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

Ian Babetskii, Luboš Komárek and Zlatuše Komárková *

Abstract

The paper considers the empirical dimension of financial integration among stock markets in four new European Union member states (the 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) an analysis of alignment (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 stock market integration on both the national and sectoral levels between the Czech Republic, Hungary, Poland and the euro area.

JEL Codes: C23, G15, G12.
Keywords: Beta convergence, new EU member states, sigma convergence, stock markets.

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Nontechnical Summary

The importance of conducting an assessment of the degree of financial integration across the euro area member countries is stressed by both central banks and academic institutions. The more integrated financial markets are, the more effectively monetary policy is transmitted through the financial system.

Joining the euro area without a sufficient degree of financial market integration can cause problems in terms of transmission of the common monetary policy and common shocks. A high degree of financial market integration implies that euro area-wide shocks dominate; hence, the 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 the 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.

The overall objective of this paper is to analyze the empirical dimension of financial integration among stock markets in four new European Union member states (the Czech Republic, Hungary, Poland and Slovakia) in comparison with the euro area. 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) an analysis of alignment (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 stock market integration on both the national and sectoral levels between the Czech Republic, Hungary, Poland, and the euro area. The results unambiguously point to the existence of β-convergence of the stock markets under review at the national and sectoral levels. Moreover, the speed at which shocks dissipate is quite high – less than half of a week. 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.

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 the 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 (2007) – see also Baele et al. (2004). In particular, the European Central Bank (2007, p. 21) emphasizes that

> *"Since monetary policy decisions are implemented and transmitted through the financial system, the degree of financial integration affects the effectiveness of this transmission. Highly integrated financial markets also allow a more efficient sharing of financial risk that ultimately enhances the stability of the financial system itself, thus facilitating and therefore contributing to the pursuit of price stability, which is the ECB's primary objective."*

In addition, financial integration changes the structure of the financial system. Since the Czech National Bank is also responsible for monitoring financial system stability, assessment of financial integration in the region brings further motivation to this study.

As financial markets expand, their fluctuations have stronger effects on real economic variables such as private consumption. Thus, 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 the benefits outweigh the costs, provided that 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 the common monetary policy and common shocks. A high degree of financial market integration implies that euro area-wide shocks dominate; hence, the 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 the 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 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 increasingly 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 a 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, for example, beta and sigma convergence. The second class of measures makes it possible to identify existing market imperfections such as frictions and barriers, because 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 and Danthine (2003), Baele et al. (2004) and Bekaert and Harvey (1997). In a hypothetical example of perfectly integrated stock markets, assets which have the same risk factor and yield are priced identically by the 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 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 for 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. the exchange rate, money and 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, where assets are considered on sectoral rather than on national levels. Indeed, the investments of many funds are made based on a 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 similarity of the underlying assets, to common shocks, or to a mixture of both effects.

This paper addresses the following three main questions, similar to those raised earlier by Adam et al. (2002) with respect to the euro area: (i) Is there 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 is it? (iii) How does the degree of financial market

[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 cannot be achieved without a successful harmonization process.

[2] News-based and quantity-based measures require the use of different data and estimation techniques; such an analysis could be a subject for future research. Notice that the degree of accommodation shock and ultimately financial integration may depend, inter alia, on the particular exchange rate regime, e.g. fixed versus floating. Another avenue for future research is to assess financial integration under alternative exchange rate arrangements.

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

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 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 markets at the national level and at the level of four industrial sectors (banking, chemicals, electricity and telecommunications). Section 4 provides a discussion of the theoretical approaches to estimating financial integration. Section 5 gives an empirical evaluation of the financial integration using the time series, panel, and state-space techniques. Section 6 concludes.

Our analysis is unique for several reasons. First, it is the first application of beta and sigma convergence to the EU-4 countries against the euro area. Second, we apply these approaches not only to the national, but also to the sectoral level. Third, we use advanced empirical techniques such as state-space techniques.

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.[4] With regard to Western Europe, analysis of capital market integration on national levels is reported by the European Commission (1999) and by Hartmann, Maddaloni and Manganelli (2003); 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 that 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 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 with the formation of the European Monetary Union (EMU), particularly since 1995.[5]

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

[4] Solnik (1974) started to solve similar problems in the course of the 1970s in order to determine optimum trends in international capital diversification.

[5] Recently, Ekinci, Kalemli-Ozcan and Sorensen (2007) report striking evidence of a low degree of capital market integration among the mature EU members, as compared to the theoretical prediction and as judged against the United States.

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. Phylaktis and Ravazzolo (2002), by simultaneously examining financial and economic linkages for Pacific-Basin countries, report that "financial integration is accompanied by economic integration" (p. 23). This observation gains relevance for the new EU member states, which are in the process of economic integration with the euro area.

