The Relationship between Czech Republic's Stock Market and Stock Markets of its Major Trading Partners: the Impact of the Global Financial Crisis

Oleg Deev, Veronika Kajurová
Masaryk University
Faculty of Economics and Administration, Department of Finance
Lipová 41a
Brno 602 00
Czech Republic
e-mail: oleg@mail.muni.cz

Abstract
This paper examines the relationship between Czech Republic's stock market and stock markets of its major trading partners. Johansen multivariate cointegration technique is used for the analysis of short- and long-run linkages between those markets. The purpose of the paper is twofold. First, it aims to test whether the degree of integration on the equity markets is comparable to the degree of economic integration. Furthermore, this paper is goaled to distinguish the change in interdependence relationships between Czech stock market and stock markets of its trading partners after the world financial crisis. Vector Error Correction Model is built to determine the initial receptor of internal shocks, while Granger causality tests are performed to form the short-run connections. The findings on notable change in stock markets' cointegration have implications for both policy makers and global investors.

Keywords: stock market integration, financial crisis, Johansen cointegration analysis
JEL codes: F36, G15

1. Introduction

The subject of international financial market integration has attracted an immense attention from researchers. Evidently, for risk management and portfolio diversification purposes, an interrelationship analysis between several stock markets gives more useful information about possible gains than correlation analysis of returns. The common technique to explore the nature of financial integration is to build a cointegration model of different stock markets. Objects for studying the cointegration relations are usually financial markets of neighboring countries (geographical approach to select the studying sample) or dependence of national stock market on the most developed ones such as United States, United Kingdom, Japan, etc. (approach based on availability and prevalence of data). However, the majority of studies just explain the cointegration degree and long-term interdependence, not acquiring the reasons for the nature of integration.

According to Pretorius (2002), the explanations of a co-movement between different stock markets are economic integration, stock market characteristics (volatility, market size, etc.) and contagion effect (described as the co-movement not caused by a common change of fundamentals). We decided to go backwards in our research and to choose countries, which are economically integrated with Czech Republic, for the study of the relationships between their financial markets. Therefore, the considered stock markets would not be chosen by a geographical criterion or market size.

The first aim of the paper is to test whether the degree of equity markets' integration is comparable to the degree of economic integration. Economic integration might be defined as an economic agreement between different countries marked by the reduction or elimination of trade barriers and the coordination of monitory and fiscal policies.[1] International economic integration determines the international financial integration through the presence of international trade in real output, which leads to a reallocation of these goods, such that the real margin product of capital would

[1] http://www.investopedia.com/terms/e/economic-integration.asp#axzz1YOfAuues

be equated internationally. Because stock prices are related to the real marginal product of capital, the stock prices in the different countries would tend to exhibit a common trend movement in the long run (Bachman et al. 1996).

We assume that stock markets of countries would have higher degree of financial integration, if their economies have higher share of bilateral trade and higher degree of economic integration. Moreover, since the degree of economic integration changes slowly over time, the degree of financial integration would change gradually as well.

Table 1: Trading Turnover by Major Partners of Czech Republic (total and % by each partner)

Country	2004		2007		2010	
	mln Kč	%	mln Kč	%	mln Kč	%
Germany	1 177 435	33,91%	1 432 526	29,4%	1 432 943	29,0%
Slovakia	239 457	6,90%	342 676	7,04%	343 236	6,94%
China	97 978	2,82%	199 743	4,10%	318 978	6,45%
Poland	173 539	5,00%	284 205	5,84%	308 885	6,25%
France	162 539	4,68%	244 917	5,03%	214 994	4,35%
Italy	167 642	4,83%	235 721	4,84%	206 472	4,18%
Austria	173 756	5,00%	204 890	4,21%	200 894	4,06%
Russia	95 079	2,74%	171 657	3,52%	197 458	3,99%
UK	131 977	3,80%	191 597	3,93%	174 075	3,52%
Total	3 471 752		4 870 552		4 944 354	

Source: Czech Statistical Office

Analyzing the international trade statistics of Czech Republic, we chose nine trading partners of Czech Republic for the study. The major trading partners were selected according to the amount of their trading turnover and their share in total amount, with Germany being the largest trading partner and holding around 30% of import-export operations. Moreover, we evaluated the stage of economic integration with these partners. Czech Republic is in the highest stage of economic integration, economic and monetary union, with Slovakia, Poland, France, Italy, Austria, UK and Germany, all of them being European Union members. The share of these partners in the international trade is stable over the studying period. We also selected two countries named Russia and China, with which the trading and, therefore, economic partnership is steadily increasing. However, the degree of economic integration between Czech Republic and those countries is still minimal. The main assumption here is that the degree of stock market integration of Czech market and its EU partners is larger and stable over time, while the integration with Russia and China is smaller, but increasing.

Furthermore, we could not neglect the importance of the global financial crisis on the degree of financial integration among different countries. Therefore, the second aim of the article is to explore the influence of the world financial crisis on the nature of financial cointegration between Czech Republic and its major trading partners. Hypothetically, fluctuations and volatility on the stock markets during the recent financial turmoil would affect the long- and short-run stock market interdependence.

Johansen (1988, 1990) procedure is employed to test the long-run cointegration and Granger causality analysis is used to explore the short-run dynamics of the stock markets. The crisis effect is investigated through the comparison of short- and long-run cointegration relations in several periods (in the spirit of Masih and Masih 1997).

