5. ARE CAPITAL MARKETS INTEGRATED? A TEST OF INFORMATION TRANSMISSION WITHIN THE EUROPEAN UNION

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Abstract

Central and Eastern European (CEE) stock markets have gradually attracted international investors' attention after 1990, and their integration into the European capital market will lead to increased maturity of these markets, accompanied by higher attractiveness to international investors. The paper analyses the stock markets of five emerging countries from the CEE region – the Czech Republic, Hungary, Poland, Romania and the Russian Federation – as against four major European Union markets – Austria, France, Germany and the United Kingdom – over the 2003-2007 period and aims at identifying the speed and significance of information transmission among them, as embedded in stock market returns. By employing co-integration and Granger causality tests with different data frequencies, we investigate the long- and short-run relationships among these markets and interpret the findings in the context of international capital market integration.

Keywords: European Union; capital market; emerging markets; co-integration; Granger causality

JEL classification: F15, F21, G15, G11

I. Introduction

The concept of "international market integration", with reference to capital markets around the world, represents nowadays one of the most prolific areas of research in international finance, and it covers various aspects of interrelationships across equity and bond markets. The empirical work performed so far focuses on the behaviour of

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international stock markets in normal and crisis times (the latter connected with the concept of financial contagion), trying to identify the manner in which stock markets are interrelated.

Global market integration can be studied from two perspectives: the general integration process at the international level, and the economic integration process, on the other hand. For the first perspective, a number of studies have been recently developed by Lane and Milesi-Ferretti (2003), Arestis and Basu (2003) and Edison *et al*. (2002), which investigate the level of international financial integration and its impact on economic growth. At the same time, these studies assess whether the relationship between financial integration and economic growth depends on the level of economic development, financial development, legal system development, government corruption, and macroeconomic policies.

The second perspective proves to be more interesting from our point of view, since it addresses the issue of connections between the capital markets that are part of an economic integration process. The European Union, as the most successful integration attempt so far, has been more and more studied, with results indicating a significant increase in correlations among the European markets, both at geographical and industrial levels. Beckers (1999) concludes that one can observe a statistically significant trend of increasing correlations among various industries of the countries belonging to the EU – the most integrated industries, from this point of view, are energy, capital and money markets and, to some extent, utilities. Freimann (1998) studies a number of four macroeconomic variables – GDP growth, inflation, bond yield spreads and exchange rate changes – to conclude that the European countries display a strong integration trend, led by the Netherlands. More recently, research on economic integration that impacts on capital markets has flourished. Fratzscher (2001) analyses the integration process of the European equity markets since the 1980s, and demonstrates that these markets have become highly integrated only since 1998. This high level of integration between the European equity markets is largely explained by the drive towards EMU through the elimination of exchange rate volatility. Adjaoute and Danthine (2003) reassess, in the light of modern financial theory, the recent evolution of capital markets in the Euro Area, and conclude that European capital markets are still segmented, which leads to higher costs for Treasuries and taxpayers, urging for measures in favour of a higher integration of these markets. Reszat (2003) shows that the contribution of the common currency to financial integration has been stronger when the national markets had more features in common.

As far as the emerging capital markets are concerned, located in countries that have initiated an economic growth process, but not reaching yet a high degree of economic development, sometimes accompanied by a significant economic and/or political instability potential, they attracted researchers' interest from the perspective of their significance for international institutional investors. Barry, Peavy III and Rodriguez (1998), Harvey (1995), Divecha, Drach and Stefek (1992), as well as Bekaert *et al*. (1998) are among the first authors to observe that these markets perform in a quite different manner as compared to developed markets. Research on emerging equity markets has suggested a number of empirical regularities: high volatility, low correlations with developed markets and within emerging markets, high long-horizon returns, and predictability above and beyond what is found for developed market returns. It is also well evidenced that emerging markets are more likely to experience shocks induced by regulatory changes, exchange rate devaluations, and political crises.

However, the traditional tool used in these empirical studies was the correlation analysis: results generally indicate that, although statistically significant, correlations among international stock markets are low. At the same time, a number of specificities are noteworthy (see Bracker *et al*., 1999): countries in proximate geographical areas tend to display greater co-movement than countries farther apart; pairs of national stock indices with similar industrial structure tend to experience more substantive co-movement; when the timing of movements is investigated, several different national markets display a significant relationship within the same 24-hour period, but beyond 24 hours they show few significant responses across markets. Nevertheless, empirical studies identify increased correlations and market interrelations as world capital markets evolved in the 1980s and 1990s, with a stronger point in the case of economically integrated markets such as the European Union.

