Time varying causality between stock exchanges in the CEE region

Cristiana Tudor

***Abstract*—** This paper analyzes the evolution of linkages and causality between six Central and Eastern European (Bulgaria, Czech Republic, Hungary, Poland, Romania, Russia) and the USA stock exchanges. The effects of the recent global financial crisis and possible changes in inter-market relationships as a result of the crisis are topics of special interest in this research. For this purpose, the panel data sample (daily observations for the 2006-2009 time period) is divided into two sub-periods corresponding to the pre-crisis and crisis period. In order to separate the two sub-periods, a secondary investigation is conducted which shows that the beginning of July 2007 is the moment when the global financial crisis began to show its full manifestations on international stock exchanges. The study concludes that stock markets in the CEE region have became increasingly integrated during crisis, while before the crisis the markets appear to be segmented, as both contemporaneous correlations and causality relationships are mostly insignificant. Also, before the crisis CEE markets were significantly influenced by innovations in the USA market, thus explaining why they were affected heavily by the crisis, which has managed to spread immediately in the region. As far as the risk-adjusted performance is concerned, the Czech market realized the best risk-adjusted performance due to its average rate of return and low risk, s followed by the Romanian, Russian and Polish stock markets, while the lowest risk-adjusted performance, as represented by the coefficient of variation was found in the case of the US stock market.

***Keywords*—**Granger causality, contemporaneous correlation, risk-adjusted performance, Central and Eastern European Stock exchanges

I. INTRODUCTION

THE concept of financial market integration is central to the international finance literature and it is well accepted that integration of financial markets is fundamentally linked to economic growth through risk sharing benefits, improvements in allocation efficiency and reductions in macroeconomic volatility (see [20]).

Nevertheless, the true process of financial market integration is dynamic and difficult to measure, and a wide range of empirical methodologies have been used to analyze the issue.

[1] Cristiana Tudor is with the International Business and Economics Department from the Bucharest Academy of Economic Studies, Romana Square No 6, Bucharest, Romania (phone: +40-723254342, e-mail: cristianat@ gmail.com).

First, the most basic technique has been the use of unconditional cross-country correlations on equity prices and returns.

Later on, atheoretical vector autoregressions (VARs) were used by [7], [14] among others.

Further, higher frequency data led to the use of ARCH variants, with [12] examining linkages and spillovers using

daily returns and [21] using hourly data to analyze major stock markets in London, New York and Tokyo.

However, it is now known that ARCH is less useful for the non-normal distributions exhibited by emerging market returns. Instead, semi-parametric ARCH (SPARCH) has been used by [2] to capture the fat tails and skewness in emerging market returns.

On another front, both univariate and multivariate cointegration/error correction models have been used to model stock returns and prices for major and emerging markets.

Finally, to address variations in stock market integration over time, researchers have performed regressions on different sub-periods to gain insight into long-term changes in stock market integration dynamics (see for example [16] or [3]). In addition, rolling and recursive windows and time varying coefficients generated by instrumental variables have also been employed (see for example [9]).

Starting from this prior research, in this article we investigate and analyze contemporaneous correlations and causal relationships among six Central and Eastern European stock markets and also the USA, given its proven determinant role at a worldwide level. We pay special attention to the effects of the 2007-2009 global financial crisis. As VAR models, co-integration tests, and Granger causality tests are very sensitive to the number of lags included (e.g. [6], [5], [18]) we implement lag-length tests and choose the optimal number of lags based on Sims' likelihood-ratio test.

II. LITERATURE REVIEW

Many empirical studies in the financial literature report substantial evidence of interdependency among world financial markets both in the short and the long run.

[7] found a substantial amount of multi-lateral interaction among the nine largest stock markets in the world (Australia, Canada, France, Germany, Hong Kong, Japan, Switzerland, the United Kingdom and the United States). In particular, they documented that shocks in the US market have the most

