UDC: 336.761
JEL Classification: C23, G15, G12
Keywords: beta convergence, new EU member states, sigma convergence, stock markets

Financial Integration of Stock Markets among New EU Member States and the Euro Area *

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Abstract
The paper considers the empirical dimension of financial integration among stock-exchange markets in four new European Union member states (Czech Republic, Hungary, Poland, and Slovakia) in comparison with the euro area. The main objective is to test for the existence and determine the degree of the four states' financial integration relative to the euro currency union. The analysis is performed at the country level (using national stock-exchange indices) and at the sectoral level (considering banking, chemical, electricity, and telecommunication indices). Our empirical evaluation consists of (1) a harmonization analysis (by means of standard and rolling correlation analysis) to outline the overall pattern of integration; (2) the application of the concept of beta convergence (through the use of time series, panel, and state-space techniques) to identify the speed of integration; and (3) the application of so-called sigma convergence to measure the degree of integration. We find evidence of respective stock-market integration on both national and sectoral levels between the Czech Republic, Hungary, Poland, and the euro area.

1. Introduction

In a monetary union, integration of financial markets (e.g. money, credit, bond, and equity markets) plays the key role in assuring the effective transmission of a common monetary policy. The importance of conducting an assessment of the degree of financial integration across the euro area member countries is stressed by the European Central Bank – see (Baele et al., 2004). As financial markets expand, their fluctuations have stronger effects on real economic variables such as, e.g., private consumption. Along with a number of benefits, financial integration brings certain costs; a detailed discussion of the costs and benefits of financial integration is provided by Agénor (2003). It is widely believed that benefits outweigh costs, provided that the mechanisms of controlling for financial stability are implemented.

Joining the euro area without a sufficient degree of financial market integration can cause problems in terms of transmission of a common monetary policy and

* This paper represents the authors' own views and do not necessarily reflect those of their institutions. However, all errors and omissions remain entirely the fault of the authors. The research is supported by the Czech National Bank research project No. C1/07 and partly by the Grant Agency of the Czech Republic within a project No. 402/05/2758.

common shocks. A high degree of financial market integration implies that euro-area-wide shocks dominate; hence, a common monetary policy can be effectively applied to react to common shocks. On the other hand, in the case of weak financial market integration local (i.e. country-specific) shocks prevail, which diminishes the effectiveness of a common monetary policy. In the case of new EU member states, which are committed to adopting the euro at some point, it is especially important to analyze the alignment of their markets including the financial ones with those of the euro area countries.

This paper focuses on financial integration among stock exchange markets in four new EU member states (the Czech Republic, Hungary, Poland and Slovakia) in comparison with the euro area. As stock markets grow in size, they represent an incresingly important but not yet well-examined segment of the financial system. Our main objective is to test for the existence and determine the degree of financial integration of the selected new member states relative to the euro area. The empirical analysis is conducted at the country level (using national stock exchange indices) and at the sectoral level (considering banking, chemical, electricity and telecommunications indices).

How can the degree of financial market integration be measured in practice? Financial market integration is a broad concept. Baele et al. (2004) propose to quantify financial integration using three main dimensions, namely (i) price-based, (ii) news-based and (iii) quantity-based measures. The first class of measures could be viewed as the direct check of the law of one price on the condition that the compared assets have similar characteristics. Price-based measures can then be quantified by means of, e.g., beta and sigma convergence. The second class of measures makes it possible to identify existing market imperfections such as frictions and barriers, due to the reason that in the integrated area new information of a local character should have a smaller impact on particular assets than global news. The third class of measures quantifies the effects of mainly legal and other non-price frictions and barriers from both the supply and demand sides of the investment decision-taking process.[1]

In this paper we make use of the price-based approach to measure stock market integration, while fully acknowledging the importance of alternative measures.[2] Adam et al. (2002) argue that "financial markets are integrated when the law of one price holds".[3] Given this definition, stock market integration implies convergence of returns on assets that are issued in different countries and generate identical cash flows – see (Adjouté, Danthine, 2003), (Baele et al., 2004), (Bekaert, Harvey, 1997). In a hypothetical example of perfectly integrated stock markets, assets which have the same risk factor and yield are priced identically by markets, regardless of the particular location where such assets are traded. Identifying such assets is a difficult task, however.

In reality, the law of one price could not hold true in the case of different assets, i.e. different national stock exchange indices, which are calculated based not on

[1] The European Commission (1997) finds that coordination and harmonization of capital market rules and conventions appear to be less important than for other financial markets before introduction of the euro. Nevertheless, a high degree of integration can not be achieved without a successful harmonization process.

[2] New-based and quantity-based measures require the use of different data and estimation techniques; such an analysis could be a subject for future research.

[3] See also (Baele et al., 2004) and (Goldberg, Verboven, 2001).

the same underlying stock exchange assets. In addition, the law of one price does not necessarily hold true in the presence of market frictions. Nevertheless, while the law of one price represents rather a very long-term phenomenon, an alternative argument of why we could expect equalization of stock market returns in the long- to medium--run is based on the Walras law of markets as applied to the financial system: if n–1 (financial) markets are in equilibrium (i.e. exchange rate, money, bond markets), then the last (stock exchange) market cannot be in disequilibrium. Another reason for convergence in stock market returns is based on the practical investor's point of view, when assets are considered on sectoral rather than on national levels. Indeed, investments of many funds are made based on the general index, which includes shares of different territories (for example, the Morgan Stanley Capital International index, MSCI). It is for this reason that we include in our analysis both national and sectoral stock market indices.

Notice that even if the underlying assets are not identical, comparing asset returns gives insight into their degree of synchronicity. Co-movement between asset returns could then be due to the similarity of the underlying assets, due to common shocks, or because of the mixture of both effects.

This paper addresses the following three main questions, similar to those earlier raised by Adam et al. (2002) with respect to the euro area: (i) Is there a convergence of stock markets between the Czech Republic, Hungary, Poland and Slovakia on one side and the euro area on the other side? (ii) If there is convergence, how fast it is? (iii) How does the degree of financial market convergence change over time at the national and sectoral levels? In particular, are there any effects related to the announcement of EU enlargement or to the EU enlargement itself?

The structure of the paper is as follows. Section 2 briefly discusses the relevant literature focusing on the integration of stock markets. Section 3 provides stylized facts on the development of the EU-4 stock exchange markets at the national level and at the level of four industrial sectors (banking, chemical, electricity and telecommunications). Section 4 provides a discussion of the theoretical approaches for estimating financial integration. Section 5 shows empirical evaluation of the financial integration by using the time series, panel, and state-space techniques. Section 6 concludes.

