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Dynamic risk spillovers in European Stock Markets: a TVP-VAR Approach

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Abstract. *In this paper, we studied the propagation of risks in European capital markets based on 17 European stock market indices using the methodology proposed by Chatziantoniou et. al. (2021) of a TVP – VAR model and an approach to the levels of connection of variables. The study covers the period November 2001 – February 2025 and focuses on the returns and volatilities of stock market indices. We use a high frequency band (to measure the short term) and a low frequency (for the long term) to measure the level of connection. We observe that the level of interconnection of capital markets is high over the entire analyzed period, and risks propagate from Western European capital markets to Eastern European capital markets, both in terms of returns and volatility. In our opinion, this analysis contributes to understanding the dynamics of European capital markets and improving investors' portfolios.*

Keywords: Risk spillover, TVP-VAR, European capital markets, stock market indices, connectedness measures.

JEL Classification: G15, C32, C58, G01, F36.

Introduction

The interconnection of global capital markets is one of the critical areas of research, especially for understanding how risk propagates across regions during periods of market stress. Risk spillovers—the transmission of volatility, uncertainty, and shocks from one capital market to another—have profound implications for market stability, portfolio management, and policy making. This study focuses on spillover dynamics between capital markets in Western and Eastern Europe, regions characterized by different levels of market maturity, economic development, and systemic integration.

Given the events that have taken place over the past 25 years, including the Great Recession of 2008–2009, the Sovereign Debt Crisis (or Euro crisis) of 2010–2012, the global COVID-19 pandemic of 2020, and the Russian-Ukrainian war that began in 2022, it is important to analyze the level of connectivity between European capital markets. Due to the visible differences between Western economies (classified as mature, developed economies) and Eastern economies (predominantly classified as developing economies), as well as European Union integration policies and the general trend toward globalization, the spread of financial risk effects is clearly a topic of interest to both capital market agents and legislative and supervisory bodies.

Therefore, in this paper, we decided to use a TVP-VAR (Time varying parameter – vector autoregression) econometric model designed by Diebold and Yilmaz (2014) and extended by Antonakakis et. al. (2020) to analyze the level of dynamic interconnection between Eastern and Western European capital markets (quantified by stock market indices with high capitalization levels for each region). Based on the literature, we have two expectations:

1) the level of interconnection has evolved positively over the last 25 years (i.e., it has grown relatively steadily over the period analyzed);
2) in times of financial/global crisis, the level of interconnection reaches its maximum values. The higher the level of interconnection, the greater the risk propagation effects (from an economic theory perspective).

The paper is structured as follows: Chapter I – Literature review, where we analyze the existing body of work on the present topic; Chapter II – Methodology, where we present the data and models used in the econometric analysis; Chapter III – Empirical results and discussions, where we present the estimates obtained and discuss them; the last chapter – Conclusions, recommendations, and limitations of the paper – in which we present the conclusions based on the above, along with the recommendations and limitations of the present study.

1. Specialized literature

The subject of analyzing the relationship between various capital markets (related to sovereign states) has always been of interest, both from the perspective of returns (ly rational agents seek to maximize their utility and wealth) and from the perspective of risk

(the same ly rational agents simultaneously seek to minimize possible losses). One of the main methods of analyzing the relationships between them is through stock market indices. Financial theory tells us that the price of a stock contains all the information necessary for rational agents to make the necessary decisions.

A number of studies have analyzed this relationship using VAR and VECM models. On the one hand, authors such as Friedman and Shachmurove (1997), Mylondis and Kollias (2010), Guidi and Ugur (2014), and Tarțâ (2023) show that there is cointegration of European capital markets, using Granger cointegration (for the short term) and Johansen (for the long term). In most of these papers, the level of cointegration is weak between markets and, in general, they identify short-term cointegration more than long-term cointegration.

Other authors, including Égert and Kočenda (2007) and Dima Dan – Mihai (2024), show that this cointegration is not observed at the level of empirical data, using the same research methodology (Granger and Johansen cointegration). There are a number of reasons for this, ranging from the period of analysis (depending on when the study was conducted) to the frequency level taken into account (e.g., Guidi and Ugur (2014) use daily data, while Égert and Kočenda (2007) used intra-day data).

Despite the fact that stock market cointegration is either weak or non-existent, the studies presented above show that there are causal relationships—bidirectional, generally between the capital markets of Western European countries, and unidirectional, generally from Western European markets to Eastern European markets. One explanation for this is that the capitalist system based on the market economy has been in place for much longer in the mature economies of Western Europe than in Eastern Europe (which was under the communist regime – the centralized socialist system).

Given the purpose of this paper (to analyze the spillover effects of risk or "risk spillovers" on European stock markets), we present below those papers that have contributed to our understanding of this topic. de Araújo and Garcia (2013) use three econometric models in their paper: GARCH, EGARCH, and TARCH to analyze "risk spillover" between European stock indices (represented by DAX, CAC40, FTSE, etc.), US indices (S&P500) and Japanese indices (NIKKEI225) for the period January 30, 1998 - July 1, 2011. The data collected is daily, and the conclusions are that, in general, there are no risk spillover effects between Northern European stock exchanges (or they are very low, with contagion spreading over a few days), unlike their Southern partners (where contagion occurs over a longer period).

Another interesting analysis is that carried out between the effect of yield propagation between intra-EMU (European Monetary Market) countries and those outside the EMU. Authors Qarni and Gulzar (2020) analyze the period November 2009–December 2016, covering stock market indices (daily frequency) for 19 EMU member states and 9 non-EMU member states (but all part of the European Union). Using a TVP-VAR econometric model, the researchers show that the level of interconnection (connectivity) is higher in

EMU countries than in non-EMU countries. The direction of propagation is asymmetric, generally from EMU countries to non-EMU countries.

As mentioned, one of the events that had a strong impact on capital markets is the COVID-19 pandemic. Aslam et al. (2021) investigated the risk propagation effect (in the form of stock market volatility) in 12 Western European Union countries. The data is in the form of "intra-day" with a (high) frequency of 5 minutes for the period December 2019 – May 2020. Using the methodology proposed by Diebold and Yilmaz (2012), they estimate the volatility spillover effect (in gross and net terms) and show that there is a significant volatility spillover effect between the 12 stock markets, suggesting weak potential for diversification between them. The level of interconnection is also significantly high.

The Russian-Ukrainian war is another event that has implications for the capital market (considering the economic relations that the two states have with European countries – both EU and non-EU members). Therefore, economic researchers analyzed the geopolitical risk and how it propagates when the war was declared and started (effectively conducting an "event study").

Ciocîrlan and Nițoi (2023) investigate the geopolitical risk presented by the Russian-Ukrainian war, using a methodology developed by Baruník & Křehlík (2018) on 23 economies, 10 of which are Western European economies, 12 are Central and Eastern European (CEE) economies, and Russia. They use daily data for stock market indices (denominated in USD) for the period January 2015 – November 2022. The impact of the outbreak of war was moderate on the level of interconnection between the selected countries. Moreover, while the emerging EU countries showed a higher overall spillover effect, they returned to pre-war values relatively quickly, unlike countries outside the EU.

Another topic of interest to economists is the recent energy crisis (which arose as a result of the war between Russia and Ukraine). Since the European energy market tends to behave (recently speaking) like the capital market, economic researchers have applied econometric models to investigate the level of interconnection and spillover effect in this area.

Cevik & Zhao (2025) analyze the energy market in 24 European countries for the period 2014–2024. Using the econometric model proposed by Diebold and Yilmaz (2014), they observe that for the analyzed time interval, 73% of the variation in forecast errors is explained by "cross-variance shares" – which shows that the volatility spillover effect (and therefore risk) dominates the behavior of European energy markets.

In addition to all these academic works, the prevailing macroeconomic context at the European level must also be taken into account. Of the 44 countries in Europe, 27 are currently part of the European Union, and 20 of the 27 EU countries are part of the eurozone/EMU. Both the Maastricht Treaty (1993) and the Lisbon Treaty (2009) suggested and even recommended the integration of member states' markets as much as possible, with monetary union resulting in the single currency, the euro, being one of the most important moments for the cohesion of the European Union.

