Zagreb International Review of Economics & Business, Vol. 29, No. 1, pp. 199-233, 2026

Faculty of Economics and Business, University of Zagreb and Sciendo. Printed in Croatia.
ISSN 1331-5609; UDC: 33+65
DOI: 10.2478/zireb-2026-0011

Dynamics of Interactions between the Stock Markets of Southeast Europe

Sasho Arsov *

Abstract: *This paper examines the interactions among the stock markets of five Southeast European countries over the 2007-2024 period. Using daily index data, the study applies correlation analysis, cointegration techniques, Vector Autoregression, and Granger causality tests to assess long- and short-term relationships under different economic conditions. The results provide no robust evidence of long-run integration, as cointegration analysis fails to confirm stable relationships among the markets. In contrast, short-term dynamics reveal varying lead-lag relationships, which intensify during periods of economic turbulence and weaken during stable periods. Croatian and Slovenian markets exhibit leading roles in earlier periods; however, this precedence is not sustained over time despite their EU membership, while the Sarajevo market remains the least integrated. Overall, the findings suggest that co-movements are driven more by external shocks and investor behavior than by persistent structural linkages, with implications for regional portfolio diversification.*

Keywords*:* stock market; returns; co-movement; stock index; Balkan countries

JEL Classification*:* G11, G15

Introduction

Investors across global stock markets continuously seek to identify patterns through which price movements and market trends are transmitted between markets, with the aim of enhancing portfolio performance. The recognition that such transmission mechanisms may exist has intensified alongside the expansion of economic and financial globalization, as well as the rapid growth of information flows enabled by modern communication technologies.

* Ss.Cyril and Methodius University, Skopje, Northern Macedonia. E-Mail: sarsov@eccf.ukim.edu.mk

The central objective of this paper is to examine whether similar linkages and interdependencies can be observed among the major stock markets of the countries that emerged from former Yugoslavia. This question is particularly relevant given the historically strong economic integration of these economies and the assumption that domestic investors may exhibit comparable behavioral tendencies. Nevertheless, over the past three decades, these countries have followed markedly different development paths. While some have been affected by armed conflicts and international sanctions, others have undergone economic restructuring and modernization under more stable conditions. In addition, a number of these countries have already become members of the European Union, whereas others remain far from achieving the common objective.

Past research has shown that certain interdependencies exist (Syriopoulos & Roumpis, 2009; Gradojević & Dobardžić, 2013; Đukić & Đukić, 2015; Naumoski et al., 2017), but they are not persistent and often intensify during periods of crisis. As most of these studies were done before the Covid-19 crisis, its episode and the associated economic impact provided an additional opportunity to explore the behavior of the markets under changing economic circumstances.

Five national stock markets are in the focus of this paper – the main stock exchanges of Slovenia, Croatia, Bosnia and Hercegovina, Serbia and North Macedonia. The respective stock indices are considered to be indicative of their performance, with a time series spanning from 2006 to 2024. The length of the time series provides an opportunity to investigate the long-term inter-linkages between the markets, as well as their behavior during different economic conditions. The study pursues several interrelated objectives. Its primary aim is to examine whether statistically significant long-term relationships exist among the analyzed markets, specifically whether historical and economic ties translate into some degree of synchronized stock market movements. In the absence of such long-term integration, the analysis shifts to identifying potential short-run linkages, which may offer valuable insights for both investors and policymakers in making short-term decisions and portfolio adjustments. Additionally, the study seeks to detect lead-lag relationships between pairs of markets in order to determine the direction of influence, where present. Finally, it aims to assess whether patterns of inter-market association remain stable over time or vary in response to changing economic conditions, thereby evaluating the persistence of these linkages.

Correlation analysis is typically the initial step in assessing co-movements between variables; however, conventional correlation coefficients capture only contemporaneous relationships and fail to account for lagged interdependencies, which are often characteristic of stock market interactions. To address this limitation, the study employs cointegration techniques to examine the presence of long-term relationships among the variables. If such relationships are identified, a Vector Error Correction Model (VECM) is utilized; otherwise, short-term dynamics are analyzed using a

Vector Autoregression (VAR) framework. Finally, Granger causality tests are conducted to identify potential lead–lag relationships between pairs of stock markets.

The main contribution of this paper lies in the field of portfolio management, although it also offers relevant implications for policymakers. From an investor perspective, a key issue is whether meaningful diversification opportunities can be achieved by allocating funds across the national stock markets in the region. This question is particularly important given that the analyzed exchanges (together with the Sofia Stock Exchange) have established a joint trading platform, SEE Link, aimed at improving regional market visibility and integration. Assessing the extent to which these markets move together is therefore essential, as stronger co-movement would reduce their effectiveness as diversification instruments. Moreover, the study considers whether the introduction of this platform may have reinforced inter-market linkages, potentially through increased cross-border capital flows.

In addition, by analyzing different sub-periods characterized by varying economic conditions, the study seeks to identify how these interrelationships evolve over time. In this context, the recent wave of global instability triggered by COVID-19 pandemic provides a valuable opportunity to reassess and extend the analysis. Finally, the findings are also relevant for policymakers, as they offer insights into the susceptibility of these markets to contagion effects and cross-market spillovers, thereby supporting more informed forecasting of potential disruptions and the design of appropriate policy responses.

The paper is organized as follows. After the introduction, the second section provides a review of the literature on the topic of stock market integration and interdependence, with emphasis on the SEE markets. In the third section, some highlights regarding the stock markets analyzed are presented, to provide the reader with the basic understanding of the markets in question. The next section elaborates the data sample and the research methodology, the results of which are contained in the following part. First, the results of the cointegration technique are presented, and in the next subsection, the VAR model results are given. The analysis is followed by robustness tests, and the next section contains a discussion of the study results. The last section covers the main conclusions of the study, as well as certain implications in the form of recommendations to investors and policymakers.

Literature review

The study of interactions and interdependencies among stock markets has attracted increasing attention since the early 1990s, driven by the intensification of globalization and the rapid expansion of information flows facilitated by the rise of the internet. With news from across the globe becoming instantly accessible, investors have become more attuned to international economic developments, while their response times to new information have significantly shortened.

The increasing integration of national economies is often viewed as a key driver of stock market co-movements. Since individual stock markets are generally expected to reflect underlying economic conditions, greater economic convergence tends to result in more synchronized market fluctuations. This effect is particularly pronounced among countries that are part of formal economic integrations such as the European Union, and even more so among those that now share a common currency. However, the results of these studies are not equivocal (Hamao et al., 1990; Ng, 2000; Fratzscher, 2002; Connolly & Wang, 2003; Baele, 2005; Wongswan, 2006; Bekaert et al., 2009; Halaç et al., 2013). The other view is that co-movements result from the transmission of the “positive mood” from one market to another. Sometimes this occurs as investible funds are moved from markets with stronger past returns to the ones with more upside potential, while in other cases they are simply as a result of a behavioral bias and the smaller markets mirroring the actions of larger ones (King & Wadhwani, 1990; Forbes & Rigobon, 2002; Égert & Kočenda, 2007; Vatsa et al., 2021; Xing et al., 2025). The latter type of spillovers usually intensifies during periods of market disorders and is commonly known as contagion.

The second perspective has been widely embraced in literature, with many studies relying primarily on stock index data rather than incorporating underlying economic fundamentals. In this context, cointegration analysis is particularly suitable, as it focuses on identifying long-term relationships among variables without the inclusion of control factors typically used in regression equations. Accordingly, much of the existing research has concentrated on determining whether major stock markets are interconnected and whether they exert influence on smaller or less developed markets. An early example of a novel approach to the issue and an application of cointegration and Vector Error Correction Models (VECM) is the work of Masih & Masih (1997), who explore and confirm the transfer of influence from established to emerging markets in their study on the leading world markets and the newly industrialized countries of southeast Asia. In another study, Longin & Solnik (2001) use a long 38-year time series of monthly data for the five largest equity markets and conclude that correlations exist, but that contagion is present only during bear markets and not under bull markets. A partial association of the New Zealand market with the global markets was found by Narayan & Smyth (2005). They conclude that the New Zealand market was cointegrated with the USA stock market, but not with other major stock exchanges, not even with the Australian market, thus providing diversification opportunities for investors. Baele (2005) confirms that the contagion spreads from the U.S. market to the European equity markets especially in periods of high volatility. As anticipated, the literature generally finds that larger and more developed markets exert influence on smaller, less developed ones (Berument & Ince, 2005; Samitas et al., 2006; Ye, 2014), but also the geographical proximity plays an important role (Wang & Lai, 2013). The positive impact of globalization on rising cointegration among stock markets was confirmed by Babaei et al. (2023) in a study of the G7 member countries. They also find that the cointegration coefficients are not persistent as they significantly depend on the variations in uncertainty and the indicators of financial sectors' stability.

Other studies incorporate additional variables to identify the underlying sources of interdependencies among the markets or the factors that contribute to their intensification or reduction. Güngör & Taştan (2021) conclude that the major determinants of the long-term dynamic conditional correlations between the stock market returns of G7 and BRICS-T countries are the differences in economic growth rates, five-year credit-default swap risk premiums, and the Economy Policy Uncertainty indices between the country pairs. As Shi (2022) finds out, the major drivers of stock market co-movements between China and its developed and emerging partners are bilateral trade and market similarities, as well as illiquidity pressures. Co-movements between China and its emerging partners are additionally affected by differences in industrial production growth and market size. The impact of geopolitical shocks on stock market co-movements in the case of ten developing countries was confirmed by Hachicha (2024) who finds a strong interdependence between geopolitical risk (resulting from the Russia-Ukraine war), investor sentiment, stock market index and the exchange rate.

The results of the studies critically depend on the econometric tools used, as, for instance, Fu & Pagani (2012) retest the results of Kasa (1992) and cast doubt on their robustness, as the newly developed techniques show that the previous results could have been biased due to the size of the sample or the time series used. Batondo & Uwilingiye (2022) implement a different approach known as wavelet analysis in the case of the BRICS countries and the US stock market. They show that trade linkages and deeper economic integration strengthen the degree of association between stock markets, with these connections becoming even more pronounced during periods of macroeconomic shocks. Evidence from Luis A. Gil-Alana et al. (2022) shows that interdependencies among the markets do exist, but the process of convergence is not irreversible as in some cases the level of integration weakens over time. Another application of the same methodology is found in Muneer et al. (2025), who find that trade agreements and enhanced regional cooperation have increased correlations between Malaysia's stock market and those of its emerging and OECD partners, with the influence of the United States remaining particularly strong across both groups. Conversely, Tessler and Venezia (2022) challenge the reliability of conventional contagion measures, arguing that they may generate misleading evidence of increased correlations during crisis periods. To address this limitation, they propose an alternative multicountry framework for assessing contagion and convergence across markets.

