Baltic countries: Latvia, Estonia, and Lithuania. The respective stock exchange indexes are used as variables, OMXR for Latvia, OMXT for Estonia, and OMXV for Lithuania. The regression equations are estimated with the use of Vector Autoregressive (VAR) model. The author employs 80 observations for the sample period from2002 Q1 to 2021 Q4. After determining the optimal lag order, the impulse response function is calculated. The variance decomposition is carried out subsequently. A causality among the stock exchanges in question is determined.

***JEL Classifications**: C51; C58; G17*

***Keywords**: Stock exchanges; VAR Model; Impulse Response Analysis; Variance Decomposition*

***Paper type**: Theoretical research article*

Introduction

The development of stock exchanges depends on many economic, social and political factors. These factors, to a greater or lesser extent, shape the financial markets of a given country and, consequently, also affect its stock exchanges. In today's global economy, it is all the more important as the free flow of capital allows for practically unlimited investment

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opportunities to individual and institutional investors. This also applies to stock exchanges. One of the consequences of such a turn of events are the processes of mergers and acquisitions of stock exchanges and the ongoing process of stock exchange consolidation. As a result, the development of stock exchanges as well as the capitalisation of companies listed in a given country may depend on some factors in other countries, regions or the situation on international financial markets. In other words, the relationships and dependencies among stock exchanges in different countries may deepen. Changes in the prices of shares listed on stock exchanges may be subject to fluctuations resulting not only from the situation in a domestic market, but also due to changes in the economic situation on foreign exchanges. This may indicate a link between the exchanges in the short term, long term or both. In this article, the author investigates whether there is a statistically significant relationship among the stock exchanges in selected Baltic countries (Lithuania, Latvia, Estonia) using the VAR method.

Literature Review

In the quantitative analysis of stock exchanges, the study of the determinants of their development, relationships, and the degree of integration among the analysed exchanges, authors use various methods. Some use the VAR model, which serves to study the determinants of the development of financial markets, stock exchanges, and the banking sector. The authors apply the VAR method together with a wide range of variables to determine the significance and direction of their impact on stock exchanges.

Thangavelu and Ang (2004) examine the relationship between financial development and economic growth in Australia with the use of the VAR model.They establish a causality from economic growth to the development of financial intermediaries and from financial markets to economic growth.

Caporale, Howells and Soliman (2004) conclude that well developed stock markets can foster economic growth in the long run. They employ the method of VAR and VAR causality tests. Their study refers to Argentina, Chile, Greece, Korea, Malaysia, Philippines, and Portugal. The quarterly data sample spans the period from 1977Q1 to 1998Q4. They use some sets of indicators like market capitalisation/GDP, total value of shares traded on the stock exchange/GDP, bank deposit/GDP, and the ratio of bank claims on the private sector/GDP.

The studies carried out by Rousseau and Wachtel (2000) on a group of 47 countries in the period of 1980-1995 use annual data. The application of econometric model uses short time series (5-year) and the VAR method. They employ the following set of indicators: M3/GDP, market capitalization/GDP, value traded/GDP. They confirm that there is a strong impact on the liquidity increase of stock exchanges and an increased market activity of financial intermediaries for economic growth.

Dritsaki and Dritsaki-Bargiota (2005) examine empirically the causal relationship among financial development, credit market, and economic growth in Greece. They use a trivariate autoregressive VAR model and conclude that there is a bilateral causal relationship between banking sector development and economic growth and a unidirectional causality between economic growth and stock market development in Greece in the period 1988.1-2002.12.

Shan (2005) uses a Vector Autoregression (VAR) approach with quarterly time-series data for the countries examined and utilises total credit as a proxy of financial development.He finds only weak evidence to support the hypothesis that financial development leads economic growth in 10 OECD countries and China.

Abu-Bader's and Abu-Qarn's (2008) empirical results strongly support the hypothesis that the finance-growth causality is bi-directional. Financial development causes economic growth through both increasing resources for investment and enhancing efficiency. The authors examine the causal relationship between financial development and economic growth in Egypt during the period 1960-2001 using the VAR model.

Dritsakis and Adamopoulos (2004) use a M2/gdp and trade flows (imports plus exports) as variables. They employ quarterly data from 1960:I to 2000: IV and the VAR method of estimation. They find that there is a causal relationship between financial development and economic growth, and between the degree of openness of the economy and economic growth in Greece in the given timeframe.

