

The Real Convergence of CEE Countries: A Study of Real GDP per capita

Andrea ZÁREMBOVÁ* – Štefan LYÓCSA** – Eduard BAUMÖHL*

Abstract

The paper examines the unconditional sigma and time-series convergence of real GDP per capita (measured in national currencies and euros) for CEE8 countries during the 1995 : Q1 – 2011 : Q1 period by applying the unit root framework using the DF-GLS test and the Lee and Strazicich (2003; 2004) test, which allows for endogenous breaks in trends and constants. We selected Germany as a benchmark country for relative real GDP per capita because of its geographical and economical position relative to all CEE8 countries. We have found that both sigma convergence and time-series convergence were present for most of the CEE8 countries prior to the breaks in trends, but after the breaks, the convergence slowed or reversed and thus indicated divergence.

Keywords: time-series convergence, sigma convergence, CEE, unit root test, structural breaks

JEL Classification: C22, G01, E0, O40, P20

Introduction

The convergence of a country, which is also known as the catch-up effect, may be observed in various frameworks: we can observe the convergence of a country to its steady-state growth rate or countries converging within themselves or converging toward a given benchmark. Thus, many authors use different

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approaches to analyze convergence. In general, two dominant approaches can be used to analyze a convergence process: the cross-sectional and time-series convergence approaches. In this paper, we distinguish between the following types of convergence (e.g., Li and Papell, 1999; Loewy and Papell, 1996; Drennan, Lobo and Strumsky, 2004): β -convergence, which may be either conditional or unconditional; σ -convergence; and time-series convergence, which may be stochastic or deterministic and conditional or unconditional.

In this paper, we test for σ -convergence and time-series convergence among CEE8 countries (Central and Eastern European countries): Slovakia (SK), the Czech Republic (CZ), Hungary (HU), Poland (PL), Slovenia (SI), Latvia (LV), Estonia (EE) and Lithuania (LT). We use real GDP per capita ($rGDP_{PC}$) in national currencies and in euros. We test for time-series convergence and σ -convergence using the DF-GLS test of Elliott, Rothenberg and Stock (1996) and the LS test of Lee and Strazicich (2004), and we allow for one-time breaks in constant and linear time trends.¹

The σ -convergence was analyzed within the following groups of countries: CEE3 (Latvia, Estonia and Lithuania), CEE4 (Slovakia, the Czech Republic, Hungary and Poland), CEE5 (CEE4 and Slovenia) and CEE8 (all countries). For time-series convergence, the benchmark country was selected to be Germany, as it is the largest economy in the EU and is geographically close to all CEE8 countries.

1. Literature Review

β -convergence is defined as a negative relationship between the growth rate of a measured economic variable and the initial level of that variable. The growth rates are averaged per country in a given time period. In a regression framework, the unconditional β -convergence is a simple regression as described above; however, the conditional form accounts for other variables, which primarily model the heterogeneity of initial conditions. In this line of research, the seminal papers of Barro (1991) and Barro and Sala-i-Martin (1992) may be considered to be instructive. Since the early 1990s, this approach has been widely used for various economic regions and variables; for example, see Cashin (1995), Garofalo and Yamarik (2002), Coulombe and Tremblay (2001), Naudé and Krugell (2006), Lill and Paas (2008), Lau (2010), and Vaio and Enflo (2011).

¹ Structural breaks in the macroeconomic variables of CEE countries were frequently observed in previous research (see, e.g., Égert et al., 2006; Fidrmuc and Tichit, 2009; Lyócsa, Baumöhl and Výrost, 2011a).

Analysis of σ -convergence uses measures of variation, primarily standard deviation (SD) or coefficients of variation, to determine the cross-sectional dispersion of the variable of interest. As we focus on $rGDP_{PC}$, the presence of convergence among countries indicates that the variation of $rGDP_{PC}$ should decrease over time. An increase may indicate divergence.

According to Bernard and Durlauf (1996, p. 165): “Countries i and j converge if the long-run forecasts of (log) per capita output for both countries are equal at a fixed time t .” More formally, country i and j converge if the following equation is satisfied:

$$\lim_{n \rightarrow \infty} E(y_{i,t+n} - y_{j,t+n} | \xi_t) = 0 \quad (1)$$

where

- ξ_t – denotes all of the information available at time t ,
- $y_{i,t}$ – the logarithm of the $rGDP_{PC}$ for country i at time t .

The previous definition assumes that if $y_{i,t} - y_{j,t}$ is the mean zero stationary process, then the two countries converge. However, the series may be stationary around a deterministic trend yet still converging.