Evidence of stock market integration among transition countries, especially those in Central and Eastern Europe (CEE), remains relatively scarce.[6] Using correlation analysis, Horská (2005) finds that the correlation among the Czech, U.S. and European stock markets increased over time, 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 Koubaa (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 related to the decreasing market premium in the CEE region. Syllignakis and Kouretas (2006) find evidence of co-integration among stock markets of selected CEE countries relative to Germany and the U.S.; in the short-run, cross-country stock market links were stronger during, for example, the Asian and Russian crises.

Cappiello et al. (2006) carry out an analysis of returns on equity market indices. The results suggest that the 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 is also 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 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 both the 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.

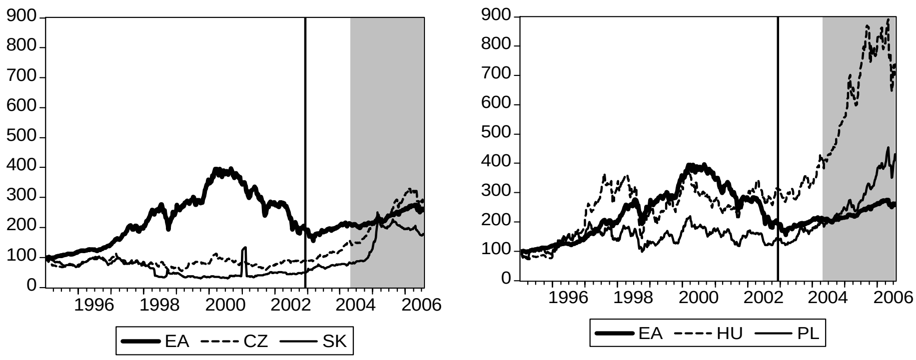
[6] Various aspects of integration in emerging European financial markets are discussed in a volume edited by Batten and Kearney (2006).

3. Development of the EU-4 Stock 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. We apply the price-based approach to these countries, which currently have similar exchange rate arrangements and therefore accommodate exogenous shocks in a similar way. Nevertheless, we cannot distinguish between genuine financial integration (integration of the legislative system, of markets, etc.) and the effects of common shocks in a satisfactory way. From this point of view we measure the degree of financial synchronization rather than financial integration.

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



Source: DataStream.

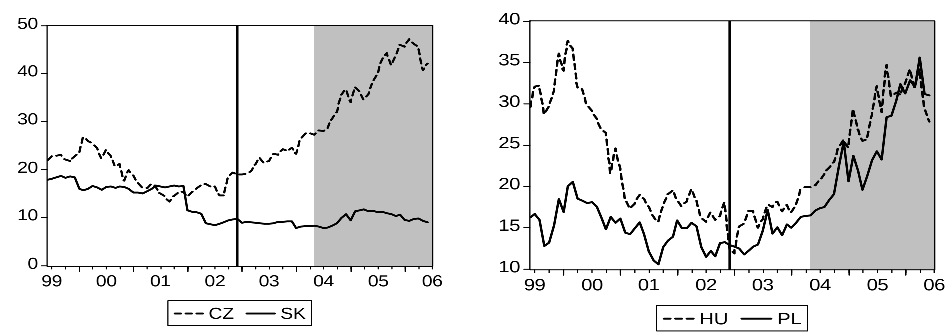
Notes: EA = Euro Area (DJES), CZ = Czech Republic (PX50), HU = Hungary (BUX), PL = Poland (WIG), SK = Slovakia (SAX). The sample covers January 1995–July 2006 (weekly averages). The shaded area indicates membership in the EU (1 May 2004) and the vertical line corresponds to the announcement of EU enlargement (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.

It can be seen that the stock exchange indices jointly increase until the beginning of 1997, then again 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).[7] 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.

[7] 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.

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 index belongs to the capital weight price indices, in which the market capitalizations of selected stocks are compared with their market capitalizations valid on the reference day. The index format is flexible, making it possible to change the representation and quantity of the individual companies in the index 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 in mid-2007 contains nine companies (four of which are foreign). In contrast, the Polish WIG index comprises the shares of 135 companies, but only five of them are foreign. The Slovak SAX index has only five stocks 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 12 euro area countries (excluding Slovenia).[8] The euro area index includes 315 shares; its market capitalization is above 50% of GDP, 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 the product 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. The BUX currently contains 12 purely Hungarian companies.

