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# Analysis of Linkages between Central and Eastern European Capital Markets[†]

A b s t r a c t. The aim of the research is analysis of short- and long-term international relations between stock exchanges in Central and Eastern Europe. The analysis is provided in 3 stages. In the first step the order of the variables integration is examined. In the second stage short-run relationships for pairs of indexes are analyzed using Granger causality test. In the last step long-run relationships for pairs of indexes are examined applying Johansen cointegration method.

K e y w o r d s: Emerging Markets, Equity CEE Markets, cointegration, Granger Causality, long-run relationships, short-run relationships.

J E L Classification: G15.

## Introduction

The analysis of common stock market movements is important for effective portfolio diversification and a possible starting point to examine the functioning of the global financial system. Therefore international market linkages has attracted investors and policy-makers' attention. Consequently, international equity market integration is a topic often discussed in literature, especially many researchers have investigated the short-term and long-term interrelationships among worldwide financial markets. The theory review, evidence and implications of international equity market integration are presented in (Kearney, Lucey, 2004; Bailey, Choi, 2005) among others. Various aspects of equity markets relationships have been considered, including:

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– volatility spillovers across markets (e.g. Engle, Susmel, 1993; Kearney, 2000; Koutmos, Booth, 1995; Ng, 2000);
– market correlation structures (e.g. Koedijk et al., 2002; Longin, Solnik, 1995) and
– financial crises contagion (e.g. Claessens, Forbes, 2001; Rigobon, 1999).

Empirical investigations discussed in literature can be classified into 3 major classes due to following criteria:
– regions and periods of provided analysis,
– length of the return intervals,
– methods of analysis.

Empirical analysis considering relations among mature markets has been provided since the end of the 20-th century (Eun, Shim 1989; Hamao et al., 1990; Kasa 1992; Engle, Susmel 1993; Lin et al., 1994; Longin, Solnik 1995, 2001; Koutmos, Booth, 1995; Kim, Rogers, 1995; Karolyi, Stulz, 1996; Choudhry, 1996; Koutmos, 1996; Serletis, Booth et al., 1997; King, 1997; Rigobon, 1999; Witkowska, 1999; Kearney, 2000; Ng, 2000; Claessens, Forbes, 2001; MacDonald, 2001; Shachmurove, Witkowska, 2001; Forbes, Rigobon, 2002; Koedijk et al., 2002; Serwa, Bohl, 2005; Sharkasi et al., 2004; Kearney, Lucey, 2004; Baur, 2004; Phylaktis, Ravazzolo, 2005). While investigation of mutual market linkages for emerging markets has shorter history, especially consideration for post-communist countries. Syriopoulos (2007) notices that despite the growing importance of the emerging Central and Eastern European stock markets (see Fig. 1), the relevant body of research remains surprisingly limited. Furthermore, the empirical findings on this topic appear rather ambiguous and contradictory. For emerging markets we should mention research provided for:
– ASEAN (Janakiraman, Lamba, 1998; Gosh et al., 1999; Masih, Masih, 2001; Siklos, Ng, 2001),
– Middle and South Americas (Phylaktis, Ravazollo, 2005; Diamandis, 2009) and
– Central and Eastern Europe (Voronkova, 2004; Gilmore et al., 2008; Syllignakis, Kouretas, 2010).

Taking into account length of the investigated samples we notice that 10-year or longer periods are very often considered, for instance (Caporale, Spagnolo, 2010; Gilmore et al., 2008; Sharkasi et al., 2004). However shorter periods are also used in comparable analysis as Dubinskas, Stunguriene (2010) who consider 2-years period or Gilmore et al. (2008) who use rolling windows approach.

The length of the returns interval is also crucial and influences the results of investigation. In fact different intervals are used, for instance daily and weekly returns are discussed by Caporale, Spagnolo (2010), monthly – in Baur (2004), and 5-minutes intraday data – in Hanousek et al. (2008) and Hanousek, Kočenda (2009).