important impact on the other national markets included in the study. [12] investigate the price and volatility spillovers in three major stock markets (New York, Tokyo, and London) and documented evidence for spillover effects from New York to Tokyo and London and from London to Tokyo, but not from Tokyo to either to New York or London. [4] show that the Scandinavian stock markets exhibit interdependencies both in term of price and volatility transmission. [17] study both Asian markets and developed countries of the OECD and find evidence of interdependency among the two categories of markets. They also attest that the markets of the USA and Britain have a dominant role both in the short and the long-run. [15] analyzed correlations between South Asian stock markets (India, Sri Lanka, Pakistan, and Bangladesh) and reported weak interdependency between these markets and global stock markets. Further, [22] studies the Romanian stock market over the period 2002 – 2008 and the results suggest that although firm-specific financial indicators are important risk factors and help explain time-variation in Romanian common stocks returns, global risks are also conditionally priced. [19] examine the capital market integration in Korea and Japan using a threshold cointegration model by analyzing the real interest rate connection between the two business environments. Very recently, [1] use the time-shift asymmetric correlation analysis method for stock exchanges with different but non-overlapping trading hours to analyze the degree of global integration between stock markets of different countries and their influence on each other. They compute next-day correlation (NDC) and same-day correlation (SDC) coefficients and analyze interrelations between major U.S. and Asia-Pacific stock market indices. Results show that most NDCs are statistically significant while most SDCs are insignificant, that NDCs grow over time and the U.S. stock market plays a pace making role for the Asia-Pacific region. [13] examine the integration and causality of interdependencies among seven major East Asian stock exchanges before, during, and after the 1997–1998 Asian financial crisis and reveal that the relationships among East Asian stock markets are time varying and change as a result of the crisis while the USA plays a determinant role in all periods. Similarly, [23] finds that the correlation between the US market and the CEE markets has increased significantly during the recent financial crisis, while before the criss the US market Granger causes the Bulgarian, Czech, Hungarian, Polish, and Romanian stock markets. [24] studies the relationship between stock markets in Shanghai, Hong Kong and US and finds that the impact of the US market on the Hong Kong market is rapidly weakening, while the impact of the Shanghai market on the Hong Kong market is increasing.

[8] studies the linkages between the Greek, Portuguese and French stock exchanges and shows that both Portugal and France are acting as one month leading indicators for the Greek stock market.

In conclusion, the majority of empirical findings attest that over the last decades international stock markets have become increasingly interdependent. In addition, the role of the USA market worldwide is dominant and the evolution of US stock indices has an important impact on the majority of financial markets.

III. DATA AND METHODOLOGY

A. Data

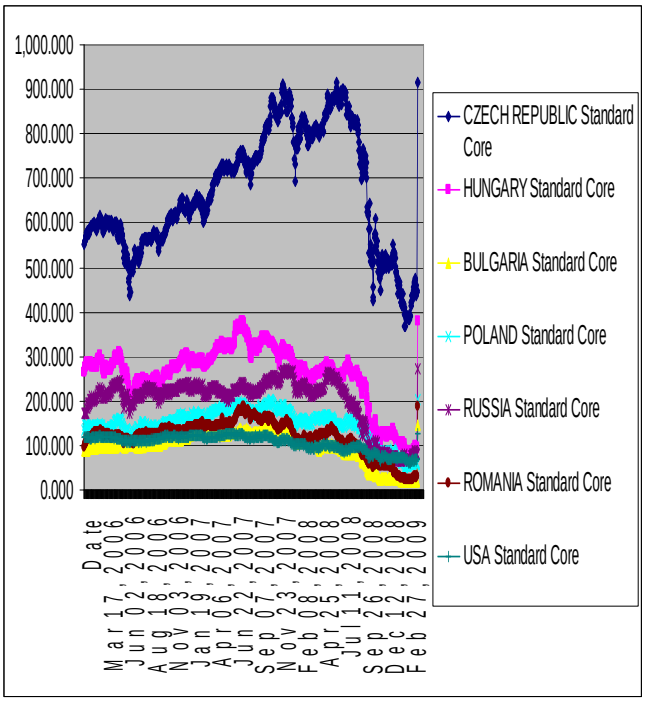
The data for this study are retrieved from Morgan Stanley Capital Indices - Barra and consist of daily stock market index closing prices from six CEE stock markets, i.e. stock exchanges from the Czech Republic, Hungary, Bulgaria, Poland, Russia and Romania. We also collect data on the USA stock market, given its proven determinant role at a global scale. The sample period extends from January 2, 2006 to March 31, 2009 and therefore includes 847 observations for each series. We subsequently take the natural logarithm of the daily closing values and daily returns are computed as the first differences of the log-transformed series in the following manner:

$$R_{i,t} = \ln(P_t) - \ln(P_{t-1}) = \ln(\frac{P_t}{P_{t-1}}) \quad (1)$$

Further, as different sample periods could result in contradictory findings, particularly when a crisis arises we split the sample into two sub-samples to capture possible time-variant stock market integration in the CEE area before and during the 2007–2009 global financial crisis. The choosing of the moment that delineated the starting point of the crisis on international stock markets must be conducted with care.

Hence, although many authors use the Lehman Brothers' collapse in September 2008 as the event which reflects the beginning of the crisis on international financial markets, a more thorough investigation shows that the manifestations of the crisis started long before that moment. Figure 1 attests that the decreasing trend of the stock indexes began in July 2007 for Hungary, Romania and USA, a few months later for Russia, Poland and Bulgaria. Only in the case of the Czech stock market the crisis showed its full manifestations only in the summer of 2008.