Caporale, Howells and Soliman (2005) confirm that investment productivity is the channel through which stock market development enhances the economic growth in the long run, especially in less-developed countries. As variables, they use gross fixed capital formation/nominal GDP, real change of GDP to the real level of total investment, the value of listed shares/GDP, and thetotal value of shares traded on the stock exchange/GDP.They employquarterly data, 1979Q1 – 1998Q4 for Chile, Korea, Malaysia, and Philippines. The method of estimation is theVAR model.

Ghirmay (2006)employs the VAR model in his research. He states that financial development affects growth through the channels of investment and its productivity in the USA. He uses productivity, investment, and financial development as a set of variables. He utilises an annual dataset for the period of 1970-2001.

Shan and Jianhong (2006) use annual data for China from 1978 to 2001. The rate of change of total credit, the rate of change of investment, trade flows/gdp, and the rate of change of labour force are variables and VAR is the method of estimation of structural parameters. They conclude that there is a bi-directional causality between financial development and economic growth in China. Financial development seems to be only the second force after labor input in contributing to economic growth in China

Theophano and Sunil (2006), using bivariate VAR models, suggest that there is a negative impact of inflation and money supply on stock returns. The study covers the period1990-1999.

Basci and Karaca (2013) examine the relationship between ISE 100 Index and a set of fourmacroeconomic variables (exchange, gold, import, export) using the Vector Autoregressive (VAR) model for Turkey. They utilise monthly data from January, 1996 to October, 2011. After running VAR, they conclude that the second default of the exchange is 31% explained by share indices.

Data and Methodology

The indexes of three NASDAQ Baltic exchanges serve as variables: OMXR for Latvia, OMXT for Estonia, and OMXV for Lithuania. They are all-share type (or broad) indexes, which means they cover all or almost all the companies listed on the respective exchanges. The author utilizes 80 observations for the sample period from 2002 Q1 to 2021 Q4. However, the final number of observations used in the model is 72 due to a data transformation applied in order to eliminate the problem of non-stationarity of variables.

The regression equations are estimated with the use of the Vector Autoregressive (VAR) model.

The regression equation can be represented in the general matrix form as follows:

$$y_t = A_0 D_t + \sum_{i=1}^{k} A_k y_{t-k} + e_t \tag{1}$$

where:

t = 1, 2, 3, …, T,

y_t – the vector of current observations of *n* variables of the model - $y_t = [y_{1t} y_{2t} \cdots y_{nt}]'$,

D_t – the vector of deterministic equation components,such as intercept, time variable, zero-one variables or other non-stochastic regressors,

A_0 – the matrix of parameters of D_t vector of variables with no zero elements,

A_i – the matrix of parameters of lagged variables of y_t vector with no zero elements

e_t – the vector of stationary error terms - $e_t = [e_{1t} e_{2t} \dots e_{nt}]'$ with normal distribution and mean and variance of zero.

3 variables are under study, so it is required to estimate 3 equations as listed below:

$$y_{1t} = \mu_1 + \sum_{i=1}^{k} \alpha_{1i} y_{1t-i} + \sum_{i=1}^{k} \beta_{1i} y_{2t-i} + \sum_{i=1}^{k} \gamma_{1i} y_{3t-i} + \varepsilon_{1t} \quad (2)$$

$$y_{2t} = \mu_2 + \sum_{i=1}^{k} \alpha_{2i} y_{1t-i} + \sum_{i=1}^{k} \beta_{2i} y_{2t-i} + \sum_{i=1}^{k} \gamma_{2i} y_{3t-i} + \varepsilon_{2t} \quad (3)$$

$$y_{3t} = \mu_3 + \sum_{i=1}^{k} \alpha_{3i} y_{1t-i} + \sum_{i=1}^{k} \beta_{3i} y_{2t-i} + \sum_{i=1}^{k} \gamma_{3i} y_{3t-i} + \varepsilon_{3t} \quad (4)$$