2. Literature Review

Stock market cointegration gained a notable deliberation of researches during the last three decades. Cointegration analysis is developing since Granger (1986), Engle and Granger (1987), Johansen (1988), Johansen and Juselius (1990). Cointegration analysis is probably one of the most popular approaches in academic research and stock market consulting. Such analysis reveals regular stochastic trends in financial time series. Cointegration analysis among national equity markets implies that there are fewer assets available to investors to achieve portfolio diversification and, hence, to minimize the non-systemic risk in holding a certain number of stocks. Moreover, cointegration would also mean Granger causality in levels and, accordingly, would be suggestive of inefficiency in the market (see Hung and Cheung, 1995).

Studies investigating relationships among world stock markets find evidence of co-movement among them. Most of the studies we reviewed focus on the equity markets of the United States, Asia and Europe using pair-wise and group analysis. It should be stated that direct comparison of studies is not completely appropriate, since different studies employ different differencing intervals (daily, weekly, monthly), different time periods and sub-periods, and different market indexes as representatives of the studied markets. Hence, these studies draw different conclusions about the interdependent relationships between the selected markets. We believe that choice of market data for the study based on the criterion of economic interaction is increasing the accuracy of the results.

The research on stock market cointegration, relevant to the following study, can be divided into two categories: (1) studies, establishing the relations between stock markets of Czech Republic and other countries, and (2) studies, finding the impact of financial crises on the integration of stock markets.

Voronkova (2004) reports significant long-run relations between the emerging Central European markets (including Czech Republic) within the region and globally. Gilmore et al. (2005) report an evidence of greater degree of integration between Czech, Hungarian and Polish equity markets with German and UK ones in the final stages of accession to the European Union. Czech stock market was found mostly integrated with Germany as a leading trade partner and with the United Kingdom. Nevertheless, Fadhlaoui et al. (2009) find no indications of a multilateral cointegration relationship between Central European and G7 equity markets.

The majority of studies of the impact of financial turmoil on the stock market integration (such as Yang et al. 2003) indicate that the long- and short-run relationships among national stock markets have strengthen during the 1997-1998 global emerging market crisis. Equity markets became more integrated after the crisis then before the crises. Authors consider financial liberalization and market deregulation among main reasons of intensified integration.

Even though the research in this area is relatively extensive, we could find only few studies addressing the impact of recent global financial crisis on the cointegration processes. Syllignakis and Kouretas (2010) noted that the global financial crisis of 2007-2009 caused a slowdown of the convergence process between the Central European stock markets and the markets of the eurozone. They suggest the increased volatility and significant deviation of daily returns during the crisis to be the explanation.

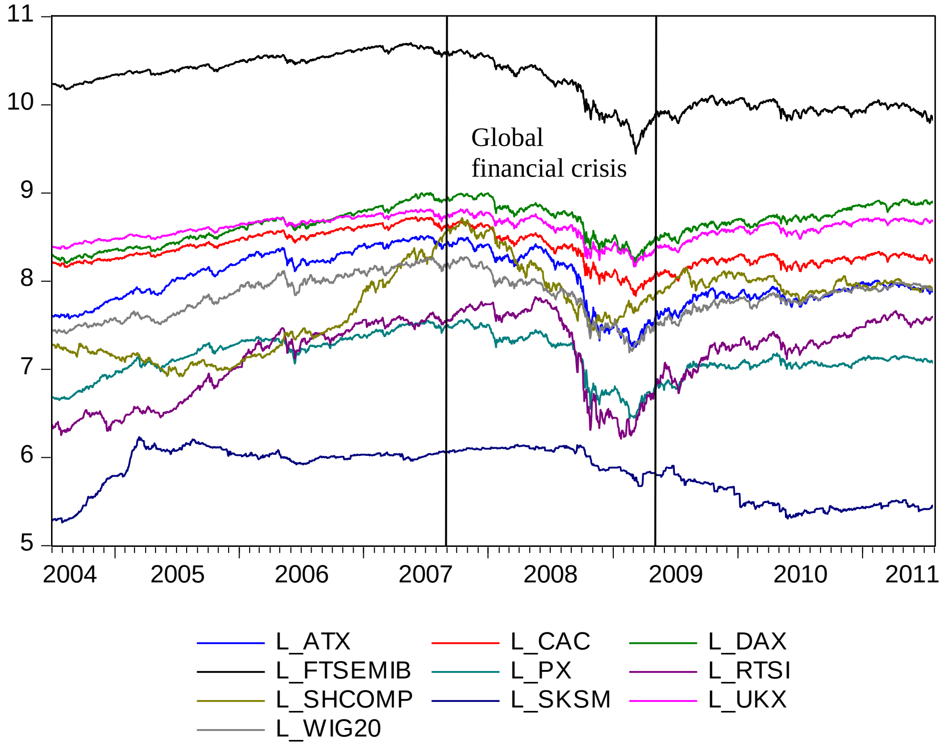
3. Data

Following the group of Czech Republic’s major trading partners established previously, we chose commonly used stock market indexes for the study, specifically:

- PX Index – Prague Stock Exchange Index;
- DAX Index – Frankfurt Stock Exchange Index;
- ATX Index – Austrian Traded Index;
- CAC Index – Paris Bourse Index;
- FTSEMIB – Borsa Italiana Index;
- RTSI$ - Russian Trading System Index (calculated in US dollars);
- SHCOMP – Shanghai Stock Exchange Composite Index;
- SKSM (name used in Bloomberg) – SAX – Bratislava Stock Exchange Index;
- UKX (name used in Bloomberg) – FTSE100 – London Stock Exchange Index;
- WIG20 – Warsaw Stock Exchange Index.