Figure 1: Evolution of CEE and US stock market indexes: January 2006 – March 2009



SOURCE: author's representation, MSCI data

We decide to choose the beginning of July 2007 as the moment when the global financial crisis began to show its full manifestations on international stock exchanges. Therefore, our first sub-sample covers the period from January 2, 2006 to June 30, 2007, or a total of 390 daily observations for each series and represents the pre-crisis period. The crisis period then starts at July 1, 2007 and ends after the first quarter of 2009 (March 31, 2009), a time window containing 457 daily observations for each series which should correspond to a genuine crisis period.

B. Descriptive statistics

Table 1 confirms that there was indeed a structural break in our time series after the second trimester of 2007. The distributions of stock returns in the pre-crisis period (Panel A) are generally slightly leptokurtic (with the exception of Hungary and USA stock indexes) and present negative skewness, while during the crisis (Panel B) all distributions became strongly leptokurtic and positively skewed. As expected, mean returns decreased significantly during crisis, while volatility accentuated. The markets that were most affected by the crisis in terms of difference in mean returns between the two sub-samples are the Hungarian, Polish and Romanian stock markets, while the least affected were the Czech and the Russian markets. Market volatility, as represented by the standard deviation of returns, increased the most on the Bulgarian and Romanian stock exchanges.

TABLE 1

DESCRIPTIVE STATISTICS OF DAILY STOCK RETURN SERIES
(Precrisis vs. crisis period)

PANEL A: Pre-Crisis (January 2, 2006 – June 29, 2007)

	CZ	***HU***	***BG***	***PL***	***RU***	***RO***	***US***
Mean	0.00072	0.00083	0.00095	0.00087	0.00066	0.00148	0.00013
Std Error	0.00068	0.00087	0.00050	0.00086	0.00102	0.00087	0.00039
Median	0.00113	0.00170	0.00013	0.00115	0.00124	0.00061	0.00018
Mode	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Std Deviation	0.01345	0.01710	0.00995	0.01692	0.02022	0.01725	0.00776
Variance	0.00018	0.00029	0.00010	0.00029	0.00041	0.00030	0.00006
Kurtosis	6.02230	0.40637	6.02489	0.60941	5.53077	5.52493	1.97276
Skewness	-0.08236	-0.12535	-0.59970	-0.21290	-0.72661	-0.05925	-0.46342
Range	0.14920	0.10425	0.09760	0.11537	0.20394	0.17822	0.06200
Minimum	-0.06205	-0.04880	-0.05965	-0.06133	-0.11276	-0.08634	-0.04050
Maximum	0.08714	0.05545	0.03795	0.05404	0.09118	0.09188	0.02150
Sum	0.27957	0.32402	0.37067	0.33738	0.25632	0.57626	0.05117
Count	390.0000	390.0000	390.0000	390.0000	390.0000	390.0000	390.0000

PANEL B: Crisis (July 2, 2007 – March 31, 2009)

	CZ	***HU***	***BG***	***PL***	***RU***	***RO***	***US***
Mean	0.0000	0.0001	0.0002	0.0001	0.0004	0.0002	0.0001
Std Error	0.0034	0.0045	0.0029	0.0031	0.0043	0.0017	
Median	0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	0.0000
Mode	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Std Deviat	0.0726	0.0966	0.0620	0.0672	0.0907	0.0917	0.0371
Variance	0.0053	0.0093	0.0038	0.0045	0.0082	0.0084	0.0014

Kurtosis	17	298.042	392.175	307.653	218.798	363.503	170.207
Skewness	10	15.5068	19.0344	15.8751	12.2564	17.8922	10.2047
Range	0.8	1.5931	2.1450	1.3119	1.4269	2.1842	0.7109
Minimum	-0	-0.19	-0.16	-0.11	-0.23	-0.33	-0.09
Maximum	0.7	1.3933	1.9845	1.1996	1.1936	1.8482	0.6195
Sum	0.2	0.0305	0.0849	0.0503	0.1758	0.0860	0.0235
Count	45	457.000	457.000	457.000	457.000	457.000	457.000

Finally, Table 2 reports descriptive statistics for the seven stock market indexes for the whole period of the analysis.