In our opinion, so far empirical studies on the interrelationship of stock markets did not provide clear cut results, as their conclusions differ, depending on the selection of markets, sample periods used, frequency of observations (daily, weekly, monthly) and various methodologies employed to explore the interdependences between stock markets. From the traditional correlation analysis, studies have moved towards more sophisticated techniques, such as vector autoregression (VAR), Granger causality tests and cointegration, able to better model dependencies between markets.

In the case when equity markets are co-integrated, the benefits of international diversification are altered, due to the presence of common factors that limit the size of independent variation and lead to joint variation of the markets. If two or more variables are co-integrated, this means that a linear combination of these variables is stationary, even though the variables themselves are non-stationary. When stock market indices are found to be co-integrated, they exhibit a stable long-run relation, despite short-term disequilibrium. A lack of cointegration typically suggests that there is no long-term link between variables and they tend to drift randomly away from each other. Cointegration among equity markets has interesting implications for international investors, as this eventually means that fewer assets would be available for them in their effort to improve the risk-return profile of their portfolios. The reasons of such long-term ties between markets are not easily identifiable, but one can think of the presence of strong economic links and coordination of macroeconomic policies between countries, deregulation and market liberalization measures, and increasing activities of multinational corporations and international investors.

Cointegration has been used to investigate equity markets in various regions. Kasa (1992) estimates an error-correction VAR model and calculates a common stochastic trend in the equity markets of the United States, Japan, the United Kingdom, Germany and Canada. Jeon and Chiang (1991) examine the behaviour of stock prices in stock markets in New York, Tokyo, London, and Frankfurt based on univariate and multivariate cointegration techniques, while Chan *et al*. (1992) and Arshanapalli *et al*. (1995) study the links between the US and Asian equity markets. More recently, Chen *et al*. (2002) investigate the dynamic interdependence of the major stock markets in

Latin America employing cointegration analysis and error correction VAR techniques. Also, Hassan (2003) uses a multivariate cointegration analysis to test for the existence of a long-term relationship between share prices in the Persian Gulf.

Emerging markets from Central and Eastern Europe, now members of the European Union and subject of stronger economic links with the developed markets in the EU and between themselves have drawn the attention of international researchers in more recent years. It is expected that correlations of the CEE markets with the developed markets in the EU would grow in time, as long as the CEE countries enter into a gradual economic harmonization process requested by the EU membership. As a consequence, the capital markets of the CEE countries would naturally see themselves in a permanent deregulation process, which in turn will lead to a higher integration into the EU capital markets. A number of empirical studies confirm such expectation for the Czech Republic, Hungary and Poland, but not for other CEE countries. Pajuste (2002) observes that the CEE capital markets differ to a large extent in terms of their correlations with the EU capital markets, with the Czech Republic, Hungary and Poland displaying higher correlations among them and with the EU market, while Romania and Slovenia demonstrate virtually zero and even small negative correlation with the EU capital market. This result is confirmed and strengthened by Pajuste *et al*. (2000) who analyze the relevant risk factors that explain stock returns in the CEE countries and find that local factors have highest explanatory power as compared to European, global or emerging countries specific factors. At the same time, Classens *et al*. (2000) investigate the potential development of the CEE capital markets and conclude that their future integration within EU will lead to their consolidation, on one hand, and to increased correlations with the EU markets, on the other hand.

Our study uses cointegration and Granger causality tests to analyse the relations among the capital markets from the European Union, using a sample that includes both developed EU markets and emerging markets from the Central and Eastern Europe. We also include in the analysed sample one of the leading emerging markets, the Russian Federation. Our major finding is that European markets are closely linked to each other, as indicated by the results of cointegration, and also serve as informational channels between them. To test for the speed of information transmission among markets we use data with different frequencies and interpret the results in the framework of market integration versus market segmentation. The paper is structured as follows: Section II presents the data and the research methodology, while Sections III and IV present the results of cointegration and Granger causality tests. Section V concludes and outlines our ideas for further research.

II. Data and research methodology

Our research employs daily, weekly and monthly logarithmic return data computed by nine market indices from eight European Union countries – Austria, the Czech Republic, France, Germany, Hungary, Poland, Romania and the United Kingdom – and the Russian Federation. Of them, four countries are classified as "developed" – Austria, France, Germany and the United Kingdom, while five are considered "emerging": the Czech Republic, Hungary, Poland, Romania and the

Russian Federation. The sample of countries was constructed in such a way as to allow the comparative observation of their behavioural patterns, within themselves and in relation to the other markets included in the sample. All the indices were provided by Morgan Stanley Capital International, except for Romania, where the Bucharest Stock Exchange BET index was used. The indices are denominated in US dollars and cover the January 6, 2003–June 29, 2007 period for all frequencies. A brief description of the data is presented in Table 1 below.