Considering the works presented above, we can extract the following research hypotheses to be tested in this study:

H1: The level of capital market interconnection tends to increase over time;

H2: The level of capital market interconnection peaks during periods of crisis and reaches its lowest point immediately after the end of the crisis;

H3: The propagation effect of stock market returns (calculated as the difference between daily stock market index values) tends to be unidirectional, from Western to Eastern European stock markets.

H4: The propagation effect of stock market volatility (calculated as the standard deviation of the difference between daily stock market index values as a 30-day rolling window) tends to be unidirectional, from Western to Eastern European stock markets.

2. Methodology

As a methodology used in this paper, we decided to analyze the collected data (namely, 17 stock indices related to the European space, these being AEX, ATH, BEL 20, BET, BUX, CAC, DAX, FMIB, HEX, IBEX, PX, SAX, SMI, SOFIX, UKX/FTSE 100, WIG 20, XU100/BIST 100), being of the "daily time series" type for the time interval November 2001 to February 2025 (totaling 5,971 observations), we use a TVP-VAR (time varying parameters – vector autoregression) econometric model.

The main work on which this type of econometric model is based is that of Koop and Korobilis (2014), who proposed using this TVP-VAR model instead of the rolling window VAR model, the latter being at that time the classic model for dynamic modeling of relationships between variables. The rolling window VAR model presents a number of problems in its application, including the arbitrary choice of size for the rolling window, loss of observations, and sensitivity of parameters to extreme values. The model proposed by Koop and Korobilis solves these problems.

Diebold and Yilmaz (2012, 2014) also proposed the use of a new methodology for calculating the level of connection between the various variables proposed for analysis. Based on these three papers, a new methodology was developed that uses both the concept of connection between variables proposed by Diebold and Yilmaz and the econometric modeling by TVP-VAR by Koop and Korobilis.

The two main papers introducing the new methodology are those by Baruník and Křehlík (2018) and Antonakakis et al (2020), respectively. Another econometric paper that improves the analysis and interpretation is that of Chatziantoniou et al (2021), which incorporates frequency bands into the TVP-VAR model (and into interconnection indices) to observe short-term (defined as 1–5), medium (5–Inf), and long (Total).

The econometric equation used in calculating the TVP-VAR model (as proposed in the aforementioned papers) has the following form:

$$x_t = \Phi_{1t} x_{t-1} + \Phi_{2t} x_{t-2} + \ldots + \Phi_{pt} x_{t-p} + \varepsilon_t$$
$$\varepsilon_t \sim N(0, \Sigma_t) \quad (1)$$

where:

x_t, x_{t-1} şi ε_t are vectors of dimensions $N \times 1$,

Σ_t and Φ_{it} i = 1, ..., p are $N \times N$ matrices where the first represents the variance-covariance matrix that varies over time, and the second matrix illustrates the coefficients calculated for the "time-varying VAR" (this methodology is in line with that presented by Chatziantoniou et al (2021)).

After calculating the econometric model, we can calculate the measures of interconnection between variables (using GFEVD – "generalized forecast error variance decomposition"), which are:

- NPDC ("Net pairwise connectedness") shows us which of two variables influences the other more;
- TO ("Total direction connectedness TO others") shows us how much of the shock of one variable is transmitted to the other variables;
- FROM ("Total direction connectedness FROM others") shows us how much a variable receives from the shocks of the other variables;
- NET ("Net total directional connectedness") shows the difference between TO and FROM, which can be interpreted as the influence of that variable on the network of variables;
- TCI ("Total connectedness index") measures the level of interconnection at the variable network level – therefore, it measures the average impact that a variable has on all other variables.

For more details on the mathematical specifications of the TVP-VAR model and interconnection indices, I recommend reading the papers mentioned in this chapter, which provide an intuitive presentation of the econometric model and interconnection measures. In applying the model presented above, I used the R software with the "ConnectednessApproach" package, which is specifically designed to run TVP-VAR models and interconnectedness measures.

3. Empirical results and discussions

After collecting data for the 17 stock indices for the period November 2001 – February 2025, we proceeded to process them. Therefore, we applied the natural logarithm and first-order differentiation to obtain the daily returns of the stock indices.

The descriptive statistics for these can be seen below, with stock indices grouped according to the type of economy of the countries where the stock exchange is located (and the stock index is calculated).

Table 1. *Descriptive statistics – market index returns for mature (Western) European economies*

	AEX	BEL_20	CAC	DAX	FMIB	FTSE_100	HEX	IBEX	SMI
Mean	0.0001	0.00009	0.0001	0.00025	0.00003	0.00009	0.00003	0.00007	0.00012
Median	0.0005	0.00038	0.00046	0.00069	0.0006	0.00034	0.00021	0.00051	0.00041
Std. Dev.	0.013	0.012	0.0136	0.01394	0.01469	0.04924	0.01361	0.01386	0.01092
Skewness	-0.2085	-0.4240	-0.1970	-0.1387	-0.6264	0.18643	-0.2962	-0.3258	-0.2715
Kurtosis	10.971	13.1676	10.3187	9.77844	12.8632	2683.418	8.05706	12.3103	11.4947
Jarque-Bera	15846	25890	1336	11447	24585	17,900,000	6448	21664	18020
Probability	0	0	0.	0.	0.	0	0	0	0
Observations	5969	5969	5969	5969	5969	5969	5969	5969	5969

Source: Own calculations.

Table 2. *Descriptive statistics – returns on emerging (Eastern) European market indices*

	D_ATH	D_BET	D_BIST_100	D_BUX	D_PX	D_SAX	D_SOFIX	D_WIG_20
Mean	-0.00009	0.0005	0.0007	0.00041	0.0002	0.00015	0.00038	0.00012
Median	0.00016	0.00039	0.00069	0.00033	0.0004	0.000	0.00006	0.000
Std. Dev.	0.017	0.01371	0.01768	0.01419	0.01237	0.01085	0.01118	0.01424
Skewness	-0.53352	-0.37765	-0.26849	-0.41778	-0.65127	-0.80527	-0.68253	-0.36948
Kurtosis	12.18278	16.6713	7.80758	11.68798	19.726	21.42304	16.58949	8.02778
Jarque-Bera	21255	46627	5820	18946	70001	85059	46393	6423
Probability	0	0	0	0.	0.	0	0	0
Observations	5969	5969	5969	5969	5969	5969	5969	5969

Source: Own calculations.

As can be seen, in general, the returns of emerging (eastern) economies in Europe tend to be higher on average than those of mature (western) economies. Here we note the exception of the ATH – Athens Composite Index, which show a negative return over the period, explained by the economic phenomena experienced by Greece (namely the Great Recession of 2007–2008, the Sovereign Debt Crisis of 2010–2012, and Greece's default in 2015).

For both Western and Eastern capital market returns, the skewness is predominantly negative, with the sole exception being the Anglo-Saxon capital market (represented by the FTSE 100 stock market index). This shows that there is a tendency to record lower-than-average returns—one explanation being the significant number of financial crises (and economic recessions) that have caused capital markets to lose significantly in each of them.

Tables 3 and 4 (in the appendix) present descriptive statistics for the volatilities of the market indices of mature (Western) European economies and emerging (Eastern) European economies, respectively. Volatilities were calculated using the rolling window methodology over a 30-day period based on previously calculated returns.

The two tables in the annexes show that in mature economies, stock market index volatility is around 0.01 (or 1%), while in emerging economies we see either values higher than 0.01 (as is the case with the ATH, BET, BIST_100, PX, and WIG_20 indices) or below 0.01 (as is the case with the SAX and SOFIX indices). Therefore, part of the reason for higher returns in the East versus the West is explained by the higher degree of volatility.