where:
k – the number of lags, in this case up to 6,
y_{1t} – the value of Latvian stock exchange indexOMXR in time *t*,
y_{2t} – the value of Estonian stock exchange index OMXT in time *t*,
y_{3t} – the value of Lithuanian stock exchange index OMXV in time *t*,
y_{1t-i} – the lagged value of Latvian stock exchange index OMXR up to the lag order of 6,
y_{2t-i} – the lagged value of Estonian stock exchange index OMXT in time up to the lag order of 6,
y_{3t-i} – the lagged value of Lithuanian stock exchange index OMXV in time up to the lag order of 6,
$\alpha_{1i}, \alpha_{2i}, \alpha_{3i}$ – structural parameters, where the first subscript denotes the number of equation and the second subscript, the number of lags,
$\beta_{1i}, \beta_{2i}, \beta_{3i}$ – structural parameters, where the first subscript denotes the equation number and the second subscript, the number of lags,
$\gamma_{1i}, \gamma_{2i}, \gamma_{3i}$ – structural parameters, where the first subscript denotes the equation number and the second subscript, the number of lags,
μ_1, μ_2, μ_3 – the intercept, where the subscript denotes the equation number,
$\varepsilon_1, \varepsilon_2, \varepsilon_3$ – error term (called shock, innovation or impulsein the VAR nomenclature), where the subscript denotes the equation number.

The basic condition for building a VAR model is the stationarity of the variables. In the first step, the stationarity is examined. At the next stage, the length of the lags that will be used to build the model is determined. The Akaike (AIC), Hannan-Qiunn (HQC), and Schwartz information criteria (BIC) are most often used. Having stationary variables and selected lag order, the model is estimated. The tests of autocorrelation, the test of ARCH effect, and thetest for the normality of residuals should be performed then. This is also where Granger causality is defined. Engle-Granger cointegration can also be examined to determine if there is a statistically significant long-term relationship between the variables under study. Then the unit roots of the equation are estimated, followed by the impulse response function. Finally, variance decomposition is carried out for individual variables and possibly a forecast for future periods. In order to test for the stationarity of variables, they are subjected to the augmented Dickey-Fuller test (ADF) with the intercept. For the purposes of the ADF test,11 lags suggested by the GRETL program are adopted. The variables turn out to be stationary, as the obtained p-values are lower than the accepted significance level of 0.05. In order to estimate the number of lags, all three information criteria are taken into account. The maximum lag of six is implemented. The function with the intercept is used. The results are presented in Table 1.

Table 1. The choice of lag order.

VAR system, maximum lag order 6					
The asterisks below indicate the best (that is, minimized) values of the respective information criteria, AIC = Akaike criterion, BIC = Schwarz Bayesian criterion and HQC = Hannan-Quinn criterion.					
Lags	loglik	p(LR)	AIC	BIC	HQC
1	181.50450		-4.708458	-4.329014	-4.557401
2	201.55305	0.00001	-5.015362	-4.351335*	-4.751011*
3	210.43053	0.03813	-5.011959	-4.063348	-4.634314
4	217.71758	0.10332	-4.964377	-3.731183	-4.473439
5	227.97677	0.01497	-4.999355	-3.481577	-4.395123
6	241.93492	0.00099	-5.137081*	-3.334720	-4.419556

Source: The author’s own calculation using GRETL.

The optimal lag order is the one for which information criterion values are the lowest, which means the lowest information loss. Not all the information criteria indicate the same order of lags. After the multiple estimation of the VAR model for all the variables including and excluding seasonal instrumental variables, the second-order lags give a statistically insignificant result for the variables in each of the three equations, therefore, the order of 6 lags is used. It is consistent with the Akaike information criterion.

In each estimation, the seasonal variables are not statistically significant and some additional tests of seasonality confirm the absence of seasonality in the analysed time series. Moreover, the estimates for the order of 2 lags give too low values of the normality of the residuals test (below the adopted significance level of 0.05). As a result, the order of six lags is adopted for the model estimation.

Empirical Results

The model estimation results indicate that the changes in the Latvian stock exchange situation depend on their changes from previous periods (1, 2, 3, 4 and 6) and on changes from previous periods (2, 3, 4 and 5) of the Estonian stock exchange index. Changes in the stock market situation as measured by the stock exchange index in Lithuania do not have a statistically significant effect on the changes in the Latvian stock exchange index (see Table 2).