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

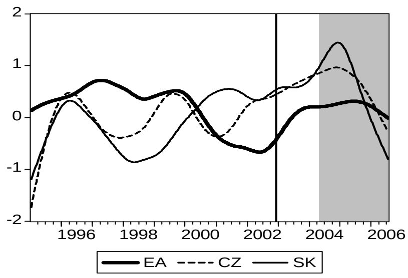


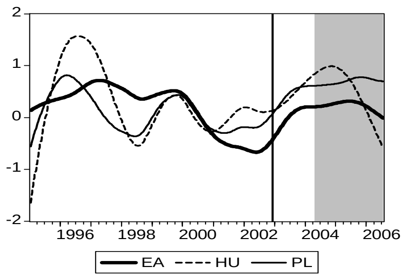
Source: Eurostat and authors' calculations.
Notes: CZ = Czech Republic, HU = Hungary, PL = Poland, SK = Slovakia. The shaded area indicates membership in the EU (1 May 2004) and the vertical line corresponds to the announcement of EU enlargement (12–13 December 2002, Copenhagen).

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 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 market plays a minor role compared to those in the other EU-4 countries.

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

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





Source: author's calculations based on DataStream.

Notes: CZ = Czech Republic, HU = Hungary, PL = Poland, SK = Slovakia. The shaded area indicates membership in the EU (1 May 2004) and 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).

Based on the 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 trends in the returns of the national stock market indices. Trend values are obtained by means of the Hodrick-Prescott filter with the smoothing parameter $\lambda = 270{,}400$, which corresponds to weekly data. All original series are found to be of I(1) type. The returns of these series appear to be stationary, according to the standard unit root tests (ADF and PP) and the alternative non-stationarity test (KPSS)[9].

The distribution of national stock market returns is illustrated in *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

As stock markets become more integrated, the country-specific component in stock returns should decrease. We try to estimate the extent to which stock returns are determined by sector rather than the country effect and hence we also conduct our analysis of sectoral indices for the euro area and new member states. Due to the limited number of companies listed on the national stock exchanges, we construct an aggregate of the sectoral indices from the companies listed on the Czech, Hungarian and Polish stock exchanges (henceforth the EU-3).[10]

The individual shares are carefully grouped by type of principal activity into four sectors: banking, chemicals, electricity and telecommunications. The banking index contains 16 issues (3 of them Czech), the chemicals index 28 issues (7 Czech), the electricity index 21 issues (3 Czech) and the telecommunications index 6 issues (1 Czech). Our sectoral indices, as well as the national indices, are calculated in accordance with the International Financial Corporation (IFC)

[9] The results are available upon request. ADF – Augmented Dickey Fuller test, PP – Phillips-Perron test (for both tests, the null hypothesis is that the series has a unit root), KPSS – Kwiatkowski, Phillips, Schmidt and Shin test (the null hypothesis is that the series is stationary).

[10] It is not possible to include the Slovak series in the sectoral indices, because of the absence of data.

methodology, as recommended for the construction of indices in emerging markets. The following expression is used:

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

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 securities of the i-th base issue used for the calculation of the index at time t, $p_i(t)$ is the price quotation of the i-th base issue at time t, and $N(t)$ is the number of base issues at time t. In each sector the number of basic shares $[q_i(t)]$ is weighted by the country's GDP level as:

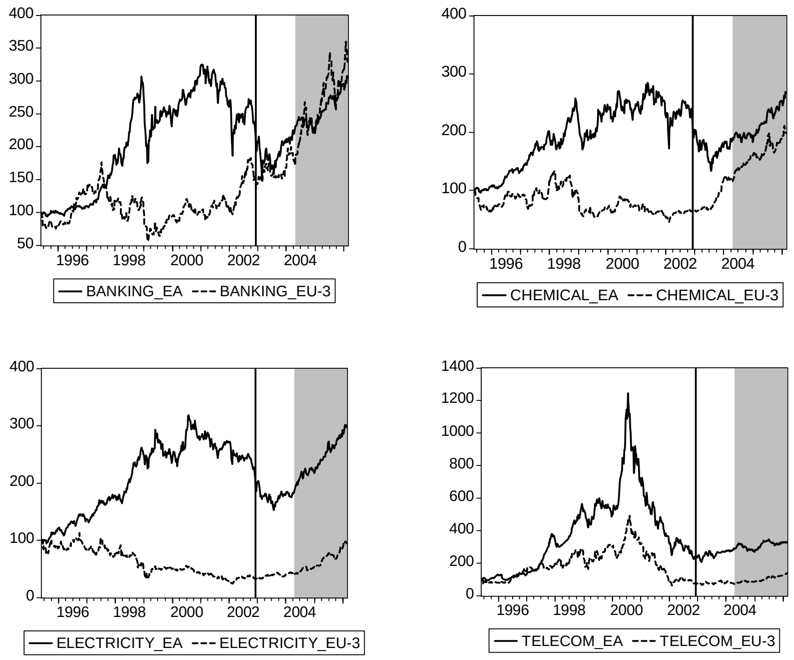
$$q_i(t) = \frac{Sq_{i,c}(t)}{\sum_{i=1}^{M(t)} Sq_{i,c}(t)} \cdot \left(\sum_{c=1}^{3} \sum_{i=1}^{M(t)} Sq_{i,c}(t) \cdot w_c \right) \tag{3}$$

where $Sq_{i,c}(t)$ denotes the real number of securities of the i-th base issue used for the calculation of the index at time t and issued in the c-th country, $M(t)$ is the number of base issues at time t, and w_c is the weight of GDP for the c-th country ($\sum_{c=1}^{3} w_c = 1$).