With respect to the CEE markets, Gilmore & McManus (2002), found only a short-run relationship between the U.S. market and three CEE markets, but no long-term association. Samitas et al. (2006) confirm the existence of a long-run association between several stock markets from the Balkan countries, however, the trends in these stock exchanges are influenced by the movements of the developed markets. A similar conclusion regarding the linkages between the emerging Central European markets and those of US and Germany was reached by Syriopulos (2007), but no evidence was found regarding the impact of the introduction of the euro on these relationships.

A different conclusion was reached by Égert & Kočenda (2007) who apply pairwise cointegration tests on a group of three Central and Eastern European (CEE) markets and three Western European markets. They find no long-run relationship within any of the market pairs analyzed, but the VAR and Granger causality tests verify the existence of some short-run dependencies. In line with this, Đukić & Đukić (2015) failed to confirm cointegration among the Balkan stock exchanges, except in the case of the Serbian and the Republic of Srpska stock exchanges.

Several studies have shown that the convergence between the CEE markets and the markets of the developed countries increases as the process of EU accession progresses (Gilmore et al. 2008, Syllignakis & Kouretas 2010). The rising association is confirmed by Kenourgios & Samitas (2011) even in the case of the markets still not in the process of EU accession. They find that a long-run cointegration exists between five Balkan emerging stock markets, and also between these markets and the US and three European developed markets, with these interlinkages having strengthened during the financial crisis of 2008.

The GARCH (Generalized Autoregressive Conditional Heteroskedasticity) models are another econometric tool helpful in investigating the transmission of impacts between the markets both in terms of returns and volatility. Examples of such studies which, in most cases, explore the transfer of impacts from mature to emerging markets, include Syriopoulos and Roumpis (2009), Dajčman & Festić (2012), Gradojević & Dobardžić (2013), Zehri (2021), etc., however, their findings are not homogeneous. Some studies confirm that the major Balkan stock markets are mutually correlated, but their correlations with the developed markets are lower (Syriopoulos & Roumpis, 2009). A similar finding was reported by Horvath and Petrovski (2012), who show that Central European markets are integrated with Western European ones, whereas Southern European markets are not. A commonly cited explanation is that the process of accession to the European Union strengthens interlinkages among stock markets, a pattern confirmed in the case of the Slovenian market (Dajčman & Festić 2012), as well as in the case of Hungary, Poland and the Czech Republic (Caporale & Spagniolo, 2011), while Gradojević & Dobardžić (2013) find that the Budapest and Frankfurt stock markets exert influence on the Belgrade Stock Exchange. In two recent contributions employing dynamic cross-correlation analysis, Ferreira (2018) and Tilfani et al. (2019) arrive at comparable findings, confirming the presence of interlinkages among Central and Eastern European members of the European Union, with the exception of Slovakia. In contrast, countries in the accession process exhibit weaker connections both among themselves and with more established markets. Furthermore, Dajčman and Festić (2012), as well as Okičić (2014), provide evidence that inter-market linkages intensify during periods of financial distress.

Several key conclusions emerge from this review. As expected, markets sharing similar characteristics, particularly those belonging to mature and highly integrated economies, tend to exhibit the strongest interlinkages and co-movement patterns. In addition, the degree of convergence appears to increase over time, especially as countries become part of broader economic integrations such as the European Union. By contrast, stock markets in Southeast Europe remain relatively less integrated, both with EU markets and among themselves, which is consistent with the above findings.

Analyzed markets - some stylized facts

The stock exchanges of the countries under analysis were established in the 1990s, a period marked by large-scale privatization of state-owned (or socially owned) enterprises. These processes, however, did not unfold simultaneously across all countries, as some were significantly disrupted by armed conflicts. Despite these differences, by the early 2000s all countries had functioning stock markets, albeit with relatively low levels of activity.

In the following decades, trading activity increased, and market dynamics began to more closely reflect global investment trends. Summary information on the stock exchanges and the performance of their respective indices is presented in Table 1. The abbreviations provided in parentheses in the table's header will be used throughout the paper to denote the analyzed stock exchanges, their indices, and corresponding returns, ensuring clarity and consistency.

Table 1: Basic data for the national stock exchanges (2024, end of year or total)

	Slovenia - Ljubljana SE (LSE)	Croatia – Zagreb SE (ZSE)	Bosnia and Herzegovina – Sarajevo SE (SASE)	Serbia - Belgrade SE (BSE)	N. Macedonia – Macedonian SE (MSE)
Number of listed companies (first segment)	8	6	2	5	24
Number of companies trading in the second segment of the market	9	18	11	166	68
Stock market capitalization – equity segment (in mil. euros)	11,900	28,948	3,876*	4,101	5,691
Total equity market capitalization / GDP	18%	36%	14.8%	5.3%	37.9%
Total market turnover (in mil. euros)	505.6	459.4	375.6	310.9	217.2
Turnover of equities (in mil. euros)	485.1	294.9	20.6**	28.1	112.3

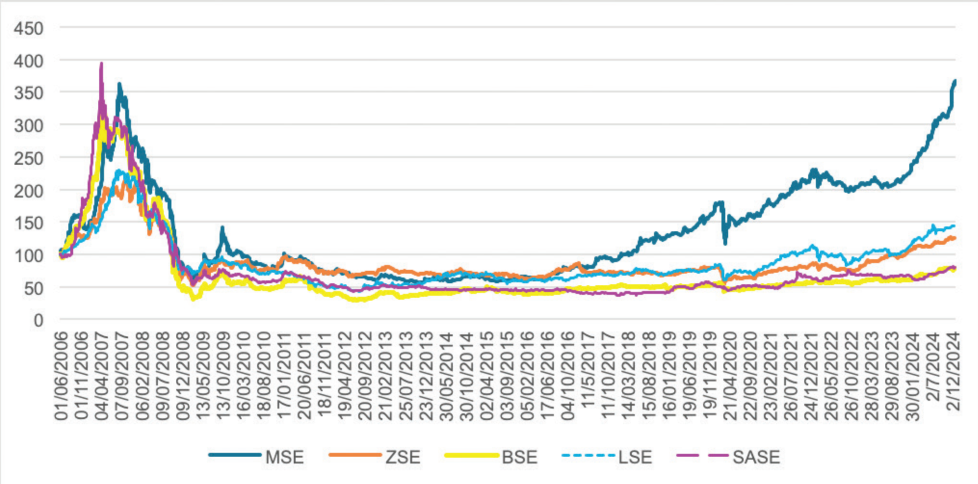
Sources: Zagreb SE (Annual Report 2024), Macedonian SE (Annual Bulletin 2024), Sarajevo SE (Annual Report 2024), Ljubljana SE (Annual Report 2024), Belgrade SE (Annual Report 2024), World Bank Statistics.

* Total market capitalization (equity capitalization not available)

** Only secondary market

In order to depict the general trends of the indices of the stock exchanges, a graphical representation of their movements is shown in Figure 1. To achieve comparability, the indices are first converted to euros and then rescaled to a basis of 100 as of June 2nd, 2006 (the earliest date of data availability for all five indices).

Figure 1: Stock market index movements (in EUR, 02.06.2006=100)



(Description of the index abbreviations: MSE (MBI-10, Macedonian Stock Exchange), ZSE (Zagreb Stock Exchange, Croatia), BSE (Belgrade Stock Exchange, Serbia), LSE (SBITOP, Ljubljana Stock Exchange, Slovenia), SASE (Sarajevo Stock Exchange, Bosnia and Hercegovina)

Several observations can be derived from Figure 1, although its visual clarity is somewhat constrained by the extended time horizon. First, the stock indices exhibit broadly similar movement patterns, suggesting the presence of a certain degree of association among the markets. Second, a visual inspection of the chart reveals at least three distinct sub-periods within the 18-year span. The first, covering 2006-2010, encompasses the market peak of 2007 followed by a sharp downturn. The second period (2010-2019) is characterized by relatively stable market performance. In contrast, the most recent sub-period displays a divergence from the common trend in at least one index, along with pronounced fluctuations associated with the COVID-19 pandemic, the Russia–Ukraine conflict, and the surge in inflation during the 2020s.

However, statistical metrics provide considerably more meaningful information compared to charts, so we first revert to the correlations between the stock index returns, calculated at daily and weekly levels. The returns are calculated as a ratio between the logged closing values of the stock indices in two consecutive periods:

$$R_{it} = ln\ (I_{it} / I_{it-1}) * 100 \quad (1)$$

where R_{it} is the return of stock market index i in period t and I_{it} is the closing value of stock market index i in period t. In the case of non-working days, the index value in the last working day was used.

To illustrate the co-movements of the markets in the different subperiods observed, the calculated correlations for each subperiod are given in table 2. (A detailed explanation with respect to the division of the time series into sub-periods is provided in the Methodology and data section below.)

Table 2: Stock market returns - pairwise correlations

	Daily returns			Weekly returns		
	2007-2011	2012-2019	2020-2024	2007-2011	2012-2019	2020-2024
BSE-ZSE	0.26	0.07	0.24	0.54	0.13	0.46
BSE-MSE	0.28	0.06	0.26	0.47	0.08	0.38
BSE-SASE	0.23	0.03	0.01	0.49	-0.02	0.01
BSE-LSE	0.03	0.04	0.20	0.14	0.06	0.38
ZSE-MSE	0.25	0.05	0.44	0.53	0.06	0.46
ZSE-SASE	0.15	0.01	0.01	0.43	0.06	-0.02
ZSE-LSE	-0.02	0.06	0.53	0.23	0.07	0.58
SASE-MSE	0.19	-0.02	-0.04	0.41	0.01	0.05
MSE-LSE	0.08	0.00	0.44	0.19	-0.02	0.47
SASE-LSE	-0.02	-0.02	-0.01	-0.00	0.03	0.01

Source: Author's calculations

The abbreviations refer to the respective market indices

Table 2 indicates that the majority of correlation coefficients are positive, suggesting the presence of co-movement among the analyzed markets. In several instances, the coefficients approach or exceed 0.5, particularly in the 2020-2024 period. At the individual market level, the Croatian (ZSE) and North Macedonian (MSE) exchanges exhibit the strongest associations with other markets, whereas the connections involving the Sarajevo Stock Exchange appear to have weakened over time.

For a clearer visualization of these patterns, Figures 2 and 3 present a graphical representation of the correlation dynamics.