In the case of Estonia (see Table 3), the changes in the stock exchange situation areinfluenced by the changes of the Estonian stock exchange index from the previous period and the changes in the stock exchange situation in Lithuania from previous periods (2, 3, 4).

On the other hand, changes in the Lithuanian stock exchange index (see Table 4) are influenced by the changes in this index in previous periods (1, 2, 3, 4, 5) and the changes in the stock market situation in Estonia from previous periods (4, 5, 6).

The coefficient of determination for subsequent equations reaches 56%, 48% and 52%, respectively, which proves an average fit of the model to the data. However, the statistic of the Durbin-Watson test seemsmore important in the VAR model, which for all equations is in the required range of 1.85-2.20 (1.89, 1.90 and 1.94, respectively) and thus indicates the desired effect of the lack of autocorrelation in the random term. In addition, the VAR model is implemented with the option of robust standard errors in order to eliminate the problem of heteroskedasticity.

After estimating the model parameters, the model's diagnostic tests should be performed - the autocorrelation test, ARCH test, andtest for the normality of residuals. All the tests are performed on a lag order of 6. The first three tests give the desired results – no autocorrelation, no ARCH effect, and a normal distribution of residuals.

Table 2. The normality of residuals test

Test for normality of residuals
Doornik-Hansen test
Chi-square(6) = 11.2643 [0.0805]

Source: The author's own calculation using GRETL.

Additionally, the Engle-Granger cointegration test is carried out, which examines the presence of a relationship between the variables. Both the Chi-square test for the normality of residuals and the ADF test for unit root in residuals estimations indicate that the residuals are normally distributed and there is a significant relationship between the variables under study.

Table 3. Testing for a unit root in residuals (uhat)

Augmented Dickey-Fuller test for uhat including 6 lags of (1-L)uhat, sample size 71
unit-root null hypothesis: a = 1
test without constant
model: (1-L)y = (a-1)*y(-1) + ... + e
estimated value of (a - 1): -3.73599
test statistic: tau_c(3) = -4.39103
asymptotic p-value 0.007234
Critical value of tau from Dickey-Fuller statistical tables = -1,94 with the significance level of 5%
There is no unit root in uhat. The result of the test indicates that time series is cointegrated

Source: The author's own calculation using GRETL.

After a positive verification of the aforementioned tests for the given VAR model, the unit roots of the characteristic equationare to be determined. In GRETL, the unit roots of the characteristic equation are estimated automatically. All the unit roots of the characteristic equation are to be less than one in terms of the modulus. The number of roots of the characteristic equation for the model consisting of three variables for six lags is 18. All the roots of the characteristic equation are inside the circle, so this condition has been met (see Figure 1).

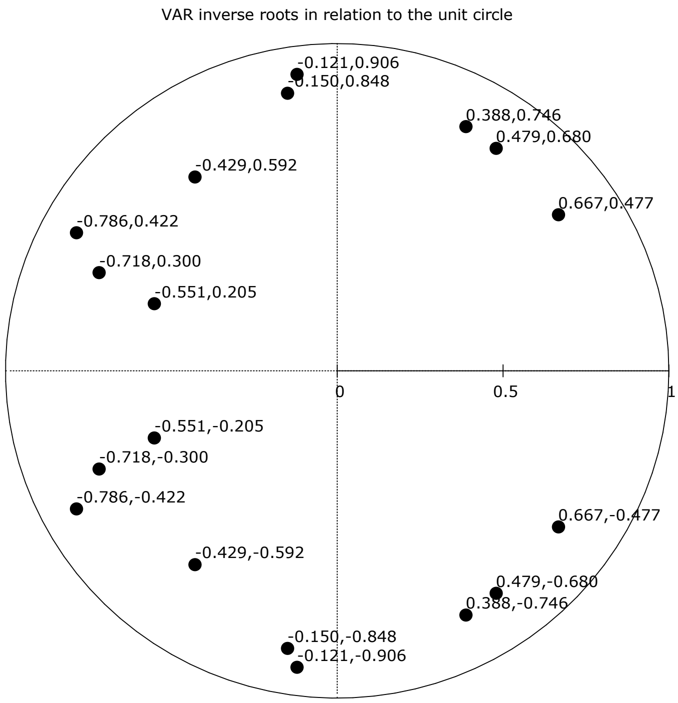

Figure 1. Characteristic equation unit roots.
Source: The author's own calculation using GRETL.