As benchmarks we use the available Dow Jones STOXX sector indices constructed from the EU stocks by STOXX Ltd.[11]

[11] Details are available at www.stoxx.com.

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

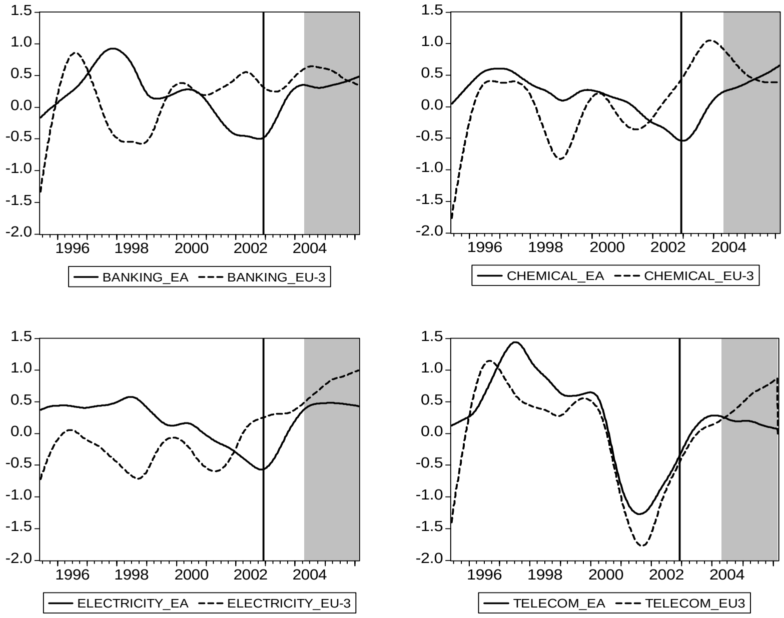


Source: DataStream and Bloomberg.

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) and the vertical line corresponds to the announcement of EU enlargement (12–13 December 2002, Copenhagen).

Figure 4 shows the development of the 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) the banking sector indices developed nearly identically. This period also coincides with the privatization of the large commercial banks. The other sectoral indices also show patterns similar to the euro area indices.

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



Source: DataStream and Bloomberg, authors' calculations.

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) and the vertical line corresponds to the announcement of EU enlargement (12–13 December 2002, Copenhagen). Trend values are obtained by means of the Hodrick-Prescott filter with the smoothing parameter λ = 270,400.

Trends in the returns of the sectoral stock indices are illustrated in *Figure 5*. As with the national indices, the sectoral returns are stationary. Details on the distribution of the sectoral returns are provided in *Figure A2 in the Appendix*. On average, the mean returns in the euro area are somewhat higher compared to the EU-3 block (in the case of the chemicals, electricity and telecommunications sectors). In the case of banking, the mean returns in the euro area and the 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 towards obtaining an outlook for stock market integration. It is based on correlation analysis – standard and rolling – of stock market returns. This analysis indicates the strength of the linear relationship between two variables; its value alone may not be sufficient to evaluate this relationship, especially where the assumption of normality is incorrect. The correlation coefficients, as summary statistics, cannot replace an 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):

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

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.[12] 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 the dynamics is to put equation (3) into the state-space form:

$$\Delta R_{i,t} = \alpha_i + \beta_t R_{i,t-1} + \sum_{l=1}^{L} \gamma_l \Delta R_{i,t-l} + \varepsilon_{i,t} \tag{5}$$

$$\beta_t = \beta_{t-1} + \mu_t \tag{6}$$

where β_t is the time-varying parameter and $\varepsilon_{i,t}$ and μ_t are the white-noise disturbance.[13] Estimates of β_t could be directly obtained by applying the Kalman filter to (5)–(6). 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).

[12] To apply this specification, the original series have to be first-difference stationary, which is the case with the national as well as sectoral indices. An alternative empirical strategy to measure financial integration is to make use of the co-integration approach.

[13] We assume that the beta coefficient follows a random walk, since we could not reject the null hypothesis of a unitary autoregressive coefficient.

