THE EVALUATION OF OUTPUT CONVERGENCE IN SEVERAL CENTRAL AND EASTERN EUROPEAN COUNTRIES

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Abstract. *The main objective of this study is to check the convergence in output for six countries from Central-Eastern Europe that are also members of the European Union. A slow convergence was obtained only for Greece during 2003–2012, for the rest of the countries (Bulgaria, Croatia, Hungary, Poland and Romania) the divergence being observed. The regression coefficients were estimated using bootstrap simulations in order to solve the problem of a small data set. However, the graphical representations suggested a convergence for Bulgaria and Romania, the assumption proved also by the application of the Augmented Dickey Fuller unit root test. There is no evidence of the convergence of each country towards Greece, this country having a specific evolution of its GDP with higher values than the rest of the countries.*

Key words: *convergence, GDP per capita, ADF tests, co-integration, steady state*

Introduction

The accession of eight Central and Eastern European countries (CEEC) in 2004 was an important event in the enlargement of the European Union (EU). Then, Bulgaria and Romania joined the European community in 2007, and they increased the number of the former Communist Bloc countries among the EU members. After the transition to market economy and consistent transformations in the legal and political systems, these countries have to catch up with the economies of Western Europe. Therefore, the economic convergence was an important task for all these countries, and common structural and monetary policies were required. The increase of the GDP per capita convergence was required along the road to the EU accession. On the other hand, the Maastricht Treaty imposed criteria for achieving nominal and real convergence before entering the European Monetary Union (EMU). So, the problem of economic convergence is essential for CEEC.

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The main aim of this study is to establish if there is a GDP per capita convergence for some countries of the Central-Eastern Europe that are also members of the European Union. Different econometric methods were applied to study the long-term behavior of GDP per capita. The results showed that only Greece's output per capita converges towards a steady state level, but the rest of the countries (Bulgaria, Croatia, Hungary, Poland, and Romania) do not converge to steady state and to the average change of GDP per capita from Greece. Given that Bulgaria, Croatia, Hungary, Poland and Romania have common roots and their economies experienced very similar challenges over time, they were included in the analysis. The regional convergence of the CEE countries can be considered an intermediary step of the CEE direct participation in the European Monetary Union.

The economic convergence is defined by taking into consideration that poorer countries have to advance faster than richer ones when various countries are at points relative to their balanced growth paths and when structural differences among the countries are considered. The rate of convergence permits the calculation of the speed of convergence of an economy towards its steady state. The economic divergence reflects the situation when the poor countries are not able to reduce the gap between them and the rich countries.

A consistent part of the literature regarding the economic convergence in the EU considered the development gap between the European Union and the Balkans. For example, Ouardighi and Kapetanovic (2009) proved that the income convergence was really higher during the 2000s for the EU-27. Most of the economic convergence was observed in the second half of the 1990s for the Balkan countries.

The rest of the paper is organized as follows. After a brief literature review, the methodology framework is presented. The empirical study for some Central-Eastern countries is described, and conclusions are drawn in the last section.

Section I. Literature review

For testing the common trends and the convergence hypothesis, some multivariate methods were used by Bernard and Durlauf (1995), showing the output convergence of 15 OECD countries. The tests are applied for trends that are linear independent stochastic, the spectral density matrix being studied has null frequency. If all the countries satisfy the convergence assumption, the rank of this matrix for output deviations from the reference country is null. Using the Johansen (1991) test for co-integration, the convergence assumption supposes the presence of p-1 co-integrating vectors. According to Evans and Karras (1996), the convergence of N economies is ensured if the logarithm of output y_{it} is not stationary, but the deviation from the average ($y_{it} - \bar{y}_t$)) is stationary.

Estrin and Urga (1997) tested the convergence of GDP in transition countries from Central and Eastern Europe in the period from 1970 to 1995, obtaining little evidence for convergence using the co-integration analysis, time-varying coefficients procedure and the unit root approach. The same poor evidence for convergence and post-communist countries was obtained by Estrin, Urga and Lazarova (2001) for 1970–1998.

Bijsterbosch and Kolasa (2010) made an industry-level investigation for studying the FDI and productivity convergence in Central- Eastern Europe. The authors have obtained a strong convergence in productivity for the countries from this region.

Azomahou, El ouardighi, Nguyen-Van and Cuong Pham (2011) proposed a semi-parametric partially linear model to assess the convergence among the EU countries, showing that there is no convergence for members with a high income. Beyaert and García-Solanes (2014) measured the impact of economic conditions on long-term economic convergence. The convergence in terms of GDP/capita is different from that of the business cycle during 1953–2010. Cuaresma, Havettová and Lábaj (2013) evaluated the income convergence dynamics and proposed some forecast models for European countries. The authors predicted that the human capital investment will determine income convergence.