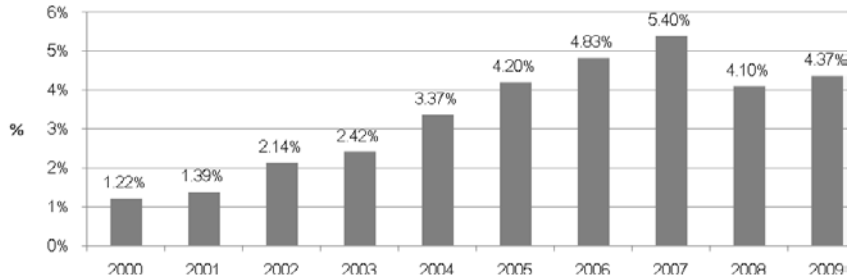


Figure 1. CEE Equity Markets Capitalization as a percentage of FESE Equity Markets Capitalization

Investigations has been provided applying different methods of analysis, the most popular are:

- correlation measures (as in: Panton et al., 1976; Watson, 1980; Meric, Meric 1989; Bailey, Stulz, 1989; Fisher, Palasvirta, 1990; Longin, Solnik, 1995),
- causality analysis (for instance Kwan et al., 1995; Roca, 1999; Huang et al., 2000; Narayan et al., 2004; Matuszewska-Janica, 2010),
- VAR models and cointegration analysis (Eun, Shim, 1989; Kasa, 1992; Richards, 1995; Hassan, Naka, 1996; Choundry, 1997, Gosh et al., 1999; Witkowska, 1999; Shachmurove, Witkowska, 2001; Masih, Masih, 2001; Siklos, Ng, 2001; Chen et al., 2002; Pascual, 2003; Yang et al., 2004; Gilmore et al., 2008; Kuçukcolak, 2008; Matuszewska-Janica, 2011),
- GARCH models (Baele, Vennet, 2001; Voronkova, 2004; Li, Majerowska, 2008),
- taxonomic methods as Kompa (2010).

The aim of the research is identification of short- and long-term international relations between stock exchanges in Central and Eastern Europe. The analysis is provided in 3 stages in which:

1. the order of the variables integration,
2. short-run relationships for pairs of indexes, using Granger causality test and
3. long-run relationships for pairs of indexes, applying Johansen cointegration method

are investigated.

## 1. Data Description

The research is provided for quotations of 14 indexes from the capital markets in Central and Eastern Europe (CEE) – Table 1, from the period: January 2000 – November 2010. In our research we consider daily, weekly and monthly (for the last quotation in the week and month respectively) data. The observations are transformed into natural logarithms and logarithmic rates of return.

Table 1. Analyzed indexes

| LP | Index | Type of index | Stock Exchange (SE) |
|---|---|---|---|
| 1 | ATX | price, blue-chip index | Vienna SE |
| 2 | PX | price, blue-chip index | Prague SE |
| 3 | PXGLOB | price, broad index | Prague SE |
| 4 | BUX | performance, blue-chip index | Budapest SE |
| 5 | SBI20 | price, broad index | Ljubljana SE |
| 6 | SAX | total return, blue chip index | Bratislava SE |
| 7 | BET | price, blue-chip index | Bucharest SE |
| 8 | SOFIX | total return, broad index | Bulgarian SE |
| 9 | OMXBB | performance, 32 companies from Baltic market – benchmark | OMX Group, Baltic countries |
| 10 | OMXT | total return, all share index | Tallin SE, OMX Group |
| 11 | OMXR | total return, all share index | Riga SE, OMX Group |
| 12 | OMXV | total return, all share index | Vilnius SE, OMX Group |
| 13 | WIG | performance, all share index | Warsaw SE (WSE) |
| 14 | WIG20 | price, blue-chip index | Warsaw SE (WSE) |

It is worth mentioning that for 2 indexes: SOFIX and SBI20 the data are available only from January 2001 till October 2010, therefore analysis is provided for 2 samples as it is shown in Table 2 where time ranges, symbols of samples and numbers of observations are presented. Missing data are completed by repeating the last observation (i.e. foregoing the lacking one).

Table 2. The considered periods, number of observations and notation of samples

| Indexes | date of first observation | date of last observation | Frequency of data | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | daily | | weekly | | monthly | |
| | | | A | B | A | B | A | B |
| OMXBB, OMXT, OMXR, OMXV, ATX, SAX, BUX, PX, PXGLOB, BET, WIG, WIG20 | 2000-01-03 | 2010-11-05 | PD1 | 2790 | 556 | PW1 | 130 | PM1 |
| SOFIX, SBI20* | 2000-12-29 | 2010-10-14 | PD2 | 2515 | 501 | PW2 | 118 | PM2 |

*Note*: A – symbol of samples, B – number of observations, * – quotation of SBI20 was stopped in October 2010.