Unit root tests are used to study the behavior of SD in situations of σ -convergence and time-series convergence. In both cases, countries may converge when a time series follows a stationary process. However, stationarity is clearly not a sufficient condition. For example, in the time-series convergence approach, if $y_{B,t}$ is the log of the output for the benchmark country and $y_{B,t} > y_{i,t}$ for all t , then if the series $(y_{B,t} - y_{i,t})$ is stationary around a deterministic but increasing trend, the two countries are clearly not converging. Thus, an inspection of the trends seems necessary.

Carlino and Mills (1993) used the augmented Dickey-Fuller (ADF) test to study regional per-capita income in the U.S. relative to the entire country and failed to reject the unit root hypothesis in all 8 regions. When allowing for exogenous trend breaks, they rejected the unit root hypothesis for 3 regions. Loewy and Papell (1996) followed the work of Carlino and Mills (1993) by applying the same data and unit root approach with endogenously estimated break dates. They were able to reject the unit root hypothesis in 7 out of 8 regions in the U.S. Li and Papell (1999) tested both stochastic and deterministic convergence among 16 OECD countries. Stochastic convergence was defined as trend stationarity and the deterministic convergence as level stationarity of the logarithm of relative output. Li and Papell (1999) followed the work of Bernard and Durlauf (1996) but used more recent data and an additional country in their sample. Bernard and Durlauf (1996) rejected convergence between 15 OECD countries, whereas Li and Papell (1999) found more evidence of convergence. To test for

stochastic convergence, they used a sequential ADF test that allowed for structural breaks (innovation outlier model) and were able to reject the unit root hypothesis for 14 out of 16 countries. They also provided evidence of deterministic convergence for 10 countries. Drennan, Lobo and Strumsky (2004) investigated per capita personal income and average wages per job and analyzed the unconditional σ -convergence of U.S. metropolitan areas. The dispersion for both metropolitan indicators was measured by the standard deviation of the natural logarithms of the series. According to the ADF and DF-GLS tests, the unit root hypothesis was not rejected; thus, they concluded that convergence among U.S. metropolitan areas was not present. Dawson and Strazicich (2010) tested stochastic convergence in 29 countries using per-capita incomes. Their unit root testing procedure was similar to our procedures but allowed for two structural breaks (in trends and constants) and found 23 countries converging.

As mentioned previously, the stationarity of a series may not be sufficient to state that two countries are converging. In this regard, Nahar and Inder (2002) suggested an interesting approach, in which they measured the average slope of the time trend (for $t = 1, 2, \dots, T$) of the variable under consideration, estimated from the following regression: $(y_{B,t} - y_{i,t}) = \alpha + \beta_1 t + \beta_2 t^2 + \dots + \beta_k t^k + u_{i,t}$. This approach was attractive from an empirical perspective because when the average slope of the estimated function is positive and significantly different from 0, then one can assume that country i is (on average) converging to the benchmark country. This approach had many followers, such as Giles and Stroomer (2006), Stroomer and Giles (2003), and Galanopoulos et al. (2006). However, Gluschenko (2011) convincingly showed that this approach is too simplistic.

Kaitila (2004) investigated both β - and σ -convergence within 15 EU countries. Using $rGDP_{PC}$, they found convergence within EU countries in two periods: 1960 – 1973 and 1986 – 2001. Matkowski and Próchniak (2004; 2007) found convergence within CEE8 countries and toward the EU as a benchmark. They applied both the β - and σ -convergence approaches to the $rGDP_{PC}$ from 1993 to 2004. Kočenda, Kutan and Yigit (2006) examined the nominal and real convergence of 10 EU countries (the CEE8 countries in addition to Malta and Cyprus). They measured real convergence by relative $rGDP_{PC}$; in this approach, the average $rGDP_{PC}$ of the EU core and the average $rGDP_{PC}$ of the EU periphery countries served as two benchmarks. All variables were calculated in euros and in local currencies. The results of Kočenda, Kutan and Yigit (2006) suggest that the CEE8 countries were converging toward their benchmarks from 1995 to 2005.²

² For the CEE8, other variables in addition to $rGDP_{PC}$ have also been studied; for example, see Kočenda et al. (2008) for fiscal convergence (debt-to-GDP and deficit-to-GDP) or Siklos (2010) for interest rates and inflation.