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:

$$\sigma_t = \sqrt{\left(\frac{1}{N-1}\right)\sum_{i=1}^{N}\left[\log(y_{it}) - \log(\bar{y}_t)\right]^2} \tag{7}$$

where y_{it} is the yield on asset i at time t, and $\bar{y}_t$ is the cross-section mean yield at time t. Index i can stand for separate countries or sectors (i = 1, 2, …, N). For the purposes of this analysis, we introduce $N = 2$, i.e. we examine the 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). By definition, σ takes only positive values. The lower σ is, the higher the level of convergence that has been reached. In theory, full integration is reached when the standard deviation is zero, while high values of σ reflect a very low degree of integration. For chart-type expression, the results were filtered using the Hodrick-Prescott filter with the recommended weekly time series coefficient λ = 270,400.

It is important to note that the two convergence indicators have different information 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 for the 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.

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

Source: DataStream and authors' calculations.
Note: ***, **, * denote significance at the 1%, 5% and 10% levels. Bold text indicates strong and significant correlation coefficients.

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

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

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

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 (correlations ranging from 0.49 to 0.60), and on the other hand vis-à-vis the euro area (correlations 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 market stands apart: its returns appear to be uncorrelated with those in the euro area (coefficient 0.06, insignificant) and only weakly correlated with the returns in the other new EU member states (low correlations of 0.09–0.14, though significant at the 1%–5% level).

The correlations 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 has the highest correlation (0.45), followed by the telecommunications (0.32), chemicals (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. 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.

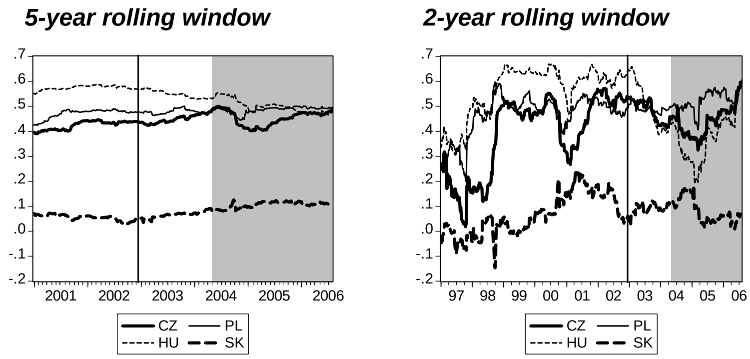
On the sectoral level (*Figure 7*), the correlation of returns exhibits richer dynamics, particularly when considered on the two-year rolling window. Overall, the correlations on the sectoral level are somewhat lower compared to the national indices.

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 beta reported in *Table 3*.[14] Notice, however, that we can still discriminate between countries, in other words the beta coefficients do not equal unity in all cases. Should such an outcome occur, the use of higher frequency data (e.g. daily indices) would be more appropriate. Next, a comparison of the periods 1995–2000 and 2001–2006 reveals that the pace of *β*-convergence of the Czech and Hungarian stock markets has increased.

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

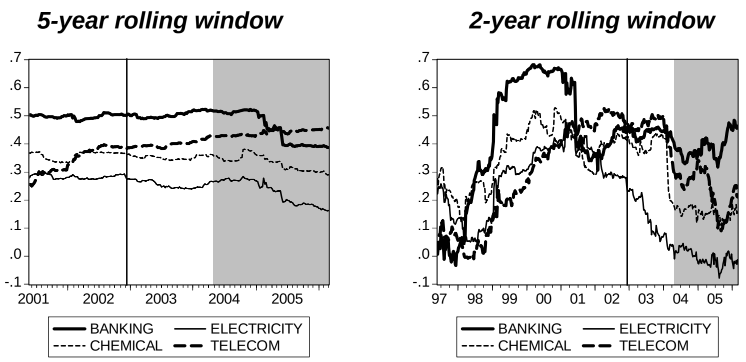


Source: DataStream, authors' calculations.

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

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

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



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

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)

Source: authors' calculations.

Notes: Time series estimates of eq. (1); β coefficients are displayed. The optimal lag length is determined to be one 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), and is 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.

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 the earlier and later periods are not significant. However, in the case of Poland, the degree of β-convergence 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.15

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)
Chemicals	-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)
Telecommun-ication	-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)

Source: authors' calculations.

Notes: Time series estimates of eq. (1); β coefficients are displayed. The optimal lag length is determined to be one 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), and is zero otherwise. Estimations are performed on the full sample 1995–2006.