TABLE 2

DESCRIPTIVE STATISTICS OF DAILY STOCK RETURN SERIES (whole period)

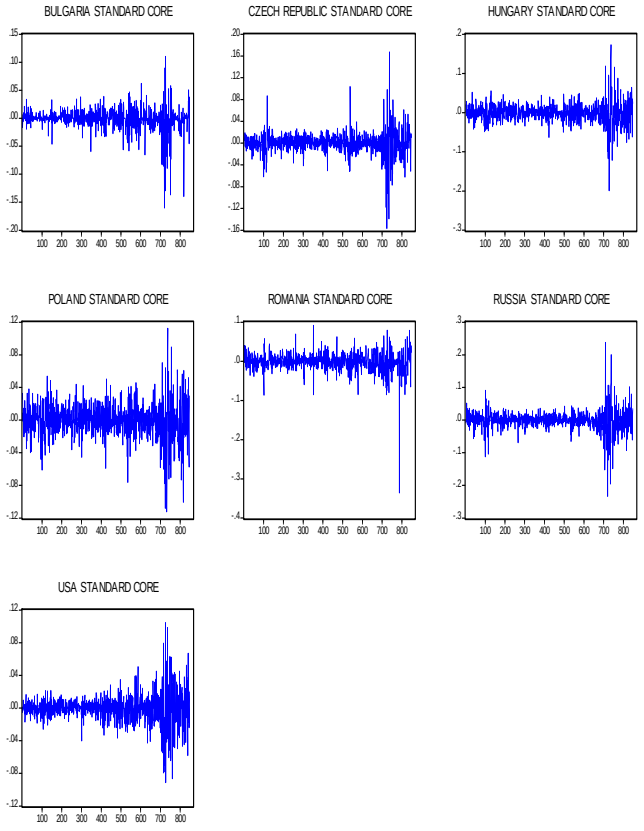
	BG	**CZ**	**HU**	**PL**	**RO**	**RU**	**USA**
Mean	0.000558	0.000593	0.000430	0.000475	0.000778	0.0005 25	9.37E-05
Median	0.0000	0.000587	-4.29E-06	6.69E-05	-0.000281	0.000357	0.000000
Maximum	1.984	0.710	1.39	1.199	1.848	1.193	0.619499
Minimum	-0.160	-0.156	-0.199	-0.112	-0.335	-0.23335 4	-0.091399
Std. Dev.	0.0071 224	0.032521	0.054549	0.046948	0.068314	0.0512 00	0.027740
Skewness	25.477 00	12.14113	19.62237	19.62305	23.20561	14.85509	13.10576
Kurtosis	711.70 97	270.8796	503.2059	503.3912	632.9723	350.7282	295.4134
Jarque-Bera	1783 8585	2556335.	8895029.	8901584.	1409 8674	4303514.	30454 73.
Prob	0.00	0.00	0.00	0.00	0.00	0.00	0.000000
Sum	0.472902	0.502648	0.364415	0.402537	0.660098	0.445396	0.079422
Sum Sq. Dev.	4.2 9 6722	0.895825	2.520282	1.866882	3.952824	2.220321	0.651788
Observations	848	848	848	848	848	848	848

When the whole period is considered, we notice that the highest average daily return is encountered on the Romanian stock exchange, while the lowest mean return is found on the US stock market. The other CEE stock markets offer similar levels of return, while the volatility is substantially different. While the daily volatility of return on the Czech market is the second lowest from the seven markets considered in the analysis (only the US offers a lower level of risk or volatility), the Romanian and the Bulgarian stock markets seem to be the riskier, with a daily standard deviation of returns equal to 0.068 and 0.071 respectively.

All return distributions are positively skewed and highly leptokurtic, with stock return series from Bulgaria and Romania deviating the most from normality.

Further, Figure 2 shows that the phenomenon of volatility clustering seems to be present especially on the Polish and US stock exchanges, suggesting that these time series could be well modeled with Garch family models.

Figure 1: Return series (January 2, 2006 - March 31, 2009)



Finally, we compute an overall market risk-adjusted performance measure (the coefficient of variation), presented in Table 3.

The coefficient of variation (CV) is a fund's standard deviation divided by its return. It gives a risk-to-return ratio, i.e., units of risk per unit of return that can be used to compare mutual fund performance on a level basis.

The Coefficient of Variation (CV) is therefore computed as:

$$CV = \frac{\overline{R}_s}{\sigma_s}$$

It is similar to the well-known Sharpe ratio, which also measures the risk adjusted return, is also called the reward-to-variability ratio and is computed with the following formula:

$$SR = \frac{\overline{R}_p - \overline{r}_f}{\sigma_p}.$$

In our case, we decided to use the coefficient of variation to measure the risk-adjusted performance of the seven stock markets during the period of the analysis.