2. Data

The non-seasonally adjusted quarterly nominal GDP in euros and in national currencies (namq_gdp_c), the deflator index for euros and national currencies (CPI100_NAC, CPI100_EUR), and the population data were obtained from the EUROSTAT database. The time span under investigation was the period from 1995 : Q1 to 2011 : Q1. For each quarter, the $rGDP_{PC}$ in national currencies was calculated as follows: ((nominal GDP in national currency / deflator index for the GDP in national currency) * 100) / population.. For the $rGDP_{PC}$ in euros, the calculation was similar: ((nominal GDP in euros / deflator index for the GDP in national currency) * 100) / population.. For the calculation of the $rGDP_{PC}$ in euros, we decided to use the deflator index for the GDP in national currency, as this index corresponds to the price-level changes in each particular country. For each country $i \in \{CEE8, \text{Germany}\}$, the seasonality in $rGDP_{PC}$ was eliminated by annualizing the quarterly $rGDP_{PC}$ ($g_{i,t} = \sum_{s=1}^4 rGDP_{PCi,t-s}$), as in Kočenda, Kutun and

Yigit (2006); thus, our series consisted of 61 observations³ and corresponds to the period from 1995 : Q4 to 2011 : Q1. The relative $rGDP_{PC}$ in euros was then calculated for all $i \neq B$ as $\ln(g_{i,t} / g_{B,t})$, where index B represents the benchmark economy, Germany. However, the seasonally adjusted $rGDP_{PC}$ in national currencies cannot be compared in this way. For each country i , we calculated an index with the first observation as the base year with an index of 100 : $IN_{g_{i,1}} = 100$, $IN_{g_{i,t}} = (1 + (g_{i,t} - g_{i,t-1}) / g_{i,t-1}) * IN_{g_{i,t-1}}$; subsequently, the relative $rGDP_{PC}$ in national currencies for all $i \neq B$ was analyzed for the series $\ln(IN_{g_{i,t}} / IN_{g_{B,t}})$. Because for all $i \neq B$ and t , $g_{i,t} < g_{B,t}$, if $\ln(g_{i,t} / g_{B,t})$ is increasing and is stationary (with trends and/or structural breaks), this result would imply the convergence of country i toward the benchmark economy. The same reasoning is also true for $\ln(IN_{g_{i,t}} / IN_{g_{B,t}})$.

To test the σ -convergence among CEE3, CEE4, CEE5 and CEE8, we have calculated the corresponding population SD_t of $g_{i,t}$ in euros. If the SD_t in the corresponding group of countries decreases and is stationary (with trends and/or structural breaks), then σ -convergence is present.

3. Methodology

The series of relative $rGDP_{PC}$ measured in national and euro currencies ($\ln(g_{i,t} / g_{B,t})$ and $\ln(IN_{g_{i,t}} / IN_{g_{B,t}})$ series) were tested for the presence of a unit root. We have used two tests. First, we have employed the DF-GLS test, which

³ A different strategy would be utilizing standard seasonal filter (e.g., X-12-ARIMA), however with only 61 observations, maximum likelihood estimation is not recommended.

was proposed by Elliott, Rothenberg and Stock (1996); subsequently, we used the test by Lee and Strazicich (2003; 2004) with one endogenous break in constants and trends. When the y_t is the analyzed series, the DF-GLS tests the hypothesis of $\varphi = 0$ in the regression:

$$\Delta \tilde{y}_t = d_t + \varphi \tilde{y}_{t-1} + \sum_{i=1}^k \delta_i \Delta \tilde{y}_{t-i} + \varepsilon_t \quad (2)$$

where

$k > 0$ – the number of lags,

$\tilde{y}_t$ – the locally detrended series y_t .

The number of lags was chosen using the modified Akaike information criterion (MAIC)⁴ for $k = 1, 2 \dots k_{\max}$. To choose the maximum lag length, we used Schwert's (1989) rule $k_{\max} = \text{int}[12(T/100)^{0.25}]$, where T is the sample size. The locally detrended series is obtained as follows:

$$\tilde{y}_t = y_t - \hat{\beta}_0 - \hat{\beta}_1 t \quad (3)$$

where $\hat{\beta}_0$ and $\hat{\beta}_1$ are obtained from the regression of $\bar{y}$ on $\bar{z}$:

$$\bar{y} = [y_1, (1 - \bar{\alpha}L)y_2, \dots, (1 - \bar{\alpha}L)y_T] \quad (4)$$

$$\bar{z} = [z_1, (1 - \bar{\alpha}L)z_2, \dots, (1 - \bar{\alpha}L)z_T] \quad (5)$$

where

$z_t = (1, t)'$ and $\bar{\alpha} = 1 + \bar{c} / T$,

$\bar{c}$ – fixed depending on the model type,

L – the lag operator.