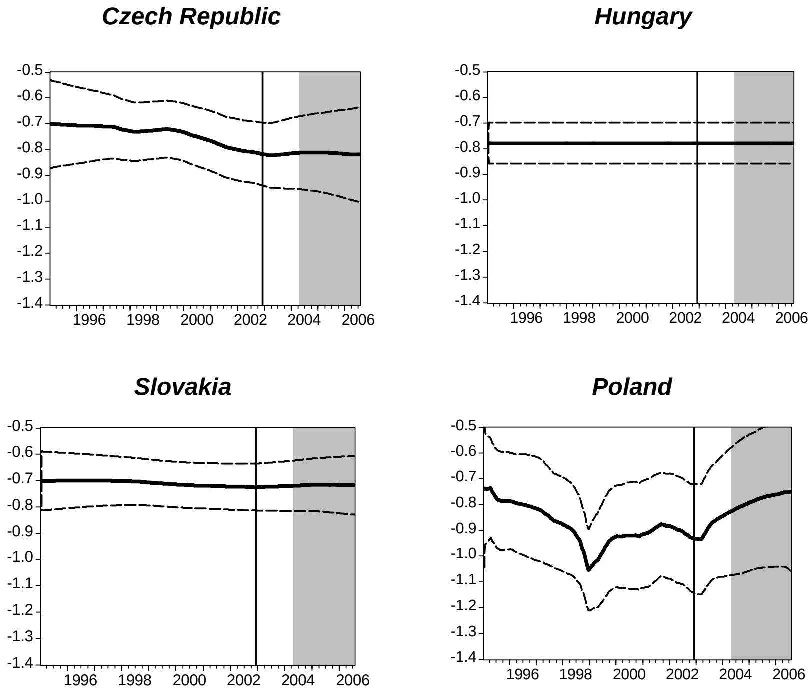
[b] For the four sectors considered together, the speed of convergence slightly decreased (at the 10% significance level) after the announcement of EU enlargement.

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 in the case of Poland. In Poland we observe 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 the time-series estimations: there has been 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. A broad international comparison of β-convergence (for Austria, Germany, Portugal and Slovenia against the euro area aggregate from 1995 to 2007) can be found in Czech National Bank (2007). Overall, the values of β for these selected euro area countries lie between –0.71 and –0.95.

[15] The Slovak stock market is much smaller and, from the perspective of investors and stock issuers, may seem less attractive than the markets of the new EU member states under review. For example, in 2006 the Czech market capitalization was €58 billion, as against only €4 billon in the Slovak case. Similarly, the Czech average daily trade amount (€123 million) was much higher than that for Slovakia (€0.31 million), and also the Czech trade volume was 1,072 million units, as compared to 5 million for Slovakia.

Figure 8: β-Convergence of National Indices – State Space Estimations



Source: authors' calculations.

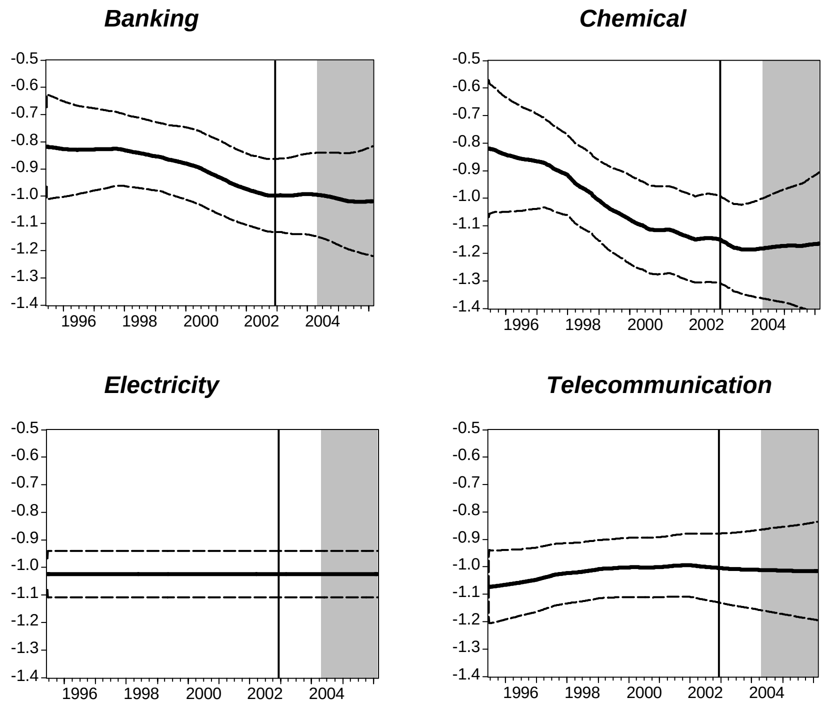
Notes: Kalman filter estimates of eq. (2)–(3); smoothed estimates of the β_t coefficients are displayed along with the ±2 RMSE bands. The optimal lag length is determined to be one according to the Schwarz information criterion. The shaded area indicates membership in the EU (1 May 2004) and the vertical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

Regarding the 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 than 0.4 of a week (for values of beta lying between –0.83 and –1.17). Notice that if the absolute values of the betas are greater than one, convergence occurs *with oscillations*, as opposed to *monotonic convergence* in the case of betas lying in the range between 0 and –1. The 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 the 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 the β-convergence of the national indices are displayed in *Figure 8*. Again, negative and close-to-unity values of β correspond to convergence of returns between the given country and the euro area. Although there are indications of rising convergence in the case of the Czech Republic, for example, the estimates of β are little changed for Hungary and Slovakia. In the Hungarian case, the estimated values of β are around –0.78 and are statistically different from –1. Such a 'constant' pattern might be due to the presence of asymmetric shocks; the Kalman filter algorithm is not able to detect a statistically significant variation of β over time. For Poland, the speed of convergence rises until the end of the 1990s and then decreases; 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 slow-down in the speed of convergence in the case of Poland since 2002.