Palan and Schmiedeberg (2010) tested the structural convergence in terms of the unemployment rate for Western European countries, observing divergence for technology-intensive manufacturing industries. Le Pen (2011) utilized the pair-wise convergence of Pesaran for the GDP per capita of some European regions.

Crespo-Cuaresma and Fernández-Amador (2013) determined the convergence patterns for the European area business cycles. In the middle of the 80s there was an obvious business cycle divergence while in the 90s the convergence was persistent.

Kutan and Yigit (2009) used a panel data approach for 8 new countries in the EU and stated that the productivity growth was determined by human capital in the period from 1995 to 2006. Monfort, Cuestas and Ordóñez (2013) utilized a cluster analysis, putting into evidence the existence of two convergence clubs in the EU-14, the Eastern European countries being divided into two groups. Andreano, Laureti and Postiglione (2013) assessed the economic growth of North African and Middle Eastern countries using the conditional beta-convergence. Iancu (2009) assessed the real convergence using the sigma approach in the EU members considering three groups: EU-10, EU-15, and EU-25, the results showing an increase of the divergence in the period from 1995 to 2006.

The novelty of our research is brought by the application of the methodology for assessing the economic convergence for several CEEC countries and on the time period that was not analyzed before in the literature. We chose six particular countries from Central and Eastern Europe with similar trends of GDP per capita (Bulgaria, Croatia, Hungary, Poland, Romania, and Greece). Except Greece, the other countries are recent members of the European Union (Croatia from 2013, Bulgaria and Romania from 2007, Poland and Hungary from 2004). However, the mentioned period included the economic crisis that strongly affected Greece's GDP per capita.

Section II. Methodology

If the logarithm of GDP per capita during the period t for the economy i is denoted by y_{it} and N economies are considered, the common trend is a_i and the country-specific parameter is μ_i:

$$\lim_{n\to\infty}\left(y_{i,t+n} - a_{t+n}\right) = \mu_i, \tag{1}$$

here μ_i – level of growth path for economy i,

a_t – common technology.

The absolute convergence implies:

$$\lim_{n\to\infty}\left(y_{i,t+n} - \bar{y}_{t+n}\right) = 0 \tag{2}$$

On a long term, $(y_{i,t} - \bar{y}_t)$ have to converge to zero.

If $\bar{y}_t$ is the steady-state information for the countries in the period t, the demeaned GDP per capita is $z_{it} = y_{i,t} - \bar{y}_t$ (the distance from the steady state), a value close to zero indicating convergence. If we consider that $w_{it} = z_{it}^2$, in case of convergence w_{it} should tend to zero, and the change rate in w_{it} in time has to be negative ($\frac{\partial}{\partial t} w_{it} < 0$). In case of absolute convergence, we have:

$$\lim_{n\to\infty} \mathrm{E_t}\left(w_{i,t+n}\right) = 0\,, \tag{3}$$

$w_{it} > 0$ and $\frac{\partial}{\partial t} w_{it} < 0$ for $n \to \infty$.

The convergence assumption is checked by assessing the sign of $\frac{\partial}{\partial t} w_{it}$. Therefore, is seen as a time trend function $f(t)$:

$$f(t) = \theta_0 + \theta_1 t + \theta_2 t^2 + \cdots + \theta_{k-1} t^{k-1} + \theta_k t^k, \tag{4}$$

here θ_i $i = 0, \ldots, k$.

The slope function is

$$\frac{\partial}{\partial t} w_{it} = f'(t). \tag{5}$$

In order to hold convergence, the average slope function of w_{it} is less than 0:

$$\frac{1}{T}\sum_{t=1}^{T} \frac{\partial}{\partial t} w_{it} < 0. \tag{6}$$

Actually we have:

$$\frac{1}{T}\sum_{t=1}^{T} \frac{\partial}{\partial t} w_{it} = \theta_1 + \theta_2 r_2 + \theta_3 r_3 + \cdots + \theta_{k-1} r_{k-1} + \theta_k r_k = r'\theta, \tag{7}$$

$$r_2 = \frac{2}{T}\sum_{t=1}^{T} t$$

$$r_{k-1} = \frac{(k-1)}{T}\sum_{t=1}^{T} t^{k-2}$$

$$r_k = \frac{k}{T}\sum_{t=1}^{T} t^{k-1}$$

$r = [0\ 1\ r_2\ ....\ r_{k-1} r_k]$,

$\theta = [\theta_0 \theta_0 \theta_1\ ....\ \theta_{k-1} \theta_k]$.