In a model with drift, $\bar{c} = -7$, whereas in a model with linear trend, $\bar{c} = -13.5$. The test statistics for the hypothesis $\varphi = 0$ will be denoted as $\tau_{\mu}^{\text{GLS}}(k_{M^*})$ for the model with constant and $\tau_{\tau}^{\text{GLS}}(k_{M^*})$ for the model with trend and constant k_{M^*} denotes the number of lag terms chosen according to the MAIC. Contrary to most empirical research that has employed the DF-GLS test (which uses asymptotic critical values as proposed by Elliott, Rothenberg and Stock, 1996), we have used the critical values presented by Cook and Manning (2004), which account for the lag length selection method and the sample size. Because we have 61 observations, we decided to use critical values for the sample size $T = 50$ (see Tables 1 and 2 in the study by Cook and Manning, 2004).

Lee and Strazicich (2003; 2004) suggested a minimum LM unit root test with endogenously determined break(s) in a constant and a trend (LS test). Since the work of Perron (1989), it has been recognized that when a series is stationary but

⁴ For further details, see Ng and Perron (2001).

has a structural break, the use of a conventional unit root test has low power. Thus, we have also decided to use the LS test, where we have allowed for two breaks – one in a constant and one in a trend.⁵ These authors consider a data-generating process of the following form:

$$y_t = \delta' z_t + X_t, \quad X_t = \beta X_{t-1} + \varepsilon_t \quad (6)$$

where z_t is a vector with deterministic variables. In our case, $z_t = [1, t, D_t, DT_t]'$, where $D_t = 1$ for $t \geq T_B + 1$ and 0 otherwise and $DT_t = t - T_B$ for $t \geq T_B + 1$ and 0 otherwise. T_B is the date of the structural break. The test statistics are calculated from the regression:

$$\Delta y_t = \delta' \Delta z_t + \varphi \tilde{S}_{t-1} + \sum_{j=1}^k \Delta \tilde{S}_{t-j} + u_t \quad (7)$$

where $\tilde{S}_t = y_t - \tilde{\psi}_x - z_t \tilde{\delta}$, $t = 2, 3, \dots, T$. $\tilde{\delta}$ are the coefficients in the regression of Δy_t on Δz_t ($\Delta z_t = [1, \Delta D_t, \Delta DT_t]'$), and $\tilde{\psi}_x$ is given by $y_1 - z_1 \tilde{\delta}$. The test statistics for the hypothesis $\varphi = 0$ will be denoted as τ^{LS} . The unit root tests are known for their low power in near unit root processes, which are in turn typical for series with high autocorrelation. Because we used annualized data, the autocorrelation in our series is considerable. Therefore, the number of lagged terms was set to a fixed number $k = \text{int}[12(T/100)^{0.25}]$, based on Schwert's rule (1989). In general, this lag order is the highest that is used for augmentation in unit root tests (as mentioned previously in the discussion of the DF-GLS test). The location of the break (T_B) is determined by searching for all possible break points and choosing a combination of breaks such that τ^{LS} is minimized. As shown by Lee and Strazicich (2003; 2004), the critical values depend on the location of the break dates. Therefore, it is necessary to calculate break date-specific critical values. We simulated 5000 non-stationary processes with the breaks at given positions and found critical values for the LS unit root test. The critical values are reported in the relevant tables with empirical results.⁶

4. Results

We use unit root tests to test both the σ -convergence and time-series convergence of $rGDP_{PC}$ in national currencies and in euros and interpret the results separately for σ -convergence and time-series convergence.

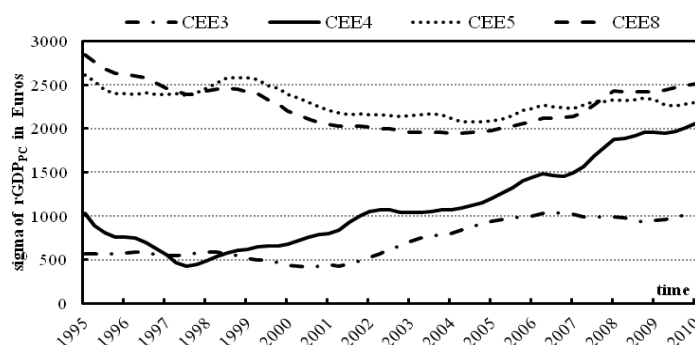
⁵ For a short review of other tests, see Lyócsa, Výrost and Baumöhl (2011).

⁶ Our R-code for the test statistic (including Monte Carlo simulations and the grid search) are available upon request and was also used in Lyócsa, Baumöhl and Výrost (2011). The original GAUSS code from J. Lee is available at <<http://www.cba.ua.edu/~jlee/gauss>>.