Figure 2: Pairwise correlations - daily returns

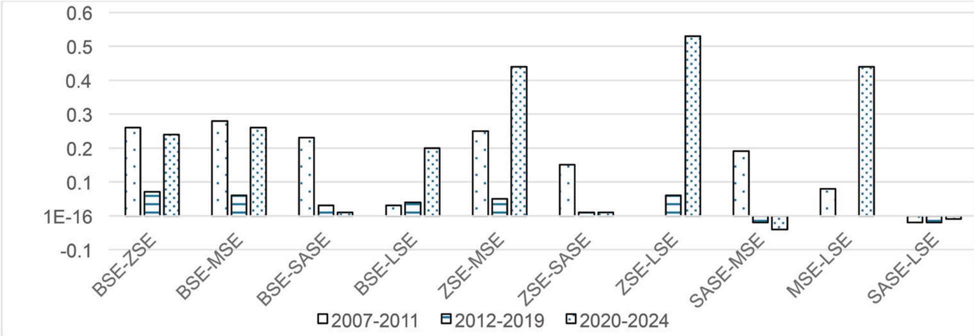
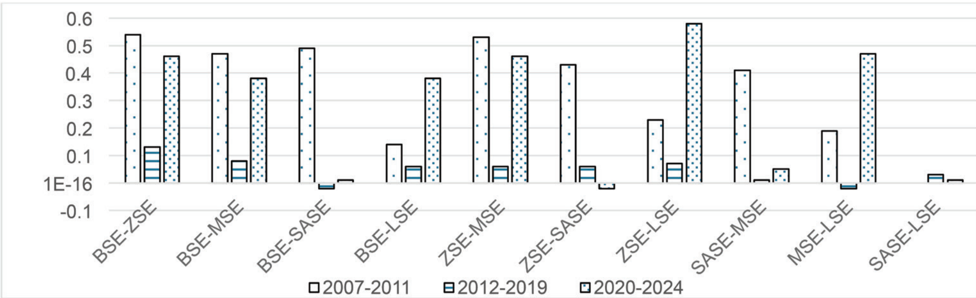


Figure 3: Pairwise correlations - weekly returns



Source: Author's calculations

The figures clearly illustrate that in a vast majority of the cases, the correlations were much higher in the "more turbulent" periods and considerably low in the "calm" period of 2012-2019.

This finding creates an additional impetus to explore the possible existence of long-term association among the markets, as correlations are not a perfect measure of mutual co-movements. They are based on simultaneous changes in the stock indices, and they do not capture the possible time lags, i.e. the spillover of effects among the exchanges. Since stock investment is typically viewed as a long-term activity, the existence of long-run relationships between markets is of primary importance. To examine these long-term dynamics, as well as different forms of causality among the markets, more advanced econometric techniques are required, including cointegration analysis and Vector Autoregression (VAR) models.

Methodology and data

In the econometric analysis, a time series of data covering the period 1.1.2007-31.12.2024 is used. The frequency of data used should depend on the assessment of the speed at which one market responds to information revealed by the prices in another market (Černy and Koblas 2008). The dynamics of these markets supports the use of daily index values, rather than higher frequency data. The time series with the closing values of the indices were constructed using the data published by the respective stock exchanges on their websites. To improve the consistency of the data, the index values were first converted to euros (for the non-Eurozone countries) and transformed into respective natural logarithm values which is the common approach for cointegration analysis of financial markets.

To assess how varying economic conditions influence market co-movements, the sample period is divided into three sub-periods. The first spans from 2007 to 2011 and captures the global financial crisis of 2008-2009, along with the subsequent European sovereign debt crisis. The second sub-period, covering 2012-2019, represents a phase of relatively stable market conditions. The third begins with the onset of the COVID-19 pandemic and the associated market downturn in early 2020, extending through the end of 2024. Although the immediate market effects of the pandemic were relatively short-lived, global economic instability persisted, driven by elevated inflation during 2021-2022 and the corresponding policy responses aimed at containing it.

The existence of a joint long-run relationship among the markets is tested using the cointegration technique, first presented by Johansen (1988) and Johansen & Juselius (1990). Cointegration is used to determine if there are any long-term relationships between two or more variables. Time series that are cointegrated are marked with a causal ordering in at least one direction. If the markets are found to be cointegrated, it would mean that there is a higher degree of integration among them, and therefore, in the long run, they provide less diversification benefits than markets which are not.

If cointegration is confirmed, that serves as a strong statistical and economic basis for a Vector Error Correction Model (VECM), which brings together short and long-run information in modeling variables. The VECM provides information on the possible speed of adjustment of the variables towards the long-run equilibrium. Estimation of the VECM can be done by standard Ordinary Least Squares (OLS) technique or using the Maximum Likelihood approach. The Maximum Likelihood method developed by Johansen (1988) is a full information approach that estimates the VECM in a single step.

In the case when more than two variables are included, the VECM takes the form:

$$\Delta y_t = \mu + \Pi y_{t-k} + \sum_{i=1}^{k-i} \Gamma_i \Delta y_{t-i} + u_t \quad (2)$$

where μ is a vector of constants, Δy_t is a vector of stock market index changes, Γ is a matrix of coefficients of the dependent variables, Π is a long-run matrix of coefficients, k is the number of lags of the dependent variable, g is the number of variables which are represented in their first differenced form and u_t is a vector of error terms. If the rank of $\Pi>0$, there is cointegration and the vector Π can be expressed as $\alpha\beta'$, where matrix β contains the long-run relationship, i.e. the cointegration relations between the observed variables, while matrix α contains the short-run adjustment parameters, i.e. it describes the short-run relationship between the changes in the dependent and the changes in the independent variables.

The main information that we want to derive from the VECM is the error correction coefficient, which is expected to be negative and significant, indicating whether the disequilibrium is being corrected for.

If no stable long-term relationship is found, a Vector Autoregression (VAR) model will be used to determine any short-term relationship between the indices. The VAR takes into consideration every variable in the system as a function of its lagged values, as well as the lagged values of all the other variables in the system. Finally, a Granger causality is applied to detect any lead-lag relationships between market pairs. Using the above methodology, we intend to test the following research hypotheses:

Hypothesis 1: The stock markets of the five analyzed economies are cointegrated, i.e. there is a long-run association among them.

Hypothesis 2: There is a short-term association between the stock markets of the analyzed economies.

Hypothesis 3: The linkages between the analyzed stock markets vary with respect to the state of the economy.

Hypothesis 4: There are lead-lag relationships between the markets analyzed.

Empirical analysis and results

Testing for cointegration

The first step in applying cointegration analysis is to determine if the variables included are stationary in levels or first differences. Namely, if the variables are stationary of order I(0), cointegration is not applicable, but if there is one unit root, i.e. the series is a I(1) series, this technique can be applied. We tested the series using Augmented Dickey-Fuller (ADF) which clearly indicated that the series are not stationary at their log levels, but they are all stationary in their first differences. This is very common for analyses of stock indices, and therefore, to save space, these results are not shown.

The next step in the procedure is to determine the optimal time lag. For this purpose, several tests are available and most of the criteria suggest using 4 as the optimal lag level for the 2007-2011 sub-period, and a 2-period lag for the other two sub-periods considered. For the model estimated over the full 2007–2024 period, a lag length of four periods is adopted, as the initially suggested six-period lag may compromise the precision of the estimates. The results of the optimal lag tests are given in the appendix (Table A-1).

After determining the optimal lag length, these values are incorporated into the cointegration analysis. The procedure is conducted jointly for all five markets, both over the full sample period and across the defined sub-periods, in order to assess not only the presence of long-term relationships but also how these relationships vary under different market conditions. The results are presented in Tables 3 to 8, where, for each period, the first table reports the cointegration test outcomes and the subsequent table presents the corresponding Vector Error Correction Model (VECM). For sub-periods in which no cointegrating relationships are detected (2020-2024), the results are reported in the appendix.

Table 3: Johansen cointegration test results (2007-2024)

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.013353	103.5820	69.81889	0.0000
At most 1	0.004312	42.92927	47.85613	0.1343
At most 2	0.003120	23.43316	29.79707	0.2255
At most 3	0.002056	9.331641	15.49471	0.3356
At most 4	1.04E-05	0.046799	3.841466	0.8287

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.013353	60.65268	33.87687	0.0000
At most 1	0.004312	19.49612	27.58434	0.3771
At most 2	0.003120	14.10152	21.13162	0.3568
At most 3	0.002056	9.284841	14.26460	0.2632
At most 4	1.04E-05	0.046799	3.841466	0.8287

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Source: Authors' calculations

Table 4: Vector Error Correction Model (2007-2024)

Error Correction:	D(BSE)	D(ZSE)	D(MSE)	D(SASE)	D(LSE)
CointEq1	-0.003356	-0.001217	-0.001608	-0.003120	-0.002099
	(0.00063)	(0.00063)	(0.00063)	(0.00061)	(0.00063)
	[-5.32303]	[-1.92419]	[-2.55984]	[-5.07897]	[-3.31557]
R-squared	0.142944	0.103055	0.148721	0.087854	0.023041
Adj. R-squared	0.138935	0.098860	0.144740	0.083588	0.018472
Akaike AIC	-6.384378	-6.377544	-6.391537	-6.436070	-6.375655
Schwarz SC	-6.353101	-6.346267	-6.360260	-6.404793	-6.344379

Source: Authors' calculations

Table 5: Johansen cointegration test results (2007-2011)

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.033132	84.13214	69.81889	0.0024
At most 1	0.023328	45.62033	47.85613	0.0799
At most 2	0.009950	18.64100	29.79707	0.5189
At most 3	0.004901	7.211172	15.49471	0.5532
At most 4	0.001395	1.595331	3.841466	0.2066

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.033132	38.51181	33.87687	0.0130
At most 1	0.023328	26.97933	27.58434	0.0596
At most 2	0.009950	11.42983	21.13162	0.6044
At most 3	0.004901	5.615841	14.26460	0.6629
At most 4	0.001395	1.595331	3.841466	0.2066

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Source: Authors' calculations

Table 6: Vector Error Correction Model (2007-2011)

Error Correction:	D(BSE)	D(ZSE)	D(MSE)	D(SASE)	D(LSE)
CointEq1	-0.023513	0.014341	0.027171	-0.008207	0.008549
	(0.00732)	(0.00712)	(0.00674)	(0.00615)	(0.00600)
	[-3.21004]	[2.01313]	[4.03049]	[-1.33428]	[1.42408]
R-squared	0.170765	0.154514	0.206576	0.179555	0.040486
Adj. R-squared	0.162714	0.146305	0.198873	0.171590	0.031171
Akaike AIC	-5.396254	-5.451945	-5.562301	-5.745565	-5.794260
Schwarz SC	-5.343400	-5.399091	-5.509447	-5.692711	-5.741406