2. Review of the Literature

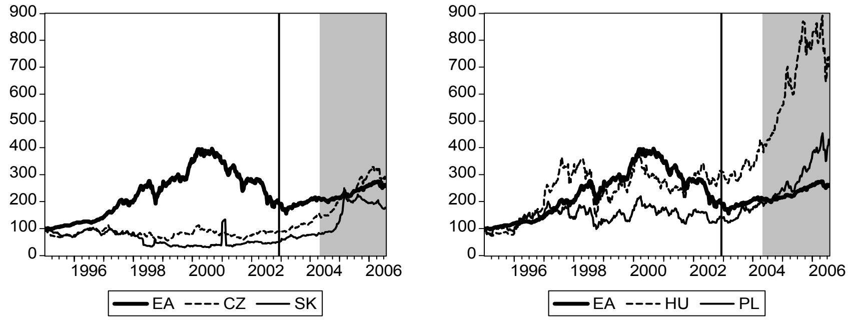
The research on stock market integration is largely conducted as applied to the developed OECD countries and the Asian emerging markets. With regard to Western Europe, analysis of capital markets integration on national levels is reported by the European Commission (1999) and by Hartmann, Maddaloni and Manganelli (2003); the analysis on national and sectoral levels is performed by Baca, Garbe and Weiss (2000) and Heston and Rouwenhorst (1995). Portes and Rey (2005) employ the gravity equation framework to describe the determinants of cross-border equity flows. A new aspect – change of integration over time – is introduced by Bekaert and Harvey (1995), who construct a time-varying measure of financial integration. Overall, their results show what world capital markets are becoming more integrated. Yet on the individual country level there are some cases of declining integration. Applying an alternative time-varying approach, Ayuso and Blanco (2000) find that financial market integration between the stock markets of the euro area countries increased during the 1990s. Besides this, Bekaert, Campbell and Lumsdaine (2000) find that when structural breaks in the series are accounted for, the degree of integration among emerging equity markets is higher than it was thought before. The impact of the introduction of the euro on capital markets has been studied by, for example, Hardouvelis, Malliaropulos and Priestley (2006). The degree of integration is found to have increased along with the formation of the European Monetary Union (EMU), particularly since 1995.

A number of studies evaluate the extent of stock market integration in non-OECD countries. Piesse and Hearn (2002) employ the co-integration approach to test for long-run relationships and Granger causality links between equity market indices in the Southern Africa Customs Union countries. Several cases of co-integration are reported. Applying similar techniques, Azman-Saini et al. (2002) find limited evidence of long-run relationships among five Asian equity markets. Yang et al. (2003) present further evidence on co-movements among ten Asian emerging stock markets and in relation to the U.S. and Japan. A distinction is made between long- and short-run linkages and the Asian financial crisis of 1997–1998 is explicitly controlled for. The degree of integration among Asian countries is found to increase for a post-crisis period; particularly strong financial linkages are detected during the crisis episode.

Evidence of stock market integration among transition countries, especially those in Central and Eastern Europe (CEE), remains relatively scarce. Using correlation analysis, Horská (2005) finds that the correlation among the Czech, U.S., and European stock markets increased in time, which restricting the room for portfolio diversification. Hanousek and Filer (2000) identify interconnections between fluctuations in equity market returns and economic variables in selected CEE countries. An application of conditional heteroscedasticity (GARCH) analysis to stock market indices in the CEE region in relation to the G-7 is reported by Égert and Kouba (2004). Stock markets in the CEE region are found to exhibit more asymmetry and volatility as compared to the G-7. Dvořák and Podpiera (2006) examine a relatively recent phenomenon – a rise in stock market prices in the accession countries followed the announcement of the European Union enlargement. It was found that about one-fifth of the observed stock price increases were found related to the decreasing market premium in the CEE region. Syllignakis and Kouretas (2006) find evidence of co-integration among stock markets of the selected CEE countries relative to Germany and the U.S; in the short-run, cross-country stock market links are stronger during the periods of, e.g., the Asian and Russian crises.

Cappiello et al. (2006) carry out the analysis of returns on equity market indices. The results suggest that integration of the new EU member states with the euro area increased during the process of EU accession. The Czech Republic, Hungary and Poland are found to exhibit return co-movements both between themselves and with the euro area. A study of co-movements between stock markets in these three Central and Eastern European countries (CEECs), on the one hand, and between the CEECs and Western European countries also represents a subject of research of Égert and Kočenda (2005). Evidence from intraday data reveals no robust co-integration relationship for either intra-CEEC or CEEC-Western European stock market linkages. The results suggest that it is rather transmission of volatility of returns, not

FIGURE 1 National Stock Market Indices (in euros; beginning of 1995 = 100)



Notes: EA = Euro Area (DJES), CZ = Czech Republic (PX50), HU = Hungary (BUX), PL = Poland (WIG), SK = Slovakia (SAX). The sample covers January 1995–July 2006 (weekly averages). The shaded area indicates membership in the EU (1 May 2004), the vertical line corresponds to the announcement of EU enlargement (12–13 December 2002). The national stock market indices were first expressed in euro equivalents, in order to account for nominal exchange rate changes, then rescaled taking the first observation as 100.

Source: DataStream

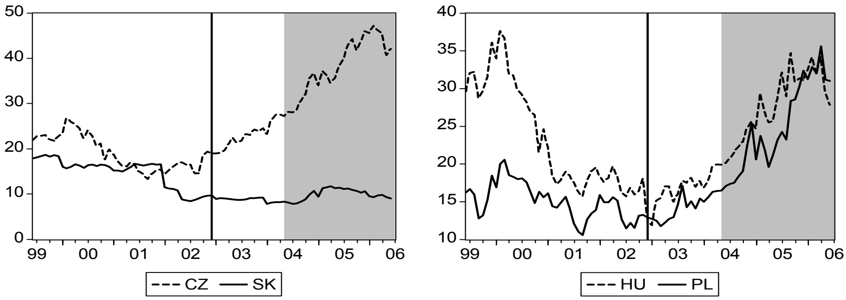
linkages in the levels of returns, which occurs in reality. Using similar intraday data of stock market indices, Černý (2004) does not find a co-integration relationship except in one particular pair of indices. However, the applied Granger causality tests show that the stock markets in Warsaw and Prague do react to price fluctuations stemming from the stock market in Frankfurt, not vice versa. Interestingly, the delay with which such fluctuations transmit from Frankfurt is about 30 minutes for the Prague market and nearly one hour for the one in Warsaw. While most of the available studies focus on national stock market indices, to our knowledge no study attempts to compare integration on national and sectoral levels. There is also limited evidence on the effects of EU enlargement or the announcement thereof on stock market dynamics in new EU member states. Our study contributes to filling this gap in the empirical literature.

3. Development on the EU-4 Stock Exchange Markets: Stylized Facts

3.1 National Stock Exchange Indices

Figure 1 displays the history of stock exchange indices in the EU-4 economies dating back more than ten years. It can be seen that these indices jointly increase until the beginning of 1997, then from 1999 to 2000 and finally from 2002 to the present, with the exception of a moderate slowdown at the beginning of 2006. Strong growth of stock exchange indices is observed since the meeting of the European Council in Copenhagen on 12–13 December 2002, during which a decision was adopted announcing that ten associated countries would join the European Union in 2004. The movements among the Czech, Hungarian and Polish capital markets have been particularly similar during the reporting period, with correlation indices of 0.57 (Czech against Hungarian), 0.49 (Czech against Polish) and only 0.14 (Czech against Slovak).[4] Especially from the second half of 2003 onwards, we observe strong growth in all the indices. These sharp increases in stock exchange indices have already opened a debate on potential overvaluation due to purchases by foreign investors searching for higher returns.