The sample data consists of daily closing index prices from July 1st, 2004 till August 1st, 2011. High-frequency daily data are preferred, taking into consideration the market environment of advanced information technology online trading and rapid general information sharing. Daily data capture speedy information as both short- and long-run dynamic linkages matter for market integration (Voronkova 2004). It might be argued that in analyzing the long-run integration of markets, it is appropriate to use a long sample period consisting of several years, rather than high-frequency daily data for a few years. At the same time, using a longer sample period would to content a structural shifts emanating from changes in the policy regime and the general economic environment (Raj and Dhal 2008).

Figure 1: Movement of Stock Indices' Prices (in logs)



Source: Bloomberg

The dataset is gained from Bloomberg. Study avoids adjustment of the indices to a common currency (the domestic currencies are used instead), so the problem of fluctuations and speculations in cross-country exchange rates is avoided. Because most markets are operating almost in the same time zone, the problem of non-overlapping trading hours does not arise, except with regard to China. When a stock exchange is closed due to a national holiday, the price from the last business day is taken.

The total number of observations for the each stock market is 1848. Time series are measured in natural logarithms in order to maintain association in the information content (in accordance to Bachman et al., 1996). Causal observation implies that each stock price series appears to be non-stationary and that these 10 stock price indices tend to move more or less together over time. This observation is the subject to conformation with the use of cointegration analysis methodology.

In order to examine the differences between non-crisis and crisis trading periods, the total sample period was divided into three sub-periods according to the clearly observed trends in the stock markets, thus avoiding the inclusion of major break points into the model. The sub-periods are pre-crisis period (July 1st, 2004 – July 31st, 2007), crisis period (August 1st, 2007 – March 31st, 2009) and post-crisis period (April 1st, 2009 – August 1st, 2011). The beginning of the study period is chosen to avoid previous turmoil on the financial markets (and especially economic instability in Eastern European countries) interfering the results (the main objective is to establish the impact of the financial crisis on markets' interdependence). We chose the crisis period to not start with the Lehman bros. bankruptcy and major panic on the markets, we would like to capture prior anticipations on the markets, when the 2007 banking crisis changed the comfort expectations with a fear of it becoming a sovereign debt crisis. Finally, since April 2009 stock markets began to steadily rise again, although the credit markets remained very tight.

4. Methodology

In this study the comovement of the index prices will be examined through the utilization of non-asset pricing models: multivariate cointegration and Granger casualty. As previously mentioned, cointegration analysis allows finding comparable long-run properties of several financial time series and it was used in many equity market integration studies. Granger casualty specifies the direction of markets cointegration in the short-run.

Following Granger (1988) and Engle and Granger (1987), variables are called cointegrated if they have a common stochastic trend. To check the stochastic non-stationarity of the data the unit root is required. We conducted standard Augment Dickey-Fuller (1981) unit root test (ADF), which constructs a parametric correction for higher-order correlation by assuming that the *y* time series follows an AR(*p*) process with *p* lagged difference terms and with or without deterministic trend $x_t'\delta$:

$$\Delta y_t = \alpha y_{t-1} + x_t'\delta + \beta_1 \Delta y_{t-1} + ... + \beta_p \Delta y_{t-p} + v_t \quad (1)$$

The appropriate lag length for the cointegration test (order of VAR) is determined by Schwarz Bayesian criterion (BIC) and Hannan-Quinn criterion (HQC).

We employ Johansen (1988, 1990) procedure to find the common trend in the multivariate time series, which is based on the vector autoregressive (VAR) model:

$$y_t = A_1 y_{t-1} + ... + A_p y_{t-p} + Bx_t + \varepsilon_t \quad (2)$$

where y_t is a *k*-vector of non-stationary *I(1)* variables, x_t is a *d*-vector of deterministic variables, and ε_t is a vector of innovations.

Model also can be expressed in its first different error correction form:

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-p} + Bx_t + \varepsilon_t \text{, where: } \Pi = \sum_{i=1}^{p} A_i - I \text{ and } \Gamma_i = -\sum_{j=i+1}^{p} A_j \quad (3)$$

The null hypothesis of no cointegration is rejected, if the rank of the coefficient matrix is at least 1. Johansen and Juselius (1990) developed two test statistics to determine the number of cointegrating vectors (the rank of the matrix) namely the trace statistic and the maximum eigenvalue statistic, which are computed for the null hypothesis as:

$$LR_{tr}(r|k) = -T \sum_{i=r+1}^{k} \log(1-\lambda_i) \quad (4)$$

$$LR_{\max}(r|r+1) = -T \log(1-\lambda_i) = LR_{tr}(r|k) - LR_{tr}(r+1|k) \quad (5)$$

Trace statistic tests the null hypothesis of *r* cointegrating relations against the alternative of *n* cointegrating relations, where *n* is the number of variables in the system for *r =0,1,2…n-1*. The maximum eigenvalue statistics tests the null hypothesis of *r* cointegrating relations against the alternative of *r+1* cointegrating relations for *r =0,1,2…n-1*. In some cases trace and maximum eigenvalue statistics may yield different results.