The null hypothesis supposes the lack of convergence ($r'\theta \geq 0$). In order to test the convergence, the following model is used:

$$w_{it} = f(t) + u_{it} = \theta_0 + \theta_1 t + \theta_2 t^2 + \cdots + \theta_{k-1} t^{k-1} + \theta_k t^k + u_{it} \tag{8}$$

u_{it} – error (i.i.d.)

$$w = X\theta + u$$

$$X = \begin{bmatrix} 1 & 1 & 1^2. & . & 1^k \\ 1 & 2 & 2^2. & : & 2^k \\ \cdot & \cdot & \cdot : & : & \cdot \\ 1 & T & T^2. & . & T^k \end{bmatrix}, w = \begin{bmatrix} w_{i1} \\ w_{i2} \\ \cdot \\ w_{iT} \end{bmatrix}, u = \begin{bmatrix} u_{i1} \\ u_{i2} \\ \cdot \\ u_{iT} \end{bmatrix}$$

The OLS estimate is: $\hat{\theta} = (X'X)^{-1}X'w$.

The estimate of the average slope is $r'\hat{\theta} = r'(X'X)^{-1}X'w$, while its standard error is $se(r'\hat{\theta}) = \sqrt{r'[s^2(X'X)^{-1}]r}$ (s^2 is the variance estimator). The test statistic is $t_\theta = \frac{r'\hat{\theta}}{se(r'\hat{\theta})}$. The test statistic follows a normal distribution under the null hypothesis. The Jarque–Bera test is used to check the normality hypothesis. The Jarque–Bera statistic follows a chi-square distribution with two degrees of freedom, and it has the following form:

$$JB = T\left[\frac{b_1}{6} + \frac{(b_2-3)^2}{24}\right] \tag{9}$$

${b_1}^{1/2} = \frac{1}{T}\sum_{t=1}^{T} \frac{\hat{e}_{it}^3}{\hat{\sigma}^3}$ (estimate of skewness coefficient)

$b_2 = \frac{1}{T}\sum_{t=1}^{T} \frac{\hat{e}_{it}^4}{\hat{\sigma}^4}$ (estimate of kurtosis coefficient)

$\widehat{\sigma^2} = \frac{1}{T}\sum_{t=1}^{T} \hat{e}_{it}^2$ (estimate of standard error).

The null hypothesis states the normal distribution.

For the function $f(t)$, a particular form is chosen and various models are estimated for each country. The best model is selected using the Akaike information criterion (AIC).

Section III. The assessment of output convergence

In this study, we have used the data for annual GDP per capita of six countries from Central-Eastern Europe that are member of the European Union: Bulgaria, Croatia, Greece, Hungary, Poland, and Romania. The data series are provided by the Eurostat (GDP per capita in PPS) covering the period from 2003 to 2012. The data series length is small, and the coefficients are estimated using bootstrap simulations. 10 000 replications are made by re-sampling the error terms.

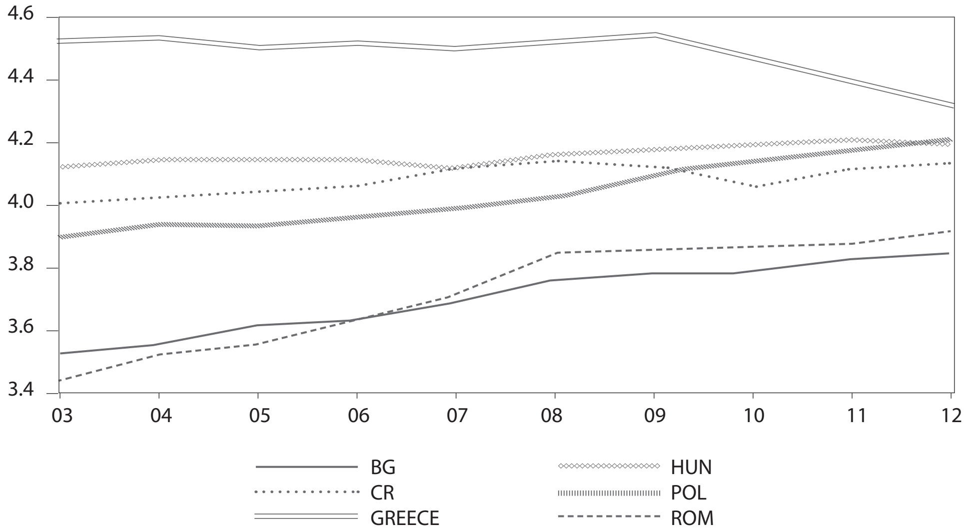

FIG. 1. **The evolution of the logarithm of GDP per capita in the six European countries**

Source: author's graph.