Source: Authors' calculations

Table 7: Johansen cointegration test results (2012-2019)

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.016855	64.71199	69.81889	0.1194
At most 1	0.006098	29.55942	47.85613	0.7412
At most 2	0.004642	16.90960	29.79707	0.6467
At most 3	0.003352	7.286910	15.49471	0.5445
At most 4	0.000166	0.343701	3.841466	0.5577

Trace test indicates no cointegration at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.016855	35.15257	33.87687	0.0351
At most 1	0.006098	12.64982	27.58434	0.9034
At most 2	0.004642	9.622691	21.13162	0.7792
At most 3	0.003352	6.943208	14.26460	0.4959
At most 4	0.000166	0.343701	3.841466	0.5577

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Source: Authors' calculations

Table 8: Vector Error Correction Model (2012-2019)

Error Correction:	D(BSE)	D(ZSE)	D(MSE)	D(SASE)	D(LSE)
CointEq1	-0.013154	-0.003385	0.000486	-0.004413	0.003341
	(0.00242)	(0.00216)	(0.00232)	(0.00283)	(0.00290)
	[-5.43539]	[-1.56486]	[0.20974]	[-1.56164]	[1.15009]
R-squared	0.026621	0.006879	0.071857	0.006600	0.007003
Adj. R-squared	0.021414	0.001565	0.066891	0.001285	0.001691
Akaike AIC	-7.193972	-7.418514	-7.279659	-6.883907	-6.828867
Schwarz SC	-7.161278	-7.385820	-7.246964	-6.851212	-6.796172

Source: Authors' calculations

The cointegration tests initially suggest the presence of long-term convergence among the markets when considering the full 2007–2024 period, as well as the first two sub-periods. Specifically, Tables 3, 5, and 7 indicate at least one cointegrating vector for these intervals. When such relationships are detected, a VECM is estimated to assess the existence of a meaningful short-run adjustment mechanism. This requires the error-correction terms in the cointegrating equations (reported in Tables 4, 6, and 8) to exhibit negative and statistically significant coefficients.

Although such coefficients are observed - for example, across all variables in the full-period model or for the BSE in the 2007-2011 sub-period - their magnitudes are very small, indicating that only a negligible portion of disequilibrium is corrected in each period. Moreover, the low explanatory power of the models, together with the failure to pass standard diagnostic tests (including those for serial correlation and heteroscedasticity), undermines the robustness of the cointegration results. Consequently, the hypothesis of cointegration is rejected, along with the first research hypothesis, as there is no reliable evidence of a statistically significant long-run relationship among the markets.

Vector Autoregression (VAR) analysis

When a long-term association is not determined, a short-term relationship needs to be explored. For this purpose, a VAR model is used, in which all the variables are treated as endogenous, and it helps to reveal if any of the variables is influenced by any other variable in the short term. The VAR model is atheoretical in that it does not imply possible dependencies between the variables a priori, i.e., all the variables are treated as endogenous. In our case, this procedure should provide us with information about the possible lead-lag relationships between the indices. In this case, the first differences of the respective indices are used, which transforms the daily value series into series of daily returns, corresponding to equation 1 above.

A five-equation vector autoregressive model is applied that incorporates the five stock exchange indices as dependent variables. The VAR equation applied is as follows:

$$X_t = f_0 + \sum_{i=1}^{L} f_{1i} X_{t-i} + u_t \tag{2}$$

where X_t is a vector that represents the daily returns on the stock indices, L is the number of lags and u_t is a vector of residuals.

Next, the optimal lag length for the VAR model is determined, noting that it differs from the cointegration framework since the analysis now focuses on returns rather than the logarithmic levels of the indices. Based on standard lag selection criteria, a lag order of two is identified as optimal. Given that a VAR model with five endogenous variables generates extensive output, Table 9 presents a condensed version, reporting only the estimated coefficients and their standard errors. As the ordering of variables in a VAR model is important, a neutral approach is adopted by arranging the markets geographically, starting with the westernmost market (Slovenia) and proceeding eastward. This ordering is not purely geographical, as it closely reflects the relative levels of economic development across the countries, with Slovenia representing the most advanced economy among the former Yugoslav republics and North Macedonia the least developed among the analyzed countries. Furthermore, the same ordering corresponds to the degree of integration with the European Union, with Slovenia being the first to join, followed by Croatia, while the remaining countries are either in various stages of accession negotiations or have yet to begin the process. As the relationships between markets are meaningfull only when the markets move in the same direction, only the positive inter-market causalities are marked as significant.

Table 9: VAR model results – daily returns

	2007-2011					2012-2019					2020-2024				
	LSE	ZSE	SASE	BSE	MSE	LSE	ZSE	SASE	BSE	MSE	LSE	ZSE	SASE	BSE	MSE
LSE(-1)	0.171**	-0.050	-0.016	0.096**	0.071**	0.041	0.004	0.021	-0.017	0.0066	0.075**	-0.0259	-0.055	0.0146	-0.0219
	[5.771]	[-1.424]	[-0.534]	[2.655]	[2.126]	[1.870]	[0.300	[0.991]	[-0.932]	[0.374]	[2.234]	[-0.873]	[-1.971]	[0.604]	[-0.678]
LSE(-2)	-0.051	0.416**	0.030	0.063	0.083**	-0.006	-0.002	-0.007	0.022	-0.001	-0.014	-0.0136	-0.0325	0.038768	-0.004
	[-1.722]	[11.770]	[0.994]	[1.747]	[2.474]	[-0.301]	[-0.141]	[-0.360]	[1.198]	[-0.037]	[-0.419]	[-0.460]	[-1.149]	[1.597]	[-0.135]
ZSE(-1)	0.024	0.135**	0.160**	0.254**	0.242**	-0.012	0.050**	-0.009	0.010	0.043	0.0211	0.008119	-0.0475	0.061**	-0.0423
	[1.007]	[4.642]	[6.394]	[8.483]	[8.746]	[-0.434]	[2.291]	[-0.314]	[0.415]	[1.819]	[0.545]	[0.237]	[-1.455]	[2.217]	[-1.138]
ZSE(-2)	0.049	-0.086	0.081**	0.014	0.066**	-0.020	-0.0381	0.004	0.075**	-0.011	0.155**	0.133**	0.0460	-0.0224	0.192**
	[1.904]	[-2.824]	[3.072]	[0.448]	[2.257]	[-0.680]	[-1.730]	[0.152]	[3.039]	[-0.494]	[4.071]	[3.958]	[1.436]	[-0.816]	[5.260]
SASE(-1)	-0.061	-0.011	0.288**	0.075**	0.032	0.027	0.017	-0.048	-0.009	0.023	0.085	0.0376	0.074**	0.0178	0.093
	[-2.112]	[-0.335]	[9.591]	[2.113]	[0.968]	[1.228]	[1.032]	[-2.203]	[-0.518]	[1.291]	[1.565]	[1.288]	[2.647]	[0.746]	[0.929]
SASE(-2)	0.046	-0.050	-0.082**	-0.028	0.040	0.027	0.018	-0.016	-0.010	0.012	0.0055	-0.0117	0.0031	-0.0098	-0.0084
	[1.610]	[-1.480]	[-2.782]	[-0.797]	[1.244]	[1.204]	[1.069]	[-0.743]	[-0.573]	[0.716]	[0.168]	[-0.402]	[0.112]	[-0.414]	[-0.266]
BSE(-1)	0.006	0.019	0.052**	0.211**	0.032	0.0270	-0.0116	-0.0371	0.061**	0.004	-0.0185	0.0311	0.0479	-0.0422	0.0008
	[0.246]	[0.628]	[2.017]	[6.748]	[1.140]	[1.026]	[-0.593]	[-1.450]	[2.790]	[0.228]	[-0.470]	[0.898]	[1.449]	[-1.491]	[0.022]
BSE(-2)	-0.032	0.104**	0.0198	0.066**	-0.003	-0.003	0.000	0.036	0.0258	0.009	0.0446	0.188	0.0255	0.105**	0.111**
	[-1.288]	[3.501]	[0.772]	[2.149]	[-0.139]	[-0.115]	[0.006]	[1.407]	[1.169]	[0.470]	[1.159]	[1.720]	[0.789]	[3.802]	[3.019]
MSE(-1)	-0.002	0.026	0.014	-0.0549	0.250**	0.058**	0.009	0.012	0.026	0.265**	-0.083	-0.103	0.084**	0.118**	0.179**
	[-0.084]	[0.809]	[0.509]	[-1.650]	[8.161]	[2.122]	[0.479]	[0.467]	[1.129]	[12.02]	[-2.468]	[-3.493]	[2.971]	[4.877]	[5.565]
MSE(-2)	-0.017	0.017	-0.013	0.008	-0.138	-0.035	0.018	0.009	-0.036	-0.020	0.135**	0.074**	-0.0118	0.0351	-0.096
	[-0.677]	[0.566]	[-0.514]	[0.274]	[-4.640]	[-1.268]	[0.873]	[0.351]	[-1.552]	[-0.942]	[3.948]	[2.468]	[-0.412]	[1.424]	[-2.916]
C	-0.001	-0.000	-0.001	-0.001	-0.000	0.000	0.000	0.000	0.001	0.0003	0.0002	0.0002	0.0002	0.0001	0.0004
	[-2.91]	[-0.498]	[-2.138]	[-1.633]	[-1.023]	[1.214]	[0.209]	[-0.017]	[1.137]	[2.162]	[1.133]	[1.308]	[1.281]	[0.711]	[1.863]
R-squared	0.038	0.151	0.178	0.163	0.195	0.016	0.025	0.045	0.032	0.071	0.112	0.132	0.118	0.125	0.144
Adj. R-sq	0.030	0.144	0.171	0.155	0.188	0.011	0.014	0.021	0.017	0.047	0.091	0.095	0.080	0.117	0.123
F-statistic	4.573	20.24	24.60	22.120	27.504	1.317	1.178	1.121	2.632	15.920	7.950	7.111	2.426	8.957	8.254

Source: Author's calculation

P-values in parentheses. ** - denotes significance at 5% level, when the coefficient sign is positive