Table 1

Descriptive statistics of returns: January 2003–June 2007

	AU	RO	CZ	FR	GR	HU	PL	RU	UK
Monthly returns – 53 observations									
Mean	0.02907	0.03870	0.03313	0.01810	0.02241	0.02925	0.02778	0.02917	0.01530
Median	0.03308	0.03666	0.03454	0.01377	0.02231	0.04532	0.04058	0.04100	0.01326
Standard deviation	0.04052	0.08437	0.06001	0.03706	0.04894	0.07585	0.07616	0.08032	0.02825
Skewness	-0.14723	0.10049	0.02418	0.57378	0.74407	-0.51356	-0.34675	-0.28760	0.51575
Kurtosis	2.85671	4.21396	2.78762	4.08236	5.04883	3.21549	2.40300	2.48538	3.00135
Jarque-Bera	0.23681	3.34364	0.10476	5.49524	14.1605	2.43234	1.84917	1.31547	2.34973
Probability	0.88833	0.18790	0.94896	0.06408	0.00084	0.29636	0.39669	0.51802	0.30886
Weekly returns – 222 observations									
Mean	0.00147	0.00218	0.00179	0.00125	0.00139	0.00076	0.00026	0.00063	0.00099
Median	0.00238	0.00192	0.00151	0.00116	0.00206	0.00232	0.00230	0.00125	0.00111
Standard deviation	0.01097	0.01430	0.01637	0.01117	0.01233	0.01635	0.02099	0.01745	0.00969
Skewness	-0.67589	-0.25410	0.12621	-0.03893	-0.11105	-0.52675	-0.34082	0.01185	0.33706
Kurtosis	.55994	7.48126	7.26480	4.50504	4.43401	4.15202	8.39076	3.73650	6.76719
Jarque-Bera	39.4120	188.144	168.833	21.0088	19.4780	22.5426	273.106	5.02280	135.477
Probability	0.00000	0.00000	0.00000	0.00002	0.00005	0.00001	0.00000	0.08115	0.00000
Daily returns – 1094 observations									
Mean	0.00108	0.00166	0.00127	0.00056	0.00073	0.00097	0.00079	0.00108	0.00048
Median	0.00148	0.00161	0.00155	0.00068	0.00133	0.00179	0.00119	0.00225	0.00058
Standard deviation	0.01028	0.01531	0.01403	0.01045	0.01191	0.01612	0.01568	0.01962	0.00893
Skewness	-0.54785	-0.47704	-0.32275	-0.21705	-0.24780	-0.28848	-0.16699	-0.65390	-0.12902
Kurtosis	5.81701	8.53427	6.06406	5.32567	4.78639	4.27137	3.74291	7.53325	5.15823
Jarque-Bera	416.454	1437.62	446.953	255.139	156.662	88.8548	30.2434	1014.71	215.362
Probability	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

As one may see, Romania's stock exchange displayed the highest returns over the period – 0.03870 in monthly terms, 0.00218 in weekly terms and 0.00166 in daily terms, while the lowest returns were recorded in the United Kingdom in monthly and daily terms – 0.01530 and 0.00048, respectively, and in Poland in weekly terms – 0.00026 average returns. In terms of risk, the lowest levels of return standard deviations were recorded in the United Kingdom, for all frequencies: 0.02825 in monthly terms, 0.00969 in weekly terms and 0.00893 in daily terms. At the other extreme, the riskiest markets were, over the period, Romania in monthly terms -

standard deviation of 0.08437, Poland in weekly terms - standard deviation of 0.02099, and the Russian Federation in daily terms – with a standard deviation of 0.01962. These results confirm, with the only exception of Poland for the weekly frequency, the vast majority of previous results on developed versus emerging markets statistics: developed markets generally tend to display lower and less risky returns as compared to emerging markets. With a few exceptions, all returns' distributions are negatively skewed and leptokurtic[1]. We also notice that the Jarque-Berra statistics show the reversion to return normality as the frequency of observations is reduced from daily towards monthly returns.