The third step is based on Granger Representation Theorem, that is if the variables in the VAR, which represents the long-run dynamics between indexes, are found to be cointegrated, then there must exist an associated error-correction model (ECM), which can be build by imposing as restrictions the number of cointegration relations previously identified.

Following Bauhmol and Vyrost (2010) we employ Granger causality test to identify the causality sense between index series (causality implies a chronological ordering of movements of the series). If we denote the first analyzed index (its daily returns) as $I_{1,t}$ and the second index (its daily returns) as $I_{2,t}$ the Granger causality model takes the following form:

$$I_{1,t} = \alpha_0 + \sum_{i=1}^{p} \alpha_i I_{1,t-i} + \sum_{j=1}^{q} \beta_j I_{2,t-j} + \varepsilon_t \quad (6)$$

Wald's test for joint significance of the parameters b_j is performed to evaluate the null hypothesis that $I_{1,t}$ does not Granger cause $I_{2,t}$.

5. Empirical Findings

5.1. Descriptive Statistics and Correlation Coefficients

The summary statistics of the chosen market index returns (or log price changes) is shown in Table 2. For the whole sample period, Russian stock market provides the highest returns, while the Polish market provides the lowest returns. Other markets included in the study show more or less similar returns. The average stock returns are marginally positive, except for France, but are close to zero. Numbers in mean and standard deviation columns illustrate the risk-return trade-off of the selected stock indexes with Russian Trading System Index being the most risky and profitable one. The indexes of developing countries included in the study (Slovakia, Poland and China), Czech Republic and Austria show higher returns than indexes of the most developed countries included in the study (France, Germany, Italy, Great Britain). According to standard deviation numbers, investors face almost the same risk levels on the selected markets, except for Russia.

Almost all indexes ale skewed left, the kurtosis measures are positive. The Jarque-Bera test, as an asymptotic test of the normality, indicates that none of the price indexes is normally distributed. Alternatively, this implies that in each stock market there exist opportunities for investors to benefit from abnormal returns.

Table 2: Descriptive Statistics of Index Returns

Index	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
PX	0.000214	0.000331	0.123641	-0.161855	0.016410	-0.558970	17.72707	16796.51
DAX	0.000292	0.000726	0.107975	-0.074335	0.013727	0.153439	12.05324	6318.259
ATX	0.000139	0.000236	0.120210	-0.102526	0.017181	-0.274797	9.685530	3464.875
CAC	-2.14E-05	6.09E-05	0.105946	-0.094715	0.014400	0.137601	11.70839	5845.203
FTSEMIB	-0.000249	0.000471	0.108742	-0.085991	0.014605	0.056336	11.38479	5414.438
RTSI	0.000663	0.001105	0.202039	-0.211994	0.022970	-0.476547	15.99906	13081.06
SHCOMP	0.000356	0.000182	0.090345	-0.092561	0.017961	-0.323352	6.287742	864.5153
SKSM	7.80E-05	0.000000	0.118803	-0.148101	0.011810	-1.770869	31.14806	61974.00
UKX	0.000139	0.000166	0.093843	-0.092656	0.012678	-0.123301	12.41445	6829.341
WIG20	0.000242	0.000000	0.081548	-0.084428	0.016019	-0.249343	6.007552	715.6425

Source: authors' calculations

Table 3 reports the correlation matrix for the chosen market index returns. The correlation matrix indicates that the correlations are positive and significant, except for Slovakia. Stock markets of European Union countries (except for Slovakia) have higher contemporaneous correlation among themselves, than markets of China and Russia with others.

Table 3: Correlation Matrix of Index Returns

	PX	DAX	ATX	CAC	FTSEMIB	RTSI	SHCOMP	SKSM	UKX	WIG20
PX	1	0.5697	0.6981	0.6161	0.6110	0.6259	0.1898	0.0338	0.6188	0.6531
DAX	0.5697	1	0.7367	0.9231	0.8541	0.5016	0.1391	-0.0056	0.8709	0.5967
ATX	0.6980	0.7367	1	0.7709	0.7517	0.5764	0.1736	0.0017	0.7505	0.6161
CAC	0.6161	0.9231	0.7709	1	0.9171	0.5302	0.1471	-0.0059	0.9272	0.6071
FTSEMIB	0.6109	0.8541	0.7517	0.9171	1	0.5101	0.1496	-0.0292	0.8537	0.5739
RTSI	0.6259	0.5016	0.5764	0.5302	0.5101	1	0.1911	-0.0138	0.5455	0.5702
SHCOMP	0.1898	0.1391	0.1736	0.1471	0.1496	0.1911	1	0.0387	0.1413	0.1463
SKSM	0.0338	-0.0056	0.0017	-0.0059	-0.0292	-0.0138	0.0387	1	-0.0055	-0.0084
UKX	0.6188	0.8709	0.7505	0.9272	0.8537	0.5455	0.1413	-0.0055	1	0.5980
WIG20	0.6532	0.5967	0.6161	0.6071	0.5739	0.5702	0.1463	-0.0084	0.5980	1

Source: authors' calculations

5.2. Unit Root Test

The logarithms of the chosen indexes are tested for unit roots using the Augment Dickey-Fuller (ADF) test with the lag length selected by the Schwarz Information Criterion (SIC). The p-values used in the test are MacKinnon one-sided p-values. Several ADF test are calculated in levels and in the first differences with inclusion of constant or constant and trend.