Table 10: Granger causality – Chi-squares

	2007-2011 Chi-sq	2012-2019 Chi-sq	2020-2024 Chi-sq
Dependent variable: LSE			
ZSE	4.7398 (0.093)	0.6808 (0.711)	16.8465*** (0.0002)
SASE	5.6338 (0.059)	2.8270 (0.243)	6.7187 (0.075)
BSE	1.6600 (0.436)	1.0562 (0.589)	1.6152 (0.4459)
MSE	0.5222 (0.770)	5.0571 (0.079)	18.473*** (0.0001)
Dependent variable: ZSE			
LSE	138.7139** (0.000)	0.1069 (0.947)	1.0530 (0.591)
SASE	2.7737 (0.249)	2.1091 (0.348)	1.7510 (0.417)
BSE	14.151** (0.000)	0.3532 (0.838)	4.7444 (0.093)
MSE	1.2628 (0.531)	1.2983 (0.522)	15.418*** (0.0004)
Dependent variable: SASE			
LSE	1.1355 (0.566)	1.0848 (0.581)	5.6414 (0.060)
ZSE	51.307** (0.000)	0.1175 (0.942)	4.2069 (0.122)
BSE	5.5413 (0.062)	3.8442 (0.146)	2.632 (0.268)
MSE	0.4243 (0.808)	0.4577 (0.795)	8.870** (0.012)
Dependent variable: BSE			
LSE	11.8478*** (0.002)	2.2161 (0.330)	3.1076 (0.211)
ZSE	72.384*** (0.000)	9.5530** (0.008)	5.6039 (0.060)
SASE	4.5243 (0.104)	0.5704 (0.751)	0.6846 (0.710)
MSE	2.7390 (0.254)	2.9764 (0.225)	29.904*** (0.000)
Dependent variable: MSE			
LSE	12.595** (0.001)	0.1409 (0.931)	0.4984 (0.779)
ZSE	82.597** (0.000)	3.4768 (0.175)	29.043*** (0.000)
SASE	3.3809 (0.184)	2.0986 (0.350)	8.580** (0.013)
BSE	1.3095 (0.519)	0.2875 (0.866)	9.126** (0.010)

Source: Author's calculation

P-values in parentheses. *** - denotes significance at 1% level; ** - denotes significance at 5% level

The VAR estimates yield several noteworthy results. First, daily market returns are primarily influenced by their own lagged values, typically one or two days prior. Second, inter-market linkages are considerably stronger during the first sub-period, with the Macedonian Stock Exchange displaying a lagging pattern relative to the other markets. In contrast, during the most recent sub-period, this pattern reverses, as returns on the Macedonian market appear to exhibit precedence, leading those of the other markets with a lag of one to two days. Third, based on the number of statistically significant cross-market relationships, the intensity of interdependence is highest in the first sub-period, declines sharply in the second, and partially recovers in the third. This pattern is consistent with the findings from the weekly pairwise correlation analysis. Overall, the results suggest that inter-market linkages tend to strengthen during periods of heightened volatility, as both the first and the last sub-periods are characterized by increased economic turbulence and global disruptions. These findings provide support for the third research hypothesis.

To further investigate causal relationships, Granger causality tests are conducted, with the results reported in Table 10, including Chi-square statistics and corresponding p-values. These results reinforce the earlier observation that market interdependencies were strongest in the first sub-period, diminished during the second, and re-emerged in the third. During the initial period, the Croatian (ZSE) and Slovenian (LSE) markets exhibited precedence over the others; however, this leading role later dissipated. This shift may be explained by the substantial presence of institutional investors from these countries in neighboring markets prior to the 2008 crisis, which declined significantly thereafter. Furthermore, the relatively weak integration of the Sarajevo Stock Exchange (SASE) is evident, as is the presence of bidirectional causality between the Macedonian Stock Exchange (MSE) and most of the other markets during the final sub-period.

Robustness check

To assess the robustness of the VAR and Granger causality findings, an additional market is incorporated into the analysis—the Vienna Stock Exchange (VSE) and its benchmark index ATX. The purpose is to control for broader European economic conditions and to detect their possible influence on the observed inter-market linkages. The selection of the Vienna market is based on two considerations. First, it represents the closest developed Western European market with the potential to influence the markets under study. Second, it has historically exhibited a strong correlation with the XETRA DAX index of the Frankfurt Stock Exchange, one of the leading markets in continental Europe (typically ranging between 0.7 and 0.9). As such, the Vienna market serves as a suitable proxy for overall economic conditions and market dynamics within the European Union, which is the effect this analysis aims to control for.

Table 11: VAR model results – daily returns

	2007-2011					2012-2019					2020-2024				
	LSE	ZSE	SASE	BSE	MSE	LSE	ZSE	SASE	BSE	MSE	LSE	ZSE	SASE	BSE	MSE
VSE(-1)	0.055**	-0.028	0.034	0.056**	0.002	-0.022	0.033**	0.015	0.028**	-0.001	0.088**	0.079**	0.008	0.022	0.050**
	[2.429]	[-1.074]	[1.454]	[2.043]	[0.081]	[-1.399]	[2.787]	[0.955]	[2.082]	[-0.143]	[4.180]	[4.302]	[0.456]	[1.488]	[2.462]
VSE(-2)	-0.013	-0.042	-0.027	-0.041	-0.028	0.012	0.012	0.022	0.042**	0.030**	0.019	0.038**	-0.023	0.006	0.024
	[-0.616]	[-1.565]	[-1.199]	[-1.49]	[-1.105]	[0.772]	[0.994]	[1.419]	[3.136]	[2.309]	[0.929]	[2.037]	[-1.284]	[0.414]	[1.182]
LSE(-1)	0.174**	-0.040	-0.013	0.100**	0.071**	0.050**	0.004	0.019	-0.015	0.007	0.050	-0.052	-0.056	0.015	-0.036
	[5.802]	[-1.141]	[-0.427]	[2.739]	[2.110]	[2.273]	[0.261]	[0.888]	[-0.811]	[0.424]	[1.465]	[-1.728]	[-1.935]	[0.616]	[-1.114]
LSE(-2)	-0.046	0.412**	0.024	0.058	0.081**	-0.014	0.006	-0.011	0.0230	0.002	-0.032	-0.032	-0.024	0.027	-0.017
	[-1.558]	[11.551]	[0.797]	[1.581]	[2.379]	[-0.641]	[0.394]	[-0.518]	[1.223]	[0.112]	[-0.947]	[-1.075]	[-0.838]	[1.117]	[-0.541]
ZSE(-1)	-0.004	0.148**	0.142**	0.223**	0.235**	-0.006	0.046**	-0.016	0.000	0.032	-0.038	-0.047	-0.048	0.042	-0.079
	[-0.149]	[4.375]	[4.842]	[6.399]	[7.293]	[-0.208]	[2.050]	[-0.569]	[0.009]	[1.319]	[-0.928]	[-1.320]	[-1.407]	[1.435]	[-2.002]
ZSE(-2)	0.054	-0.064	0.106**	0.046	0.076**	-0.023	-0.042	-0.002	0.050	-0.012	0.144**	0.110**	0.060	-0.026	0.172**
	[1.850]	[-1.822]	[3.498]	[1.276]	[2.260]	[-0.780]	[-1.890]	[-0.087]	[1.982]	[-0.494	[3.586]	[3.113]	[1.777]	[-0.892]	[4.608]
SASE(-1)	-0.064	-0.003	0.279**	0.067	0.034	0.025	0.020	-0.046	-0.003	0.022	0.077	0.030	0.071**	0.015	0.089**
	[-2.162]	[-0.088]	[9.152]	[1.863]	[1.018]	[1.132]	[1.195]	[-2.077]	[-0.188]	[1.221]	[1.332]	[1.031]	[2.553]	[0.644]	[2.802]
SASE(-2)	0.060**	-0.059	-0.068	-0.020	0.041	0.022	0.021	-0.014	-0.001	0.016	0.002	-0.013	0.007	-0.016	-0.011
	[2.069]	[-1.712]	[-2.253]	[-0.580]	[1.241]	[0.989]	[1.268]	[-0.630]	[-0.087]	[0.862]	[0.067]	[-0.447]	[0.284]	[-0.677]	[-0.351]
BSE(-1)	0.008	0.044	0.039	0.196**	0.042	0.024	-0.009	-0.037	0.068**	0.000	-0.026	0.032	0.037	-0.045	-0.005
	[0.332]	[1.431]	[1.484]	[6.156]	[1.427]	[0.934]	[-0.482]	[-1.460]	[3.087]	[0.011]	[-0.679]	[0.932]	[1.125]	[-1.614]	[-0.140]
BSE(-2)	-0.026	0.105**	0.016	0.049	-0.001	0.011	-0.005	0.039	-0.001	0.003	0.059	0.170	0.028	0.111**	0.121**
	[-1.044]	[3.484]	[0.635]	[1.599]	[-0.017]	[0.419]	[-0.293]	[1.543]	[-0.061]	[0.181]	[1.561]	[1.484]	[0.886]	[3.983]	[3.285]
MSE(-1)	-0.016	0.020	0.008	-0.057	0.252**	0.057**	0.008	0.008	0.027	0.251**	-0.104	-0.121	0.083**	0.109**	0.170
	[-0.585]	[0.615]	[0.283]	[-1.695]	[8.111]	[2.075]	[0.413]	[0.313]	[1.191]	[11.27]	[-3.072]	[-4.073]	[2.904]	[4.449]	[5.240]
MSE(-2)	-0.027	0.019	-0.003	0.030	-0.135	-0.044	0.024	0.015	-0.039	-0.012	0.137**	0.070**	-0.004	0.041	-0.100
	[-1.018]	[0.621]	[-0.130]	[0.926]	[-4.470]	[-1.589]	[1.207]	[0.581]	[-1.668]	[-0.537]	[3.998]	[2.311]	[-0.151]	[1.658]	[-3.018]
C	-0.001	-0.000	-0.001	-0.001	-0.001	0.000	0.000	-0.001	0.000	0.0003	0.000	0.000	0.0002	0.000	0.000
	[-2.852]	[-0.447]	[-2.147]	[-1.674]	[-0.991]	[1.238]	[0.089]	[-0.065]	[1.000]	[2.112]	[1.323]	[1.5526	[1.233]	[0.7856	[1.998]
R-squared	0.0853	0.1546	0.176	0.163	0.196	0.181	0.154	0.162	0. 119	0.067	0.173	0.146	0.119	0.167	0.167
Adj. R-sq.	0.0850	0.1454	0.167	0.154	0.188	0.172	0.135	0.154	0.113	0.061	0.164	0.124	0.110	0.158	0.158
F-statistic	4.392	16.903	19.750	18.052	22.639	1.3743	1.9503	1.1455	3.347	12.105	8.410	7.933	2.092	7.647	7.656

Source: Author's calculation

P-values in parentheses. ** - denotes significance at 5% level, when the coefficient sign is positive

Table 12: VAR model results – summary of impacts

	2007-2011					2012-2019					2020-2024				
	LSE	**ZSE**	**SASE**	**BSE**	**MSE**	**LSE**	**ZSE**	**SASE**	**BSE**	**MSE**	**LSE**	**ZSE**	**SASE**	**BSE**	**MSE**
VSE(-1)	X			X			X		X		X	X			X
VSE(-2)									X	X		X			
LSE(-1)	X			X	X	X									
LSE(-2)		X			X										
ZSE(-1)		X	X	X	X		X								
ZSE(-2)			X		X						X	X			X
SASE(-1)			X										X		X
SASE(-2)	X														
BSE(-1)				X					X						
BSE(-2)		X												X	X
MSE(-1)					X	X				X			X	X	
MSE(-2)											X	X			

Source: Author's calculation

X denotes existence of causality, according to Table 11

The VAR results are given in Table 11, and the Granger causality results are presented in Table 13. Table 12 is an auxiliary table that summarizes the results presented in Table 11 to enhance visual clarity. To save space, the results with respect to the Vienna Stock Exchange as a dependent variable are not given, as the impact of the other markets on VSE is neither analyzed, nor logical.