In Table 1, the values of the AIC indicator for different models of squared demanded GDP per capita for the six countries are displayed. From this table, we select the models that are the best for each country, the polynomials having different degrees for the selected countries. For Bulgaria, Croatia, and Romania the degree of the polynomials is 2, for Hungary and Poland 3, and for Greece 5. These econometric results conduct us to conclude that from the economic point of view Bulgaria, Romania, and Croatia have similar trends of GDP per capita in the analyzed period. On the other hand, Greece is placed in a separate cluster with the levels of GDP per capita and the trend that are different as compared to the other countries in the group of analysis.

The results of the Jarque–Bera test for each best model show us that there is not enough evidence to reject the normality hypothesis for the errors' distribution.

TABLE 1. **The value of Akaike Information Criterion for different models of squared demeaned GDP per capita for the six countries**

Country	Model $w_{it} = f_k(t) + u_{it}$ $f_k(t) = \theta_0 + \theta_1 t + \theta_2 t^2 + ... + \theta_{k-1} t^{k-1} + \theta_k t^k$				
K	1	2	3	4	5
Bulgaria	-1.3852	**-4.7870**	-3.2848	-2.6191	-2.2724
Croatia	-3.141	**-3.8168**	-3.5196	-3.3484	-3.2549
Greece	-2.2806	-2.8738	-3.3208	-3.7724	**-4.1788**
Hungary	-4.0576	-5.0103	**-5.1761**	-5.0832	-4.9052
Poland	-1.4324	-4.5771	**-4.9154**	-3.7065	-3.0658
Romania	-0.5752	**-2.9570**	-1.9386	-1.4407	-1.1720

Source: author's calculations.

TABLE 2. **Estimates and average slopes and the *p*-value associated to *t*-ratios for testing the convergence in the six countries**

Country	Average slope for output gap	*p*-value associated with *t*-ratio
Bulgaria	0.0377	0.0000
Croatia	0.0121	0.0102
Greece	-2.04E-05	0.0001
Hungary	7.42E-05	0.0023
Poland	0.00031	0.0000
Romania	0.055	0.0000

Source: author's calculations.

A negative average slope was registered only for Greece, only for this country being available the evidence of convergence. For the rest of the countries, the positive average slopes indicate a divergence. So, Greece tends to an economic convergence in the output per capita, the fact that is not met yet in other CEEC countries like Bulgaria, Croatia, Hungary, Poland, and Romania.

The estimates of the average slopes can be interpreted as the average convergence rate for each country towards the average level of the six countries. The convergence rate for Greece is very low (0.0024%), while for Bulgaria, Croatia, Hungary, Poland, and Romania the divergence rates are 3.761%, 1.209%, 0.0074%, 0.0314%, and 5.496%. For Hungary and Poland the divergence rate is very low.

According to the cluster analysis based on k-means, there is an evidence of ascending values in the period from 2003 and 2007. The crisis period (2008–2012) is characterized by the descending values of the output for all the six countries.

The following table reports the results of the Augmented Dickey–Fuller test for unit roots of the GDP per capita gap from Greece. These models include only a constant without trend. According to Bernard and Durlauf (1995), the rejection of the null hypothesis of the unit root supposes convergence.

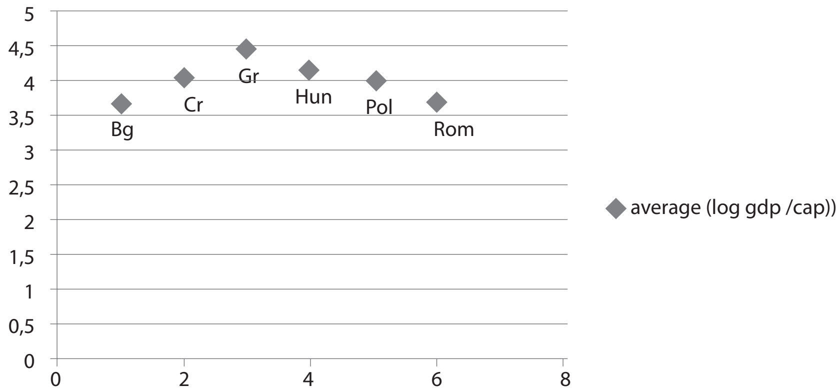

FIG. 2. **The distribution of the average of the logarithm of GDP per capita for the six countries**

Source: author's graph.