TABLE 3

RISK-ADJUSTED STOCK MARKET PERFORMANCE

	CZ	***HU***	***BG***	***PL***	***RU***	***RO***	***US***
CV	0.018	0.007	0.0078	0.010	0.010	0.0113	0.0033

The Czech market realized the best risk-adjusted performance (CV of 0.018), due to its average rate of return and low risk. It is followed by the Romanian, Russian and Polish stock markets (both with a CV of 0.01), which had high mean returns (Romania) and average levels for return and risk (Poland and Russia). The combination of return and risk resulted in a CV for the US stock market equal to 0.0033, the lowest in our data sample. Finally, Hungary and Bulgaria had a similar risk-adjusted performance, with coefficients of variation equal to 0.007.

C. Contemporaneous correlations

A simple investigation of the correlation matrix between index return series can provide important information for the subsequent Granger causality tests. The correlation coefficients of daily stock market returns for the two sub-sample periods are reported in Table 4. The correlation coefficients for the pre-crisis period are relatively low (Panel A), in particular in the case of Romania, Bulgaria and USA, which does not seem to be correlated neither with other markets in the sample, nor amongst each other. Some linkages appear to exist only among stock markets in Czech Republic, Hungary, Poland and Russia in the pre-crisis period. The situation changes dramatically during crisis times, when all correlation coefficient increase significantly and stock markets become strongly interconnected (see Panel B). Even the three markets which moved independently before the crisis (i.e. Romania, Bulgaria and USA) are now correlated with the others. For example, the correlation between stock exchanges from Bulgaria and Romania increased from 0.11 before crisis to a strong level of 0.94 during crisis. The correlation between the US market and the six CEE markets also increased significantly in the second sub-sample, while the four markets that showed important linkages before the crisis (i.e. Czech Republic, Hungary, Poland and Russia) seem to move almost identically during crisis time.

TABLE 4
CORRELATION MATRIX FOR THE SEVEN STOCK MARKET INDEXES

PANEL A: Pre-Crisis

	CZECH REPUBLIC	*HUNGARY*	*BULGARIA*	*POLAND*	*RUSSIA*	*ROMANIA*	*USA*
CZECH REPUBLIC	1						
HUNGARY	**0.58**	1.00					
BULGARIA	-0.04	-0.07	1.00				
POLAND	**0.58**	**0.71**	-0.06	1.00			
RUSSIA	**0.61**	**0.54**	-0.02	**0.51**	1.00		
ROMANIA	0.12	0.15	0.11	0.17	0.15	1.00	
USA	0.20	0.09	-0.12	0.14	0.20	0.04	1

PANEL B: Crisis

	CZECH REPUBLIC	*HUNGARY*	*BULGARIA*	*POLAND*	*RUSSIA*	*ROMANIA*	*USA*
CZECH REPUBLIC	1						
HUNGARY	0.87	1.00					
BULGARIA	0.82	0.90	1.00				
POLAND	0.89	0.94	0.91	1.00			
RUSSIA	0.87	0.87	0.85	0.90	1.00		
ROMANIA	0.84	0.91	0.94	0.92	0.86	1.00	
USA	0.69	0.79	0.75	0.77	0.75	0.77	1

Hence, the above results provide insight that the correlations between the seven stock markets increased sharply during the crisis, information which should also be attested by Granger causality tests.

Further, we implement unit root tests to examine whether the log-transformed stock market indices are stationary (not reported). Using a 0.05 significance level, the Augmented Dickey–Fuller (ADF) tests as well as the Phillips–Perron tests suggest that all series are integrated at level, i.e. I(0). Finally, and most importantly, the ADF-test results for the two sub-periods (i.e. pre-crisis and crisis) also indicate that all indices in both sub-periods are stationary in the level, therefore we have no restrictions in conducting Granger causality tests on our dataset.

D. Granger causality tests

Testing causality, in the Granger sense, involves using F-tests to test whether lagged information on a variable Y provides any statistically significant information about a variable X in the presence of lagged X. If not, then "Y does not Granger-cause X." In other words, a variable Y is said not to Granger-cause a variable X if the distribution of X, conditional on past values of X alone, equals the distribution of X, conditional on past realizations of both X and Y. If this equality does not hold, Y is said to Granger-cause X. If Y can predict future X, over and above what lags of X itself can, then Y Granger causes X.

We test for Granger causality by estimating the following VAR models for each pair-wise combination of stock returns series ([9], [10]):

$$X_t = \mu_1 + \sum_{i=1}^{p} \alpha_{1,i} Y_{t-i} + \sum_{i=1}^{p} \beta_{1,i} X_{t-i} + \varepsilon_{1,t} \quad (2)$$

If the null hypothesis: $H_0 : \sum_{i=1}^{p} \alpha_{1,i} = 0$ is rejected Y is said to Granger cause X.

$$Y_t = \mu_2 + \sum_{i=1}^{p} \alpha_{2,i} X_{t-i} + \sum_{i=1}^{p} \beta_{2,i} Y_{t-i} + \varepsilon_{2,t} \quad (3)$$

If the null hypothesis: $H_0 : \sum_{i=1}^{p} \alpha_{2,i} = 0$ is rejected X is said to Granger cause Y.