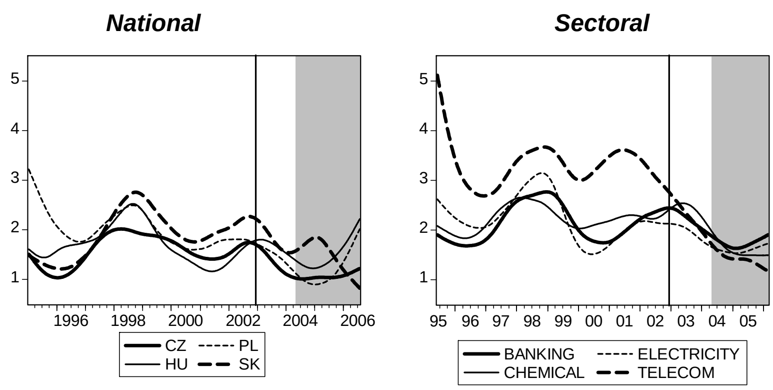
Figure 9: β-Convergence of Sectoral Indices – State Space Estimations



Source: authors' calculations.

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

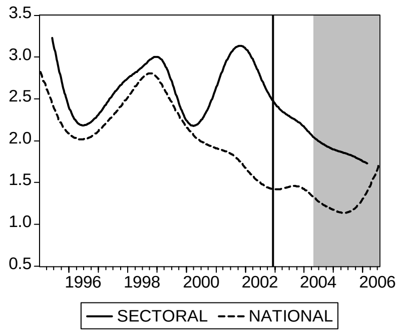
Figure 10: σ-Convergence of National and Sectoral Indices to the Euro Area, 1995–2006



Source: authors' calculations.

Notes: CZ = Czech Republic, HU = Hungary, PL = Poland, SK = Slovakia. The shaded area indicates membership in the EU (1 May 2004) and 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.

Figure 11: σ-Convergence – Comparison between National and Sectoral Indices, 1995–2006



Source: authors' calculations.
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, chemicals, electricity and telecommunication sectors in the EU-3.
The shaded area indicates membership in the EU (1 May 2004) and the vertical line corresponds to the announcement of EU enlargement (12–13 December 2002, Copenhagen).

Concerning the 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. In the electricity sector, convergence has been at values close to unity throughout the estimation period, meaning that 'full' convergence has been reached. This is also the level to which the telecommunications sector had 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 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 eurozone 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 development of the Slovak stock market. Measured on the period from 1995 to 2007, σ-convergence is also observed for Austria, Germany, Portugal and Slovenia against the euro area aggregate (see Czech National Bank, 2007).

On the sectoral level, the dynamics of *σ*-convergence for banking, chemicals 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 the national indices, there are signs 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 level than at the sectoral level. However, by 2006 the paths of the national and sectoral sigma lines had converged.

6. Conclusion

In this paper we have discussed selected aspects of financial integration in the Czech Republic, Hungary, Poland and Slovakia (i.e. the EU-4). The objective of this working paper was to test for the existence and analyze the dynamics of integration in the stock markets with 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), for which the original series have to be stationary in first differences. 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 to the three research questions stated at the beginning, (i) the results unambiguously point to the existence of β-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 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, when 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 the financial markets. Future research could be extended to include a broader examination of integration of the money, bond and credit markets in the enlarged EU.