In Western European capital markets, the most volatile market is the Anglo-Saxon market, with an average value of approximately 1.32%. The least volatile of these is the Swiss market, with an average value of 0.96% over the period. Among Eastern European capital

markets, the most volatile are the Turkish (1.63%) and Greek (1.52%) markets. The least volatile Eastern European market is Bulgaria (0.91%).

Below, we will present and discuss the results obtained using the methodology presented in the previous chapter. Thus, in Tables 5, 6, and 7 (attached in the appendix), we can observe the levels of dynamic interconnection between the 17 stock indices—both overall and in the short term (coded "1-5") and in the long term (coded "5-Inf").

The tables are interpreted as follows: the column shows the spillover effect transmitted to other variables, and the row shows the spillover effect received from other variables. The NET row shows whether capital markets (represented by stock market indices) are net transmitters or net receivers.

According to Table 5, overall, the net transmitters are stock indices for Western European countries (or mature European economies), namely FTSE 100, AEX, BEL, CAC, DAX, FMIB, HEX, IBEX, and SMI. The French capital market is the net transmitter (with a CAC index value of 29.8), followed by the Dutch capital market through AEX (24.41) and the German capital market - DAX (23.54). The net recipients are the capital markets of Eastern European countries (or emerging European economies) represented by stock indices, namely ATH, BET, BIST 100, BUX, PX, SAX, SOFIX, and WIG 20. The Romanian capital market receives the most from the risk propagation effect, with a value of -24.39 for BET, followed by the Turkish capital market - BIST 100 (-23.22) and the Greek capital market - ATH (-22.77).

In the short term (Table 6), the trend observed at the total level continues (namely, Western European capital markets are net transmitters and Eastern European capital markets are net receivers). The net transmitters with the highest values are still CAC (20.78), AEX (17.7), and DAX (16.06). The net receivers with the lowest values are BIST 100 (-17.32), ATH (-15.86), and BET (-14.9), respectively. In the long term (Table 7), the trends observed previously are maintained, with the observation that the capital market where the propagation effects are most felt is the Romanian one, as observed by the value of the BET index (-9.45), followed by the Bulgarian capital market through SOFIX (-8.44) and the Greek capital market through ATH (-6.49).

The following three tables (Tables 7, 8, and 9) attached in the appendix show the level of interconnection between the 17 stock indices in terms of their volatility. In terms of volatility, we observe that, when calculated over the entire time interval, net transmitters and net receivers tend to be the same, with the sole exception being the WIG 20 stock index – corresponding to the Warsaw Stock Exchange in Poland. An economic explanation for this fact may be given by the interdependence between the German and Polish economies, which means that, from a volatility perspective, the Polish stock index follows the same trends as the volatility of the DAX index.

In the short term, we observe that the trend observed in short-term returns for stock indices is maintained, with the exception of the PX stock index (related to the Prague Stock Exchange, Czech Republic) – which is a net transmitter in this case (with a value of 0.08 >

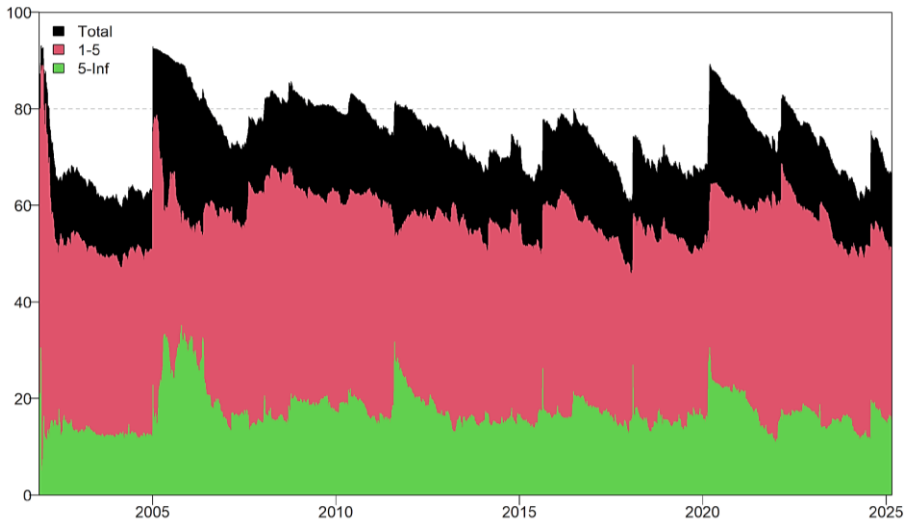
0), but with a value so close to 0, we can actually interpret that in the short term, the PX does not transmit or receive significant shocks from other stock indices. At the same time, the SMI acts in the short term as a net receiver of risk propagation (with a value of -0.53 < 0). In the case of the Swiss stock index, it is a (relatively) weak receiver of the risk propagation effect from other stock indices, an economic explanation for this being the size of the Swiss economy (small) relative to its geographical neighbors (namely France, Austria, Germany, significantly larger economies).

In the long term, we again observe a change in the interconnection between the volatility of European stock indices and the long-term behaviour of European stock index returns. Thus, in terms of volatility, the WIG 20 index (in addition to other classic net transmitters, related to mature Western European economies) shows positive values of the NET index (for WIG 20 –> 2.83 >> 0), thus also being a net transmitter of spillover effects. The main stock indices to which it transmits risk ("spillover") are BUX (6.88) and PX (6.14).

Based on the six tables presented above, we can say that our research hypotheses H3 and H4 are confirmed (to the extent of the available data and with the present methodology), namely that Western European stock indices transmit spillover risk to Eastern European stock indices, both in terms of daily returns and volatility.

Next, using the "ConnectednessApproach" package, we generated figures to observe how connectivity levels manifest themselves over the studied time interval (ergo, from a dynamic perspective). Thus, Figures 1 and 2 attached below represent the TCI ("Total Connectivity Index") connectivity index.

Figure 1. *Total Dynamic Connectivity – stock index returns*



Source: Own processing.

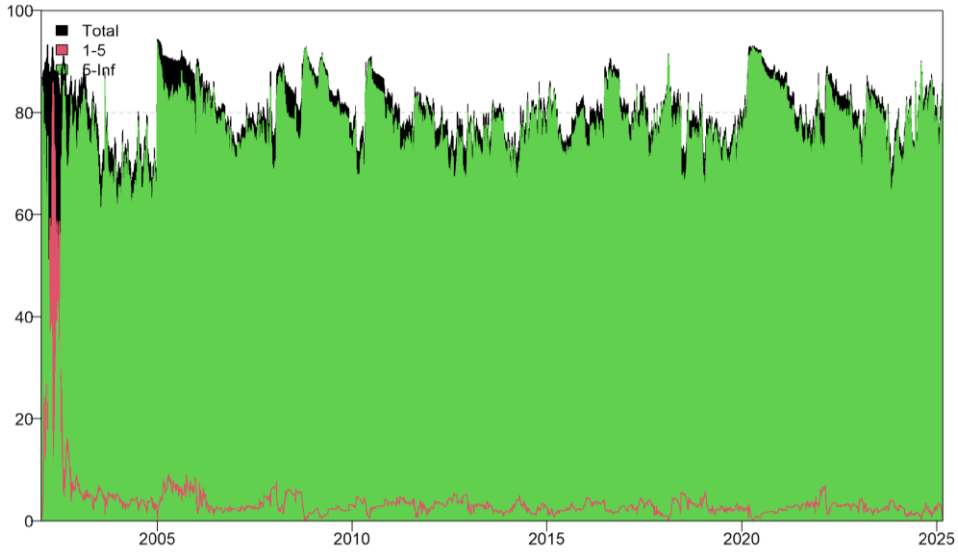
As can be seen in Figure 1, at the level of daily stock index returns, the connectivity level (on a scale of 0 to 100) has fluctuated between 70 and 90 over the last 24 years (with a

general average of around 78 for the entire time interval). Of the total value, around 20% of the connectivity level is explained by short-term yield movements, while most of the interconnection level is explained by long-term yield developments.