If the null hypothjesis is rejeted from both cases, it is said that there is a feedback relationship between X and Y.

As Granger causality test results are very sensitive to the number of lags chosen, we first run the models with 20 days as maximum lag length and we further implement a lag-length test.

IV. EMPIRICAL RESULTS

For the pre-crisis period, the Granger causality test results suggest that the exchanges from USA and Russia are two interactive markets, as the US stock market Granger causes the Russian market while the Russian stock index also leads the US stock market index, and this bilateral causality is significant at 1% and 5%, respectively, being stronger from the American stock market to the Russian one. Other interactive pairs of stock exchanges in the pre-crisis period are Romania-Hungary and Russia Hungary. When considering the overall role of the US market in the analyses, we observe that it leads the Bulgarian, Czech, Hungarian, Polish, and Romanian stock markets while only the Russian market has some marginally leading effect (as stated earlier) on the US market in the pre-crisis period, suggestion a leading role for the Russian market in the CEE region before the crisis.

For the crisis period, results reveal that causal relationships have increased during the 2007–2009 global financial crisis. Bilateral causality is now present between stock market in Hungary-Bulgaria, USA-Bulgaria, USA- Czech Republic, USA-Romania and USA-Russia, while strong unilateral causality is found from Romania to Bulgaria, from the Czech Republic to Hungary, from Romania to the Czech Republic, from Poland to Hungary, from Romania to Hungary, from Russia to Hungary, from Romania to Poland. In other words, results suggest that the linkages among CEE stock markets are generally larger during the crisis than before. Considering only the interactions between the CEE region and the USA, we find that during the crisis this linkages have become generally bi-directional, and the evolution of Central and Eastern European stock markets is more often reflected in the subsequent evolution of the US stock exchange. Table 5 reveals the Granger causality test results between each pair of markets in our dataset for the two sub-periods.

TABLE 5

RESULTS OF GRANGER CAUSALITY TESTS

H_0: X does not Granger cause Y	***Pre-Crisis***	***Crisis***
CZECH Republic → BULGARIA	0.25458	3.20367***
BULGARIA → CZECH Republic	0.00055	0.32537

HUNGARY → BULGARIA	1.31778	4.67027**
BULGARIA → HUNGARY	0.37999	5.88830**
POLAND → BULGARIA	0.42672	0.20182
BULGARIA → POLAND	0.41187	6.67296**
ROMANIA → BULGARIA	0.10938	45.4535*
BULGARIA → ROMANIA	1.20872	0.76627
RUSSIA → BULGARIA	0.05372	0.03185
BULGARIA → RUSSIA	20.6093*	1.70694
USA → BULGARIA	20.4032*	6.52363**
BULGARIA → USA	0.22428	62.0235*
HUNGARY → CZECH Republic	0.54750	1.73693
CZECH Republic → HUNGARY	0.15498	21.7962*
POLAND → CZECH Republic	0.30035	0.33348
CZECH Republic → POLAND	0.37284	4.47299**
ROMANIA → CZECH Republic	0.69153	47.4041*
CZECH Republic → ROMANIA	6.66731**	1.30228
RUSSIA → CZECH Republic	1.83256	0.25430
CZECH Republic → RUSSIA	11.9293*	1.81421
USA → CZECH Republic	30.3674*	15.4548*
CZECH Republic → USA	1.71908	103.526*
POLAND → HUNGARY	0.31966	11.9502*
HUNGARY → POLAND	0.04731	0.08832
ROMANIA → HUNGARY	2.81149***	68.4111*
HUNGARY → ROMANIA	2.78696***	0.31084
RUSSIA → HUNGARY	9.70624**	9.55204*
HUNGARY → RUSSIA	2.92076***	2.08579
USA → HUNGARY	2.78000***	0.22444
HUNGARY → USA	1.25798	5.13534**
ROMANIA → POLAND	0.83449	14.5677*
POLAND → ROMANIA	3.56401***	0.81652
RUSSIA → POLAND	0.82116	0.15364
POLAND → RUSSIA	11.9656*	2.15235
USA → POLAND	13.2372*	0.82947
POLAND → USA	0.46815	63.1564*
RUSSIA → ROMANIA	1.51315	0.99028
ROMANIA → RUSSIA	25.0197*	33.1299*
USA → ROMANIA	16.1896*	11.2758*
ROMANIA → USA	0.55412	3.0E+18*
USA → RUSSIA	10.4599*	4.80548**
RUSSIA → USA	4.76270**	25.0383*

* Significant at 1%
**significant at 5%
***significant at 10%

To sum up, Granger causality tests, as well as the correlation analysis point out that the stock markets in the CEE region have became increasingly integrated in recent years, reflecting this geographical area's increased importance in the European and in the world economy. Also, before the crisis CEE markets were significantly influenced by innovations in the USA market, thus explaining why they were affected heavily by the crisis, which has managed to spread immediately in the region.