Another perspective on the researched markets is offered by the data in Table 2 that presents the correlations between the samples of markets for the monthly frequency for the overall period. The correlations between developed markets, all EU members, are higher as compared to correlations between the developed markets and the emerging markets, on one hand, and correlations between all emerging markets, on the other hand. The highest correlation in Table 2 is the one for France and Germany – 0.93963 in monthly returns, while the lowest is recorded between Germany and Romania – 0.24932. As an interesting observation, the average correlation between developed markets was 0.7657, while the average correlation between emerging markets (the Russian Federation included) was significantly lower – 0.5409. Even more interesting, the average correlation between the developed and emerging countries was lower (0.4705) than the average correlation recorded only for the emerging markets, which might represent an indication of a certain degree of segmentation between these two types of markets.

Table 2

Correlations of monthly returns: January 2003–June 2007

	AU	RO	CZ	FR	GR	HU	PL	RU	UK
AU	1.00000								
BET	0.43801	1.00000							
CZ	0.61427	0.48727	1.00000						
FR	0.65590	0.31182	0.54307	1.00000					
GR	0.62178	0.24932	0.42023	0.93963	1.00000				
HU	0.60768	0.56352	0.73025	0.47853	0.41147	1.00000			
PL	0.57346	0.43062	0.68182	0.57844	0.56168	0.70713	1.00000		
RU	0.38185	0.41528	0.48384	0.37084	0.26633	0.44746	0.46169	1.00000	
UK	0.67620	0.37401	0.65250	0.87335	0.82708	0.56082	0.58295	0.37280	1.00000

Our research objective, as pointed above, is directed towards the detection of significant interactions among these markets that would confirm the general

[1] The positively skewed distributions are recorded for the Romanian, Czech, French and German markets for the monthly frequency, and for the Czech and Russian markets when weekly returns are used. The platykurtic distributions belong to Austria, the Czech Republic, Poland and Russia, and only for monthly returns. These results confirm to some extent the previous research on capital markets in terms of the return distribution "fat tails", but contradict the general finding on returns that is positively skewed, particularly for emerging markets.

expectation related to a higher integration among them – particularly among European Union countries, given their intensified commercial and financial links. We developed our analysis by using a standard Granger causality test to explore the speed of information transmission embedded in returns from one market to another. Generally speaking, the quicker the information transmission from one market to another, the higher the degree of integration among the markets is. The Granger causality test (Granger, 1969) was developed as a more efficient approach as compared to the basic correlation tool, which does not imply causality between correlated variables in any significant sense of the word. The Granger test addresses the issue of whether the current value of a variable y - y_t can be explained by past values of the same variable y_{t-k} and then whether adding lagged values of another variable x – x_{t-k} improves the explanation of y_t. As such, the variable y is said to be Granger-caused by *x* if the coefficients on the lagged values of *x* are found to be statistically significant. The general form of a Granger test is the following:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + ... + \alpha_k y_{t-k} + \beta_1 x_{t-1} + \beta_2 x_{t-2} + ... + \beta_k x_{t-k} + \varepsilon_t$$

$$x_t = a_0 + a_1 x_{t-1} + a_2 x_{t-2} + ... + a_k x_{t-k} + b_1 y_{t-1} + b_2 y_{t-2} + ... + b_k y_{t-k} + u_t$$

where: α_0 and a_0 are the constants, and ε_t and u_t are residuals.

The statement “x Granger causes y” does not necessarily imply that y should be seen as the effect or results of x, since the Granger test measures only precedence and information content on variable y, and does not indicate causality in the common sense of the word. The only significant piece of information the Granger test reveals is whether the *x* variable helps in a better prediction of the *y* variable[2].

In our research, we performed bivariate Granger causality tests on monthly, weekly and daily returns, using the standard methodology proposed by Granger (1969, 1986) and Engle and Granger (1987). All tests are performed on the first differences in the natural logarithms of the indices using simple OLS procedures. In order to test for Granger causality among stock market indices x_t and y_t we estimated the equation

$$\Delta \ln y_t = c + \sum_{i=1}^{k} \delta_i \Delta \ln y_{t-i} + \sum_{i=1}^{k} \beta_i \Delta \ln x_{t-i} + \varepsilon_t \quad (1)$$

and performed a F-test for joint insignificance of the coefficients β_i, i=1…k.

The null hypothesis is that x_t does not Granger cause y_t. Therefore, when the null hypothesis is rejected this indicates the presence of Granger causality. For each pair of stock market indices we performed two Granger causality tests in order to identify unilateral causation (x_t causes y_t *or* y_t causes x_t), bilateral causation (x_t causes y_t *and* causes x_t) or no causation.