It can be seen that there are peaks reached throughout the analyzed period (in 2001, 2007–2008, 2012, and 2020–2021, respectively). The peaks coincide with moments of financial crisis (the years 2000–2001 being influenced by the global speculative "Dot com" bubble). At the same time, it can be seen that after each period of crisis, there is a decrease in the level of interconnection of capital markets (which is in line with economic logic – the financial market becomes a so-called "bearish market" – where investors seek to protect their investments and take refuge in safe assets, such as bonds or treasury bills rather than stocks and options).

We can also see that there is no upward or downward trend in capital markets in terms of their level of interconnection. Capital markets show a relatively high level of interconnection throughout the analysis period (from a yield perspective).

Figure 2. *Total Dynamic Connectivity – Stock Index Volatility*



Source: Own processing.

Figure 2 also shows the level of interconnection of stock indices (from the perspective of volatility this time) using the TCI index. Here we observe, unlike in the case of daily returns, that almost the entire level of interconnection is explained by long-term movements, while short-term volatilities had a significant impact in the early 2000s and then stabilized.

In terms of the level of connectivity of capital market volatilities, we observe that there are still a number of peaks (in the same periods as in the case of returns, namely 2000–2001, 2007–2012, here we have the combination at European level of the Great Recession with

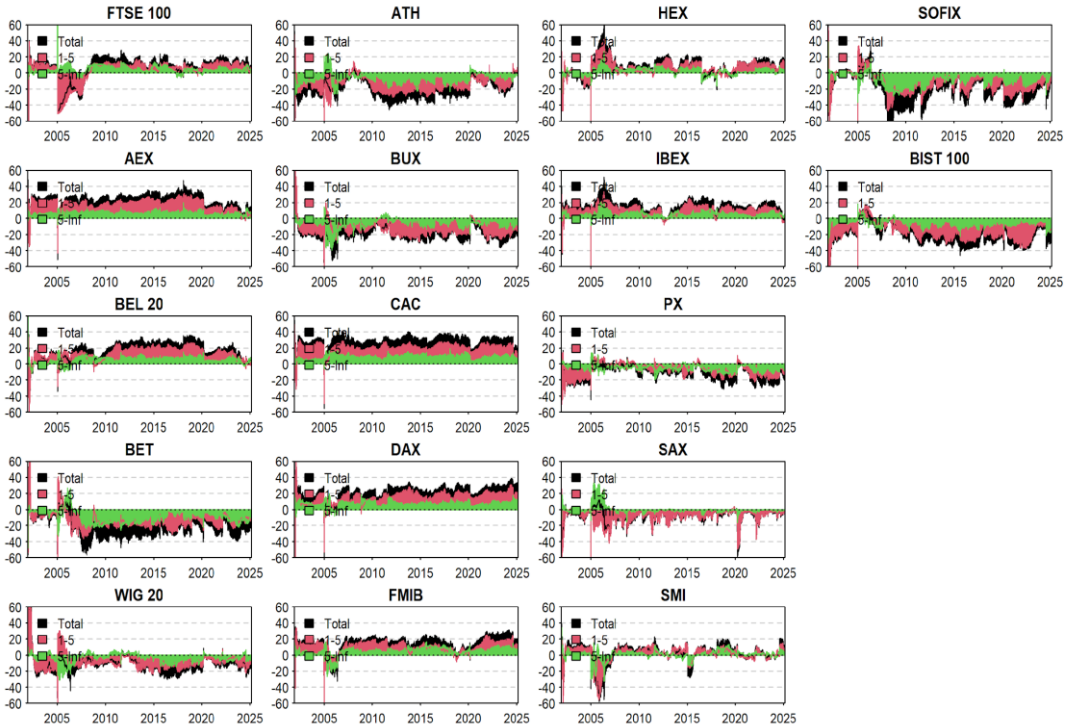
the Sovereign Debt Crisis and 2020–2021). Also, after each peak period, there is an immediate trough period (or moment), which is in line with our expectations.

An interpretation of the above figure from an economic perspective is provided by the concept of the rational agent (a concept that is prevalent in academic works in the economic and financial field). Given that agents active in the stock markets behave like rational investors, they monitor and adjust their investment portfolios based on long-term expectations of volatility, rather than analyzing short-term fluctuations. This does not mean that there are no agents who react in the short term (the red line representing the interconnection value due to short-term movements also shows peaks during periods of financial crisis/economic turmoil).

Based on these two figures, we can say that the first research hypothesis is rejected—because we do not have a clear trend of increase (or decrease) in the level of capital market interconnecti e over the time interval studied, and the second research hypothesis is confirmed in light of the maximum and minimum points observed in our analysis for the period 2001–2025.

To complete the analysis, we have generated a series of figures to observe how various stock indices influence each other over time (and proxies, European capital markets).

Figure 3. *NET Spillover – at the level of European stock market index returns*



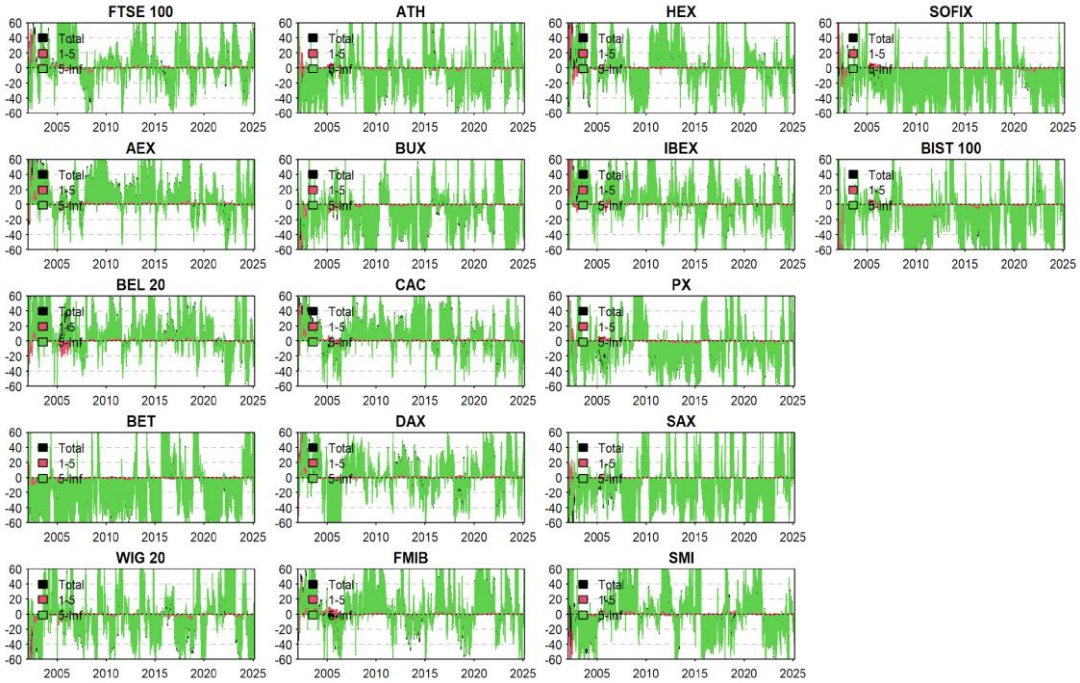
Source: Own calculations.

Figure 3 shows the evolution over time of the net risk spillover effect per stock market index (as daily returns). As can be seen in the tables above, for the capital markets of Western European economies, it can be seen that they tend to transmit their risk to other capital markets over the entire period. It is interesting to note that, in general, short-term movements tend to coincide with long-term movements, but there are also moments/periods of time when opposite trends can be observed.

For example, the FTSE 100 was clearly risk-seeking in the short term between 2005 and 2007, while in the long term, during the same period, it was clearly risk-transferring. Another interesting phenomenon can be observed in the SMI index, which was strongly risk-seeking between 2004 and 2006 (especially when calculated in the short term) and again in 2015.