FIGURE 2 Stock Market Capitalization in the EU-4 (as % of GDP)



Notes: CZ = Czech Republic, HU = Hungary, PL = Poland, SK = Slovakia. The shaded area indicates membership in the EU (1 May 2004), the vertical line corresponds to the announcement of EU enlargement (12 –13 December 2002, Copenhagen).

Source: Eurostat and authors' calculations.

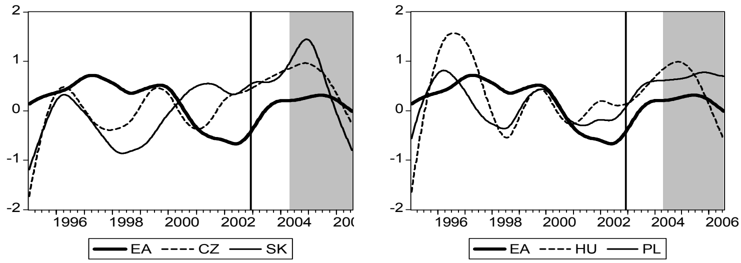
The Czech (PX), Polish (WIG) and Slovak (SAX) stock exchange indices are calculated in line with the IFC (International Finance Corporation) methodology, which is recommended for the stock market indices of emerging countries. This type of indices belongs to capital weight price indices, in which the market capitalizations of selected stocks are compared with their market capitalizations valid on the referential day. The index format is flexible and it makes it possible to change the representation of the individual companies in the index and their quantity due to their merchantability on the market, or due to the entry of a new company into the capital market. Nevertheless, in the case of changes in the structure of the "national" index, corrective factors are set in order to guarantee the continuation of the index. The Czech PX index includes at present nine companies (four of which are foreign companies). In comparison with the Polish WIG index, this includes 135 shares, but only five of them are foreign companies. The Slovak SAX index includes only five shares and the market capitalization for Slovakia is very low (see *Figure 2*). The Dow Jones EURO STOXX Index is a broad yet liquid subset of the Dow Jones STOXX 600 Index. With a variable number of components, the index represents large, medium-sized and small capitalization companies of the 12 euro area countries.[5] The euro area index includes 315 shares; market capitalization is above 50 %, which is higher than for any of the EU-4 countries under consideration. The Hungarian BUX index is set up in a different way. While the three previously mentioned indices use market capitalization as the weight, which is a multiplication of the current share price and the number of shares issued, the Hungarian index is weighted by the number of issued shares floating in the market which are held by different entities and the number is then multiplied by the current price. BUX currently includes 12 purely Hungarian companies.

Figure 2 confirms that the highest market capitalization (as % of GDP) is in the Czech Republic (since the second half of 2002) and that in all EU-4 countries

[4] Both the very low correlation of stock market indices and the low level of market capitalization for Slovakia as compared to other new member states (see *Figure 2)* suggest that the Slovak capital market is relatively small and underdeveloped.

[5] http://www.stoxx.com/indices/components.html?symbol=SXXE

FIGURE 3 Returns of the National Stock Market Indices, 1995–2006



Notes: CZ = Czech Republic, HU = Hungary, PL = Poland, SK = Slovakia. The shaded area indicates membership in the EU (1 May 2004), the vertical line corresponds to the announcement of EU enlargement (12–13 December 2002, Copenhagen). Returns (R) are calculated as:

$R = 100 * \left[\ln SE_t - \ln SE_{t-1}\right]$, where SE denotes the stock exchange index (national or sectoral).

Source: author's calculations based on DataStream

the levels are increasing (strongly in the Czech Republic, Hungary and Poland, and weakly in Slovakia), while remaining below the euro area level (approximately 50 %). The Slovak stock exchange market plays a minor role compared to those in the other EU-4 countries.

Based on national stock exchange indexes, available over 1995-2006 at a daily frequency, we construct the weekly averages to be used in our analysis. *Figure 3* shows the development of trends in the returns of national stock market indices. Trend values are obtained by means of the Hodrick-Prescott filter with the smoothing parameter $\lambda = 270400$, which corresponds to the weekly data. All returns appear to be stationary, according to the standard unit root (ADF and PP) and non-stationarity (KPSS) tests.[6]

The distribution of national stock market returns is illustrated on *Figure A1 in the Appendix.* While the mean returns of the Hungarian (0.33) and Polish (0.24) stock markets largely exceed those in the euro area (0.16), the Czech (0.18) and Slovak (0.13) mean returns are around the euro area benchmark. The distribution of returns is not normal in all countries, as indicated by the high values of the Jarque-Bera statistics.

3.2 Sectoral Stock Market Indices

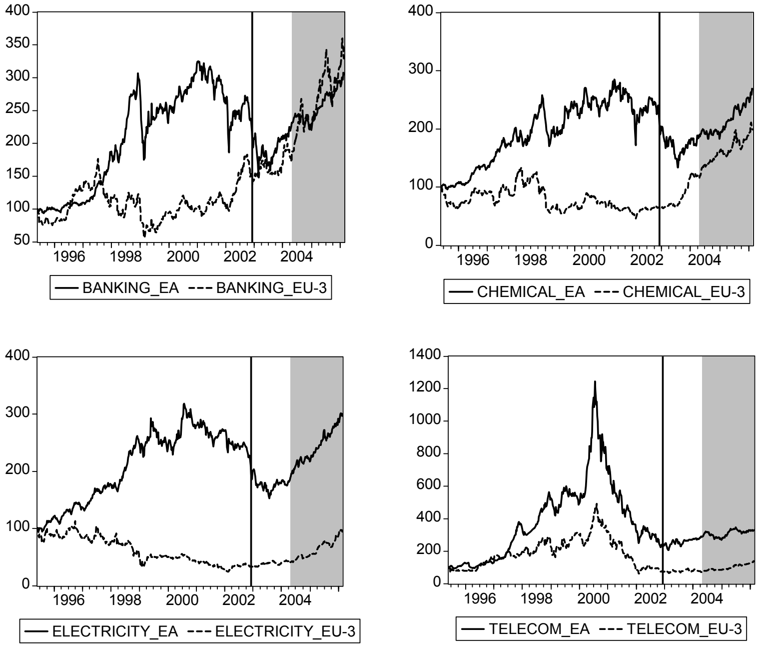
We also conduct our analysis of sectoral indices for the euro area and new member states. Due to a limited number of companies listed on national stock exchanges, we construct an aggregate of sectoral indices the Czech Republic, Hungary and Poland (EU-3 henceforth).[7]

Individual shares are carefully grouped according to the type of the principal activity into four sectors: banking, chemical, electricity and telecommunications. Our sectoral indices are calculated in accordance with the International Financial Corporation (IFC) methodology, recommended for construction of indices in emerging markets. The following expression is used:

[6] The results are available upon request. ADF – Augmented Dickey Fuller test, PP – Phillips-Perron test, KPSS – Kwiatkowski, Phillips, Schmidt and Shin test.