## 2. Results

In the first step the order of the variables integration is identified applying augmented Dickey-Fuller (ADF) test[1]. The results indicate, that all examined time series of indexes are nonstationary while all returns are stationary so indexes are I(1).

[1] For technical details see e.g. Maddala, Kim (1998), Elder, Kennedy (2001).

In the second step, short-run relationships between all indexes are examined employing Granger causality test[2]. For two indexes (X and Y) we denote the direction of Granger causality by the arrow (i.e. X→Y means that X causes changes in Y, and Y→X the opposite). Causality analysis is provided for 182 mutual relations (for 14 indexes), considering from 1 to 10 lags for each investigated relation. Hypotheses are verified at the significance level 0.05. Table 3 contains the results presented as percentage of cases when the null hypothesis is rejected. More detailed results are presented in Tables A1–A3 in the Appendix.

For daily data the greatest percentage of rejections is obtained for following relations: WIG20→Y (93%), BUX→Y (92%), WIG→Y (87%), X→SOFIX (93%) and X→SBI20 (82%). On another words, daily changes of WIG20, WIG and BUX are the most often causes of changes in other investigated indexes, while SOFIX and SBI20 are the most sensitive indexes. The smallest number of $H_0$ rejections is observed for following relations: SAX→Y (22%), OMXR→Y (23%), X→WIG20 (18%) and X→WIG (35%). Thus the changes of SAX and OMXR influence other indexes very rarely while the less sensitive to changes of other indexes are WIG and WIG20. It can be explained by the fact that Warsaw Stock Exchange is the biggest market in CEE region and it reacts due to the world biggest markets changes.

Table 3. Results of the Granger causality test – percentage of rejection $H_0$

| Relation | % rejections of the $H_0$ | | | Relation | % rejections of the $H_0$ | | |
|---|---|---|---|---|---|---|---|
| | PD1/PD2 | PW1/PW2 | PM1/PM2 | | PD1/PD2 | PW1/PW2 | PM1/PM2 |
| ATX→Y | 78% | 55% | 59% | X→ATX | 66% | 45% | 2% |
| BET→Y | 48% | 71% | 23% | X→BET | 72% | 55% | 4% |
| BUX→Y | 92% | 44% | 33% | X→BUX | 57% | 59% | 9% |
| OMXBB→Y | 75% | 36% | 17% | X→OMXBB | 75% | 74% | 48% |
| OMXR→Y | 23% | 41% | 2% | X→OMXR | 72% | 42% | 42% |
| OMXT→Y | 71% | 25% | 15% | X→OMXT | 74% | 85% | 64% |
| OMXV→Y | 64% | 43% | 20% | X→OMXV | 65% | 45% | 37% |
| PX→Y | 86% | 82% | 43% | X→PX | 65% | 25% | 6% |
| PXGLOB→Y | 85% | 83% | 45% | X→PXGLOB | 66% | 27% | 6% |
| SAX→Y | 22% | 12% | 0% | X→SAX | 55% | 56% | 5% |
| WIG→Y | 87% | 64% | 25% | X→WIG | 35% | 53% | 15% |
| WIG20→Y | 93% | 53% | 15% | X→WIG20 | 18% | 54% | 22% |
| SOFIX→Y | 31% | 76% | 15% | X→SOFIX | 93% | 60% | 38% |
| SBI20→Y | 42% | 42% | 7% | X→SBI20 | 82% | 48% | 23% |

Taking into account number of lags (Table A1) we notice that the biggest number of cases, when $H_0$ is rejected for all 10 lags, is obtained for relations: WIG20→Y (11 times for 13 considered cases), WIG→Y (11) ATX→Y (10), X→SOFIX (12) and X→SBI20 (10). The biggest number of cases, when $H_0$ is

[2] See Charemza, Deadman (1997), Osińska (2008).

not rejected for any considered lag, is observed for relations: SOFIX→Y (6), OMXR→Y (6), SAX→Y (5), X→WIG20 (8) and X→WIG (7).