The effective application of the Granger test raises a number of issues that are critical for the significance of the test results. The first issue is related to the number of lags used in the OLS regressions, since the test results are highly sensitive to this number (Gujarati, 2003; Hamilton, 1994; Wooldridge, 2006). Various approaches towards the finding of the critical lag are proposed (see Cerny, 2004; Wooldridge, 2006; Foresti,

[2] *It is important to mention that, frequently, the two-way causation is the case, rather than the exception.*

2007; Murinde and Poshakwale, 2004), that are more or less of the "trial and error" type. The method we used, based on the estimation of an autoregressive model for y_t and performing t- and F-tests to determine how many lags should appear in the equation, for both variables.

The second issue critical to the Granger test refers to data frequency. Therefore, we performed the Granger test using data of three frequencies – daily, weekly and monthly. The aim of this procedure was to discover the time structure of the stock markets' reaction to the information embedded in the returns observed in the other markets. This time structure can be also linked to the speed of information transmission from one market to another and, furthermore, to their degree of integration. An important point should be made here, though: our research does not directly deals with the contagion between markets versus the reaction of these markets to other influences, such as macroeconomic fundamentals. We were only testing for the quickness of information transmission among markets, as a better understanding of markets interactions.

The third issue is linked to the specification of the Granger causality tests. As shown by MacDonald and Kearney (1987), Miller and Russek (1990) and Lyons and Murinde (1994), the Granger causality tests are well specified if they are applied in a standard vector autoregressive form to first differenced data only for non-cointegrated variables. The concept of cointegration was first developed by Engle and Granger (1987), which discussed the case of variables that were I(1) and were included in a regression. We know that I(1) variables should be differenced before they are used in linear regressions in order to make them I(0), otherwise the regression is spurious. Engle and Granger advance the idea that sometimes the regression of two I(1) variable might not be spurious, but meaningful, in case the two variables are cointegrated. Generally, if y_t and x_t are two I(1) processes, then, in most of the cases, $y_t - \beta x_t$ is also a I(1) process for any number β. Nevertheless, it is possible that for some $\beta \neq 0$, $y_t - \beta x_t$ is not an I(1), but an I(0) process, with a constant mean, constant variance and autocorrelation that depends only on the time distance between any two variables in the series, and it is asymptotically uncorrelated. If such β exists, the series y_t and x_t are said to be cointegrated and β is called the cointegrating parameter. As a result, a regression of y_t on x_t would be meaningful, not spurious. Economically speaking, cointegration of two variables indicates a long-term or equilibrium relationship between them, given by their stationary linear combination (also called the cointegrating equation). Statistically, the presence of cointegration excludes non-causality between the variables under consideration. Therefore, if two variables are found to be cointegrated, then there must exist causality in the Granger sense between them, either uni-directionally or bi-directionally. We test for the existence of cointegration between the stock market indices considered, for all frequencies, using the Engle and Granger (1987) methodology. This is a procedure that involves an OLS estimation of a pre-specified cointegrating regression between indices, followed by a unit root test performed on the regression residuals previously identified. The null hypothesis of no cointegration is rejected if it is found that the regression residuals are stationary.

III. Cointegration analysis

Before specifying any cointegration test, we test for unit root in the index levels. Table 3 exhibits the results of the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests in terms of t-statistic for the indices levels. The ADF tests involved the estimation of the following regression

$$\Delta x_t = \alpha + \beta t + \delta x_{t-1} + \sum_{i=1}^{k} \Delta x_{t-1} + \varepsilon_t \tag{2}$$

where *x* is the variable under consideration.

The PP test corrects for some form of serial correlation and heteroskedasticity and is known to handle structural breaks better than ADF. As one can observe, the indices are non-stationary in levels in their vast majority, the only exceptions being the Czech market index, which is found to be stationary by both ADF and PP tests when using weekly observation, the French index, found stationary for weekly and daily frequencies, the Polish index, stationary for monthly and daily observations and the British market index when using weekly and daily observations. Given these results, we have analysed the correlograms for all these variables and our decision was to treat them as being all non-stationary.

Table 3

Unit root tests on stock market indices

	ADF tests			PP tests		
	monthly	weekly	daily	monthly	weekly	daily
AU	-1.6861	-2.0678	-1.9528	-1.8106	-2.1138	-2.0683
RO	-2.2272	-2.1879	-1.9898	-2.4303	-1.9910	-1.9968
CZ	-2.2258	-4.3967*	-2.6136	-2.3354	-4.3366*	-2.4954
FR	-2.7105	-3.1010	-4.0900*	-2.5704	-4.1298*	-3.9769*
GR	-3.4425	-2.3248	-2.5814	-2.4683	-3.1067	-2.5170
HU	-1.9701	-2.7736	-1.8246	-1.9186	-2.8370	-1.9094
PL	-4.4800*	-2.3248	-3.8502	-4.4903*	-3.1067	-4.1893*
RU	-2.2601	-2.7736	-2.4121	-2.2949	-2.8370	-2.5165
UK	-2.5698	-3.5190*	-3.7791**	-2.5075	-3.2229	-3.5821**