[7] It is not possible to construct any sectoral data for Slovakia.

FIGURE 4 Sectoral Stock Market Indices (in euros; beginning of 1995 = 100)



Notes: EA = euro area, EU-3 = Czech Republic, Hungary and Poland. The sample covers January 1995– –March 2006 (weekly averages). The shaded area indicates membership in the EU (1 May 2004), the vertical line corresponds to the announcement of EU enlargement (12–13 December 2002, Copenhagen).

Source: DataStream and Bloomberg

$$\text{Index}(t) = K(t) \cdot \frac{M(t)}{M(0)} \cdot 1000 \tag{1}$$

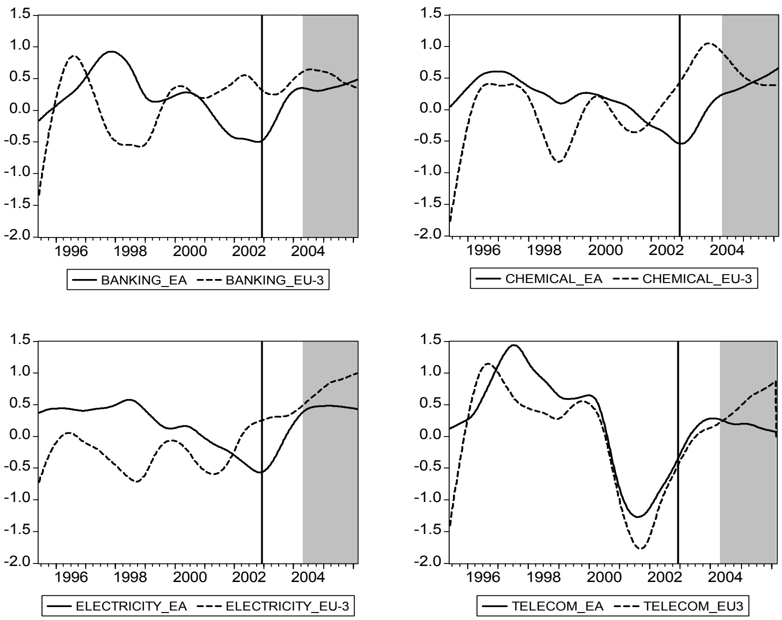
where $K(t)$ is the chaining factor at time t, which accounts for changes in the base of the index. For the initial observation – 6 January 1995 in our case – $K(0)$ is set to unity; $M(0)$ is the initial market capitalization – 6 January 1995 in our case; $M(t)$, capitalization at time t is defined as:

$$M(t) = \sum_{i=1}^{N(t)} q_i(t) \cdot p_i(t) \tag{2}$$

where $q_i(t)$ denotes the number of i-th basic share, $p_i(t)$ is the close price of the i-th basic emission, and $N(t)$ is the number of basic emissions at time t. In each sector the number of basic shares [$q_i(t)$] is weighted by the country's GDP level. The number of basic shares does not change over time.

Figure 4 shows the development of four EU-3 sectoral indices, which are compared with the euro area sectoral stock market indices. As can be seen, after the announcement of EU enlargement (12–13 December 2002 in Copenhagen) banking sector indices developed nearly identically. This period also coincides with privatization

FIGURE 5 Returns of the Sectoral Stock Market Indices (in euros, 1995–2006)



Notes: EA = euro area, EU-3 = Czech Republic, Hungary and Poland. The sample covers January 1995––March 2006 (weekly averages). The shaded area indicates membership in the EU (1 May 2004), the vertical line corresponds to the announcement of EU enlargement (12–13 December 2002, Copenhagen). Trend values are obtained by means of Hodrick-Prescott filter with the smoothing parameter λ = 270400.

Source: DataStream and Bloomberg, authors' calculations

of the large commercial banks. Other sectoral indices also show patterns similar to the euro area indices.

Trends in returns of the sectoral stock indices are illustrated in *Figure 5*. As for national indices, sectoral returns are stationary. Details on the distribution of sectoral returns are provided in *Figure A2 in the Appendix*. On average, mean returns in euro area are somewhat higher compared to the EU-3 block (in the case of the chemical, electricity and telecommunications sectors). In the case of banking, mean returns in the euro area and EU-3 are quite similar at around 0.20.

4. Approaches to Measuring Financial Integration

4.1 Analysis of Alignment

Analysis of alignment is the first step to giving an outlook on stock market integration. It is based on the correlation analysis – standard and rolling – of the stock market returns. This analysis indicates the strength of a linear relationship between two variables; its value alone may not be sufficient to evaluate this relationship, especially in the case where the assumption of normality is incorrect. The correlation coefficients, as summary statistics, cannot replace the individual examination of the data.

4.2 Concept of β-Convergence

The concept of β-convergence originated in the growth literature. Following the approach advocated by Adam et al. (2002), we make use of this concept to determine the speed of convergence of returns of the underlying stock market series. This measure involves estimating the following regression (in time series or panel frameworks):

$$\Delta R_{i,t} = \alpha_i + \beta R_{i,t-1} + \sum_{l=1}^{L} \gamma_l \Delta R_{i,t-l} + \varepsilon_{i,t} \tag{3}$$

where $R_{i,t}$ represents the return spread of specific assets (national or sectoral stock exchange index) between country i and the benchmark rate (Dow Jones EURO STOXX, DJES) at time t, Δ is the difference operator, α_i is the country-specific constant, and $\varepsilon_{i,t}$ is the white-noise disturbance. The lag length L is based upon the Schwarz information criterion; the maximum length is taken as 4 since we are using weekly data and the memory of stock markets is quite short. The size of β is a direct measure of the speed of convergence in the overall market. To analyze whether the speed of convergence is greater in one period relative to another, one can decompose β as $\beta = \beta_1 I + (1 - I)\beta_2$, where I is a dummy variable that takes on the value of 1 in a particular sub-period. An alternative way to address dynamics is to put equation (3) into the state-space form:

$$\Delta R_{i,t} = \alpha_i + \beta_t R_{i,t-1} + \sum_{l=1}^{L} \gamma_l \Delta R_{i,t-l} + \varepsilon_{i,t} \tag{4}$$

$$\beta_t = \beta_{t-1} + \mu_t \tag{5}$$

where β_t is the time-varying parameter, $\varepsilon_{i,t}$ and μ_t are the white-noise disturbance. Estimates of β_t could be directly obtained by applying the Kalman filter to (4)–(5). The interest in using the state-space representation is that it addresses the issue of structural changes: the speed of convergence is allowed to change over time. Details on the space-state model are provided by Bekaert and Harvey (1995); its recent application to the Czech, Hungarian, Polish and Slovak asset markets is available in (Komárková, 2006).

While β-convergence measures the speed of convergence, it does not indicate to what extent markets are already integrated. To answer this question, we have to move to the concept of sigma-convergence, which was also proposed by Adam et al. (2002).