V. CONCLUSIONS

This paper investigates interdependencies among six selected stock exchanges in the CEE region, while also considering their linkages with the USA market. As major economic events can influence the relationships among stock markets, we pay special attention to the effects of the 2007-2009 global financial crisis. Thus, we split the sample into two sub-samples to capture possible time-variant stock market integration in the CEE area before and during the crisis, while paying special consideration to finding the moment that delineated the starting point of the manifestations of the crisis on international stock markets. Descriptive statistics showed that the markets that were most affected by the crisis in terms of difference in mean returns between the two sub-samples are the Hungarian, Polish and Romanian stock markets, while the least affected were the Czech and the Russian markets. Also, market volatility, as represented by the standard deviation of returns, increased the most on the Bulgarian and Romanian stock exchanges. The Czech market realized the best risk-adjusted performance due to its average rate of return and low risk. It is followed by the Romanian, Russian and Polish stock markets which had high mean returns (Romania) and average levels for return and risk (Poland and Russia). The combination of return and risk resulted in a coefficient of variation for the US stock market equal to 0.0033, the lowest in our data sample, while Hungary and Bulgaria had a similar risk-adjusted performance.

Further, in line with previous findings in the literature, a simple correlation analysis revealed that all stock markets move together during crisis, while in the pre-crisis period the markets were fragmented, some linkages appearing only among stock indexes from the Czech Republic, Hungary, Poland and Russia. Results of the Granger causality tests also confirm that the interdependencies among CEE stock markets are generally larger during the crisis than before and also that

the relationships between CEE markets and the US market have become generally bi-directional. We also find that in the pre-crisis period the US stock market leads the Bulgarian, Czech, Hungarian, Polish, and Romanian stock markets while only the Russian market has some marginally leading effect on the US market, suggestion a leading role for the Russian market in the CEE region before the crisis.

ACKNOWLEDGEMENT:

This work was supported by CNCSIS-UEFISCU, Project number PN II-RU 662/2010, Director Dr. Cristiana Tudor

REFERENCES

[1] Aityan, Sergey K., Alexey K. Ivanov-Schitz, Sergey S. Izotov. 2010. "Time-shift asymmetric correlation analysis of global stock markets". *Journal of International Financial Markets, Institutions and Money*, doi:10.1016/j.intfin.2010.07.006;

[2] Bekaert, Geert, Campbell R. Harvey. 1997. "Emerging equity market volatility". *Journal of Financial Economics*, Vol. 43 (1): 29 – 77.

[3] Bodart, Vincent, Paul Reding .1999. "Exchange rate regime, volatility and international correlations on bond and stock markets". *Journal of International Money and Finance* 18(1): 133–151.

[4] Booth, Geoffrey G., Teppo Martikainen and Yiuman Tse. 1997. "Price and Volatility Spillovers in Scandinavian Stock Markets". *Journal of Banking & Finance* 21(6): 811-823.

[5] Chung, Pin, Donald Liu. 1994. "Common stochastic trends in Pacific-Rim stock markets". *Quarterly Review of Economics and Finance*, 34(5): 241−259.

[6] Click, Reid. W. and Michael G. Plummer. 2005. "Stock Market Integration in ASEAN After the Asian Financial Crisis" *Journal of Asian Economics* 16(1), 5-28.

[7] Eun, Cheol S. and Sangdal Shim. 1989. "International Transmission of Stock Market Movements". *Journal of Financial and Quantitative Analysis* 24(2): 241-256.

[8] Filis, George, Leon Costas. 2006. "Time-Varying Dynamics in the Greek Stock Market Integration with the EMU Stock Markets ", Proceedings of the 7-th Wseas International Conference on Mathematics & Computers in Business and Economics, Cavtat, Croatia, June 2006, pp 64-71.

[9] Fratzscher, Marcel. 2002. "Financial market integration in Europe: On the effects of the EMU on stock markets". *International Journal of Finance and Economics* 7 (3), 165–193.

[10] Granger, C. W., & Morgenstern, O. (1970). *Predictability of Stock Market Prices*. MA: Lexington.

[11] Granger, C.W. 1969. "Investigating causal relations by economic models and cross-spectral methods". *Econometrica* 37(3): 424–38.