*Note: * and ** indicate significance at 1% and 5% levels, respectively.*

The next step consisted in carrying out a pairwise cointegration test. We estimate a simple linear relationship between pairs of time series represented by the index levels, as follows:

$$\ln y_t = c_1 + \alpha \ln x_t + e_t \quad \text{and} \quad \ln x_t = c_2 + \alpha \ln y_t + u_t \tag{3}$$

Then, we apply the ADF test to the estimated residuals e_t and u_t from each of the above equations, which means we estimate the equations

$$e_t = c + \delta e_{t-1} + \varphi t + \sum_{i=1}^{k} \phi_i \Delta e_{t-1} + \varepsilon_t \quad \text{and} \quad u_t = h + \lambda u_{t-1} + \beta t + \sum_{i=1}^{k} \eta_i \Delta u_{t-1} + \upsilon_t \tag{4}$$

In the case the time series of the residuals ε_t is stationary, we claim that the stock market indices y_t and x_t are cointegrated. Otherwise, the residuals ε_t are non-stationary and no cointegration relationship is detected. Cointegration between the indices x_t and y_t indicates the presence of a long-run equilibrium relationship represented by the linear relation between them. At the same time, the presence of a cointegrating relationship among the variables indicates that performing a Granger causality test in a standard form is useless, since at least a unidirectional causality between them should exist.

Table 4 presents the results of the cointegration tests, indicating the presence of cointegration for monthly, weekly and daily frequencies. We report in the table only the relations between the variables for which we found stationary residuals that are statistically significant at 1% and 5% only. The highest number of cointegrating relations occurs when weekly values of the indices are used (17), followed by the daily frequency (9) and the monthly frequency (only 7).

Table 4

Cointegrating relations between the market indices

Monthly frequency	Weekly frequency	Daily frequency
AU – RO **	AU – RU *	AU – RO *
AU – PL **	AU – UK **	AU – CZ *
RO – CZ *	CZ – FR *	AU – PL **
CZ – RU *	CZ – GR **	RO – CZ *
HU – RU *	CZ – PL **	RO – PL **
RU – UK *	CZ – RU **	CZ – PL *
	CZ – UK **	FR – PL *
	FR – HU **	FR – UK *
	FR – RU *	PL – UK *
	GR – HU **	
	GR – UK *	
	HU – UK **	
	RU – RO *	
	RU – GR *	
	RU – HU **	
	RU – PL *	
	RU – UK **	

*Note: * and ** indicate significance at 1% and 5% levels, respectively.*

The results of the cointegration tests suggest that markets from the EU are more connected to each other than one might expect. These connections occur on the long-, medium- and short-term, as indicated by their presence for all frequencies employed. An interesting result is indicated by the highest number of relations arising in the case of weekly frequency, for which we do not attempt to provide an explanation that might be purely speculative. Another attention-grabbing fact is related to the presence of these relations between all types of markets: for the monthly frequency we identified cointegrating relations between developed and emerging markets, on the one hand, and between emerging markets, on the other hand; for the weekly frequency all types of relations are found – developed to developed (Austria and the United Kingdom, and Germany and the United Kingdom), developed to emerging and emerging to emerging; for the daily frequency also all types of relations are found. Refraining ourselves from guesswork, we would only interpret these results as long-term equilibrium relations among these markets. We do not explore in the present work the short-term deviations from equilibrium for the pairs of cointegrated markets.

Following these results, the next step involved the Granger causality tests on the variables that do not display a cointegration relationship for each data frequency. The results of these tests are presented in the next section.

IV. Granger causality tests

The unit root tests performed on the first differences of stock market indices by using ADF and PP, reported in Table 5, indicate that the first differences are stationary at the 1% level. Both tests included a constant and a trend term.