4.1. σ -convergence

According to Figure 1, from 1995 : Q4 to the beginning of 2005, the disparities between the economies in the CEE8 countries were decreasing and subsequently began to increase. The behavior of the disparities in the CEE5 group was similar. Interestingly, disparities within the CEE4 group (which is the CEE5 group without Slovenia) decreased until the beginning of the 1998 and subsequently increased. The growth of the economies of the CEE4 countries observed at the beginning of the millennia did not share the same pattern. For example, the economy of Slovakia has consistently grown (in $rGDP_{PC}$ measured in euros) only since the third quarter of 2001. Poland and Hungary were characterized by strong swings during the entire period, whereas the Czech Republic demonstrated growth with only mild declines in a few quarters. Of course, at the end of the observed period (during the recent crisis), all economies tumbled. Thus, both the different patterns of real GDP and the growth in exchange rates growth may have caused the increase of disparities between economies. Again, the evolution of the disparities between the CEE3 countries could be visually divided into two regimes. Until the end of 2001, we observe a stable period followed by an increase in disparities. However, to obtain a more formal conclusion, we evaluated the stationarity properties of these series.

Figure 1
 σ -convergence of Selected Groups of CEE Countries



Note: CEE3 (Latvia, Estonia and Lithuania), CEE4 (Slovakia, the Czech Republic, Hungary and Poland), CEE5 (CEE4 and Slovenia) and CEE8 (all countries). Time trends are significant for each series, positive for CEE4 and CEE3 and negative for CEE5 and CEE8.

Source: Authors.

Using the DF-GLS test with and without time trends, we were unable to reject the unit root hypothesis for any group of CEE3, CCE4, CEE5 or CEE8 countries. This result was not surprising, as our data are characterized by high autocorrelations (the lowest first-order autoregressive coefficient was 0.933), and the visual

inspection of the data also suggests more trending regimes. These attributes of the time series lower the power of the classical univariate tests. Therefore, we continued our analysis by employing the LS test of Lee and Strazicich (2003; 2004).

Table 1

Results from the DF-GLS and LS Tests of σ -convergence

Group	Test statistics			Critical values (LS test)			Convergence		
	$\tau_{\mu}^{\text{GLS}}(k_{M^*})$	$\tau_{\tau}^{\text{GLS}}(k_{M^*})$	τ^{LS}	1%	5%	10%	break (trend)		
CEE3	-0.073 (7)	-1.245 (8)	-3.695*	-4.341	-3.743	-3.430	NO	2004 : Q4	NO
CEE4	0.353 (2)	-0.887 (2)	-3.649**	-4.275	-3.629	-3.361	YES	2001 : Q4	NO
CEE5	-1.180 (1)	-1.851 (1)	-4.551***	-4.262	-3.707	-3.408	YES	2005 : Q3	NO
CEE8	-1.122 (5)	-1.249 (5)	-3.401**	-3.774	-3.215	-2.931	YES	1998 : Q4	NO

Note: $\tau_{\mu}^{\text{GLS}}(k_{M^*})$ represents the test statistic of the DF-GLS test with a constant, where the critical values are -2.72 (10%), -3.00 (5%), and -3.59 (1%); $\tau_{\tau}^{\text{GLS}}(k_{M^*})$ represents the test statistic of the DF-GLS test with a constant and a trend, where the critical values are -1.86 (10%), -2.14 (5%), and -2.74 (1%); and τ^{LS} represents the LS test statistic. The critical values for the DF-GLS test are obtained from the work of Cook and Manning (2004). Significance levels are denoted as *, **, and *** for 10%, 5% and 1%, respectively. In the convergence column, NO corresponds to the divergence in the given period, and YES corresponds to the convergence. CEE3 (Latvia, Estonia and Lithuania), CEE4 (Slovakia, the Czech Republic, Hungary and Poland), CEE5 (CEE4 and Slovenia) and CEE8 (all countries).

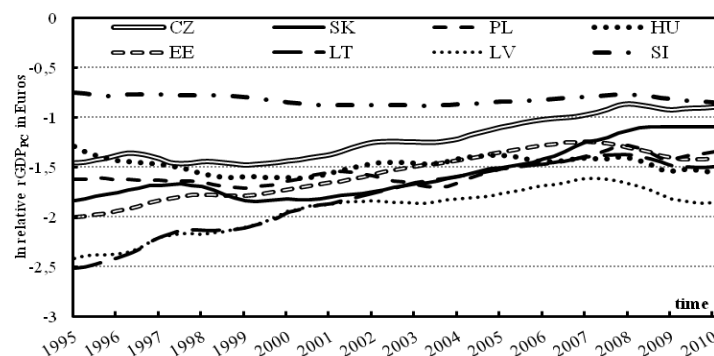
Source: Authors.