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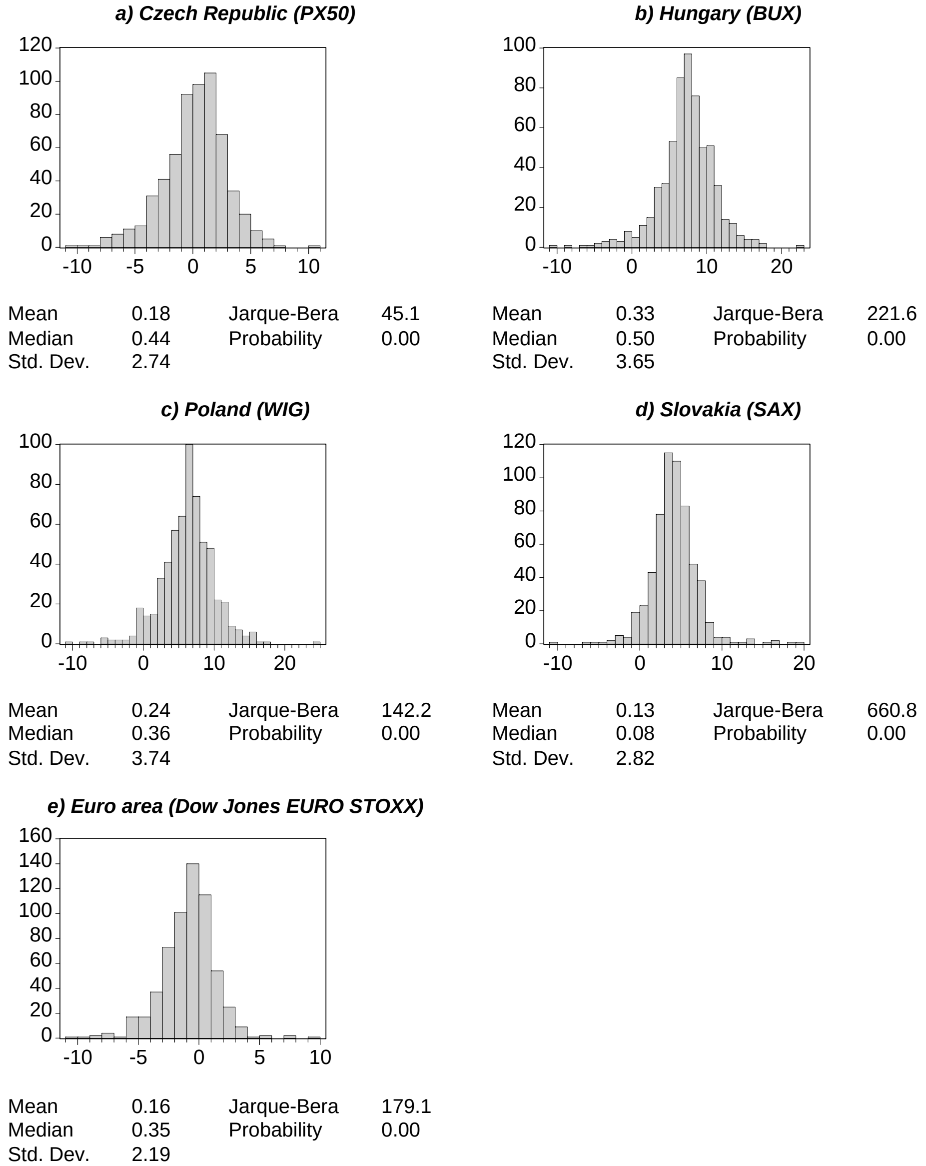
Appendix

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

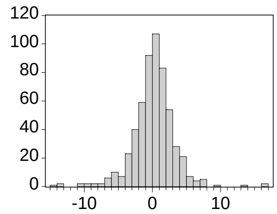


Source: DataStream, Bloomberg and authors' calculations.
Notes: Returns (R) are calculated as: $R = 100 * [\ln SE_t - \ln SE_{t-1}]$, where *SE* denotes the stock exchange index (national or sectoral).

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

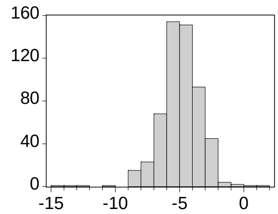
Banking

Euro Area



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

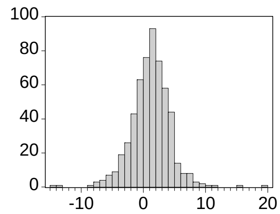
EU-3



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

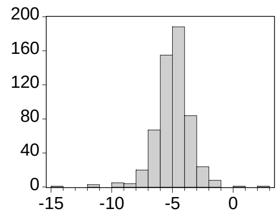
Chemicals

Euro Area



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

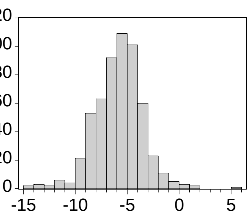
EU-3



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

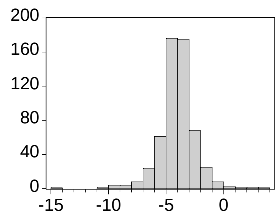
Electricity

Euro Area



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

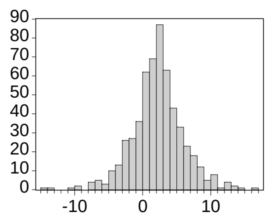
EU-3



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

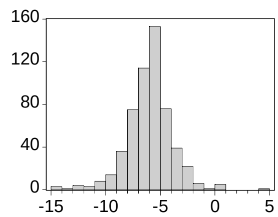
Telecommunication

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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