Table 5

Unit root tests on first differences of stock market indices

	ADF tests (t-statistic)			PP tests (adjusted t-statistic)		
	monthly	**weekly**	**daily**	**monthly**	**weekly**	**daily**
RETAU	-6.3018*	-16.234*	-31.286*	-6.2614*	-16.226*	-31.305*
RETRO	-6.2506*	-13.238*	-28.827*	-6.2234*	-15.777*	-28.783*
RETCZ	-6.8392*	-17.206*	-29.394*	-6.9373*	-19.537*	-29.276*
RETFR	-6.6740*	-19.309*	-33.727*	-6.9695*	-21.597*	-34.194*
RETGR	-6.4209*	-19.089*	-34.169*	-6.4178*	-19.860*	-34.209*
RETHU	-6.9958*	-16.503*	-29.834*	-7.1848*	-16.503*	-29.981*
RETPL	-9.1176*	-15.438*	-31.024*	-9.9616*	-15.444*	-31.073*
RETRU	-7.3424*	-15.100*	-32.004*	-7.3694*	-15.388*	-31.996*
RETUK	-6.8625*	-17.882*	-35.331*	-6.8870*	-19.636*	-35.661*

*Note: * indicates significance at 1% level.*

The next step is represented by the Granger causality tests performed on the first differences of indices (or stock market returns). We only performed the tests on the variables for which no cointegration was detected. In the implementation of the Granger equation (1) above we used the Akaike (AIC) criterion to determine the lag lengths of the right-hand-side variables[3]. The same number of lags was applied to

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[3] Other methods are suggested and used in the literature for the determination of the lag length in the Granger test, such as the Factor Prediction Error (FPE) criterion, the Schwarz (SC) criterion, or a trial and error procedure starting with the highest number of lags and successive reduction in the number until statistical significance of the highest lag is achieved. We chose this method given the significance of the Granger test: it basically shows whether lags in an independent variable have explanatory power for what concerns the current value of a dependent variable, after the previous lags on the dependent variable have been tested for their explanatory power. Therefore, performing first an autoregressive test on the dependent

both the dependent and the independent variables. Table 6 presents the results of the Granger causality tests of the first differences of stock market indices.

The first observation induced by our results refers to the number of causal relations in the Granger sense between the stock markets, depending on the frequency of data. As expected, the number of relations is the highest for the daily frequency (29), while for the weekly and monthly frequency we were able to find only five such relations. This suggests in our opinion that the stock markets in the region react quite quickly to the information revealed by the stock prices in the other markets. As a result, when they are investigated over the medium and long-term, the information transmission already took place, so the number of causality relations decreases significantly. This confirms the findings of Cerny (2004) that uses intra-day data and shows that the researched markets – the United States, the United Kingdom, France, Poland and the Czech Republic – are strongly interconnected, as indicated by the Granger causality relations identified among the indices of these markets. One may interpret this result as an indication of an increased degree of integration among these markets, implied by investors' speediness in adjusting the market prices following information discovered in the prices of other markets.

Almost all relations indicate unilateral causality, only six bilateral causality relations being identified in our research: between Germany and Poland for monthly frequency, between Romania and Poland for weekly frequencies, and between Austria and Hungary, Romania and Hungary, Romania and the Russian Federation, France and Germany for daily frequencies.

Table 6

Granger causality tests

Monthly returns									
	RETAU	**RETRO**	**RETCZ**	**RETFR**	**RETGR**	**RETHU**	**RETPL**	**RETRU**	**RETUK**
RETAU (1)									
RETRO (1)									
RETCZ (1)									
RETFR (1)									
RETGR (1)							**4.7362****		
RETHU (1)									
RETPL (1)			3.4925***	3.3424***	**4.6912****				
RETRU (1)									
RETUK (1)							4.0918**		
Weekly returns									
	RETAU	**RETRO**	**RETCZ**	**RETFR**	**RETGR**	**RETHU**	**RETPL**	**RETRU**	**RETUK**
RETAU (1)									
RETRO (5)					2.0481***	2.0569***	**1.9814*****		
RETCZ (4)		3.0116**							
RETFR (1)									
RETGR (1)									
RETHU (1)									

variable to select the significant number of lags that have explanatory power for its current value seemed to us as the most natural of the approaches.

Weekly returns									
RETPL (6)		**1.8676*****							
RETRU (1)									
RETUK (1)									
Daily returns									
	RETAU	**RETRO**	**RETCZ**	**RETFR**	**RETGR**	**RETHU**	**RETPL**	**RETRU**	**RETUK**
RETAU (8)					2.1901**	**1.7855*****			1.9924**
RETRO (7)				3.1171*	2.4327*	**4.1085***		**2.1032****	2.0079**
RETCZ (1)									
RETFR (7)			2.2358**		**2.4187****	2.0425**			
RETGR (14)			1.7202**	**2.1149***			1.8425**		
RETHU (1)	**4.7077****	**4.0414****	2.9617***		5.2658**		4.2922**		
RETPL (4)									
RETRU (1)	10.335*	**3.4596*****	11.617*	6.6939*	7.4908*	9.4520*	7.1144*		10.621*
RETUK (5)			2.8105**		2.4374**				

Note: The variable in row is Granger caused by the variable in column; the figures indicate the F-statistics for the Granger equation and the significance at 1% (*), 5% (**) and 10% (***). The figures in brackets indicate the number of lags used for the Granger test when the respective variable is the dependent variable. The figures in bold indicate the bilateral Granger causality relations.