For weekly data the greatest percentage of rejections is obtained for following relations: PXGLOB→Y (83%), PX→Y (82%), X→OMXT (85%), X→OMXBB (74%). Such results denotes that weekly changes of PXGLOB and PX cause weekly changes of other analysed indexes most often. OMXT and OMXBB are the most sensitive to changes of other indexes. The smallest number of $H_0$ rejection is observed for following relations: SAX→Y (12%), OMXT→Y (25%), X→PX (25%) and X→PXGLOB (27%). The weekly changes of index SAX cause (in Granger sense) the changes of other indexes most rarely. The same result we obtain for daily data but, in contradistinction to daily changes, PX and PXGLOB are the less sensitive to weekly changes of other indexes appear (Table A2).

With change from daily to weekly data, number of relations when $H_0$ is rejected for all lags (from 1 to 10) is decreasing, and number of cases when $H_0$ is not rejected for any lag is increasing. It can be interpreted that by broadening of the time interval for returns calculations, the number of causal relations (in Granger sense) is reduced.

For monthly data the greatest percentage of rejections is obtained for the following relations: ATX→Y (59%), PXGLOB→Y (45%), PX→Y (43%), X→OMXT (64%), X→OMXBB (48%). While the smallest number of $H_0$ rejections is observed for: SAX→Y (0%), OMXR→Y (5%), SBI20→Y (7%), X→ATX (2%) and X→BET (4%) – Table A3. In comparison to results, obtained for weekly data, number of causal (in Granger sense) relations is decreasing.

As it is visible in Tables A1 – A3, we obtain similar results for WIG and WIG20 since both indexes cause changes of other investigated indexes while they do no influence WIG20 and WIG for daily data. However there are two exceptions for:

– weekly data since WIG20→SAX but ¬WIG→SAX, and BUX→WIG20 but ¬BUX→WIG,
– monthly data since WIG→SBI20 but ¬WIG20→SBI20, and OMXR→WIG20 but ¬OMXR→WIG.

Therefore it does not matter if Warsaw Stock Exchange is represented by WIG (performance, all share index) or WIG20 (price, blue-chip index). One could also notice that (Granger) causal short-run relation between WIG and WIG20 for weekly and monthly returns is bilateral (WIG↔WIG20) while for daily observation only changes of WIG20 cause changes of WIG (WIG20→WIG). The last statement could be explained by high capitalization of companies represented by WIG20[3].

[3] Capitalization of WIG20 is 69.5% of whole market capitalization represented by WIG (www.gpw.pl, September 23, 2011).

The next step of investigation is cointegration analysis provided by Johansen method[4]. As it was mentioned, cointegration analysis is applied in order to check if effective international portfolio (risk) diversification between two capital markets from CEE region is possible. Number of cointegrating vectors are presented in Tables 4–6.

Table 4. Number of cointegrating vectors for pairs of indexes – daily data

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BET | 1* | | | | | | | | | | | | |
| BUX | 0 | 1 | | | | | | | | | | | |
| OMXBB | 0 | 1 | 0 | | | | | | | | | | |
| OMXR | 1 | 1* | 0 | 0 | | | | | | | | | |
| OMXT | 0 | 1 | 0 | 1* | 0 | | | | | | | | |
| OMXV | 0 | 1 | 0 | 1 | 0 | 1 | | | | | | | |
| PX | 0 | 0 | 0 | 0 | 1* | 0 | 0 | | | | | | |
| PXGLOB | 0 | 0 | 0 | 0 | 1* | 0 | 0 | 0 | | | | | |
| SAX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| WIG | 0 | 0 | 1* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| WIG20 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | | |
| SOFIX | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| SBI20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| X \ Y | ATX | BET | BUX | OMXBB | OMXR | OMXT | OMXV | PX | PXGLOB | SAX | WIG | WIG20 | SOFIX |

*Note*: Hypotheses are verified at the significance level $\alpha=0.05$; * represents statistical significance at the 0.1.

For daily data all indexes but one, i.e. SAX, are cointegrated with other indexes from CEE capital markets. The greatest number of long-run relations is observed for BET (8 cases from 13 analyzed). Thus we can conclude that Bulgarian Stock Exchange could be the most sensitive market for international shocks (in the region) so it creates the less number of diversified portfolios. Two cointegrating vectors are observed in relations WIG – WIG20, therefore we suppose that indexes from WSE have stronger relationship among themselves then with other indexes.