Table 4: Augment Dickey-Fuller Unit Root Test Statistics

Index	Level		First Differences	
	Intercept	Intercept and Trend	Intercept	Intercept and Trend
PX	-2.059974	-2.216597	-31.47409	-31.50588
ATX	-1.549679	-1.921190	-40.59417	-40.62063
CAC	-1.556387	-1.996610	-45.79864	-45.80468
DAX	-1.798695	-1.793057	-44.15491	-44.14834
FTSEMIB	-0.491422	-1.903313	-42.86292	-42.89055
RTSI	-1.685449	-1.612979	-38.04298	-38.03955
SHCOMP	-1.152049	-0.887750	-43.32547	-43.32647
SKSM	-1.391646	-3.671851	-28.28679	-28.51981
UKX	-2.072535	-2.047677	-21.27090	-21.27051
WIG20	-1.832200	-1.764931	-41.50015	-41.50112

Note: MacKinnon critical values are -3.41 and -3.13 for 5% and 10% level of significance respectively
Source: authors' calculations

The results of the ADF unit root test show that at logarithm levels all stock price indices are non-stationary series with a deterministic trend. However, the ADF tests performed at first differences suggest that data are stationary, hence all variables are first-order integrated series or *I(1).*

5.3. Analysis of Cointegration Relationships

Having confirmed that all stock indices can be characterized as integrated series with order one, *I(1),* we first examine the long-run relations among selected stock indices. Vector Autoregressive model of ten stock markets indicates that the appropriate lag order in the full sample and each sub-period sample is one, which is selected by both Schwarz Information Criterion and Hannan-Quinn Information Criterion. The results of Johansen multivariate cointegration tests with a deterministic trend are presented in Appendix 1. Numbers of cointegrating relations in the models were chosen in accordance to the trace and maximum eigenvalue statistics. The three cointegration vectors reported for the model of the full sample, while three, two and one cointegration relation is detected for pre-crisis, crisis and post-crisis periods respectively.

The primary finding obtained from the Johansen cointegration test is that a stationary long-run relationship exists between Czech Republic's stock market and stock markets of its major trading partners. A time varying nature of stock markets' comovement is recognized from the results. Selected markets are found to be less cointegrated in the long run during and after the recent global financial crisis, which contradicts the results of most previous studies. We assume that the main explanation of the reduced cointegration is a change of specific market conditions, especially regulation rules. The apparent influence of increased regulation on the long-run cointegration of stock markets is a subject of further investigation and approval.

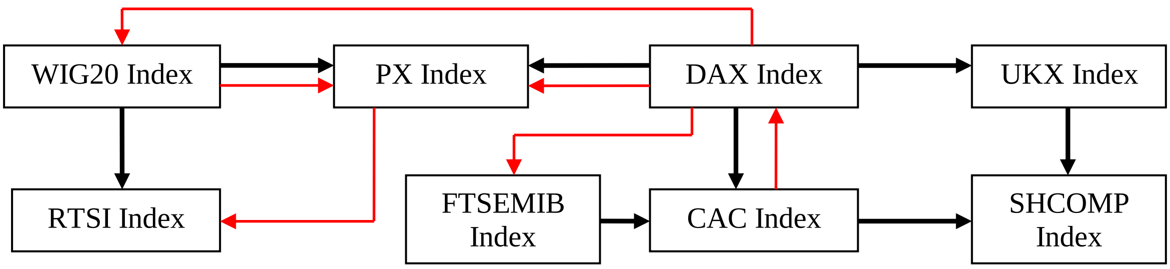
After ascertaining the number of cointegration relations and building an according VEC model (results not shown here but available on request), it is of interest to derive some useful perspectives from the sign and size of the coefficients in the established long-run cointegration in regard to Czech Republic's stock market. Generally, the coefficients of stock index indicators in the cointegration relation do not have similar signs, which mean differential risks associated with trading partners' markets relative to the Czech Republic's market. Signs of the coefficients do not change over the studied time period, except for some changes in the crisis sub-period. French and Chinese markets contributed negatively to cointegration relation in the crisis period, while having positive sign in the non-crisis periods. It is also worth to mention the increase of the negative influence of UK market and positive contribution of Polish market to the cointegration relation. German and Polish markets have the most statistically significant contributions to the explanation of index returns of the Czech market, apart from the cointegration relations.

A cursory look at the statistical significance of the reported coefficients of error-correction terms provides us a knowledge, whether the left hand side variable in each equation of the system is endogenous or weakly exogenous. If the coefficient of the error-correction term is not significantly different from zero, it usually implies that that variable is weakly exogenous, otherwise, it is endogenous. Therefore, it is possible to distinguish an initial receptor of external shocks in each model. In the pre-crisis period it is markets of Germany, France, Italy and UK, however each in a different cointegration relation. Unfortunately, it is not possible to establish the initial receptor of shocks during the crisis period. Post-crisis period model gives us an interesting result of possibility of all markets, except for Russia and Poland, to be an initial receptor of external shocks. We suppose that in the examined periods of long-run disintegration the country-specific shocks started to play a more dominant role.

5.4. Analysis of Granger Causality Tests Based on VECM

In order to find short-run linkages between selected stock markets we conduct Granger tests for intertemporal causality. Appendix 2 shows the results of Granger Causality/Block Exogeneity Wald tests. It estimates the chi-squared value of coefficient on the lagged endogenous variables. The causality is investigated in there periods. The hypothesis in this test is that the lagged endogenous variables do not “Granger cause” the dependent variable.