4.3 Concept of σ-Convergence

Like the concept of β-convergence, the concept of σ-convergence was also originally used in the growth literature. Its application to financial markets involves calculating the cross-sectional dispersion in the return spread of specific assets (again national stock exchange indices) as a measure of the degree of integration. In the present context, the degree of financial integration increases when the cross-sectional standard deviation of a variable, such as interest rates, is trending downward (typically one calculates the standard deviation of the log values of the variable of interest). If the cross-sectional distribution collapses to a single point, and the standard deviation converges to zero, full integration is achieved.

For quantification of σ-convergence, a calculation is used of the (cross-section) standard deviation (σ), according to the formula:

$$\sigma_t = \sqrt{\left(\frac{1}{N-1}\right)\sum_{i=1}^{N}\left[\log\left(y_{it}\right)-\overline{y}_t\right]^2} \tag{6}$$

where y_{it} is the yield on asset i at time t, and $\overline{y}_t$ is the cross-section mean yield at time t. Index i can stand for separate countries or sectors ($i = 1, 2, \ldots, N$). For the purposes of this analysis, we introduce $N = 2$, i.e. we examine development of the σ-convergence over time between the euro area and one of the countries under review (in the case of national indices) and between the euro area and EU-3 aggregate (when considering sectoral indices). The value of σ takes only a positive value in theory. The lower σ is, the higher the level of convergence that has been reached. In theory, full integration is reached, where the standard deviation is zero, while high (several-digit) values of σ reflect a very low degree of integration. For the chart-type expression, the results were filtered using the Hodrick-Prescott filter with the recommended weekly time series coefficient $\lambda = 270400$.

It is important to note that the two convergence indicators have different informational contents: β-convergence does not imply σ-convergence. In fact, β-convergence could even be associated with σ-divergence – see (Quah, 1993) for further details on this issue. Therefore, we propose both notions of convergence to assess financial integration.

β- and σ-convergence are estimated for the EU-4 countries on the national level and EU-3 countries on the sectoral level. Since the number of observations for each country is substantially greater than the number of cross-section units, the model described by (1) is estimated using a method suitable for time-series panel data. There are essentially two procedures applied to time-series panels. At one extreme, one can estimate each equation separately for each country and then look at the distribution of the estimated coefficients across countries. One can thus be looking at the mean, median or mode of the distribution where the mean would be of primary interest. However, such an estimator does not take into account the possible homogeneity of some coefficients across countries. At the other extreme are the traditional panel data estimators, e.g. the fixed effect estimator, which allows the intercepts to vary across countries while constraining all the other coefficients, including the error variance, to be the same. In our study we use both approaches and compare their results.

5. Empirical Results

5.1 Analysis of Alignment

Simple period-average correlations of stock market returns, shown in *Table 1*, indicate that the Czech, Hungarian and Polish markets are strongly linked, on the one hand among themselves (correlation from 0.49 to 0.60), on the other hand vis-à-vis the euro area (correlation in the range of 0.42–0.50). The respective pair-wise correlation coefficients are all significant at the 1% level. In contrast, the Slovak stock

TABLE 1 Correlation of National Stock Market Returns (weekly averages, 1995–2006)

	Czech Rep.	Hungary	Poland	Slovakia	Euro area
Czech Republic	1.00				
Hungary	***0.57****	1.00			
Poland	***0.49****	***0.60****	1.00		
Slovakia	0.14***	0.13***	0.09**	1.00	
Euro Area	***0.42****	***0.50****	***0.44****	0.06	1.00

Note: ***, **, * denote significance at the 1%, 5% and 10% levels. Bold italic indicate strong and significant correlation coefficients.

Source: DataStream and authors' calculations

TABLE 2 Correlation of Sectoral Stock Market Returns between the Euro Area and EU-3 (weekly averages, 1995-2006)

	Banking	Chemical	Electricity	Telecommunication
(Euro Area, EU-3)	0.45***	0.31***	0.22***	0.32***

Note: EU-3 = Czech Republic, Hungary and Poland. *** denotes significance at the 1% level.

Source: DataStream, Bloomberg and authors' calculations.

market stands apart: its returns appear to be uncorrelated to those in the euro area (coefficient 0.06, insignificant) and only weakly correlated with returns in other new EU member states (low correlation of 0.09–0.14, though significant at the 1%–5% level).

Correlation between euro area and EU-3 returns on the sectoral level are illustrated in *Table 2*. All correlations are significant at the 1% level. The banking sector is characterized by the highest correlation (0.45), followed by the telecommunications (0.32), chemical (0.31) and electricity (0.22) sectors.

Figures 6 and *7* show the evolution of EU-4 stock market returns vis-à-vis the euro area, using rolling window correlations. The shorter the window (two years against five years), the more volatile the correlation coefficient is. Nevertheless, one can observe pronounced co-movement between the Czech, Hungarian and Polish markets, with correlation of returns around 0.5 by the end of 2006. Again, the Slovak stock market returns remain weakly correlated with the euro area benchmark.

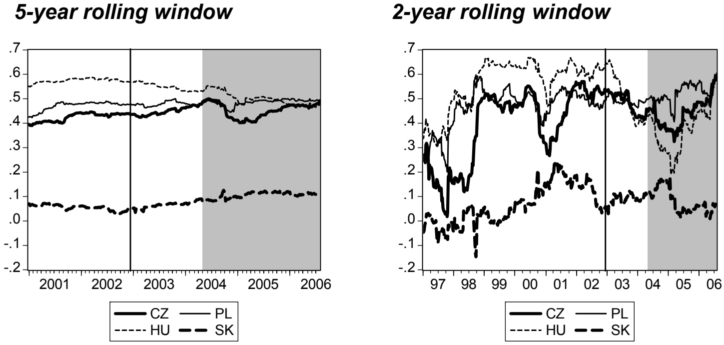
On the sectoral level (*Figure 7*), correlation of returns exhibits richer dynamics, particularly when considered on the two-year rolling window. Overall, correlations on the sectoral level are somewhat lower compared to the national indices.

5.2 β-convergence

5.2.1 Time Series and Panel Regression Analysis

The results of the β-convergence analysis are given in *Table 3*. All the values in the table are negative; hence there is convergence of stock market returns. The absolute values of the β-coefficient are close to one for all of the countries, which means that the leveling of newly arising differences in return differentials between the relevant national economy and the euro area can be labeled as fast. Indeed, the shock half-life, defined as the period during which the magnitude of a shock becomes half of the initial shock, is less than a week for the values of betas reported in *Table 3*[8]. A comparison of the periods 1995–2000 and 2001–2006 reveals that the pace of β-con-

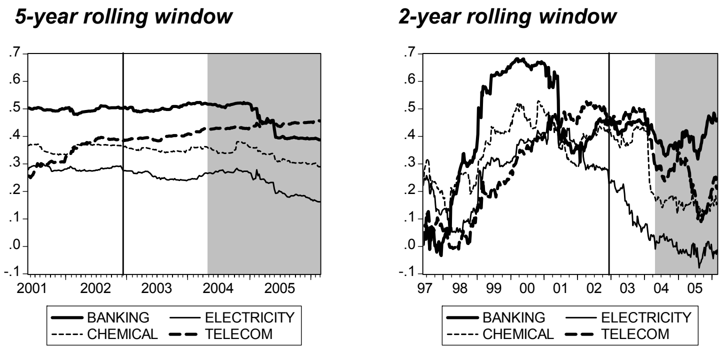
FIGURE 6 Rolling Correlations of National Stock Market Returns vis-à-vis the Euro Area (weekly averages, 2001–2006)



Note: The length of the rolling window is 5 and 2 preceding years. The shaded area indicates membership in the EU (1 May 2004), the vertical line corresponds to the announcement of EU enlargement (12–13 December 2002).