For weekly data we observe smaller number of long-run relations than for daily data. Indexes OMXR and BET build the biggest number of cointegrating relations, 4 and 3, respectively. Indexes BUX, OMXBB, SOFIX and SBI20 are not cointegrated with other analyzed indexes. We observe that WIG and WIG20 are cointegrated only between themselves with 2 cointegrating vectors only in shorter period. It seems to be two reasons of this phenomenon. Firstly, Johansen tests results are sensitive on investigation period (see Gilmore et al., 2008 and Pascual, 2003 among others). Secondly, WSE could be not influenced by changes that appear on other CEE capital markets.

[4] Usually Johansen tests statistics $\lambda_{trace}$ and $\lambda_{max}$ yield the same results but in some cases they are different. In such situation it is accepted $\lambda_{max}$ test indication (the $\lambda_{max}$ test is considered superior to the $\lambda_{trace}$ test, see Kennedy, 2003, p. 355).

Table 5. Number of cointegrating vectors for pairs of indexes – weekly data

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BET | 0 | | | | | | | | | | | | |
| BUX | 0 | 0 | | | | | | | | | | | |
| OMXBB | 0 | 0 | 0 | | | | | | | | | | |
| OMXR | 1 | 0 | 0 | 0 | | | | | | | | | |
| OMXT | 0 | 1 | 0 | 0 | 0 | | | | | | | | |
| OMXV | 0 | 1 | 0 | 0 | 0 | 0 | | | | | | | |
| PX | 0 | 0 | 0 | 0 | 1* | 0 | 0 | | | | | | |
| PXGLOB | 0 | 0 | 0 | 0 | 1* | 0 | 0 | 0 | | | | | |
| SAX | 0 | 1* | 0 | 0 | 1* | 0 | 0 | 0 | 0 | | | | |
| WIG | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| WIG20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2[a] | | |
| SOFIX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| SBI20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| X \ Y | ATX | BET | BUX | OMXBB | OMXR | OMXT | OMXV | PX | PXGLOB | SAX | WIG | WIG20 | SOFIX |

*Note*: Hypotheses are verified at the significance level α=0.05; * represents statistical significance at the 0.1.
[a] – 2 cointegrating vectors are obtained for sample PW2, for sample PW1 $H_0$ that cointegration does not exist is not rejected.

Table 6. Number of cointegrating vectors for pairs of indexes – monthly data

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BET | 0 | | | | | | | | | | | | |
| BUX | 0 | 0 | | | | | | | | | | | |
| OMXBB | 0 | 0 | 0 | | | | | | | | | | |
| OMXR | 0 | 0 | 1* | 1 | | | | | | | | | |
| OMXT | 0 | 1* | 0 | 0 | 0 | | | | | | | | |
| OMXV | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| PX | 0 | 1* | 0 | 0 | 1* | 1 | 0 | | | | | | |
| PXGLOB | 0 | 1* | 0 | 0 | 1* | 1 | 0 | 0 | | | | | |
| SAX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| WIG | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| WIG20 | 1 | 0 | 0 | 0 | 0 | 1* | 0 | 0 | 0 | 0 | 2 | | |
| SOFIX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| SBI20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| X \ Y | ATX | BET | BUX | OMXBB | OMXR | OMXT | OMXV | PX | PXGLOB | SAX | WIG | WIG20 | SOFIX |

Note: Hypotheses are verified at the significance level α=0.05; * represents statistical significance at the 0.1.

For monthly data we observe smaller number of long-run relations than for daily data however number of linkages is bigger than for weekly data. Indexes OMXR, OMXT and BET build the biggest number of cointegrating relations – 3 each. Indexes OMXV, SAX, SOFIX and SBI20 are not cointegrated with other investigated indexes. WIG and WIG20 are cointegrated with 2 vectors. In opposite to WIG, only WIG20 is cointegrated with other foreign indexes (i.e. ATX and OMXT).

In literature it is remarked that Johansen tests power does not increase when the higher frequency data are used but with the time span of the data (see Hakkio, Rush, 1991; Diamandis 2009). Hence we can suppose that indication of the Johansen test is more trustworthy for weekly or monthly data than for daily ones. So taking into consideration two capital markets from CEE region, international portfolio risk diversification can be achieved. But we also have to take into account sensitiveness on the changes that appear at the world biggest markets since these shocks are quickly transmitted into global market.