The next step is to evaluate the impulse response function. The impulse is set at one standard error of the residuals. The response from Latvia in the first equation, Estonia in the second equation, and Lithuania in the third equation to the shock from individual variables are statistically significant in the initial period, while in the following quarters this effect fades away. This is illustrated in detail for all the equations in Figure 2.

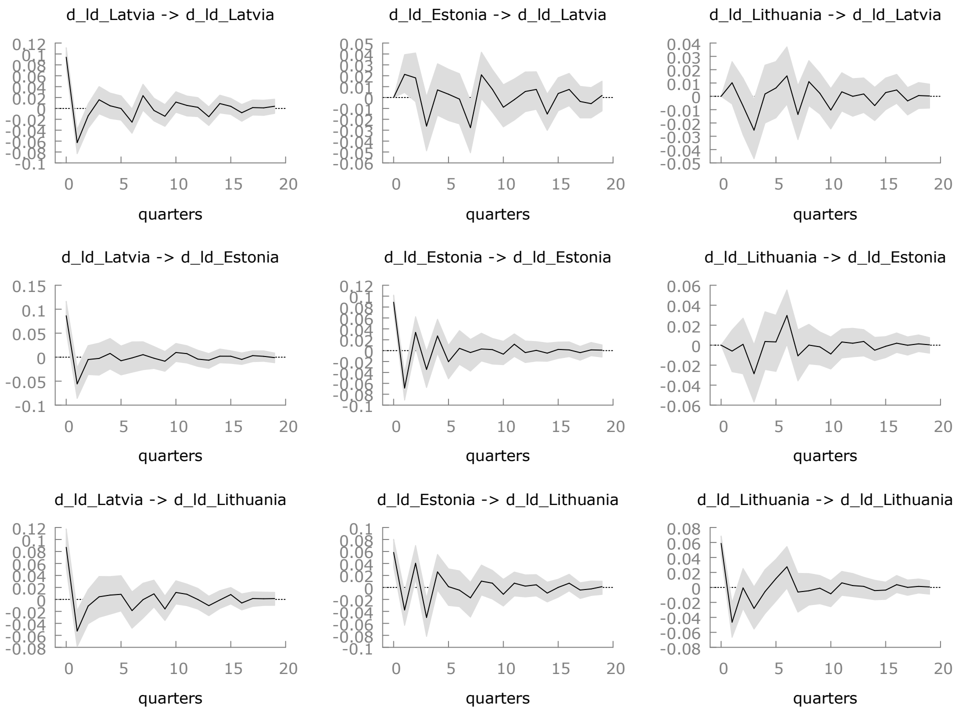

Figure 2. Impulse response functions.
Source: The author’s own calculation using GRETL.

The final step in presenting the VAR model is the variance decomposition. Table 4 presents its course for Latvia. After some initial fluctuations, the variables are fairly stable since the ninth period. In the case of the Estonian stock exchange index (see Table 5), after some fluctuations in the initial period, the variables remain stable starting from the seventh period.As far as Lithuania is concerned, after some initial fluctuations, the variables remain stable from the fifth period onwards (see Table 6).

Table 4. The decomposition of variance for the variable Latvia

period	std. error	d_ld_Latvia	d_ld_Estonia	d_ld_Lithuania
1	0.0940372	100.0000	0.0000	0.0000
2	0.115513	95.8350	3.3849	0.7801
3	0.117923	93.2927	5.5793	1.1280
4	0.124468	85.3590	9.4495	5.1915
5	0.124773	85.0961	9.7178	5.1861
6	0.124967	84.8327	9.7462	5.4211
7	0.12843	84.2056	9.2405	6.5540
8	0.134148	80.2408	12.7197	7.0395
9	0.136259	77.8495	14.6705	7.4799
10	0.137231	77.8364	14.7625	7.4012
11	0.138396	77.2406	14.9280	7.8314
12	0.13856	77.2148	14.9125	7.8727
13	0.138685	77.0967	15.0448	7.8585
14	0.139732	77.1380	15.1049	7.7570
15	0.141007	76.1548	15.9844	7.8608
16	0.141137	76.0902	16.0238	7.8860
17	0.141635	75.8694	16.1877	7.9429
18	0.141731	75.7779	16.2312	7.9909
19	0.141848	75.6586	16.3621	7.9793
20	0.141917	75.6635	16.3646	7.9719

Source: The author’s own calculation using GRETL.