From the perspective of the returns of Eastern European stock indices (emerging European economies), there is a general tendency among them to be net risk takers from other stock indices. As with Western stock indices, there is a tendency for short-term movements to be in tandem with long-term ones. We have cases such as SOFIX, where we can see that since 2007–2008, the Bulgarian capital market has continuously and systematically taken on the risks of other capital markets, reaching its peak values in 2007–2008. We also have cases such as the SAX index, related to the Slovak capital market, where short-term returns (and their associated spillover effect) explain most of the net negative value.

Figure 4. *NET Spillover - at the level of European stock market volatility*



Source: Own calculations.

Figure 4 shows the evolution over time of the net spillover effect, but at the level of European stock market volatility. As can be seen at first glance, short-term volatility is not significant for capital markets in general. At the level of Western European capital markets (mature economies), we observe that the trend is rather to be net transmitters than net receivers (although there are periods of time, specifically when there have been global or European economic and financial crises), during which they were also net receivers.

At the same time, capital markets tend to show fluctuations in the level of risk propagation over time, as is the case with the Spanish capital market (at the IBEX index level, we can see that after being a strong risk taker, it is immediately followed by a period of strong risk transmission, continuing at this pace after 2012). The same phenomenon can also be seen in the Finnish capital market (through the HEX stock index), where there are longer periods of time in which, from the perspective of volatility propagation, the market is a net transmitter or a net taker.

Eastern European capital markets (of emerging economies) tend to fluctuate significantly more than their neighbors, with a tendency to be more net receivers than net transmitters of the propagation effect (of risks), the clearest examples being BET, BIST 100, and SOFIX.

Another interesting observation is that of the 17 capital markets, the only one that was not net welcoming (ergo, was a net transmitter) during the COVID-19 pandemic was that of the Anglo-Saxon economy (the FTSE 100 stock index).

Conclusions, recommendations, and limitations of the paper

The purpose of this paper was to investigate the risk propagation effect (from a dynamic perspective) of risks on European capital markets using the TVP-VAR methodology. To achieve the aim of the paper, we collected data from 17 European stock indices (to act as a proxy for capital markets) over the period November 2001 – February 2025 as daily time series. We transformed the data by applying the natural logarithm and first-order differentiation (to obtain daily returns) and calculated the 30-day volatility.

By applying the "ConnectednessApproach" package in R to the obtained returns and volatilities, we obtained a TVP-VAR model (Eng. "Time varying parameters – Vector Autoregression") model, based on which we were able to calculate the interconnection indices of European capital markets and observe whether the propagation comes from west to east, is bidirectional, or comes from east to west.

The results obtained and presented in the paper show that, over the period studied, the propagation of risks is predominantly from Western European capital markets (which are net transmitters) to Eastern European markets (which are net receivers). Moreover, these results are all the more relevant as the model applied shows us that, overall, capital markets are strongly interconnected and the level of interconnection increases in times of crisis (whether global or European).

Given what we've talked about in our analysis, the recommendation would be for capital market players to be aware that in times of economic crisis, markets tend not to isolate themselves but to become even more connected, so there's no greater protection from risk by investing in your own country (in the literature, this phenomenon is known as "home bias"). When investment portfolios are created, an analysis such as the one carried out in this paper can contribute significantly to identifying the main transmitters of risk to one market or another in order to develop hedging techniques against them.

The limitations of this paper are due to data availability, data frequency, and the geographical area chosen (a future paper could address the relationships between European capital markets and the US capital market, or between European and Asian capital markets).

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Appendices

Table 3. *Descriptive statistics – volatility of market indices in mature (Western) European economies*

	VOL_AEX	VOL_BEL_20	VOL_CAC	VOL_DAX	VOL_FMIB	VOL_HEX	VOL_FTSE_100	VOL_IBEX	VOL_SMI
Mean	0.0113	0.0107	0.012	0.012	0.013	0.0121	0.0132	0.0123	0.0096
Median	0.0094	0.0090	0.0101	0.0103	0.0115	0.0098	0.0081	0.0105	0.0080
Std. Dev.	0.0069	0.006	0.0066	0.0067	0.0068	0.0062	0.0484	0.0065	0.0054
Skewness	2.4719	2.4360	2.2005	2.1176	2.0206	1.5119	13.5515	2.1279	2.6812
Kurtosis	10.802	11.2237	9.3502	8.4026	8.9863	5,1339	187.7234	9.3063	12.613
Jarque-Bera	21116	22612.76	14774	11664	12911	3390.1	8627186	14326	29991
Prob	0	0	0	0	0	0	0	0	0
Obs	5940	5940	5940	5940	5940	5940	5940	5940	5940

Source: Own calculations.

Table 4. *Descriptive statistics – volatility of market indices for emerging (eastern) European economies*

	VOL_ATH	VOL_BET	VOL_BIST_100	VOL_BUX	VOL_PX	VOL_SAX	VOL_SOFIX	VOL_WIG_20
Mean	0.015	0.0115	0.0163	0.01	0.01	0.0098	0.00914	0.013161
Median	0.0131	0.0089	0.0146	0.01	0.0089	0.0093	0.0073	0.011894
Std. Dev.	0.0082	0.0074	0.0066	0.0064	0.006	0.0045	0.00595	0.005426
Skewness	1.7293	2.1145	1.381804	2.8278	3.8232	1.4434	2.35199	2.085144
Kurtosis	6.9572	8.6821	5.160489	15.095	26.658	6.8943	10.1710	9.545644
Jarque-Bera	6836	12417	3045.547	44125	1530	5816.2	18203.9	14,908.6
Prob	0	0	0	0	0	0	0	0
Obs	5940	5940	5940	5940	5940	5940	5940	5940

Source: Own calculation.

Table 5. *Yield spillover index – total*

	FTSE 100. Total	AEX. Total	BEL 20 Total	BET. Total	WIG 20. Total	ATH. Total	BUX. Total	CAC. Total	DAX. Total	FMIB. Total	HEX. Total	IBEX. Total	PX. Total	SAX. Total	SMI. Total	SOFIX. Total	BIST 100 Total	FROM. Total
FTSE 100	16.17	9.31	8.05	2.03	3.82	2.82	2.87	9.43	8.31	7.45	7.13	7.65	3.53	0.62	7.41	1.09	2.32	83.83
AEX	8.03	12.26	8.92	2.05	4.02	3.13	2.96	10.3	9.55	8.36	7.5	8.05	3.71	0.48	7.49	0.89	2.3	87.74
BEL 20	7.41	9.46	13.01	2.02	3.77	3.36	3.05	9.74	8.94	8.39	7.34	8.44	4.06	0.49	7.29	0.95	2.28	86.99
BET	4.21	4.83	4.65	39.93	3.5	3.1	3.38	4.79	4.59	4.08	4.69	4.21	4.54	1.03	4.07	2.1	2.28	60.07
WIG 20	5.57	6.55	5.89	2.35	22.6	3.7	5.92	6.73	6.77	5.98	6.1	6	5.42	0.71	5.21	1.06	3.43	77.4
ATH	4.81	6.09	6.2	2.58	4.43	27.04	3.54	6.45	6.29	6.32	5.41	6.31	5.16	0.55	4.86	1.08	2.89	72.96
BUX	4.84	5.78	5.65	2.57	6.99	3.6	27.04	6.03	5.93	5.4	5.35	5.28	6.07	0.4	4.67	1.08	3.23	72.96
CAC	7.75	9.85	8.82	1.98	3.92	3.16	3	11.72	9.83	8.95	7.49	8.78	3.72	0.5	7.33	0.92	2.28	88.28
DAX	7.32	9.66	8.59	1.95	4.09	3.21	3.06	10.41	12.44	8.86	7.43	8.4	3.65	0.5	7.2	0.8	2.37	87.56
FMIB	6.95	8.98	8.59	1.86	3.9	3.4	3.04	10.04	9.37	13.17	6.92	9.7	4.02	0.48	6.54	0.86	2.18	86.83
HEX	7.14	8.83	8.18	2.23	4.38	3.31	3.22	9.22	8.71	7.6	14.68	7.61	4.05	0.6	6.66	1.16	2.41	85.32
IBEX	7.1	8.69	8.65	1.98	3.89	3.37	2.97	9.91	8.94	9.75	6.98	13.4	4.08	0.55	6.46	0.94	2.34	86.6
PX	5.08	6.23	6.63	3.08	5.63	4.36	5.15	6.59	6.09	6.31	5.85	6.46	22.7	0.58	4.79	1.45	3.02	77.32
SAX	1	1.06	1.12	1.42	1.36	1.03	0.9	1.16	1.15	0.9	1.57	1.27	1.14	80.81	0.95	1.79	1.28	19.19
SMI	7.86	9.12	8.37	2.25	3.96	3.06	2.98	9.28	8.67	7.42	6.93	7.28	3.49	0.65	15.56	1.04	2.08	84.44
SOFIX	2.76	2.75	2.82	3.3	2.14	2.17	1.95	2.9	2.84	2.51	3.25	2.79	3.08	1.32	2.41	59.16	1.87	40.84
BIST 100	4.51	4.98	4.66	2.02	4.85	3.37	3.83	5.1	5.1	4.21	4.58	4.78	4.03	0.85	3.6	1.28	38.25	61.75
TO	92.33	112.1	105.8	35.68	64.66	50.1	51.83	118.1	111.1	102.56	94.53	103	63.8	10.41	86.93	18.56	38.54	1260.1
Inc. Own	108.5	124.4	118.81	75.61	87.26	77.2	78.87	129.8	123.5	115.73	109.2	116.39	86.4	91.22	102.5	77.72	76.78	cTCI/TCI
Net	8.5	24.41	18.81	-24.39	-12.74	-22.77	-21.13	29.8	23.54	15.7	9.2	16.39	-13.6	-8.78	2.48	-22.28	-23.22	78.76/74.12
NPDC	10	15	13	2	7	5	4	16	14	12	9	11	6	0	8	1	3	