In the last step of the analysis, VECM models for relations WIG or WIG20 with other foreign index are estimated. The obtained results are presented in Table 7.

Table 7. Selected results of the estimation of the VECM models (for WIG and WIG20 indexes)

| Pair of indexes | Variable order in the model | Equation | ECM parameter |
|---|---|---|---|
| WIG i BUX daily | WIG, BUX | First for WIG | –0.0036 * |
| | | Second for BUX | 0.0031 |
| WIG i SBI20 daily | SBI20, WIG | First for SBI20 | –0.0021 *** |
| | | Second for WIG | 0.0045 |
| WIG20 i BET daily | BET, WIG20 | First for BET | –0.0010 *** |
| | | Second for WIG20 | 0.0003 |
| WIG20 i SBI20 daily | SBI20, WIG20 | First for SBI20 | –0.0014 *** |
| | | Second for WIG20 | 0.0010 |
| WIG i SBI20 weekly | SBI20, WIG | First for SBI20 | –0.0106 *** |
| | | Second for WIG | 0.0021 |
| WIG20 i SBI20 weekly | SBI20, WIG20 | First for SBI20 | –0.0070 *** |
| | | Second for WIG20 | 0.0052 |
| WIG20 i ATX monthly | WIG20, ATX | First for WIG20 | – 0.0070** |
| | | Second for ATX | 0.0253 |
| WIG20 i OMXT monthly | WIG20, OMXT | First for WIG20 | –0.1301*** |
| | | Second for OMXT | –0.0542 |

*Note*: ECM parameters significant *** – at the level 0.01, ** – at the level 0.05, * – at the level 0.1.

Error correction mechanism is significant for all presented cases. For daily observations, index WIG in relation to BUX has the highest speed of adjustment (circa 0.3% of the discrepancy in these two indexes from the previous day is eliminated in present day). While for weekly data the highest speed of adjustment has index SBI20 with relation to WIG, and for monthly data the highest speed of adjustment has index OMXT with relation to WIG20. We can observe that restoring the equilibrium is quicker (from period to period) for monthly data.

## Conclusions

Integration of financial markets has important implications since highly integrated markets are not isolated from international shocks. It could be also the reason that the effective portfolio risk diversification between integrated markets cannot be achieved[5].

For investigated time series many short-run Granger causal relationships are found out. It is also noticed that with broadening of intervals (for which returns are computed) many relations disappear, thus the data frequency does matter[6]. It is also worth mentioning that for the 10 years period of observation only a few long-run relationships are diagnosed, similarly to the results obtained by other researchers (e.g. Gilmore et al, 2008; Pascual, 2003).

The results show that changes at the Warsaw Stock Exchange cause (in Granger sense) changes at other capital markets from CEE region. While WSE indexes are less sensitive to the changes that appear at other investigated markets. Thus it could be considered as a premise that WSE is the most developed capital market in CEE region[7] since situation at WSE influences other markets in the region while it is not sensitive on shocks that appear in other CEE markets.

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[5] See e.g. Hassan, Naka (1996), Phylaktis, Ravazzolo (2005), Syriopoulos (2007). Numerous studies concerning long-run relationships among stock exchanges are quoted in the last mentioned paper.

[6] For daily data $H_0$ is rejected for every lag (from 1 to 10) in 74 cases in investigated 182 relations, for weekly data we obtained only 39 such cases while taking into consideration monthly data only 15 such cases are observed.

[7] Another explanation of mentioned observation is clamming that matured and great capital markets transmit changes to emerging markets.

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## Analiza relacji pomiędzy rynkami kapitałowymi Europy Środkowej i Wschodniej

Z a r y s t r e ś c i. Celem analizy jest ocena związków krótkookresowych (w zakresie przyczynowości) i długookresowych (kointegracja) pomiędzy rynkami kapitałowymi Europy Środkowej i Wschodniej, a w szczególności pomiędzy giełdą w Warszawie i pozostałymi rynkami. Analizie poddano dzienne, tygodniowe i miesięczne stopy zwrotu indeksów notowanych na tych rynkach. Badania obejmują okres od stycznia 2000 do listopada 2010.

S ł o w a k l u c z o w e: giełdy Europy Środkowej i Wschodniej, rynki rozwijające się, kointegracja, przyczynowość w sensie Grangera, krótkookresowe i długookresowe relacje pomiędzy rynkami.