Source: DataStream, authors' calculations.

FIGURE 7 Rolling Correlation of Sectoral Stock Markets Returns vis-à-vis Euro Area (weekly averages, 2001–2006)



Note: The length of the rolling window is 5 and 2 preceding years. The shaded area indicates membership in the EU (1 May 2004), the vertical line corresponds to the announcement of EU enlargement (12–13 December 2002).

Source: DataStream, authors' calculations.

vergence of the Czech and Hungarian stock markets has increased. The greatest progress in that respect has been recorded by the Czech Republic (from –0.71 to –0.91), followed by Hungary (from –0.75 to –0.84). For Poland and Slovakia, the differences between earlier and later periods are not significant. However, in the case of Poland, the degree of β-converge is already high, at the level of the Czech Republic and Hungary. On the other hand, the Slovak market is characterized by the lowest degree of convergence.[9]

[8] The half-life is calculated as $H\text{-}L = \ln(0.5)/\ln(|\beta + 1|)$. The H-L is 0.6 week for β equal to 0.7 and 0.3 week if β equals 0.9.

[9] The Slovak stock market is much smaller (as measured, for example, by market capitalization) and, from the perspective of investors and stock issuers, may seem less attractive than the markets of the new EU member states under review.

TABLE 3 β Convergence of National Indices – Time Series and Panel Estimations

	1995–2006	1995–2000	2001–2006	Impact of announcement [a] $(\beta_1;\beta_2)$	EU: enlargement [a] $(\beta_1;\beta_2)$
Eq.(1), time series estimations					
Czech Republic	-0.76	-0.71	-0.91	Insignificant (-0.87; -0.73)	Insignificant (-0.75; -0.76)
Hungary	-0.78	-0.75	-0.84	Insignificant (-0.84; -0.77)	Insignificant (-0.77; -0.79)
Poland	-0.88	-0.89	-0.87	Insignificant (-0.86; -0.91)	Sign. at 5 % [b] (-0.70; -0.92)
Slovakia	-0.71	-0.72	-0.76	Insignificant (-0.71; -0.71)	Insignificant (-0.58; -0.73)
Eq. (1), panel estimations					
EU-4	-0.78	-0.79	-0.83	Insignificant (-0.79; -0.78)	Sign. at 10 % [b] (-0.69; -0.80)
EU-4 excluding Poland	-0.75	-0.73	-0.82	Insignificant (-0.78; -0.73)	Insignificant (-0.68; -0.76)

Notes: Time series estimates of eq. (1); coefficients β are displayed. The optimal lag length is determined to be zero according to the Schwarz information criterion. All estimates are statistically significant at the 1% level.

[a] Wald test of the restriction $\beta_1 = \beta_2$ in $\beta = \beta_1 I + (1-I)\beta_2$, where I = 1 for the period following the announcement of EU enlargement (12–13 December 2002) or EU membership (1 May 2004), zero otherwise. Estimations are performed on the full sample 1995–2006.

[b] For Poland (at 5 %) and the EU-4 (at 10 %), the speed of convergence decreased after joining the EU.

Source: authors' calculations

TABLE 4 β Convergence of Sectoral Indices – Time Series and Panel Estimations

	1995–2006	1995–2000	2001–2006	Impact of announcement [a] $(\beta_1;\beta_2)$	EU: enlargement [a] $(\beta_1;\beta_2)$
Eq.(1), time series estimations					
Banking	-0.91	-0.82	-1.05	Insignificant (-1.01; -0.88)	Insignificant (-1.09; -0.89)
Chemical	-1.05	-0.83	-1.17	Insignificant (-1.19; -0.99)	Insignificant (-1.17; -1.03)
Electricity	-1.02	-1.03	-1.05	Insignificant (-0.96; -1.04)	Insignificant (-0.94; -1.03)
Telecommu-nication	-1.02	-1.04	-0.99	Insignificant (-1.12; -1.01)	Insignificant (-1.08; -1.02)
Eq. (1), panel estimations					
Four sectors	-1.01	-0.99	-1.06	Sign. at 10% [b] (-1.08; -0.99)	Insignificant (-1.08; -1.00)

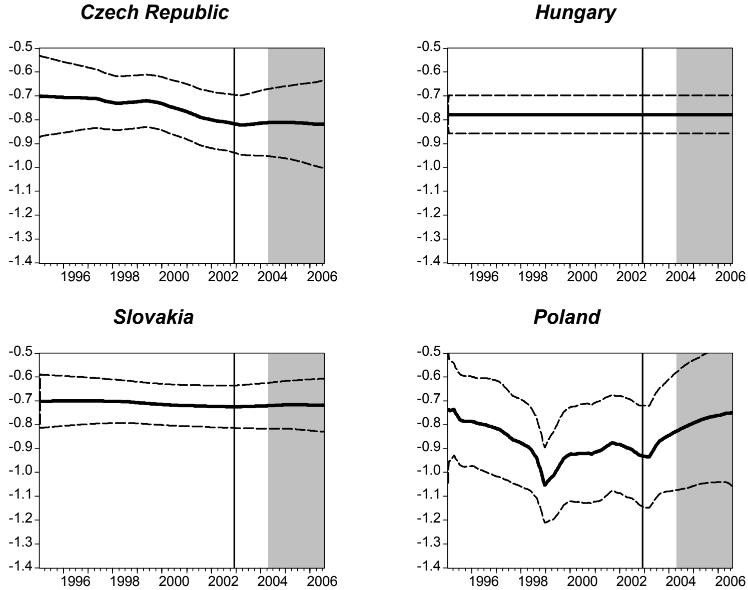
Notes: Time series estimates of eq. (1); coefficients β are displayed. The optimal lag length is determined to be zero according to the Schwarz information criterion. All estimates are statistically significant at the 1% level.

[a] Wald test of the restriction $\beta_1 = \beta_2$ in $\beta = \beta_1 I + (1-I)\beta_2$, where I = 1 for the period following the announcement of EU enlargement (12–13 December 2002) or EU membership (1 May 2004), zero otherwise. Estimations are performed on the full sample 1995–2006.

[b] For the four sectors considered together, the speed of convergence slightly decreased (at the 10% significance level) after the announcement of EU enlargement.

Source: authors' calculations

FIGURE 8 β-Convergence of National Indices – State Space Estimations



Notes: Kalman filter estimates of eq. (2)–(3); smoothed estimates of the coefficients β_t are displayed along with the ±2 RMSE bands. The optimal lag length is determined to be zero according to the Schwarz information criterion. The shaded area indicates membership in the EU (1 May 2004), the vertical line corresponds to the announcement of EU enlargement (12–13 December 2002, Copenhagen).