Figure 2: Short-run causal channels



Source: authors’ illustration

The results of Granger causality tests in the crisis and post-crisis periods are more important for the study. Figure 2 depicts some short-run linkages with DAX index being the dominant market. Black lines illustrate short-run relations after the financial crisis and red lines illustrate the relations during the crisis. It is found that German and Polish stock markets “Granger cause” Czech stock market at 5% significance level in both crisis and post-crisis periods. It means that the PX index follows its mature counterparts in the short-run and there exists a lead-lag relationship between them. Regarding the linkages between other markets, they are mostly formed during the crisis period with some of them disappeared after the crisis.

6. Conclusions

Using multivariate cointegration tests and performing multivariate error-correction analysis and Granger causality tests, we document evidence that Czech Republic’s stock market is influenced by the development in the stock markets of its major trading partners. German and Polish stock markets are found to be the main contributors to the change of PX Index in both short- and long-run. This result is somewhat expected, since Germany is the main trading partner of Czech Republic and the trading turnover between Czech Republic and Poland is significant (about 5-7% of total amount). However, the VEC models do not depict the long- or short-run relations with some other countries having the same share of trading turnover (such as China) or same degree of economic integration (other EU members). Apparently, there are other explanations of the degree of the financial integration, rather than just degree of economic integration.

Although VEC model does not establish the initial receptor of external shock during the crisis period, we discovered that almost any country from the selected sample might be an initial receptor of shocks after the crisis. Policy makers and global investors should be also aware of short-run linkages in the studied group of equity markets. Nevertheless, the reduced degree of cointegration between selected equity markets indicates that the regulation policy, conducted worldwide to lessen the degree of financial crisis, had an impact on the markets' interdependence, which earlier led to the global character of financial crisis in 2007.

References

BACHMAN, D. – CHOI, J.J. – JEON B.N. – KOPECKY, K. (1996). Common Factors in International Stock Prices: Evidence From a Cointegration Study. *International Review of Financial Analysis*, vol. 5 no.1, pp. 39-53.

BAUHMOL, E. – VYROST, T. (2010). Stock Market Integration: Granger Causality Testing with Respect to Nonsynchronous Trading Effects. *Czech Journal of Economics and Finance*, 60, no.5, pp. 414-425.

DICKEY, D.A. – FULLER, W.A. (1981). Likelihood Ratio Tests for Autoregressive Time Series with a Unit Root. *Econometrica*, 49, pp. 1057-1072.

ENGLE, R.F. – GRANGER, C.W. (1987). Co-integration and Error Correction: Representation, Estimation and Testing. *Econometrica*, 55, pp. 251-276.

FADHLAOUI, K. – BELLALAH, M. – DHERRY, A. – ZOUAOUII, M. (2009). An Empirical Examination of International Diversification Benefits in Central European Emerging Equity Markets. *International Journal of Business*, 14 (2), pp. 163-173.

GILMORE, C. – LUCEY, B. – McMANUS, G. (2005). The Dynamics of Central European Equity Market Integration. *Institute for International Integration Studies Discussion Paper*, No.69.

GRANGER, C.W. (1986). Developments in the Study of Cointegrated Economic Variables. *Oxford Bulletin of Economics and Statistics*, 3, pp. 213-228.

HUNG, W.S – CHEUNG, Y.L. (1995). Interdependence of Asian Emerging Equity Markets. *Journal of Business Finance and Accounting*, 22(2), pp. 281-288.

JOHANSEN, S. – JUSELIUS, K. (1990). Maximum Likelihood Estimation and Inferences on Cointegration – with applications to the demand for money. *Oxford Bulletin of Economics and Statistics*, 52, pp. 169-210.

JOHANSEN, S. (1988). Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control*, 12, pp. 231-254.

MASIH, A. – MASIH, R. (1997). Dynamic Linkages and the Propagation Mechanism Driving Major International Stock Markets: An Analysis of the Pre- and Post-Crash Eras. *The Quarterly Review of Economics and Finance*, vol.37 no.4, pp. 859-885.

PRETORIUS E. (2002). Economic Determinants of Emerging Stock Market Interdependence. *Emerging Markets Review*, 3, pp. 84-105.

RAJ, J. – DHAL, S. (2008). Integration of India's Stock Market with Global and Major Regional Markets. *BIS Papers*, No 42, pp. 202-236.

SYLLINGAKIS, M. – KOURETAS, G. (2010). German, US and Eastern European Stock Market Integration. *Open Economies Review*, vol. 21 no. 4, pp. 607-628.

VORONKOVA, S. (2004). Equity Market Integration in Central European Emerging Markets: a Cointegration Analysis with shifting regimes. *International Review of Financial Analysis*, no. 13, p. 633-647.

YANG, J. – KOLARI J. – MIN, I. (2003). Stock Market Integration and Financial Crises: the Case of Asia. *Applied Financial Economics*, vol.13 no.7, pp.477-486.