Source: Own calculations.

Table 6. *Yield spillover index – short term*

	FTSE 100.1-5	AEX. 1-5	BEL 20.1-5	BET. 1-5	WIG 20.1-5	ATH. 1-5	BUX. 1-5	CAC. 1-5	DAX. 1-5	FMIB. 1-5	HEX. 1-5	IBEX. 1-5	PX. 1-5	SAX.1 -5	SMI. 1-5	SOFIX. 1-5	BIST 100.1-5	FROM. 1-5
FTSE 100	13.4	7.47	6.3	1.6	3.05	2.26	2.33	7.59	6.65	5.99	5.77	6.15	2.84	0.55	5.93	0.94	1.9	67.47
AEX	6.35	9.67	6.95	1.59	3.17	2.41	2.34	8.11	7.5	6.6	5.89	6.3	2.88	0.34	5.94	0.65	1.77	68.77
BEL 20	5.81	7.36	10.13	1.54	2.94	2.56	2.39	7.6	6.96	6.56	5.72	6.53	3.14	0.34	5.71	0.68	1.76	67.6
BET	2.94	3.36	3.21	30.87	2.5	2.24	2.44	3.36	3.2	2.82	3.34	2.98	3.36	0.78	2.81	1.6	1.56	42.49
WIG 20	4.2	4.96	4.43	1.76	18.07	2.84	4.7	5.1	5.15	4.6	4.61	4.49	4.22	0.49	4.01	0.73	2.58	58.91
ATH	3.54	4.48	4.54	2.01	3.3	21.02	2.67	4.78	4.61	4.64	4.03	4.62	3.95	0.42	3.6	0.82	2.18	54.19
BUX	3.68	4.35	4.25	1.96	5.38	2.69	21.51	4.55	4.45	4.1	4.03	3.96	4.61	0.32	3.57	0.76	2.41	55.09
CAC	6.22	7.89	7.02	1.57	3.15	2.49	2.41	9.41	7.86	7.18	5.99	6.99	2.96	0.36	5.9	0.7	1.79	70.47
DAX	5.86	7.68	6.78	1.51	3.24	2.51	2.43	8.29	9.93	7.09	5.89	6.66	2.86	0.36	5.8	0.65	1.84	69.47
FMIB	5.57	7.15	6.81	1.43	3.1	2.64	2.4	8.01	7.45	10.61	5.5	7.7	3.17	0.33	5.28	0.63	1.67	68.82
HEX	5.52	6.79	6.26	1.7	3.46	2.54	2.54	7.1	6.7	5.89	11.56	5.84	3.14	0.44	5.18	0.84	1.84	65.79
IBEX	5.63	6.85	6.8	1.52	3.07	2.62	2.3	7.85	7.06	7.73	5.48	10.59	3.22	0.39	5.13	0.69	1.81	68.18
PX	3.78	4.57	4.83	2.32	4.25	3.34	3.94	4.84	4.46	4.68	4.32	4.74	18	0.42	3.55	1.09	2.26	57.39
SAX	0.87	0.91	0.99	1.25	1.18	0.85	0.77	1.01	0.99	0.87	1.4	1.11	1.01	68.4	0.8	1.55	1.1	16.65
SMI	6.1	7.1	6.46	1.79	3.1	2.35	2.33	7.27	6.7	5.8	5.42	5.69	2.72	0.53	12.43	0.84	1.62	65.92
SOFIX	1.85	1.81	1.88	2.39	1.52	1.44	1.38	1.95	1.92	1.7	2.17	1.84	2.13	0.99	1.68	45.78	1.26	27.92
BIST 100	3.41	3.73	3.48	1.55	3.74	2.56	3	3.84	3.83	3.2	3.4	3.58	3.08	0.6	2.74	0.91	30.67	46.66
TO	71.43	86.47	81.06	27.56	50.15	38.33	40.43	91.25	85.52	79.44	72.97	79.17	49.3	7.69	67.62	14.08	29.3	971.82
Inc. Own	84.83	96.15	91.19	58.43	68.22	59.35	61.94	100.7	95.45	90.04	84.53	89.76	67.3	76.09	80.06	59.87	60.01	cTCI/TCI
Net	3.96	17.7	13.46	-14.9	-8.76	-15.86	-14.67	20.78	16.05	10.61	7.18	10.99	-8.1	-8.96	1.71	-13.84	-17.32	61/57
NPDC	9	15	13	2	7	5	4	16	14	12	10	11	6	0	8	1	3	

Source: Own calculations.