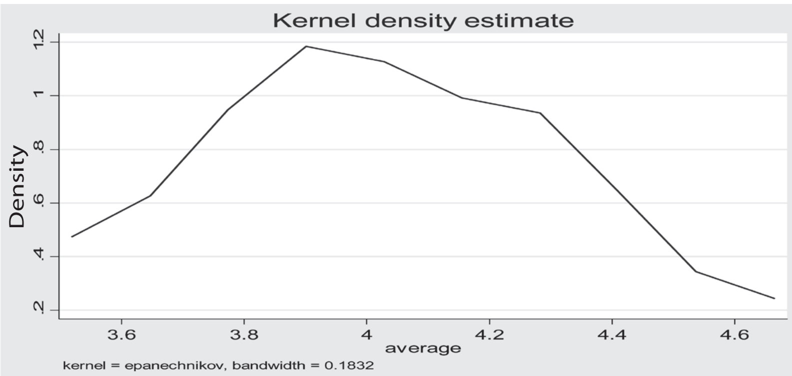

FIG. 3. **The Kernel density estimate for the output average of the six countries during 2003-2012**

Source: author's graph.

The results of ADF tests show that there is no evidence of convergence for any country towards Greece's output. The graphical representation also shows higher values for Greece. According to the graph, three convergence clubs might be identified (the cluster of the most recent members of the EU – Croatia, Bulgaria and Romania, the cluster represented by Poland and Hungary and the cluster with a former country like Greece). The ADF test is applied again for each group of two countries for which the output might converge.

The ADF test for a comparison between Romania and Bulgaria indicates divergence between the two countries even if the graph shows a close value of the output for Bulgaria and Romania. It should not be surprising that the ADF test gives a misleading impression. The value of AR(1), which is very close to unit, implies the non-rejection of the null hypothesis of the unit root. The model with trend has alleviated this conclusion, suggesting the rejection of the null hypothesis. For the rest of the groups of the countries, the ADF tests did not suggest the evidence of convergence.

TABLE 3. **Augmented Dickey–Fuller (ADF) tests for the GDP per capita gap from Greece**

Country	Value of ADF statistics	Conclusion
Bulgaria	1.037353	Do not reject the hypothesis of unit root
Croatia	0.050255	Do not reject the hypothesis of unit root
Hungary	0.192226	Do not reject the hypothesis of unit root
Poland	1.424165	Do not reject the hypothesis of unit root
Romania	0.285654	Do not reject the hypothesis of unit root

The models include the intercept but not the trend. The critical value for the ADF test is–3.3350 for the 5% level of significance.

Source: author's calculations.

TABLE 4. **Augmented Dickey–Fuller (ADF) tests for the GDP per capita gap for groups of countries**

Cluster	Value of ADF statistic (only intercept is included)	Value of ADF statistic (intercept and trend are included)	Final conclusion
Bulgaria–Romania	-1.351395	-0.034982	Reject the hypothesis of unit root
Poland–Hungary	0.708173	-3.560869	Do not reject the hypothesis of unit root
Poland–Croatia	-0.540680	-2.223739	Do not reject the hypothesis of unit root
Hungary–Croatia	-2.322237	-2.018181	Do not reject the hypothesis of unit root

The critical value for ADF test with intercept is –3.3350 and for the model with trend and intercept –4.1961 at the 5% level of significance.

Source: author's calculations.

The limit of this approach is that the rejection of the unit root does not necessarily suppose the convergence. A significant trend must be positive. Even if it is positive and the error is stationary, the convergence is not surely ensured because the long-run predictions of the output gap will not converge to zero. So, a relative convergence was observed in the pairs of countries like Poland–Hungary, Poland–Croatia and Hungary-Croatia. This indicates that countries like Poland, Hungary, and Croatia made efforts to increase their GDP per capita level.

Section IV. Conclusions

In this research, we have checked if there is a convergence in the GDP per capita for six individual economies from Central-Eastern Europe towards a common steady state level. A slow convergence was obtained only for Greece during 2003–2012, for the rest of the countries (Bulgaria, Croatia, Hungary, Poland, and Romania) the divergence being present.

However, the graphical representations suggested a convergence for Bulgaria and Romania, the assumption was proved also by the application of the Augmented Dickey Fuller unit root test. There is no evidence of convergence of each country towards Greece, this country having a specific evolution of GDP with higher values than the rest of the countries.

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