The results presented in Tables 11 and 13 closely align with those obtained in the initial analysis, confirming the previously identified lead-lag relationships in the majority of cases. Furthermore, movements in the VSE appear to exhibit precedence over those of nearly all stock exchanges in the five former Yugoslav countries, although this pattern is not consistent across the entire sample period and is less evident for the Sarajevo Stock Exchange. These findings suggest that, despite their relatively lower level of development, the analyzed markets remain responsive to developments in more advanced economies and their corresponding stock markets.

Table 13: Granger causality – Chi-squares

	2007-2011	**2012-2019**	**2020-2024**
	Chi-sq	**Chi-sq**	**Chi-sq**
Dependent variable: LSE			
VSE	6.287** (0.043)	2.444 (0.294)	18.355*** (0.000)
ZSE	3.432 (0.179)	0.668 (0.715)	13.899*** (0.001)
SASE	7.070 (0.054)	2.160 (0.339)	5.5021 (0.064)
BSE	1.114 (0.572)	1.111 (0.573)	2.9969 (0.223)
MSE	1.758 (0.415)	5.541 (0.062)	21.287*** (0.000)
Dependent variable: ZSE			
VSE	3.600 (0.165)	9.084** (0.010)	22.698*** (0.000)
LSE	133.93*** (0.000)	0.235 (0.889)	4.4248 (0.109)
SASE	3.255 (0.196)	2.904 (0.234)	1.1999 (0.548)
BSE	16.453*** (0.000)	0.340 (0.843)	5.0504 (0.080)
MSE	1.001 (0.605)	1.997 (0.368)	18.870*** (0.000)
Dependent variable: SASE			
VSE	3.557 (0.168)	3.085 (0.213)	1.8556 (0.395)
LSE	0.728 (0.694)	1.014 (0.602)	4.6982 (0.095)

	2007-2011	2012-2019	2020-2024
	Chi-sq	**Chi-sq**	**Chi-sq**
ZSE	36.957*** (0.000)	0.337 (0.844)	5.2686 (0.071)
BSE	3.035 (0.219)	4.216 (0.121)	1.9699 (0.373)
MSE	0.084 (0.958)	0.560 (0.755)	8.6421** (0.013)
Dependent variable: BSE			
VSE	6.430** (0.040)	14.925*** (0.001)	2.3899 (0.303)
LSE	11.667*** (0.002)	2.062 (0.356)	1.7341 (0.420)
ZSE	43.222*** (0.000)	3.940** (0.009)	2.9221 (0.232)
SASE	3.478 (0.175)	0.041 (0.979)	0.8106 (0.667)
MSE	3.1672 (0.205)	3.429 (0.180)	26.699*** (0.000)
Dependent variable: MSE			
VSE	1.228 (0.540)	5.334 (0.069)	7.4758** (0.024)
LSE	12.008 *** (0.002)	0.197 (0.905)	1.6277 (0.441)
ZSE	59.570 *** (0.000)	1.929 (0.381)	25.721*** (0.000)
SASE	3.503 (0.173)	2.143 (0.342)	7.8711** (0.019)
BSE	2.095 (0.350)	0.033 (0.983)	10.874*** (0.004)

Source: Author’s calculation

P-values in parentheses. *** - denotes significance at 1% level; ** - denotes significance at 5% level

Discussion of results

The analysis of the results leads to several noteworthy conclusions. Although the former country ceased to exist more than 35 years ago, the stock markets of its successor states still exhibit relatively strong co-movement, particularly in terms of weekly return correlations. Values around 0.5 are frequently observed, especially during periods of heightened market turbulence. In contrast, these correlations nearly vanish during more stable periods, suggesting that the co-movement is driven less by economic linkages and more by investors’ reactions to external shocks. This interpretation is supported by the presence of Granger causality alongside the absence of significant cointegration. The lack of long-term relationships indicates that these markets do not move together in a sustained manner, which creates opportunities for diversification across the region.

The VAR analysis indicates that daily returns are predominantly driven by their own lagged values, typically with one- or two-day delays. This pattern may reflect a gradual adjustment of investors to new information or the presence of behavioral biases, such as anchoring. During the first sub-period, marked by the global financial crisis and the European sovereign debt crisis, the Ljubljana and Zagreb stock exchanges exhibited precedence, with their movements subsequently followed by other markets in the region. This dynamic can be linked to the more advanced development of the investment fund industry in these countries and their substantial investment exposure to neighboring, less developed markets. In contrast, the Macedonian Stock Exchange displayed a lagging pattern, consistent with its position as a net recipient of foreign capital. In particular, in 2007, foreign investors accounted for approximately 60% of buy-side transactions and around 30% of sell-side transactions, whereas in 2008 this structure reversed entirely.[1] Following the relatively stable second sub-period, the VAR results suggest a renewed strengthening of inter-market connections. However, the direction of these relationships is less uniform, with the Croatian (ZSE) and North Macedonian (MSE) markets emerging as the most interconnected with the rest of the group.

The strengthening of inter-market linkages during turbulent periods aligns with findings from previous studies (Baele, 2005; Dajčman & Festić, 2012; Okičić, 2014). Granger causality results confirm similar dynamics to the VAR analysis, indicating that market trends are transmitted across countries with time lags, although this does not imply direct causation. In our case, Granger causation means that the returns on one of the markets precede the market returns on another market with an appropriate time lag, or, in other words, it can only explain if and how the trends are transferred from one market to another, but not necessarily that the second market is influenced by the first. In the first sub-period, a clear west-to-east transmission pattern is observed, originating from Ljubljana and Zagreb toward Belgrade and Skopje. It is no surprise that trends are transferred from more developed markets towards the less developed ones (Samitas et al., 2006; Ye, 2014), but also the geographic proximity enhances this order of events (Wang & Lai, 2013). However, these linkages largely disappear during more tranquil periods (Naumoski et al. 2017), only to re-emerge between 2020 and 2024, albeit with some structural changes, including stronger influence from Zagreb and increased bidirectional relationships involving the Macedonian market. The existence of several external shocks is the possible explanation for the reversal of the trend (in line with Wang & Lai, 2013). Also, the change in the direction of transmission of impacts is not unknown, as Su et al. (2022) have reached the same conclusion in the case of 10 explored European stock markets post-Covid. The lower association of Sarajevo stock exchange could possibly be explained by the share of foreign investors on the buy-side on Sarajevo Stock Exchange, which in 2008 accounted for about 44%, but dropped to slightly more than 4% of the total turnover in 2025. Another interesting finding is that the markets of Slovenia and Croatia do not indicate a high degree of interconnectedness or an increase in the mutual association, despite the fact that these are the only countries that emerged from former Yugoslavia that have already become members of the European Union. This confronts the general theory that the membership in economic association reflects on the level of mutual association between the stock markets (Ferreira, 2018; Tilfani et al., 2019; Babaei et al., 2023).

Additional robustness checks including the Vienna Stock Exchange confirm the initial findings, showing that more developed markets tend to lead regional trends. This effect is particularly evident in recent years for Slovenia (LSE), Croatia (ZSE), and North Macedonia (MSE). This is consistent with the findings of Syllignakis & Kouretas (2010) and Kenourgios & Samitas (2011). In contrast, the Sarajevo and Belgrade exchanges appear increasingly disconnected, likely due to declining market activity. The annual turnover on the SASE remained relatively stable at around EUR 250 million during the 2019-2025 period, although the number of transactions has been declining. It is important to note that a large portion of this turnover is driven by public offerings rather than secondary market trading. Conditions on the BSE are even less favorable, as equity turnover, which stood between EUR 50 and 150 million in the mid-2010s, has fallen significantly to a range of EUR 13 to 40 million over the past five years, following a clear downward trend. A similar decline is evident in the number of transactions. In contrast, the MSE has experienced notable growth in activity between 2020 and 2025, with annual equity turnover increasing to between EUR 70 and 200 million, compared to EUR 40-70 million in the preceding decade. Meanwhile, the ZSE has maintained relatively stable turnover levels over the past ten years, culminating in a record high of approximately EUR 500 million in 2025. Overall, our evidence suggests that diminishing market activity is associated with reduced co-movement and weaker transmission of market dynamics.

Conclusions and recommendations

The primary aim of this study was to examine potential linkages among the stock markets of countries that emerged from the former Yugoslavia and to draw conclusions regarding their existence, direction, and persistence. The underlying assumption was that economies which once operated within a unified system might continue to exhibit similarities, and that such similarities could be reflected in comparable stock market dynamics. Additionally, similarities in the behavioral patterns of domestic investors were considered a possible driver of common movements across these markets.

The empirical analysis began with an examination of pairwise correlations of both daily and weekly returns across the five observed markets. The findings revealed several important patterns. First, correlations were generally stronger during periods of heightened global instability, such as the financial crisis, the European debt crisis, and the COVID-19 period, compared to more stable intervals. Second, daily correlations increased in the most recent sub-period relative to the earlier one in nearly all cases, with the exception of the Sarajevo Stock Exchange. While earlier research (e.g., Naumoski et al., 2017) suggested a decline in interlinkages, recent crises appear to have triggered their partial re-emergence. Results for weekly returns are less uniform, although, overall, weekly correlations tend to exceed daily ones, indicating that longer observation horizons smooth short-term fluctuations.

The cointegration analysis does not provide robust support for the existence of long-run equilibrium relationships. Although cointegrating vectors were occasionally detected, subsequent statistical testing failed to confirm their significance, leading to the rejection of the cointegration hypothesis. Consequently, a VAR framework was employed to explore short-run dynamics. The results indicate the presence of multiple lead-lag relationships, consistent with the earlier observation that market interdependence intensifies during turbulent periods.