Table 7. *Yield spillover index – long term*

	FTSE 100.5-Inf	AEX. 5-Inf	BEL 20.5-Inf	BET. 5-Inf	WIG 20.5-Inf	ATH. 5-Inf	BUX. 5-Inf	CAC. 5-Inf	DAX. 5-Inf	FMIB. 5-Inf	HEX. 5-Inf	IBEX. 5-Inf	PX. 5-Inf	SAX. 5-Inf	SMI. 5-Inf	SOFIX. 5-Inf	BIST 100.5-Inf	FROM. 5-Inf
FTSE 100	2.77	1.84	1.67	0.37	0.77	0.57	0.54	1.84	1.66	1.45	1.36	1.5	0.6	0.08	1.47	0.15	0.42	16.36
AEX	1.68	2.59	1.97	0.46	0.86	0.72	0.62	2.19	2.05	1.76	1.61	1.75	0.83	0.14	1.55	0.24	0.53	18.96
BEL 20	1.6	2.09	2.88	0.4	0.8	0.8	0.6	2.15	1.98	1.8	1.62	1.91	0.92	0.15	1.59	0.27	0.52	19.39
BET	1.26	1.46	1.44	9.06	1	0.89	0.94	1.42	1.39	1.27	1.34	1.23	1.18	0.26	1.26	0.5	0.71	17.58
WIG 20	1.33	1.58	1.46	0.59	4.53	0.86	1.22	1.63	1.62	1.39	1.5	1.5	1.2	0.2	1.2	0.3	0.85	18.49
ATH	1.27	1.62	1.66	0.57	1.14	6.02	0.87	1.66	1.68	1.67	1.38	1.69	1.21	0.12	1.26	0.26	0.71	18.76
BUX	1.16	1.42	1.4	0.6	1.61	0.91	5.5	1.48	1.48	1.3	1.31	1.32	1.46	0.1	1.1	0.32	0.82	17.87
CAC	1.54	1.96	1.8	0.41	0.77	0.6	0.5	2.31	1.97	1.77	1.5	1.79	0.76	0.13	1.4	0.22	0.49	17.8
DAX	1.46	1.98	1.8	0.4	0.85	0.7	0.6	2.11	2.51	1.7	1.54	1.74	0.78	0.14	1.4	0.23	0.53	18.09
FMIB	1.39	1.84	1.79	0.44	0.8	0.76	0.6	2.03	1.92	2.56	1.42	2	0.84	0.15	1.26	0.23	0.51	18.01
HEX	1.62	2.03	1.93	0.53	0.92	0.76	0.68	2.12	2.01	1.71	3.11	1.77	0.91	0.19	1.47	0.31	0.57	19.53
IBEX	1.46	1.84	1.85	0.46	0.82	0.75	0.64	2.06	1.89	2.01	1.5	2.8	0.87	0.16	1.33	0.25	0.53	18.43
PX	1.3	1.66	1.8	0.7	1.3	1.02	1.2	1.76	1.63	1.64	1.53	1.72	4.7	0.15	1.24	0.36	0.76	19.92
SAX	0.13	0.15	0.14	0.17	0.17	0.18	0.13	0.15	0.16	0.12	0.17	0.16	0.13	12.41	0.15	0.25	0.19	2.54
SMI	1.69	2.02	1.91	0.45	0.86	0.71	0.66	2.01	1.95	1.62	1.51	1.59	0.78	0.11	3.12	0.2	0.46	18.53
SOFIX	0.91	0.93	0.94	0.91	0.62	0.73	0.56	0.95	0.92	0.81	1.08	0.95	0.95	0.32	0.73	13.38	0.61	12.92
BIST 100	1.1	1.25	1.1	0.4	1.1	0.82	0.83	1.26	1.27	1.01	1.18	1.2	0.95	0.2	0.86	0.36	7.58	September 15
TO	20.9	25.67	24.73	8.13	14.51	11.86	11.41	26.83	25.57	23.13	21.56	23.83	14.5	2.72	19.3	4.48	9.2	288.27
Inc. Own	23.67	28.26	27.62	17.18	19.04	17.88	16.93	29.14	28.08	25.69	24.67	26.63	19.2	15.1	22.43	17.85	16.78	cTCI/TCI
Net	4.54	6.71	5.35	-9.45	-3.98	-6.91	-6.46	9.02	7.48	5.12	2.03	5.4	-5.47	0.18	0.77	-8.44	-5.9	18/17
NPDC	10	14	10	1	6	5	3	16	15	12	8	11	5	10	8	0	2	

Source: Own calculations.

Table 8. *Volatility spillover index - total*

	FTSE 100.Total	AEX. Total	BEL 20Total	BET. Total	WIG 20. Total	ATH. Total	BUX. Total	CAC. Total	DAX. Total	FMIB. Total	HEX. Total	IBEX. Total	PX. Total	SAX. Total	SMI. Total	SOFIX. Total	BIST 100Total	FROM. Total
FTSE 100	20.51	7.47	6.5	3.16	4.96	3.7	3.47	6.48	5.81	5.88	6.21	6.13	4.15	2.69	6.74	2.93	3.18	79.49
AEX	7.79	11.96	8.44	2.65	4.68	3.8	3.46	8.97	7.98	7.37	7.09	6.97	4.25	2.13	7.58	2.34	2.52	88.04
BEL 20	7.32	9.15	13.07	2.77	4.76	4.27	3.33	8.4	6.95	7.59	6.44	7.21	4.51	2.13	7.09	2.36	2.67	86.93
BET	6.47	4.27	4.86	24.22	4.85	4.88	4.62	3.9	3.66	4.62	5.82	4.48	4.96	3.7	5.3	4.13	5.25	75.78
WIG 20	6.04	6.43	5.98	3.34	21.58	4.72	4.97	5.14	5.1	5.31	5.77	5.3	5.3	2.56	5.87	2.99	3.57	78.42
ATH	4.82	5.28	6.1	4.13	5.14	23.43	4.03	4.85	4.33	6.07	4.5	5.97	5.33	3.06	5.72	3.27	3.95	76.57
BUX	5.73	5.61	5.41	3.55	7.14	4.24	21.11	4.9	4.53	5.37	5.6	5.45	6.1	3.43	5.18	3.25	3.37	78.89
CAC	7.42	9.31	8.38	2.82	4.33	3.79	3.36	10.96	8.83	8.56	6.55	8	3.99	2.06	7.1	2.16	2.37	89.04
DAX	7.24	9.2	7.64	2.7	4.81	3.76	3.64	9.04	11.35	7.87	6.79	7.41	4.23	2.15	7.33	2.26	2.57	88.65
FMIB	6.74	8.08	7.81	2.81	4.64	4.21	3.52	8.76	8.17	13.46	5.87	8.91	4.15	2.07	5.97	2.48	2.33	86.54
HEX	6.58	8.23	7.19	2.83	4.92	4.09	3.88	7.55	7.01	6.73	14.41	6.64	4.45	2.7	6.89	2.95	2.95	85.59
IBEX	6.71	7.67	7.8	2.63	4.41	4.29	3.5	8.62	7.5	9.29	6.09	13.28	4.5	2.17	6.24	2.45	2.79	86.72
PX	5.83	5.43	5.88	3.93	6.32	5.08	6.25	5.04	4.44	5.48	6.52	5.68	17.4	4.03	5.35	3.57	3.81	82.64
SAX	3.67	3.42	4.28	2.83	3.46	3.59	3.24	3.34	3.41	3.7	3.97	4.08	3.4	42.07	4.15	3.88	3.5	57.93
SMI	7.38	8.51	7.85	2.88	4.95	3.96	3.61	7.38	6.82	6.55	6.7	6.22	4.45	2.25	14.75	2.64	3.1	85.25
SOFIX	4.77	3.89	4.21	4.44	4.89	4.32	4.97	3.66	3.69	4.44	5.04	4.55	4.99	4.95	3.95	28.5	4.75	71.5
BIST 100	4.93	4.58	4.53	3.03	5.19	4.81	4.76	4.03	3.63	4.34	4.92	4.86	4.51	3.29	5.21	3.64	29.73	70.27
TO	99.44	106.5	102.94	50.49	79.46	67.51	64.66	100.1	91.85	99.16	93.91	97.87	73.3	45.36	95.67	47.31	52.69	1368.2
Inc. Own	119.95	118.5	116	74.71	101.04	90.94	85.78	111.0	103.2	112.62	108.3	111.14	90.7	87.4	110.4	75.81	82.42	cTCI/TCI
Net	19.95	18.5	16	-25.3	1.04	-9.06	-14.22	11.03	3.2	12.62	8.32	11.14	-9.32	-12.56	10.42	-24.19	-17.58	85/80
NPDC	16	15	13	1	7	5	4	14	11	11	8	9	4	4	11	0	3	

Source: Own calculations.