Source: authors' calculations

Concerning the effect of the EU-4 joining the EU in May 2004 or the announcement thereof in December 2002, the impact on β-convergence is not statistically different, except for Poland. In Poland we observe rather a decrease in β-convergence from –0.92 to –0.70 following the EU enlargement.

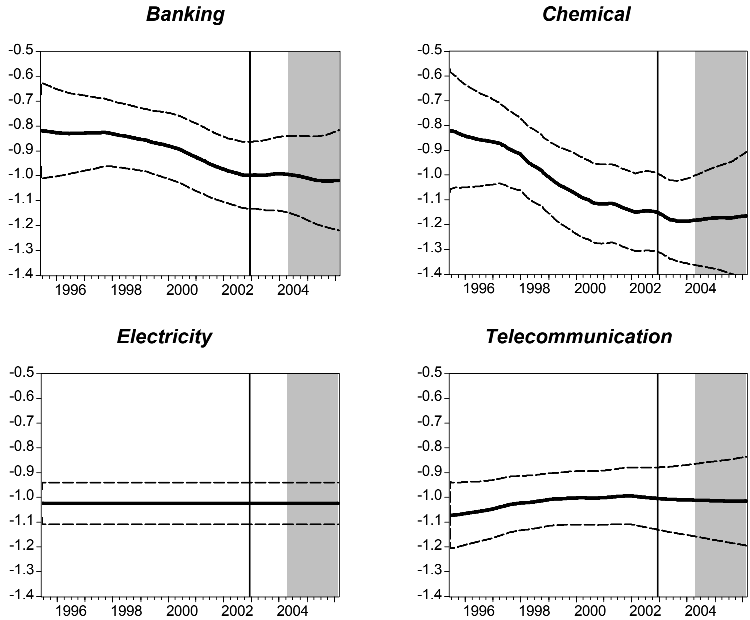
The results of the panel regression are in line with time-series estimations: there is a slight increase in convergence over the past five years; the impact of EU enlargement is marginally negative in the EU-4 and insignificant when Poland is excluded.

Regarding sectoral stock market indices (*Table 4*), negative and close to unity values of the beta coefficient indicate the presence of fast convergence. The corresponding half-life of shocks is less then 0.4 week (for the values of beta lying between –0.83 and –1.17). Notice that if the absolute values of betas are higher than one, convergence occurs *with oscillations*, as opposed to *monotonic convergence* in the case of betas lying in the range between 0 and –1. Time series results show that neither the EU enlargement nor its announcement had a significant impact on the speed of convergence. In the case of panel estimates, the announcement of EU enlargement is associated with a slight slowdown in β convergence (significant at the 10% level).

5.2.2 State-Space Model

Time varying estimates of β-convergence of national indices are displayed in *Figure 8*. Again, negative and close to one values of β correspond to convergence of

FIGURE 9 β-Convergence of Sectoral Indices – State Space Estimations



Notes: Kalman filter estimates of eq. (2)–(3); smoothed estimates of the coefficients β_t are displayed along with the ±2 RMSE bands. The optimal lag length is determined to be zero according to the Schwarz information criterion. The shaded area indicates membership in the EU (1 May 2004), the vertical line announced decision of EU enlargement (12–13 December 2002, Copenhagen).

Source: authors' calculations

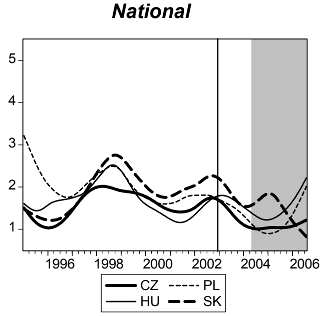
returns between the given country and the euro area. Although there are indications of rising convergence in the case of, e.g., the Czech Republic, the estimates of β are little changed for Hungary and Slovakia. For Poland, the speed of convergence rises until the end of the 1990s, followed by a decrease afterwards; yet large confidence intervals surround the Polish estimates. There is no significant change in β-convergence since EU enlargement or the announcement thereof, except for a gradual slowdown of the speed of convergence in the case of Poland since 2002.

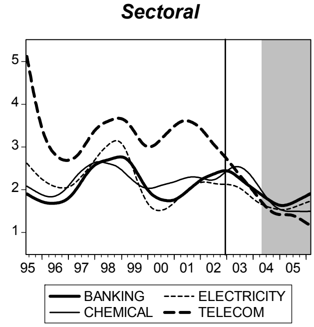
Concerning sectoral indices (*Figure 9*), one can observe rising convergence in the banking sector, from –0.8 in 1995 to –1.0 in 2006. For chemicals, convergence rose until 1998 and then, after reaching its maximum degree of –1, started slowing down afterwards. In the electricity sector, convergence has been at values close to unity during the whole estimation period. This is also the level to which the telecommunications sector converged by 2006.

5.3 σ-Convergence

Figure 10 illustrates the σ-convergence analysis vis-à-vis the euro area for each country (left) as well as for each sector (right). Overall, one can observe a decrease in volatility during 1995–2004, i.e. σ-convergence. The national indices indicate that since 2005 the stock markets of the Czech Republic, Hungary and Poland

FIGURE 10 *σ* Convergence of National and Sectoral Indices to Euro Area, 1995–2006

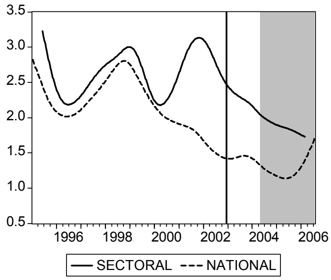




Notes: CZ = Czech Republic, HU = Hungary, PL = Poland, SK = Slovakia. The shaded area indicates membership in the EU (1 May 2004), the vertical line corresponds to the announcement of EU enlargement (12–13 December 2002, Copenhagen). Lower standard deviations (vertical axis) correspond to a higher convergence level.

Source: authors' calculations

FIGURE 11 *σ*-Convergence – Comparison between National and Sectoral Indices, 1995-2006



Notes: Lower standard deviations (vertical axis) correspond to a higher convergence level.
National = dispersion across national indices of the EU-3 (Czech Republic, Hungary and Poland).
Sectoral = dispersion across banking, chemical, electricity and telecommunication sectors in the EU-3.
The shaded area indicates membership in the EU (1 May 2004), the vertical line corresponds to the announcement of EU enlargement (12–13 December 2002, Copenhagen).

Source: authors' calculations

have diverged from the euro area stock market. This result is not surprising given the fact that the EU-4 stock markets experienced high growth exceeding the growth of the benchmark euro zone index. Hungary – followed by Poland – has the lowest degree of stock market integration with the euro area at the end of the period under review. Although the stock market in Slovakia displays convergence, this result should be interpreted with caution given the moderate state of the development of the Slovak stock market. On the sectoral level, the dynamics of *σ*-convergence for banking, chemical and electricity is fairly similar. The telecommunications sector, which had above-average volatility in the past, has converged to the other three sectors since the end of 2002. Similar to national indices, there are sings of *σ*-divergence since 2005.