Applying the LS unit root test to the same groups of countries, we can reject the unit root hypothesis for CEE5 at the 1% significance level, for CEE4 and CEE8 at the 5% significance level, and for CEE3 at the 10% significance level. Thus, we conclude that we have found evidence of stationarity with breaks in constant and trend for SD_t . However, this evidence does not necessarily suggest σ -convergence. The trend changes from decreasing to increasing after the trend break for the CEE4, CEE5 and CEE8 groups. However, the trend did not change for the CEE3 group; the trend was increasing during the entire time period. The results in Table 1 indicate that σ -convergence among CEE3, CEE4, CEE5 and CEE8 countries is currently not present.

4.2. Time-series Convergence – $rGDP_{PC}$ in Euros

We applied a time-series approach to determine whether the CEE8 countries are converging to the benchmark economy – Germany. If a CEE country experiences more rapid growth than Germany, then the relative $rGDP_{PC}$ should be increasing. Therefore, both stationary and increasing relative $rGDP_{PC}$ are considered to be evidence of convergence among the two countries. Examining Figure 2, we observe that in terms of the $rGDP_{PC}$ in euros, all CEE8 countries (with the exception of Slovenia) were converging toward Germany. Slovenia's economy was primarily increasing in a faster rate than that of Germany. However, the weakening of the Slovenian tolar before the accession of Slovenia into the Economic and Monetary Union (EMU) of the European Union may cause that from the perspective of the euro currency, the two countries were not converging.

Figure 2
Time-series Convergence of the CEE8 Group in Euros



Source: Authors.

By applying the DF-GLS test, we have found some evidence that the relative $rGDP_{PC}$ values for the Czech Republic, Slovakia and Slovenia stationary (see Table 2). However, these results were significant only at the 10% level. For the entire time period, the relative $rGDP_{PC}$ values were increasing for the Czech Republic and Slovakia (convergence), whereas the trend for Slovenia was decreasing (divergence). For other countries, we were unable to reject the unit root hypothesis.

Table 2
Results from the DF-GLS and LS Tests of $rGDP_{PC}$ in Euros

Country	Testing statistics			Critical values (LS test)			Convergence		
	$\tau_{\mu}^{GLS}(k_{M^*})$	$\tau_{\tau}^{GLS}(k_{M^*})$	τ^{LS}	1%	5%	10%	break (trend)		
CZ	-0.022(5)	-1.891(2)*	-3.805*	-4.372	-3.822	-3.524	YES	2004 : Q2	YES
SK	-0.451(1)	-2.069(1)*	-3.201*	-4.036	-3.401	-3.118	NO	2001 : Q2	YES
PL	-0.563(3)	-1.561(4)	-4.381***	-4.162	-3.486	-3.184	YES	2007 : Q1	YES
HU	-1.884(9)	-1.502(2)	-4.210**	-4.310	-3.693	-3.381	YES	2006 : Q3	NO
SI	-1.338(1)	-2.126(1)*	-4.317***	-4.304	-3.675	-3.389	YES	2006 : Q1	YES
EE	0.045(5)	-1.456(4)	-5.581***	-4.334	-3.672	-3.342	YES	2006 : Q1	NO
LV	-0.731(1)	-1.340(4)	-3.644**	-3.899	-3.353	-3.041	YES	1998 : Q4	YES
LT	-0.100(6)	-0.701(4)	-4.272**	-4.366	-3.707	-3.373	YES	2005 : Q4	NO

Note: $\tau_{\mu}^{GLS}(k_{M^*})$ represents the test statistic of the DF-GLS test with a constant, where the critical values are -2.72 (10%), -3.00 (5%), and -3.59 (1%); $\tau_{\tau}^{GLS}(k_{M^*})$ represents the test statistic of the DF-GLS test with a constant and a trend, where the critical values are -1.86 (10%), -2.14 (5%), and -2.74 (1%); and τ^{LS} represents the LS test statistic. The critical values for the DF-GLS test are obtained from the work of Cook and Manning (2004). Significance levels are denoted as *, **, and *** for 10%, 5% and 1%, respectively. In the convergence column, NO corresponds to the divergence in the given period, and YES corresponds to the convergence.

Source: Authors.