Table 5. The decomposition of variance for the variable Estonia

period	std. error	d_ld_Latvia	d_ld_Estonia	d_ld_Lithuania
1	0.123986	48.5775	51.4225	0.0000
2	0.152349	45.5031	54.3474	0.1495
3	0.15606	43.4620	56.3925	0.1455
4	0.162367	40.1756	56.5909	3.2335
5	0.164811	39.2176	57.5938	3.1886
6	0.166258	38.7368	58.0909	3.1723
7	0.168957	37.5172	56.3132	6.1696
8	0.169409	37.4145	56.0546	6.5309
9	0.169451	37.4127	56.0595	6.5278
10	0.169677	37.5582	55.9222	6.5196
11	0.170306	37.6082	55.6536	6.7382
12	0.170907	37.5306	55.7427	6.7267
13	0.171005	37.5447	55.7231	6.7321
14	0.171163	37.6106	55.6215	6.7679
15	0.171311	37.5602	55.5982	6.8416
16	0.17134	37.5603	55.5964	6.8432
17	0.171421	37.5998	55.5501	6.8501
18	0.171491	37.6058	55.5497	6.8445
19	0.171511	37.6074	55.5434	6.8492
20	0.171516	37.6080	55.5427	6.8493

Source: The author's own calculation using GRETL.

Table 6. The decomposition of variance for the variable Lithuania

period	std. error	d_ld_Latvia	d_ld_Estonia	d_ld_Lithuania
1	0.120148	52.3606	23.6507	23.9887
2	0.144224	49.7458	23.2313	27.0229
3	0.150162	46.4345	28.6358	24.9298
4	0.160823	40.5551	34.6719	24.7730
5	0.163155	39.5971	36.2142	24.1887
6	0.163808	39.5532	35.9325	24.5143
7	0.167226	39.2110	34.5544	26.2346
8	0.168242	38.7396	35.2062	26.0543
9	0.168884	38.7485	35.3235	25.9279
10	0.169785	39.2204	35.1224	25.6572
11	0.170776	39.2269	35.1650	25.6082
12	0.171247	39.2631	35.1428	25.5940
13	0.171278	39.2490	35.1458	25.6052
14	0.171655	39.4445	35.0562	25.4993
15	0.171972	39.3023	35.2315	25.4661
16	0.172198	39.4185	35.1390	25.4426
17	0.172483	39.4080	35.1880	25.4039
18	0.172545	39.3869	35.2273	25.3858
19	0.172572	39.3784	35.2373	25.3843
20	0.172583	39.3795	35.2382	25.3823

Source: The author's own calculation using GRETL.

Conclusion

The article analyses the relationships among some selected stock exchanges in the countries of the Baltic Sea region - Lithuania, Latvia, and Estonia. The VAR method is usedto estimate the parameters of the regression equation. When the impulse response function is estimated, the response from the Latvian stock exchange to the shock from independent variables expires after the seventh quarter. The response of the Estonian stock exchange to the shocks from independent variables expires after the fourth quarter. The response of the Lithuanian stock exchange to shocks from independent variables discontinues after the third quarter.

In the case of variance decomposition for the Riga stock exchange, after some initial fluctuations the variables are fairly stable since the ninth period. The standard error of changes in the Latvian stock exchange index depends primarily on this variable.

In the case of the Estonian stock exchange index, after some fluctuations in the initial period, the variables remain stable starting from the seventh period. The standard error of changes in the stock exchange index in Estonia depends in more than half on this variable and in 1/3 on the changes of Latvian stock exchange index.

As far as Lithuania is concerned, after some initial fluctuations, the variables remain stable from the fifth period onwards. The standard error of changes in the stock exchange index in Lithuania depends only in 25% on changes in this variable and to a greater extent on changes in other variables - 39% on the changes in the stock exchange index in Latvia and 35% on the changes in the Estonian stock exchange index, respectively. This seems to be a surprising result, but it may arise from the small size of the Lithuanian stock exchange and, at the same time, its greater union with the exchanges of the analyzed neighboring countries.

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