The dynamics of σ-convergence at the national and sectoral levels were quite similar until 2002 (see *Figure 11*). Since then, one can observe higher convergence at the national than at the sectoral level. However, by 2006 the paths of national and sectoral sigma lines approached each other.

6. Conclusion

In this paper we have discussed selected aspects of financial integration in the Czech Republic, Hungary, Poland and Slovakia (i.e. EU-4). The objective of the study was to test for the existence and analyze the dynamics of integration in the stock exchange markets in reference to the adopted definition based on the law of one price. Our measures of financial integration are built upon complementary concepts, namely β-convergence (measuring the speed of convergence) and σ-convergence (measuring the degree of financial integration). The empirical analysis is based on the following quantitative methods: standard and rolling correlation analysis, time series and panel regression, and the state-space model.

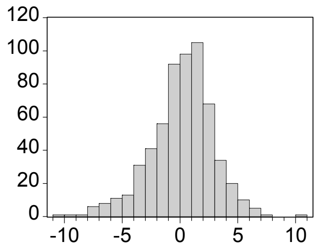
To summarize our answers on the three research questions stated at the beginning, (i) the results unambiguously point to the existence of beta-convergence of the stock markets under review at the national and sectoral levels; (ii) moreover, the speed at which shocks dissipate is quite high – less than half of a week; (iii) we do not find a major impact of either EU enlargement or the announcement thereof on β-convergence. In fact, the high speed of β-convergence was achieved much earlier, during the 1990s. Furthermore, the dynamics of the σ-convergence for the EU-4 block suggest overall convergence, yet some diverging increase in volatility since 2005.

In conclusion, while evaluating the degree of stock market integration between euro-candidates and the euro area one should bear in mind that this is a relatively small yet important segment of financial markets. Future research could be extended to a broader examination of integration of the money, bond, and credit markets in the enlarged EU.

APPENDIX

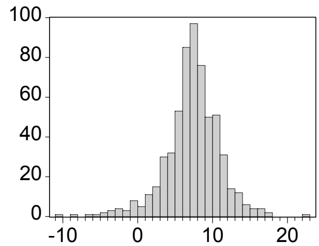
FIGURE A1 National Stock Market Returns (weekly averages, 1995–2006, 603 obs.)

a) Czech Republic (PX50)



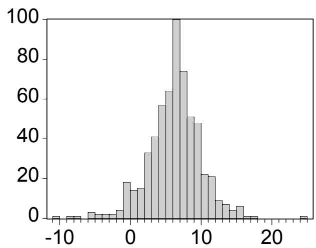
Mean	0.18	Jarque-Bera	45.1
Median	0.44	Probability	0.00
Std. Dev.	2.74		

b) Hungary (BUX)



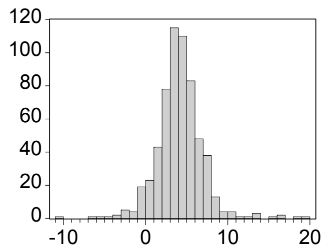
Mean	0.33	Jarque-Bera	221.6
Median	0.50	Probability	0.00
Std. Dev.	3.65		

c) Poland (WIG)



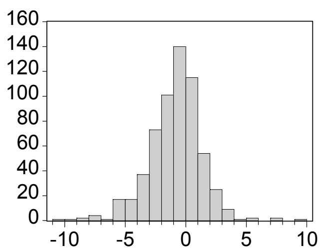
Mean	0.24	Jarque-Bera	142.2
Median	0.36	Probability	0.00
Std. Dev.	3.74		

d) Slovakia (SAX)



Mean	0.13	Jarque-Bera	660.8
Median	0.08	Probability	0.00
Std. Dev.	2.82		

e) Euro area (Dow Johns EURO STOXX)



Mean	0.16	Jarque-Bera	179.1
Median	0.35	Probability	0.00
Std. Dev.	2.19		

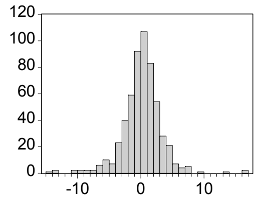
Notes: Returns (R) are calculated as: $R = 100 * [\ln SE_t - \ln SE_{t-1}]$, where SE denote the stock exchange index (national or sectoral).

Source: DataStream, Bloomberg and authors' calculations

FIGURE A2 Sectoral Stock Market Returns (weekly averages, 1995–2006, 561 obs.)

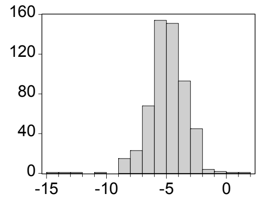
Banking

Euro Area



Mean	0.20	Jarque-Bera	690.2
Median	0.18	Probability	0.00
Std. Dev.	3.09		

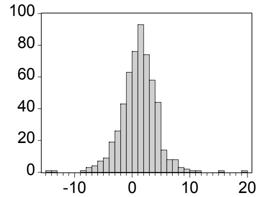
EU-3



Mean	0.21	Jarque-Bera	486.2
Median	0.31	Probability	0.00
Std. Dev.	3.95		

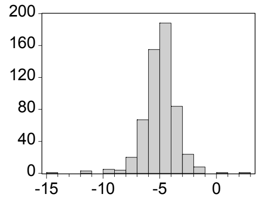
Chemical

Euro Area



Mean	0.18	Jarque-Bera	406.3
Median	0.18	Probability	0.00
Std. Dev.	3.17		

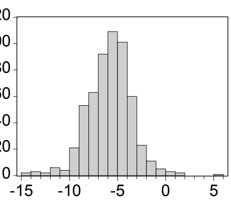
EU-3



Mean	0.12	Jarque-Bera	707.4
Median	0.31	Probability	0.00
Std. Dev.	3.66		

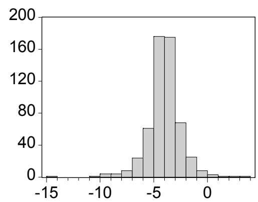
Electricity

Euro Area



Mean	0.19	Jarque-Bera	76.1
Median	0.28	Probability	0.00
Std. Dev.	2.31		

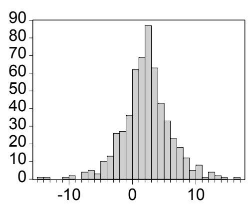
EU-3



Mean	-0.01	Jarque-Bera	1035.9
Median	0.04	Probability	0.00
Std. Dev.	3.92		

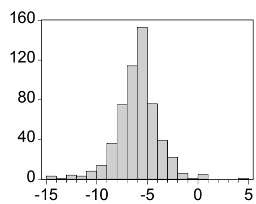
Telecommunication

Euro area



Mean	0.21	Jarque-Bera	87.5
Median	0.27	Probability	0.00
Std. Dev.	3.83		

EU-3



Mean	0.06	Jarque-Bera	211.8
Median	0.32	Probability	0.00
Std. Dev.	5.21		

Notes and *Source*: As for Figure A1.

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