Appendix 1

Results of Johansen Cointegration Rank Tests

Hypothesized number of CE	Eigenvalue	Trace statistic	5% critical value	Maximum eigenvalue statistic	5% critical value
Full Sample (10/07/2004 – 30/09/2011)					
None	0.040689	331.6272	251.2650	76.76647	65.30016
At most 1	0.038241	254.8607	208.4374	72.05641 *	59.24000
At most 2	0.026580	182.8043 *	169.5991	49.78447	53.18784
At most 3	0.023028	133.0199	134.6780	43.05335	47.07897
At most 4	0.016773	89.96652	103.8473	31.25995	40.95680
At most 5	0.013414	58.70656	76.97277	24.95725	34.80587
At most 6	0.007513	33.74931	54.07904	13.93576	28.58808
At most 7	0.006276	19.81355	35.19275	11.63513	22.29962
At most 8	0.003102	8.178420	20.26184	5.740830	15.89210
At most 9	0.001318	2.437590	9.164546	2.437590	9.164546
At most 10	0.040689	331.6272	251.2650	76.76647	65.30016
Pre-crisis period (01/07/2004 – 31/07/2007)					
None	0.084459	301.1309	239.2354	71.03307 *	64.50472
At most 1	0.063819	230.0978	197.3709	53.08679	58.43354
At most 2	0.062117	177.0110 *	159.5297	51.62492	52.36261
At most 3	0.051477	125.3861	125.6154	42.54349	46.23142
At most 4	0.036483	82.84259	95.75366	29.91828	40.07757
At most 5	0.024181	52.92431	69.81889	19.70468	33.87687
At most 6	0.016360	33.21963	47.85613	13.27839	27.58434
At most 7	0.013326	19.94125	29.79707	10.79959	21.13162
At most 8	0.009733	9.141651	15.49471	7.873523	14.26460
At most 9	0.001574	1.268128	3.841466	1.268128	3.841466
At most 10	0.084459	301.1309	239.2354	71.03307	64.50472
Crisis period (01/08/2007 – 31/03/2009)					
None	0.194122	327.0073	239.2354	94.09864	64.50472
At most 1	0.155411	232.9087 *	197.3709	73.64243 *	58.43354
At most 2	0.089316	159.2662	159.5297	40.79163	52.36261
At most 3	0.082451	118.4746	125.6154	37.51754	46.23142
At most 4	0.060751	80.95705	95.75366	27.32620	40.07757
At most 5	0.043804	53.63085	69.81889	19.52949	33.87687
At most 6	0.040736	34.10136	47.85613	18.13288	27.58434
At most 7	0.019857	15.96848	29.79707	8.744923	21.13162
At most 8	0.014598	7.223560	15.49471	6.411808	14.26460
At most 9	0.001860	0.811752	3.841466	0.811752	3.841466
At most 10	0.194122	327.0073	239.2354	94.09864	64.50472
Post-crisis period (01/04/2009 – 01/08/2011)					
None	0.080735	240.8751 *	239.2354	51.26592	64.50472
At most 1	0.069441	189.6091	197.3709	43.82941	58.43354
At most 2	0.058181	145.7797	159.5297	36.50470	52.36261
At most 3	0.052029	109.2750	125.6154	32.53974	46.23142
At most 4	0.044961	76.73530	95.75366	28.01591	40.07757
At most 5	0.036009	48.71939	69.81889	22.33398	33.87687
At most 6	0.021166	26.38540	47.85613	13.02863	27.58434
At most 7	0.012722	13.35678	29.79707	7.797234	21.13162
At most 8	0.008845	5.559543	15.49471	5.410534	14.26460
At most 9	0.000245	0.149010	3.841466	0.149010	3.841466
At most 10	0.080735	240.8751	239.2354	51.26592	64.50472

* denotes rejection of the null hypothesis at the 5% level
Source: authors' calculations