Regarding the direction of causality, as assessed through Granger causality tests, the previously dominant role of Ljubljana Stock Exchange observed before the crisis has diminished. The Zagreb Stock Exchange retains some degree of precedence over markets located to the east, while the strongest interactions are identified between the Macedonian market and the other exchanges. Once again, the strengthening of inter-market relationships during periods of instability is clearly confirmed.

Robustness checks incorporating the Vienna Stock Exchange confirm most of the earlier findings and further indicate that this market assumes a dominant leadership role, particularly in relation to other EU-member markets and the Macedonian Stock Exchange. In contrast, its relationships with less liquid markets remain weak or negligible. Additionally, while the Vienna market exhibits clear precedence over the more active regional exchanges, a similar leading role is not observed for other stock markets in countries that have joined the European Union (LSE and ZSE).

In summary, the empirical evidence leads to the rejection of Hypothesis 1, as no persistent long-term relationships among the markets were identified. Hypothesis 2 is only partially supported, given that short-term linkages exist but vary across market pairs and time periods, with the strongest connections observed during episodes of economic turbulence. These findings, together with correlation and Granger causality results, lend support to Hypothesis 3. Hypothesis 4 is also partially confirmed, as causality is present in certain instances; however, the lack of persistence in lead-lag structures suggests that these relationships are not stable over time. This implies that practical application of the findings requires caution, and that investors should rely on up-to-date information.

Overall, the results do not allow for a definitive conclusion that the observed market linkages stem from underlying economic ties or the shared historical legacy of a common federation. Instead, they are more likely driven by investor behavior and responses to broader market developments. This interpretation is reinforced by the observed influence of the Vienna Stock Exchange, particularly on markets that exhibit stronger mutual connections. The earlier impact of institutional investors appears to have diminished, while the role of EU integration remains ambiguous.

Although some results confirm earlier evidence, particularly the increase in interconnectedness during periods of volatility, the study also contributes several new insights. Notably, the inclusion of the COVID-19 period and the subsequent geopolitical and economic disruptions demonstrates that previously weakening linkages can reappear under stress conditions. This suggests that the absence of long-term relationships does not imply complete independence among markets. Furthermore, the analysis shows that markets characterized by low and declining turnover tend to exhibit weaker integration. For example, despite representing a smaller economy, the Macedonian Stock Exchange appears more engaged in regional lead-lag dynamics than the Sarajevo and Belgrade exchanges. Finally, EU membership does not necessarily confer a dominant or leading position in regional market interactions.

From an investment perspective, the findings carry several implications. Given the absence of consistent co-movement, incorporating these regional markets into investment portfolios offers diversification benefits, with the Sarajevo Stock Exchange presenting the greatest potential due to its relatively low integration with other markets. Conversely, declining liquidity and turnover on the Belgrade Stock Exchange increase its divergence from more active markets, potentially encouraging Serbian investors to diversify internationally. In the short term, investors in the Macedonian market may benefit from closely monitoring developments in northern and western regional markets. These findings are likely to be more relevant for individual investors, as institutional investors typically follow long-term investment strategies and may derive limited benefits from short-term market dynamics. Nevertheless, institutional portfolios could still benefit from investing in companies that align with their specific investment criteria, irrespective of broader market movements. Policymakers can also use these insights to better anticipate market shocks and assess potential spillover effects.

Future research should broaden the analytical framework by incorporating additional variables that could help explain the underlying drivers of co-movement, as well as by applying alternative econometric methods capable of capturing these relationships more effectively. In particular, including additional global or European benchmark indices could provide valuable insights, given the increasing speed of information transmission and financial integration. Moreover, macroeconomic fundamentals such as GDP growth, interest rates, and exchange rates could be considered, although their lower frequency relative to financial market data presents methodological challenges that would need to be carefully addressed.

Declarations/acknowledgement

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest/Competing interests

There is no conflict of interest/Competing interests

Availability of data and material

The data that support the findings of this study are openly available in the websites of the stock exchanges analyzed in the paper.

Code Availability

The computer program results are shared through the tables in the manuscript.

Authors' Contributions

Not applicable.

REFERENCES

Baele, L. (2005). Volatility Spillover Effects in European Equity Markets. *The Journal of Financial and Quantitative Analysis*, Vol. 40, No. 2, pp.373-401

Babaei, Hamid, Georges Hübner, Aline Muller (2023). The effects of uncertainty on the dynamics of stock market interdependence: Evidence from the time-varying cointegration of the G7 stock markets. *Journal of International Money and Finance*, Vol. 139, https://doi.org/10.1016/j.jimonfin.2023.102961.

Batondo, M., & Uwilingiye, J. (2022). Comovement across BRICS and the US Stock Markets: A Multiitem Scale Wavelet Analysis. *International Journal of Financial Studies*, *10*(2), 27. https://doi.org/10.3390/ijfs10020027

Bekaert, G., Hodrick, R.J. & Zhang, X. (2009). International Stock Return Comovements, *The Journal of Finance*. 64: 2591-2626, https://doi.org/10.1111/j.1540-6261.2009.01512.x

Berument, H. & Ince, O. (2005). Effect of S&P500'S return on emerging markets: Turkish Experience. *Applied Financial Economics Letters*, Vol. 1, pp.59–64, http://dx.doi.org/10.1080/1744654052000314662

Caporale, G.M. & Spagnolo, N. (2011). Stock Market Integration between Three CEECs, Russia, and the UK. *Review of International Economics*, 19: 158-169, https://doi.org/10.1111/j.1467-9396.2010.00938.x

Connolly, R.A. & Wang, F.A. (2003). International equity market comovements: Economic fundamentals or contagion?. *Pacific-Basin Finance Journal*, Vol. 11, No.1, pp. 23–43.

Černy, A. & Koblas, M. (2008). Stock market integration and the speed of information transmission. *Czech Journal of Economics and Finance*, Vol. 58, pp. 2–20.

Dajčman, S. & Festić, M. (2012). Interdependence between the Slovenian and European Stock Markets – a DCC-GARCH Analysis. *Economic Research - Ekonomska istraživanja*, Vol. 25, No. 2, pp.379-396. http://dx.doi.org/10.1080/1331677X.2012.11517513

Đukić, Đ. & Đukić M. (2015). Interdependencies of Markets in Southeastern Europe and Buyback of Shares on Shallow Capital Markets: The Application of Cointegration and Causality Tests. *Panoeconomicus*, Volume 62, No. 4, pp. 469-491. http://dx.doi.org/10.2298/PAN1504469D

Égert, B. & Kočenda, E. (2007). Time-Varying Comovements in Developed and Emerging European Stock Markets: Evidence from Intraday Data. *William Davidson Institute University of Michigan Working Paper* 861-07.

Ferreira, P. (2018). What guides Central and Eastern European stock markets? A view from detrended methodologies. *Post-Communist Economies*, *30*(6). 805–819, https://doi.org/10.1080/14631377.2018.1460155

Forbes, K.J. & Rigobon, R. (2002). No Contagion, Only Interdependence: Measuring Stock Market Comovements. *Journal of Finance,* Vol. 57, pp. 2223-2261. http://dx.doi.org/10.1111/0022-1082.00494

Fratzscher, M. (2002). Financial market integration in Europe: on the effects of EMU on stock markets. *International Journal of Finance and Econonomics*, 7: 165-193, https://doi.org/10.1002/ijfe.187

Fu, R. & Pagani, M. (2012). On the cointegration of international stock indices. *Journal of Economics and Finance* 36, 463–480 (2012), https://doi.org/10.1007/s12197-010-9136-9

Gilmore, C. G. & McManus G. M. (2002). International portfolio diversification: US and Central European equity markets. *Emerging Markets Review,* Volume 3, Issue 1, 2002, Pages 69-83

Gilmore, C., Lucey B. & McManus, G. (2008). The Dynamics of Central European Equity Market Integration. *Quarterly Review of Economics and Finance*, Vol. 48, No. 3, 605-622. http://dx.doi.org/10.2139/ssrn.686113

Gradojević, N. & Dobardžić, E. (2013). Causality between Regional Stock Markets: A Frequency Domain Approach. *Panoeconomicus*, Vol. 60, No.5, pp. 633-647.

Gungor, A.C., & Taştan, H. (2021). On macroeconomic determinants of co-movements among international stock markets: evidence from DCC-MIDAS approach. *Quantitative Finance and Economics*. DOI:10.3934/QFE.2021002

Hachicha F. (2024), Sentiment investor, exchange rates, geopolitical risk and developing stock market: evidence of co-movements in the time-frequency domain during Russia-Ukraine war. *Review of Behavioral Finance*, Vol. 16, No. 3, pp. 486–509, doi: https://doi.org/10.1108/RBF-04-2023-0119

Halaç, U., Taşkin, F.D. & Çağlı, E.Ç. (2013). The Turkish Stock Market Integration with Oil Prices: Cointegration Analysis with Unknown Regime Shifts. *Panoeconomicus*, Vol. 60, No. 4, pp. 499-513, doi: 10.2298/PAN1304499H

Hamao, Y., Masulis, R.W. & Ng, V. (1990). Correlations in Price Changes and Volatility across International Stock Markets. *The Review of Financial Studies*, Vol. 3, No. 2, pp. 281-307

Horvath, R. & Petrovski, D. (2012). International Stock Market Integration: Central and South Eastern Europe Compared. *Economic Systems*, Vol. 37, No. 1, pp. 81-91.

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control*, Vol. 12, pp. 231-254.

Johansen, S. & Juselius, K. (1990). Maximum Likelihood Estimation and Inference on Cointegration—With Applications to the Demand for Money. *Oxford Bulletin of Economics and Statistics*, 52, 169-210.

Kasa, K. (1992). Common Stochastic Trends in International Stock Markets. *Journal of Monetary Economics*, 29, 95-124, https://doi.org/10.1016/0304-3932(92)90025-W

Kenourgios, D. & Samitas, A. (2011). Equity market integration in emerging Balkan markets. *Research in International Business and Finance*, Vol. 25, No. 3, pp. 296-307. http://dx.doi.org/10.1016/j.ribaf.2011.02.004

King, M. & Wadhwani, S. (1990). Transmission of Volatility between Stock Markets. *Review of Financial Studies*, Vol. 3, No. 1, pp. 5-33.

Longin, F. & Solnik B. (2001). Extreme Correlation of International Equity Markets. *The Journal of Finance*, Vol. 56, No. 2, pp. 649-676

Luis A. Gil-Alana, Juan Infante, Miguel Angel Martín-Valmayor (2023). Persistence and long run co-movements across stock market prices, *The Quarterly Review of Economics and Finance*, Volume 89, https://doi.org/10.1016/j.qref.2022.10.001.