[12] Hamao, Yasushi., Ronald W. Masulis and V. Ng. 1990. "Correlations in price changes and volatility across international stock markets". *The Review of Financial Studies* 3(2): 281-307.

[13] Huyghebaert, Nancy and Lihong Wang. 2010. "The co-movement of stock markets in East Asia. Did the 1997–1998 Asian financial crisis really strengthen stock market integration?". *China Economic Review* 21: 98-112.

[14] King, Mervyl, Sushil Wadhwani. 1990. "Transmission of volatility between stock markets". *Review of Financial Studies* 3(1): 5–33.

[15] Kumar, Rakesh, Raj S. Dhankar. 2010. "Empirical Analysis of Conditional Heteroskedasticity in Time Series of Stock Returns and Asymmetric Effect on Volatility". *Global Business Review* 11 (1): 21-33.

[16] Longin, Francois, Bruno Solnik. 1995. "Is the correlation in international equity returns constant: 1960–1990?" *Journal of International Money and Finance* 14 (1): 3–26.

[17] Masih Abul MM, Rumi Masih. 1997. "Dynamic linkages and the propagation mechanism driving major international stock markets". *Quarterly Review of Economics and Finance* **37(4)**: 859-885.

[18] Miron, Dumitru, Cristiana Tudor. 2010. "Asymmetric Conditional Volatility Models: Empirical Estimation and Comparison of Forecasting Accuracy". *Romanian Journal for Economic Forecasting* 13 (3): 74-92.

[19] Norrbin, Stefan., Joanne Li, Edward Flaherty. 2000. "Examining capital market integration in Korea and Japan using a threshold cointegration model", WSEAS Conference Proceedings, Jamainca.

[20] Pagano, Marco. 1993. "Financial markets and growth: An overview". *European Economic Review* 37(2-3): 613–622.

[21] Susmel, Raul, Robert F. Engle. "Hourly volatility spillovers between international equity markets". *Journal of International Money and Finance* 13(1), 1994, 3–25.

[22] Tudor, Cristiana. 2009. "Price Ratios and the Cross-section of Common Stock Returns on Bucharest Stock Exchange: Empirical Evidence," *Romanian Journal for Economic Forecasting*, 10 (2): 132-146.

[23] Tudor, Cristiana. 2010. "Causal relationships among CEE stock markets. The impact of the global financial crisis", *WSEAS Conferences, Tenerife.*

[24] Zhou, Wei. 2009. "Evolution of Correlations among Stock Markets in Hong Kong, Shanghai and the U.S.", *Advances in Marketing, Management and Finances, WSEAS Conferences, AMMF*, Houston, pp. 49-55.

Cristiana Tudor is Assistant Professor within the Department of International Business and Economics from the Academy of Economic Studies Bucharest and she holds a PhD in Economics, with a specialization on International Business and Economics since 2009. The PhD Dissertation is entitled: *Managing international portfolios: Selection, Analysis, Risk Management.* The main domains for academic development and research are represented by the portfolio management, asset pricing and asset allocation models, financial asset valuation, econometric modeling of time series, behavioral finance, risk management in the framework of international investments, including currency risk management, international capital markets integration and segmentation, corporate finance.

At the Academy of Economic Studies, Ms Tudor is currently teaching courses in International Commodities Exchanges (English module) and seminaries in International Capital Markets for graduate studies, in International Financial Markets and International Asset Pricing at the Master Program in International Financial Risk Management and in International Financial Transactions at the Master Program in International Business Management, both master programs being thought at the Faculty of International Business and Economics. Ms. Tudor attended and completed training courses in various financial fields organized by prestigious institutions in the Romanian capital market. One such training course is entitled Investment consultants on the capital market organized by the Romanian National Association of Securities Companies (ANSVM), owning both a graduation certificate, and a certificate issued by the Romanian Securities and Exchange Commission. Another specialization course attended by Ms. Tudor is entitled Culture and ethics in banking, organized by ABN AMRO Bank Romania.

In addition, Cristian Tudor is enrolled in the prestigious international program Chartered Financial Analysts (CFA): she has passed Level 1(June 2008) and Level 2 (june 2009), being currently a June 2010 Level 3 candidate. Due to her theoretical and practical experience in the field of capital markets and stock transactions, Ms. Tudor has been invited to support the Capital Markets section for the online magazine Markmedia, where she publishes bi-monthly studies and articles on the evolution of Bucharest Stock Exchange since 2005.

DrTudor is member of the Research Center in International Business and Economics, Faculty of International Business and Economics, ASE Bucharest, a Member of the Romanian Economic Society (SOREC) and of the Society for the Study of Emerging Markets (USA).