Using the LS test, we rejected the unit root hypothesis for all countries (except the Czech Republic, all other series were stationary at least at the 5% significance level). The breaks in trends are located throughout the entire time span, although there is some tendency of occurrences from 2005 to 2007. Perhaps, this

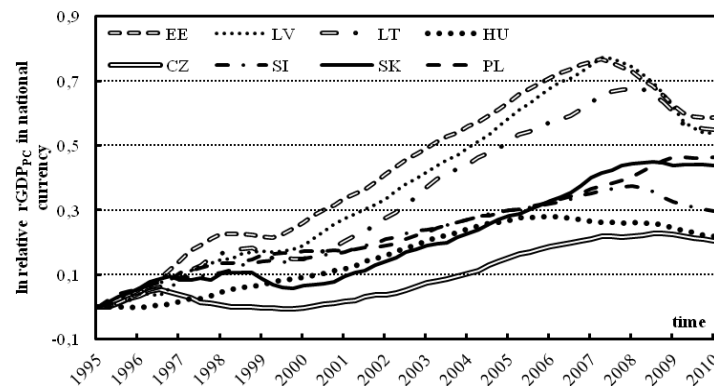
may be attributed to some post-EU accession effects. Before these breaks, all countries (except Slovenia) were converging toward Germany; subsequently, only Estonia, Lithuania and Hungary were diverging from Germany.

4.3. Time-series Convergence – $rGDP_{PC}$ in National Currencies

With regard to convergence, we consider the results for the $rGDP_{PC}$ in national currencies as more suitable, as they do not account for exchange rate changes between national currencies and the euro. Figure 3 shows that the relative $rGDP_{PC}$ was increasing for all countries until approximately 2007, when the trend changed. This point in time approximately corresponds to the beginning of the recent crisis.⁷

Figure 3

Time-series Convergence of the CEE8 Group in National Currencies



Source: Authors.

Applying the DF-GLS test for the Czech Republic, Lithuania and Latvia, we rejected the unit root hypothesis. These results suggest convergence of the three economies toward Germany during the entire time period. However, it is difficult to ignore the evident break in the trend at the beginning of 2007. A test that accounts for such breaks seems to be a more appropriate choice. The pattern of relative $rGDP_{PC}$ values for the Czech Republic differed from those of two Baltic states, as the pattern for the Czech Republic seems stable (increasing) during the entire period.

⁷ As one of the reviewers noted, both in Figures 1 and 2, the dynamics of the series for Estonia should be the same, as the country was keeping its currency policy with stable exchange rates. In Figures 1 and 2 the differences in the dynamics between the series for Estonia is just illusive. The Pearson's correlation coefficient is equal to 0.99999994.

Table 3

Results from the DF-GLS and LS Tests of $rGDP_{PC}$ in National Currencies

Country	Testing statistics			Critical values (LS test)			Convergence		
	$\tau_{\mu}^{GLS}(k_{M^*})$	$\tau_{\tau}^{GLS}(k_{M^*})$	τ^{LS}	1%	5%	10%	break (trend)		
CZ	-0.452(1)	-2.189(1)**	-4.800***	-3.591	-3.023	-2.748	YES	1997 : Q2	YES
SK	0.034(5)	-1.661(1)	-3.495*	-4.235	-3.548	-3.234	YES	2006 : Q4	NO
PL	-0.596(3)	-1.716(1)	-2.806	-3.654	-3.059	-2.815	not stationary		
HU	-0.861(1)	-1.070(1)	-4.210**	-4.179	-3.571	-3.272	YES	2001 : Q4	YES
SI	-0.596(1)	-1.735(1)	-3.491*	-4.331	-3.715	-3.346	YES	2006 : Q1	YES
EE	0.050(5)	-1.461(4)	-5.597***	-4.291	-3.645	-3.360	YES	2006 : Q1	NO
LV	-0.478(1)	-2.411(1)**	-4.078**	-4.408	-3.733	-3.435	YES	2006 : Q1	NO
LT	-0.310(1)	-2.041(4)*	-4.635***	-4.305	-3.659	-3.351	YES	2006 : Q1	NO

Note: $\tau_{\mu}^{GLS}(k_{M^*})$ represents the test statistic of the DF-GLS test with a constant, where the critical values are -2.72 (10%), -3.00 (5%), and -3.59 (1%); $\tau_{\tau}^{GLS}(k_{M^*})$ represents the test statistic of the DF-GLS test with a constant and a trend, where the critical values are -1.86 (10%), -2.14 (5%), and -2.74 (1%); and τ^{LS} represents the LS test statistic. The critical values for the DF-GLS test are obtained from the work of Cook and Manning (2004). Significance levels are denoted as *, **, and *** for 10%, 5% and 1%, respectively. In the convergence column, NO corresponds to the divergence in the given period, and YES corresponds to the convergence.

Source: Authors.