Table 9. *Volatility spillover index – short term*

	FTSE 100.1-5	AEX. 1-5	BEL 20.1-5	BET. 1-5	WIG 20.1-5	ATH. 1-5	BUX. 1-5	CAC. 1-5	DAX. 1-5	FMIB. 1-5	HEX. 1-5	IBEX. 1-5	PX. 1-5	SAX. 1-5	SMI. 1-5	SOFIX. 1-5	BIST 100.1-5	FROM. 1-5
FTSE 100	1.68	0.45	0.36	0.05	0.13	0.12	0.11	0.46	0.39	0.35	0.31	0.39	0.17	0.06	0.	0.1	0.08	3.83
AEX	0.45	0.91	0.56	0.06	0.17	0.15	0.13	0.72	0.61	0.56	0.45	0.56	0.23	0.09	0.38	0.14	0.09	5.37
BEL 20	0.4	0.67	1.06	0.06	0.2	0.	0.1	0.65	0.5	0.5	0.43	0.55	0.2	0.12	0.41	0.13	0.13	5.39
BET	0.08	0.11	0.11	2.1	0.09	0.1	0.09	0.12	0.12	0.11	0.09	0.13	0.14	0.05	0.09	0.1	0.07	1.62
WIG 20	0.2	0.38	0.33	0.1	2.07	0.17	0.2	0.36	0.37	0.32	0.34	0.37	0.3	0.1	0.2	0.1	0.1	4.17
ATH	0.17	0.23	0.24	0.1	0.1	1.97	0.1	0.2	0.2	0.2	0.2	0.3	0.2	0.05	0.17	0.1	0.1	2.83
BUX	0.2	0.3	0.26	0.09	0.26	0.1	1.89	0.3	0.2	0.29	0.31	0.3	0.3	0.12	0.21	0.18	0.16	3.8
CAC	0.46	0.72	0.55	0.06	0.15	0.16	0.13	0.95	0.7	0.6	0.47	0.6	0.2	0.09	0.38	0.14	0.08	5.63
DAX	0.43	0.68	0.49	0.07	0.15	0.14	0.12	0.78	1.02	0.65	0.48	0.65	0.25	0.08	0.36	0.15	0.06	5.53
FMIB	0.41	0.63	0.54	0.06	0.15	0.16	0.13	0.76	0.67	1.13	0.44	0.76	0.24	0.08	0.32	0.16	0.07	5.57
HEX	0.35	0.57	0.42	0.05	0.16	0.18	0.15	0.6	0.56	0.48	1.39	0.6	0.32	0.11	0.33	0.18	0.09	5.17
IBEX	0.43	0.65	0.53	0.07	0.16	0.21	0.16	0.77	0.67	0.75	0.54	1.22	0.31	0.12	0.36	0.2	0.09	6.01
PX	0.2	0.31	0.25	0.1	0.1	0.2	0.1	0.3	0.3	0.2	0.3	0.3	1.4	0.08	0.19	0.17	0.11	3.6
SAX	0.1	0.1	0.1	0.04	0.07	0.08	0.09	0.17	0.16	0.16	0.18	0.21	0.12	3.87	0.09	0.13	0.07	2
SMI	0.38	0.53	0.42	0.06	0.15	0.16	0.14	0.54	0.47	0.41	0.39	0.46	0.21	0.09	1.09	0.14	0.09	4.63
SOFIX	0.21	0.23	0.15	0.11	0.08	0.11	0.11	0.24	0.23	0.23	0.24	0.28	0.19	0.09	0.11	2.21	0.05	2.67
BIST 100	0.15	0.2	0.1	0.07	0.1	0.1	0.16	0.19	0.17	0.16	0.19	0.22	0.2	0.07	0.15	0.1	2.4	2.5
TO	4.7	6.85	5.53	1.14	2.37	2.48	2.27	7.22	6.4	6.2	5.44	6.87	3.67	1.38	4.1	2.24	1.47	70.35
Inc. Own	6.41	7.76	6.6	3.2	4.43	4.44	4.16	8.17	7.42	7.33	6.83	8.08	5.16	5.25	5.19	4.45	3.93	cTCI/TCI
Net	0.89	1.49	0.14	-0.48	-1.8	-0.36	-1.54	1.59	0.87	0.6	0.27	0.86	0.08	-0.63	-0.53	-0.43	-1.06	4.40
NPDC	15	15	10	4	1	6	1	15	13	10	10	12	8	3	6	5	2	

Source: Own calculations.

Table 10. *Volatility spillover index – long term*

	FTSE 100.5-Inf	AEX. 5-Inf	BEL 20.5-Inf	BET. 5-Inf	WIG 20.5-Inf	ATH. 5-Inf	BUX. 5-Inf	CAC. 5-Inf	DAX. 5-Inf	FMIB. 5-Inf	HEX. 5-Inf	IBEX. 5-Inf	PX. 5-Inf	SAX. 5-Inf	SMI. 5-Inf	SOFIX. 5-Inf	BIST 100.5-Inf	FROM. 5-Inf
FTSE 100	18.83	7.02	6.19	3.11	4.82	3.58	3.35	6.03	5.42	5.52	5.9	5.74	3.98	2.63	6.44	2.82	3.11	75.66
AEX	7.34	11.05	7.88	2.6	4.51	3.65	3.33	8.25	7.37	6.81	6.64	6.4	4.03	2.03	7.2	2.2	2.43	82.67
BEL 20	6.91	8.48	12.01	2.71	4.55	4.07	3.15	7.74	6.46	7.05	6.01	6.66	4.28	2.02	6.67	2.23	2.54	81.54
BET	6.39	4.16	4.75	22.12	4.76	4.77	4.53	3.78	3.54	4.52	5.73	4.36	4.82	3.65	5.2	4.03	5.18	74.16
WIG 20	5.78	6.05	5.65	3.24	19.51	4.55	4.71	4.78	4.72	4.98	5.42	4.93	5.05	2.47	5.62	2.85	3.44	74.26
ATH	4.65	5.05	5.87	4.03	5.02	21.46	3.91	4.61	4.13	5.83	4.29	5.67	5.1	3.01	5.55	3.18	3.8	73.74
BUX	5.52	5.31	5.15	3.45	6.88	4.07	19.22	4.61	4.25	5.09	5.32	5.09	5.77	3.31	4.97	3.06	3.21	75.08
CAC	6.96	8.59	7.83	2.75	4.19	3.64	3.23	10.01	8.12	7.89	6.08	7.34	3.77	1.98	6.72	2.02	2.29	83.41
DAX	6.8	8.52	7.15	2.64	4.66	3.62	3.53	8.26	10.33	7.23	6.31	6.76	3.98	2.07	6.98	2.11	2.51	83.12
FMIB	6:33	7.45	7.28	2.75	4.49	4.05	3.38	8	7.5	12.34	5.43	8.16	3.92	1.99	5.65	2.32	2.26	80.97
HEX	6.23	7.66	6.77	2.78	4.76	3.91	3.74	6.95	6.45	6.24	13.02	6.02	4.13	2.59	6.56	2.77	2.86	80.43
IBEX	6.28	7.02	7.27	2.56	4.25	4.07	3.38	7.85	6.83	8.54	5.55	12.06	4.19	2.06	5.88	2.25	2.7	80.71
PX	5.61	5.12	5.63	3.83	6.14	4.88	6.08	4.73	4.14	5.19	6.18	5.31	15.9	3.95	5.16	3.4	3.7	79.04
SAX	3.56	3.24	4.13	2.78	3.39	3.51	3.15	3.18	3.25	3.54	3.78	3.87	3.27	38.2	4.06	3.75	3.43	55.92
SMI	7	7.99	7.43	2.81	4.8	3.8	3.47	6.84	6.35	6.14	6.31	5.76	4.24	2.16	13.66	2.51	3.01	80.62
SOFIX	4.56	3.66	4.06	4.34	4.82	4.21	4.85	3.42	3.46	4.2	4.8	4.2	4.79	4.85	3.83	26.3	4.7	68.82
BIST 100	4.7	4.3	4.36	2.96	5.04	4.66	4.61	3.84	3.45	4.17	4.73	4.63	4.31	3.22	5.06	3.54	27.27	67.74
TO	94.71	99.69	97.4	49.35	77.09	65.03	62.4	92.86	85.45	92.95	88.47	91	69.6	43.99	91.57	45.06	51.22	1297.9
Inc.Own	113.54	110.7	109.41	71.46	96.6	86.49	81.62	102.9	95.78	105.29	101.5	103.06	85.5	82.19	105.2	71.36	78.5	cTCI/TCI
Net	19.06	17.02	15.86	-24.8	2.83	-8.71	-12.69	9.45	2.33	11.99	8.05	10.29	-9.4	-11.94	10.95	-23.76	-16.52	81.12/76.35
NPDC	16	15	14	1	7	5	4	13	11	11	8	9	4	4	11	0	3	

Source: Own calculations.