Appendix 2

Results of Granger Causality/Block Exogeneity Wald Tests Based on VECM

Dependent variable	D(L_PX)	D(L_DAX)	D(L_ATX)	D(L_CAC)	D(L_FTSEMIB)	D(L_RTSI)	D(L_SHCOMP)	D(L_SKSM)	D(L_UKX)	D(L_WIG20)	All
Crisis period (01/08/2007 – 01/04/2009)											
D(L_PX)	-	5.035299 (0.0248)**	0.845527 (0.3578)	0.272247 (0.6018)	0.680347 (0.4095)	0.268262 (0.6045)	2.375274 (0.1233)	3.706767 (0.0542)*	0.863377 (0.3528)	4.251916 (0.0392)**	20.86484 (0.0133)**
D(L_DAX)	0.998605 (0.3176)	-	0.398304 (0.5280)	4.597840 (0.0320)**	0.048852 (0.8251)	1.195168 (0.2743)	2.621127 (0.1054)	0.772381 (0.3795)	0.548726 (0.4588)	0.002361 (0.9612)	18.59302 (0.0289)**
D(L_ATX)	0.860719 (0.3535)	5.621981 (0.0177)**	-	0.751959 (0.3859)	0.302133 (0.5825)	4.004071 (0.0454)**	5.532506 (0.0187)**	1.581036 (0.2086)	0.017363 (0.8952)	1.854589 (0.1733)	22.72821 (0.0068)***
D(L_CAC)	0.022023 (0.8820)	15.37077 (0.0001)***	0.500397 (0.4793)	-	0.046657 (0.8290)	0.113800 (0.7359)	2.266403 (0.1322)	1.158300 (0.2818)	0.956129 (0.3282)	2.219102 (0.1363)	22.61613 (0.0071)***
D(L_FTSEMIB)	0.072723 (0.7874)	10.44655 (0.0012)***	0.014739 (0.9034)	2.190682 (0.1388)	-	0.275045 (0.6000)	1.781719 (0.1819)	1.364058 (0.2428)	0.193007 (0.6604)	3.358628 (0.0669)*	17.08423 (0.0474)**
D(L_RTSI)	4.950466 (0.0261)**	4.445731 (0.0350)**	5.421373 (0.0199)**	1.808947 (0.1786)	1.183279 (0.2767)	-	5.048409 (0.0246)**	1.219465 (0.2695)	0.452874 (0.5010)	0.106333 (0.7444)	26.84769 (0.0015)***
D(L_SHCOMP)	0.374363 (0.5406)	0.027561 (0.8681)	0.683384 (0.4084)	1.873211 (0.1711)	1.027051 (0.3109)	0.336680 (0.5618)	-	1.301384 (0.2540)	6.186448 (0.0129)	3.253979 (0.0713)*	22.52499 (0.0074)***
D(L_SKSM)	0.269201 (0.6039)	0.874953 (0.3496)	0.177810 (0.6733)	0.015206 (0.9019)	0.003702 (0.9515)	10.42039 (0.0012)***	0.311721 (0.5766)	-	0.142692 (0.7056)	0.063554 (0.8010)	22.44764 (0.0076)***
D(L_UKX)	0.084765 (0.7709)	11.22680 (0.0008)***	0.272914 (0.6014)	2.974421 (0.0846)*	0.436892 (0.5086)	0.031694 (0.8587)	2.002031 (0.1571)	0.657798 (0.4173)	-	0.728673 (0.3933)	18.67641 (0.0281)**
D(L_WIG20)	0.310302 (0.5775)	11.29847 (0.0008)***	0.676955 (0.4106)	1.531128 (0.2159)	0.060465 (0.8058)	0.058497 (0.8089)	3.500694 (0.0613)*	0.983377 (0.3214)	0.128515 (0.7200)	-	17.57987 (0.0404)**
Post-crisis period 01/04/2009 – 01/08/2011)											
D(L_PX)	-	4.060848 (0.0439)**	0.910863 (0.3399)	0.698158 (0.4034)	0.272508 (0.6017)	3.632405 (0.0567)*	1.597102 (0.2063)	0.683437 (0.4084)	0.005288 (0.9420)	3.975101 (0.0462)**	30.50414 (0.0004)***
D(L_DAX)	0.000544 (0.9814)	-	2.243376 (0.1342)	0.381435 (0.5368)	1.301673 (0.2539)	0.021682 (0.8829)	0.022434 (0.8809)	0.432142 (0.5109)	1.021906 (0.3121)	0.742011 (0.3890)	5.127700 (0.8230)
D(L_ATX)	2.630130 (0.1049)	0.107451 (0.7431)	-	0.343393 (0.5579)	3.299201 (0.0693)*	0.016361 (0.8982)	0.330629 (0.5653)	1.005073 (0.3161)	0.337389 (0.5613)	0.709869 (0.3995)	19.23634 (0.0233)**
D(L_CAC)	0.066273 (0.7968)	3.828108 (0.0504)*	2.752646 (0.0971)	-	7.310996 (0.0069)***	0.064285 (0.7998)	0.005990 (0.9383)	0.279944 (0.5967)	2.602487 (0.1067)	0.667002 (0.4141)	14.61278 (0.1021)
D(L_FTSEMIB)	0.530423 (0.4664)	2.073740 (0.1499)	1.599062 (0.2060)	0.323125 (0.5697)	-	0.539568 (0.4626)	0.160803 (0.6884)	0.489167 (0.4843)	2.104586 (0.1469)	0.438593 (0.5078)	8.987876 (0.4384)
D(L_RTSI)	1.206140 (0.2721)	0.350800 (0.5537)	0.913140 (0.3393)	0.018109 (0.8930)	1.598105 (0.2062)	-	0.009213 (0.9235)	1.666128 (0.1968)	0.869640 (0.3511)	7.311125 (0.0069)**	20.01174 (0.0178)**
D(L_SHCOMP)	0.070813 (0.7902)	0.685594 (0.4077)	0.063391 (0.8012)	4.705750 (0.0301)**	1.911955 (0.1667)	2.461490 (0.1167)	-	0.905519 (0.3413)	3.241954 (0.0718)*	0.070009 (0.7913)	19.46895 (0.0215)**
D(L_SKSM)	0.215332 (0.6426)	0.002066 (0.9638)	0.054453 (0.8155)	0.695774 (0.4042)	0.106352 (0.7443)	0.307455 (0.5792)	0.159838 (0.6893)	-	2.074023 (0.1498)	0.025439 (0.8733)	4.820456 (0.8497)
D(L_UKX)	0.009023 (0.9243)	5.273268 (0.0217)**	1.722594 (0.1894)	0.014754 (0.9033)	2.892014 (0.0890)*	0.027862 (0.8674)	0.228384 (0.6327)	0.009442 (0.9226)	-	1.079390 (0.2988)	11.44968 (0.2461)
D(L_WIG20)	0.263730	2.778881	2.210617	1.072096	0.153248	2.588054	0.044311	0.653345	0.034606	-	12.42396

	(0.6076)	(0.0955)*	(0.1371)	(0.3005)	(0.6955)	(0.1077)	(0.8333)	(0.4189)	(0.8524)		(0.1904)

Note: chi-squared statistics, probability in ()

*,**,*** indicate significance at 10%, 5% and 1% level.