The LS test rejected the unit root hypothesis for all countries except Poland, but Slovenia and Slovakia were significant only at the 10% level. The break in the trend for the Czech Republic occurred at 1997 : Q2 and was rather surprising (and essentially unique because we do not interpret results for Poland). Except Hungary, the breaks in trends occurred during 2006. Similar to that which was observed in the previous analysis, breaks tend to occur toward the end of the sample period. However, there seems to be some bias in the break date estimation, as we deductively know that the crisis began after this date. Therefore, we expected that the breaks would occur later-perhaps at the end of 2007. We can conclude that all countries (except Poland) were converging toward Germany before the break in the trend, but the Baltic states and Slovenia began to diverge in 2006.

Conclusion

When accounting for structural breaks in trend and constant the unconditional σ -convergence of $rGDP_{PC}$ can be characterized as a stationary process. During the entire time period, the σ -convergence was not a uniform process as before the breaks in trends; the CEE4, CEE5 and CEE8 groups were converging, but all country groups have been diverging since that time. The strong growth rate and the crisis during the last decade do not seem to have assisted in mitigating the differences among CEE countries. Similar results were also found for time-series convergence.

When we calculated the slopes of the linear trend for each series before and after the breaks in trends, we were able to analyze the tendencies toward (non) convergence. The results are captured in the following table. First, the results

from unit root tests suggest that the relative $rGDP_{PC}$ can be characterized as a stationary process with structural breaks in almost all cases. With some exceptions, after the breaks in linear time trends, most of the slopes have decreased or even changed from increasing to decreasing slopes. However, we may observe some differences according to whether the $rGDP_{PC}$ was measured in euros or in national currencies.

In most countries, national currencies had been appreciating with respect to the euro; from the EMU perspective, the growth in output was even stronger. Based on results of the relative $rGDP_{PC}$ valued in euros, one interpretation is that the convergence tendencies in CEE countries were stronger when their economies were growing and their currencies were appreciating. Prior to the identified breaks, all countries (except Slovenia) had been converging; after the breaks, all countries (except Hungary, Estonia and Lithuania) were diverging marginally.

Table 4

Slopes and Breaks of Relative $rGDP_{PC}$ Values

	Euros			National currency		
	slope	break	slope	slope	break	slope
CZ	0.006	2004 : Q2	0.014	0.009	1997 : Q2	0.006
SK	0.005	2006 : Q1	0.023	0.006	2006 : Q1	0.008
PL	0.003	2007 : Q1	0.001		not stationary	
HU	0.001	2006 : Q3	-0.009	0.006	2001 : Q4	0.002
SI	-0.004	2001 : Q2	0.003	0.007	2006 : Q4	-0.003
EE	0.016	2006 : Q1	-0.010	0.016	2006 : Q1	-0.010
LV	0.024	1998 : Q4	0.008	0.014	2006 : Q1	-0.011
LT	0.025	2005 : Q4	-0.001	0.012	2006 : Q1	-0.002

Source: Authors.

The breaks in the trends of relative $rGDP_{PC}$ values measured in euros were not identified in the same periods but were scattered throughout the entire time period. The most interesting difference of the results for the relative $rGDP_{PC}$ values measured in national currencies was that the breaks in trends for five countries were identified in 2006. In the Baltic states and Slovenia, the process of convergence changed from converging to diverging. In the Czech Republic and Hungary, the slopes decreased although they are still positive; thus, the speed of convergence decreased. Slovakia is an exception, as its slope increased. For Poland, we are unable to interpret the results in this way, as the convergence of the relative $rGDP_{PC}$ was not found to be stationary.

In general, it is tempting to interpret our result by positing that the countries were converging before the recent crisis and that the process of convergence slowed or began to diverge after the crisis began. However, as mentioned in the previous section, most of the breaks in trends were found in 2006, which was prior to the beginning of the recent crisis. This finding may have arisen as a result of our procedure for estimating breaks because our procedure was based on a unit

root testing statistics or it may be attributed to some post-EU accession effects. Our visual inspection of the data suggests that the breaks in trends occurred in 2007 and that economies diverged from Germany during the crisis. We hypothesize that the slowed growth of a benchmark country does not necessarily indicate that the convergence should decrease, but our empirical results suggest that it does.

Therefore, the effect of the slowing of the benchmark economy on the CEE countries seems to be non-linear. This effect would be in accordance with the hypothesis that due to the foreign direct investments and exports, the smaller economies⁸ are depending on the growth of the larger economies. In this case, the larger economy is Germany.

In the future, it would be interesting to increase the scope of this study by using multiple benchmark countries. For example, Kočenda, Kutan and Yigit (2006; 2008) calculated benchmarks from different countries. Furthermore, the analysis could be expanded by using conditional models of convergence.

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⁸ Except Poland, but in case of Poland the geographic location near Germany makes the Polish economy even more dependent on Germany.

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