In terms of leading and led markets, our results do not point out to any specific pattern. Although one might expect for the developed markets to generally lead the emerging markets, our results suggest that this is not necessarily the case. When only the unilateral relations are taken into account, the developed markets are led by and lead other developed markets, as well as other emerging markets. The same is true for all emerging markets in the sample. More specifically, Poland is the most interesting market when monthly frequencies are used: it leads the British market and is led by the French and the Czech markets. In terms of weekly frequencies, Romania's market returns are led by the German and Hungarian markets' returns, while it influences the Czech market's returns. For the daily frequencies, the market that receives the highest number of influences from past returns of the other markets is the Russian one, practically all other markets providing information for the returns on its market. It is followed by Romania (its returns are preceded by the returns recorded in France, Germany and the United Kingdom) and Hungary (this market's returns are preceded by the returns recorded in the Czech, German and Polish markets). The leading markets are the three developed ones – France, Germany and the United Kingdom, as well as the Czech and the Hungarian markets.

The causal relations that we least expect are the ones that indicate unilateral causality going from an emerging market to a developed one, on the one hand, and those going from an emerging market to another emerging market. Concerning the emerging towards developed markets relations, our results identify such relations only for the daily frequency – the Czech market Granger causes the French market, the German market and the British market; the Hungarian market Granger causes the French market; the Polish market Granger causes the German market. Added to the relations that involve a developed market as a leader and an emerging market as a follower, these results suggest a higher degree of integration between all these markets as one might have previously thought. At the same time, emerging markets seem to react quite quickly to the information contained in the prices and returns on the other emerging markets. Such reactions are indicated by the Granger causality relations present for all frequencies. The slowest in terms of reaction is the Polish market: its returns respond within a month to the evolutions on the Czech market, while faster responses (within a day) are identified for the Czech–Hungarian markets (the Czech market leads), the Czech–Russian markets (the Czech market leads), the Polish–Hungarian markets (the Polish market leads), the Hungarian–Russian markets (the Hungarian market leads), and the Polish–Russian markets (the Polish market leads). Actually, while looking at these relations, all emerging markets, except for Romania, seem to react, directly or indirectly, to the information revealed in the other markets. This might be understood as a certain degree of segmentation of the Romanian market among the emerging markets in the region, given its smaller market capitalization and, most probably, the reduced interest from the part of international investors[4].

IV. Conclusions and further research

Using a set of data that covers four years and a half and different index and return frequencies, we investigate the issue of market integration from a new perspective. We interpret the degree of market integration or segmentation from the standpoint of the rapidity embedded in the markets' reactions to the information revealed in the past in the other markets. As an original contribution, our research involved a sample of markets that are members of the European Union, both developed – Austria, France, Germany and the United Kingdom, and emerging – the Czech Republic, Hungary, Poland and Romania, to which we added the Russian Federation, as one of the leading emerging markets in the world. After performing cointegration and Granger causality tests, our results indicate that the markets react quite quickly to the information included in the returns on the other markets, and that this flow of information takes place in both directions, from the developed markets to the emerging ones, and vice versa. At the same time, investors on emerging markets seem to take into account information from the other emerging markets in the region. Our research results cannot definitely indicate whether we encounter here a direct transmission of information from one market to another or a common reaction of the markets we investigated to some other information relevant to them, either on a European or a global level. Nevertheless, after considering the results of the cointegration tests, which show that many of these markets maintain a long-term relation between them, we believe that their degree of integration is higher than previously thought and made known by the use of other tests.

For a better understanding of the process of information transmission between the stock markets, we intend to continue this research by using vector error correction

[4] *At the end of 2006, the market capitalization in the CEE region differed to a large extent from one market to another, both in terms of absolute value and percentage of GDP. As such, it reached 57.92 billions euro in Prague (50.82% in GDP), 31.64 billions euro in Budapest (35.20% in GDP), 112.83 billions euro in Warsaw (41.55% in GDP) and only 21.68 billions euro in Bucharest (22.32% in GDP).*

models in order to account for the cointegrationg relations between variables and to increase the data frequency aiming at uncovering patterns of information transmission that cannot be discerned even with daily frequencies.

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