Masih, A.M. & Masih, R. (1997). A comparative analysis of the propagation of stock market fluctuations in alternative models of dynamic causal linkages. *Applied Financial Economics, 7*, 59-74, doi:10.1080/096031097333853

Muneer S, Waris M, Kanwal S, Tripathi A (2026), Dynamic co-movements of stock markets and implications for portfolio managers: evidence from wavelet approach. *International Journal of Emerging Markets*, Vol. 21 No. 2 pp. 488–512, https://doi.org/10.1108/IJOEM-04-2024-0737

Narayan, P.K., & Smyth, R. (2005). Cointegration of stock markets between New Zealand, Australia and the G7 economies: searching for co-movement under structural change, *Australian Economic Papers*, 44: 231-247, https://doi.org/10.1111/j.1467-8454.2005.00262.x

Ng, A. (2000). Volatility Spillover Effects from Japan and the US to the Pacific-Basin. *Journal of International Money and Finance*, Vol. 19, pp. 207-233.

Naumoski, A., Arsov, S., Gaber, S. & Gaber-Naumoska, V. (2017). Diminishing inter-linkages of the South East European stock markets, *Economic Computation and Economic Cybernetics Studies and Research*, *51*(3). 91-108.

Okičić, J. (2014). An Empirical Analysis of Stock Returns and Volatility: the Case of Stock Markets from Central and Eastern Europe. *South East European Journal of Economics and Business*, Vol. 9, No. 1, pp. 7-15.

Samitas, A., Kenourgios, D. & Paltalidis N. (2006). Short and long run parametric dynamics in the Balkans stock markets. *International Journal of Business, Management and Economics*, Vol. 2, No. 8, pp. 5-20

Shi,Yujie (2022). What influences stock market co-movements between China and its Asia-Pacific trading partners after the Global Financial Crisis?. *Pacific-Basin Finance Journal*, Vol. 72, https://doi.org/10.1016/j.pacfin.2022.101722.

Su, Chi-Wei, Syed Kumail Abbas Rizvi, Bushra Naqvi, Nawazish Mirza, Muhammad Umar (2022). COVID19: A blessing in disguise for European stock markets?, *Finance Research Letters*, Vol. 49, https://doi.org/10.1016/j.frl.2022.103135

Syllignakis, M. & Kouretas G. (2010). German, US and Central and Eastern European Stock Market Integration. *Open Economies Review*, Vol. 21, No. 4, pp. 607-628

Syriopoulos, T. (2007). Dynamic Linkages between Emerging European and Developed Stock? Has the EMU Any Impact?. *International Review of Financial Analysis*, 16, 41-60.

Syriopoulos, T. & Roumpis E. (2009). Dynamic Correlations and Volatility Effects in the Balkans Equity Markets. *International Financial Markets, Institutions and Money,* Vol. 19, No. 4, pp. 565-585.

Tilfani, O., Ferreira, P. & El Boukfaoui, M. Y. (2019). Revisiting stock market integration in Central and Eastern European stock markets with a dynamic analysis. *Post-Communist Economies*, *32*(5). 643–674. https://doi.org/10.1080/14631377.2019.1678099

Vatsa P, Basnet H, Mixon F (2022), "Stock market co-movement in Latin America and the US: evidence from a new approach". *Journal of Financial Economic Policy*, Vol. 14 No. 2 pp. 162–171, doi: https://doi.org/10.1108/JFEP-02-2021-0047

Wang, K-M. & Lai, H.-C. (2013). Which Global Stock Indices Trigger Stronger Contagion Risk in the Vietnamese Stock Market? Evidence Using a Bivariate Analysis. *Panoeconomicus*, Vol. 60, No. 4, pp: 473-497, doi: 10.2298/PAN1304473W.

Wongswan, J. (2006). Transmission of Information across International Equity Markets. *The Review of Financial Studies*, Vol. 19, No.4, pp.1157-1189.

Xing, Shuo, Tingting Cheng, Liping Qiu, Xiaoyang Li (2025). The evolution of herding behavior in stock markets: Evidence from a smooth time-varying analysis, *Pacific-Basin Finance Journal*, Volume 90, https://doi.org/10.1016/j.pacfin.2025.102664.

Ye, G.L. (2014). The Interactions between China and US Stock Markets: New Perspectives. Journal of International Financial Markets, Institutions and Money. Vol.31, pp. 331-342.

Zehri, Chokri (2021). Stock market comovements: Evidence from the COVID-19 pandemic, *The Journal of Economic Asymmetries*, Volume 24, https://doi.org/10.1016/j.jeca.2021.e00228.

NOTES

[1] All the statistical data in this part are taken from the websites of the respective stock exchanges.

APPENDIX

Table A-1: Lag length information criteria for the entire period and every sub-period (Cointegration)

Lag	LogL	LR	FPE	AIC	SC	HQ
2007-2024						
0	4992.14	NA	8.65e-08	-2.0732	-2.0664	-2.0708
1	75676.32	141192.0	1.51e-20	-31.447	-31.406	-31.433
2	76351.94	1348.15	1.16e-20	-31.717	-31.643	-31.691
3	76546.03	386.895	1.08e-20	-31.788	-31.680	-31.750
4	76739.14	384.527	1.00e-20	-31.857	-31.716*	-31.808*
5	76787.85	96.8963	9.95e-21	-31.867	-31.692	-31.806
6	76827.38	78.558*	9.89e-21*	-31.873*	-31.665	-31.800
2007-2011						
0	3711.42	NA	1.03e-09	-6.5024	-6.4804	-6.4941
1	15781.05	24012.20	6.86e-19	-27.633	-27.5008	-27.583
2	16015.62	464.6123	4.75e-19	-28.001	-27.7579	-27.909
3	16120.05	205.9445	4.13e-19	-28.140	-27.7868	-28.006
4	16220.13	196.4739	3.62e-19*	-28.272*	-27.8080*	-28.096*
5	16242.17	43.062*	3.64e-19	-28.266	-27.6923	-28.049
6	16254.14	23.28569	3.73e-19	-28.244	-27.5590	-27.985
2012-2019						
0	9608.83	NA	6.22e-11	-9.3105	-9.2969	-9.3055
1	36720.28	54065.19	2.45e-22	-35.5698	-35.4879*	-35.539
2	36811.33	181.1409	2.30e-22*	-35.6338*	-35.4837	-35.578*
3	36824.45	26.0418	2.33e-22	-35.6223	-35.4039	-35.542
4	36839.78	30.3355	2.35e-22	-35.6129	-35.3263	-35.507
5	36861.60	43.0880	2.36e-22	-35.6098	-35.2549	-35.479
6	36882.85	41.8712*	2.37e-22	-35.6062	-35.1831	-35.451
2020-2024						
0	22259.80	NA	6.94e-22	-34.530	-34.492	-34.523
1	22356.98	193.442	6.20e-22	-34.642	-34.510	-34.597
2	22427.04	138.929	5.78e-22	-34.712	-34.522*	-34.702*
3	22522.69	188.936	5.18e-22	-34.822	-34.502	-34.664
4	22547.65	49.102	5.18e-22	-34.822	-34.401	-34.651
5	22588.60	80.237	5.06e-22	-34.851*	-34.326	-34.630
6	22616.41	54.288*	5.04e-22*	-34.847	-34.230	-34.618

Source: Author's calculations

Description: LR - sequential modified LR test statistic (each test at 5% level), FPE - Final prediction error, AIC - Akaike information criterion, SC - Schwarz information criterion, HQ - Hannan-Quinn information criterion

Table A-2: Johansen cointegration test results (2020-2024)

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.020060	62.73432	69.81889	0.1612
At most 1	0.012695	36.53279	47.85613	0.3699
At most 2	0.010296	20.01285	29.79707	0.4220
At most 3	0.005079	6.631540	15.49471	0.6208
At most 4	3.67E-05	0.047438	3.841466	0.8276

Trace test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.020060	26.20152	33.87687	0.3086
At most 1	0.012695	16.51994	27.58434	0.6213
At most 2	0.010296	13.38131	21.13162	0.4177
At most 3	0.005079	6.584102	14.26460	0.5394
At most 4	3.67E-05	0.047438	3.841466	0.8276

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Source: Author's calculations

Table A-3: Lag order selection criteria (VAR model)

2007-2011						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
1	18006.28	NA	5.04e-19	-27.94293	-27.88957	-27.90531
2	18125.94	237.4623	4.35e-19	-28.09004	-27.91911*	-28.10693*
3	18234.45	214.4915	3.82e-19	-28.22981*	-27.84270	-28.04984
4	18262.73	55.68316	3.80e-19*	-28.21491	-27.82397	-28.01478
5	18276.83	27.65243	3.86e-19	-28.20797	-27.70680	-28.07440
6	18298.67	42.66729*	3.88e-19	-28.20307	-27.60166	-27.97730
7	18313.08	28.03494	3.95e-19	-28.18661	-27.48497	-27.92322
8	18326.91	26.78860	4.02e-19	-28.16924	-27.36736	-27.86822

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

2012-2019						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
1	36664.12	NA	2.49e-22	-35.55685	-35.54320*	-35.55185
2	36758.82	188.8668	2.32e-22*	-35.62447*	-35.54253	-35.59443*
3	36773.82	29.82314	2.35e-22	-35.61476	-35.46455	-35.55969
4	36789.53	31.19213	2.37e-22	-35.60576	-35.38727	-35.52566
5	36812.14	44.75797	2.37e-22	-35.60344	-35.31668	-35.49831
6	36834.15	43.45956*	2.38e-22	-35.60053	-35.24550	-35.47037
7	36845.50	22.36066	2.41e-22	-35.58730	-35.16398	-35.43210
8	36858.40	25.34183	2.44e-22	-35.57556	-35.08397	-35.39533

2020-2024						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
1	22356.98	193.4421	6.20e-22	-34.64232	-34.51031	-34.59723
2	22427.04	138.9290	5.78e-22	-34.71224	-34.52219*	-34.70162*
3	22522.69	188.9368	5.18e-22	-34.82187	-34.50152	-34.66398
4	22547.65	49.10242	5.18e-22	-34.82180	-34.40134	-34.65114
5	22588.60	80.23755	5.06e-22	-34.85091*	-34.32597	-34.62957
6	22616.41	54.28831*	5.04e-22*	-34.84654	-34.23023	-34.61793
7	22630.55	27.49370	5.12e-22	-34.83406	-34.11327	-34.56350
8	22648.14	34.05016	5.18e-22	-34.82255	-34.00166	-34.51442

Source: Author's calculations