## APPENDIX

Table A1. Lags for $H_0$ rejection in Granger causality test: daily data (PD1, PD2)

| X \ Y | ATX | BET | BUX | OMXBB | OMXR | OMXT | OMXV | PX | PXGLOB | SAX | WIG | WIG20 | SOFIX | SBI20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ATX | X | 1-10 | 1-10 | 1-10 | 1-10 | 1-10 | 1-10 | 1-10 | 1-10 | 7 | | | 1-10 | 1-10 |
| BET | 1-10 | X | | 1-7 | | 1-3 | 2 | 1-10 | 1-10 | 4;5;7 | | | 1-10 | 1-9 |
| BUX | 1-10 | 1-10 | X | 1-10 | 1;2; 4-10 | 1-10 | 1-10 | 1-10 | 1-10 | 1;4-10 | 4-10 | 5-10 | 1-10 | 1-10 |
| OMXBB | 8-10 | 3-10 | 4-10 | X | 1-10 | 1;2;4-10 | 1-10 | 4-10 | 4-10 | 2-10 | 1;4-10 | 1 | 1-10 | 1-10 |
| OMXR | 8-10 | 5-10 | 7-10 | | X | | | 8-10 | 8-10 | | | | 1-10 | 6 |
| OMXT | 4-10 | 5-10 | 4-10 | 1-10 | 1-10 | X | 1-10 | 4-10 | 4-10 | 2-10 | | | 1-10 | 1-10 |
| OMXV | 2;7-10 | 3-10 | 2-10 | 1;6-10 | 1-10 | 1-10 | X | 7-10 | 7-10 | 2-6;8-10 | | | 1-10 | 1-10 |
| PX | 1-10 | 2-10 | 1-7 | 1-10 | 1-10 | 1-10 | 1-10 | X | 1-3 | 4-10 | 2-10 | 2;5-10 | 1-10 | 1-10 |
| PXGLOB | 1-10 | 2-10 | 1-7 | 1-10 | 1-10 | 1-10 | 1-10 | 1 | X | 4-10 | 2-10 | 2;3; 5-10 | 1-10 | 1-10 |
| SAX | | | 3 | 3-10 | 3-7 | 5-10 | 1;3 | | | X | 1-4 | 1 | 3 | |
| WIG | 1-10 | 1-10 | 1-10 | 1-10 | 1-10 | 1-10 | 1-10 | 1-10 | 1-10 | 4;9;10 | X | | 1-10 | 1-10 |
| WIG20 | 1-10 | 1-10 | 1-10 | 1-10 | 1-3 | 1-10 | 1-10 | 1-10 | 1-10 | 3-10 | 1-10 | X | 1-10 | 1-10 |
| SOFIX | | | 1-10 | 6-10 | | 6-10 | | 6-10 | 6-10 | 1-10 | | | X | 1-10 |
| SBI20 | 3-10 | 3-10 | 7 | 9 | 4-10 | 2;5;6 | 10 | 4-10 | 4-10 | | | | 1-10 | X |

*Note*: Bolded are cases when the $H_0$ is rejected for all considered lags, shaded - when no $H_0$ is rejected.

Table A2. Lags for $H_0$ rejection in Granger causality test: weekly data (PW1, PW2)

| X \ Y | ATX | BET | BUX | OMXBB | OMXR | OMXT | OMXV | PX | PXGLOB | SAX | WIG | WIG20 | SOFIX | SBI20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ATX | X | 1-5; 8-10 | 2;3;8;9 | 1-10 | | 1-10 | 9 | 8 | 8;9 | 2-7;10 | 3-10 | 3-10 | 1-10 | 7-10 |
| BET | 2-10 | X | 2;3;6-8 | 2-10 | 6;7 | 2-10 | 4-9 | 2-10 | 2-10 | 3-10 | 2-4;6-8 | 2-10 | 1-10 | 8;9 |
| BUX | | 1-8; 10 | X | 1-10 | 4-7 | 1-10 | 5 | 6 | | 2-10 | | 1 | 4-10 | 5;7-10 |
| OMXBB | 3 | 1 | 2-8 | X | 1-10 | 1-4; 8-10 | 1 | | | 1-4;10 | 2-5;8 | 2-7 | 1;3 | 1-3 |
| OMXR | 1-3; 9;10 | 2-10 | 1-9 | | X | 4-10 | 1 | 1-5;7; 9;10 | 1-5;7; 9;10 | 7;8 | | | | 1;2; 6;8 |
| OMXT | | | 2-4 | 8-10 | 1;3-10 | X | | | | 1;2;8;10 | 2-5; 7-10 | 2-7;10 | | |
| OMXV | 3;6;7; 9;10 | 9;10 | 2-10 | 2-7 | 1;2;4; 5;7 | 1-10 | X | | | 1-3 | 2-4; 8;9 | 2;3;8;9 | 1-4 | 1-3 |
| PX | 1;4-10 | 1-10 | 1-10 | 1-10 | 4-8 | 1-10 | 4-10 | X | | 1-10 | 1-10 | 1-10 | 1-10 | 3-10 |
| PXGLOB | 1;4-10 | 1-10 | 1-10 | 1-10 | 4-8 | 1-10 | 2;4-10 | | X | 1-10 | 1-10 | 1-10 | 1-10 | 3-10 |
| SAX | | | | | | | 1-10 | | | X | | | | 3-5; 7;9;10 |
| WIG | 1;4-6 | 1-8 | 1-10 | 1-10 | 4-7 | 1-10 | 1-9 | | | | X | 2-10 | 1-10 | 1;2; 4-10 |
| WIG20 | 4-8 | 1-10 | 1 | 1-10 | 4-7 | 1-10 | 1-5;6;8 | | | 2-4 | 2-10 | X | 1;2; 4-10 | 1;2;4 |
| SOFIX | 1-5; 7-9 | | 1-10 | 1-10 | 2-10 | 1-10 | 1-10 | 1-4 | 1-5;7 | 1-10 | 1-8 | 1-7 | X | 1-7 |
| SBI20 | 5-10 | 6-10 | | 3-10 | | 4-10 | | 1-10 | 1-10 | 3-4 | | | 3-6; 8;10 | X |

*Note*: Bolded are cases when the $H_0$ is rejected for all considered lags, shaded - when no $H_0$ is rejected.

Table A3. Lags for $H_0$ rejection in Granger causality test: monthly data (PM1, PM2)

| X \ Y | ATX | BET | BUX | OMXBB | OMXR | OMXT | OMXV | PX | PXGLOB | SAX | WIG | WIG20 | SOFIX | SBI20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ATX | X | | 1-10 | 1-10 | 1-10 | 1-10 | 1;4-10 | 5-10 | 2;5-10 | | | | 1-10 | 1-4;9;10 |
| BET | | X | | 1-5;8 | 2-5 | 1-6 | 2;4;8-10 | | | 1-3 | | | 1-6 | |
| BUX | | | X | 1-10 | 1-6;8 | 1-10 | 1-5 | | | | 3 | 3;4 | 1-4;6 | 1;3;4 |
| OMXBB | | 3 | | X | 1-4;7-9 | 1-10 | | | | | | | 1 | 6-8 |
| OMXR | | 1 | | | X | | | | | | | 3 | 1 | |
| OMXT | 3;4;6 | 3;4 | | 1-10 | 3;7-10 | X | | | | | | | | |
| OMXV | | | 1;2 | | 2 | 1-4;9 | X | 2 | | | 1;3;5 | 1-7 | 1;6 | 1;3;4; 6;7 |
| PX | | | | 1-10 | 1-4 | 1-10 | 1-10 | X | | | 3;6-9 | 3-9 | 1-6 | 2-5 |
| PXGLOB | | | | 1-10 | 1-5 | 1-10 | 1-10 | | X | | 3;6-9 | 3-9 | 1-7 | 2-5 |
| SAX | | | | | | | | | | X | | | | |
| WIG | | | | 1-3;7 | 1;3 | 1-10 | 1-4;7-9 | | | | X | 1-4 | 1-3;4 | 1;2 |
| WIG20 | | | | 1;2 | 1 | 1-4; 7;9;10 | 1-3 | | | | 1-4;10 | X | 1;2 | |
| SOFIX | | | | | 1-8 | 1;2;5-7 | | | | 1;8;9 | | | X | 1;9;10 |
| SBI20 | | 2 | | | | | | 2 | 2 | | | | 1-6 | X |

*Note*: Bolded are cases when the $H_0$ is rejected for all considered lags, shaded - when no $H_0$ is rejected.