Mariusz Próchniak

Collegium of World Economy
Warsaw School of Economics

Bartosz Witkowski

Collegium of Economic Analysis
Warsaw School of Economics

Stochastic Convergence of the European Union Countries: A Conditional Approach[1]

Summary

The article is devoted to the analysis of the stochastic convergence of the EU countries to the EU15 GDP weighted average. Apart from the relatively common concept of stochastic absolute convergence, the conditional stochastic convergence is considered. In order to check for the latter, the Bayesian averaged model is used so as to attain the influence of the growth factors on the growth processes and in order to eliminate it from the series. The results indicate that only few countries converge stochastically, both in the absolute as well as in the conditional sense.

Keywords: stochastic convergence, Bayesian model averaging, absolute convergence, relative convergence

1. Introduction

Parallel to the classical definitions of convergence and methods of analysis (like β or σ convergence)[2], the concept of stochastic convergence has been theoretically and empirically developed in the literature. The range of tools available for empirical

[1] The research project has been financed by the National Science Centre in Poland (decision number DEC-2012/07/B/HS4/00367).

[2] See e.g. R.J. Barro, X. Sala-i-Martin, *Economic Growth*, The MIT Press, Cambridge–London 2003; N.G. Mankiw, D. Romer, D.N. Weil, *A Contribution to the Empirics of Economic Growth*, "Quarterly Journal of Economics" 1992, vol. 107, pp. 407–437.

analysis of stochastic convergence has rapidly increased with the gradual development of panel data based stationarity tests. The idea of stochastic convergence, dating from the early 1990 s and described fully by e.g. Bernard and Durlauf[3], is based on time series approach rather than – as in the case of β convergence – cross section. Contrary to the β-convergence-type thinking in which it is the current situation and the recent influence of the lagged GDP on current growth, in the case of stochastic convergence it is the expected value of future differences between the GDP levels in different countries that are taken into account. In the case of stochastic convergence, the basic concept is to expect the difference between the level of GDP per capita to be zero in the infinite time horizon. Although all the concepts of convergence are interrelated, they should be tested separately and treated as complementary rather than substitutive since the results of the analyses need not be the same[4].

The analysis covers 28 European Union countries (EU28) over the 1994–2013 period. We examine the stochastic convergence of the individual EU countries toward the EU15 weighted average of the GDP per capita. A new element of our analysis is the extension of the classical concept of stochastic convergence. The stochastic convergence, implying that GDP differences against the group average diminish over time, is called the absolute stochastic convergence. However, as in the case of β convergence, we extend this approach for conditional convergence which reflects the belief that there are numerous factors of economic growth and it is unreasonable to assume that all the countries tend to the same steady state in view of the fact that different countries are characterized by different levels of particular growth factors. Thus we adjust the GDP time series by eliminating the impact of selected economic growth determinants. The analysis of stochastic convergence on the adjusted-GDP time series is the core of the concept of stochastic conditional convergence, also described by Próchniak and Witkowski[5]. ADF tests are used to test for stationarity of the series of differences between the GDP of a considered country and (weighted) mean GDP of the considered group of countries (as in Bernard and Durlauf[6]) – stationarity of the series of such differences is the proof of stochastic absolute convergence of the given country to the EU15 group

---

3 A.B. Bernard, S.N. Durlauf, *Convergence in International Output*, "Journal of Applied Econometrics" 1995, vol. 10, pp. 97–108.

4 For example, Bernard and Durlauf (A.B. Bernard, S.N. Durlauf, *Interpreting Tests of the Convergence Hypothesis*, "Journal of Econometrics" 1996, vol. 71, pp. 161–173) argue that time series tests are based on a stricter notion of convergence than the cross-section tests; hence, under certain assumptions, the cross-section tests can spuriously reject a no-convergence hypothesis while time-series tests do not.

5 M. Próchniak, B. Witkowski, *On the Use of Panel Stationarity Tests in Convergence Analysis: Empirical Evidence for the EU Countries*, Institute of Economic Research and Polish Economic Society Branch in Toruń, Institute of Economic Research Working Papers no. 90/2015.

6 A.B. Bernard, S.N. Durlauf, *Convergence*…, op.cit.

average level. The GDP series might though not converge due to serious diverging trends caused by different values of GDP growth factors in different countries. That is why we follow by checking the existence of conditional stochastic convergence by first estimating a panel-data-based convergence equation. We use the estimates of parameters on the growth factors to eliminate their influence from the GDP growths of different countries and follow by reconstructing the GDP level series, applying the *ceteris paribus* rule with regard to the considered growth factors. We then repeat the above mentioned procedures of Bernard and Durlauf with the series from which the influence of the growth factors has been eliminated[7].

The literature includes plenty of empirical studies on β and σ convergence (e.g. Abreu et al.[8] found an enormous number of 1650 empirical articles on convergence while Matkowski et al.[9] present a wide review of empirical studies on convergence for the EU countries, and Goczek[10] presents a review of econometric methods used in such analyses). However, the analyses in which stochastic convergence is tested appear less frequently. The studies in which stochastic convergence (in different operational form) with the use of time-series techniques was examined for various groups of countries include among others: Pesaran[11] for more than 100 countries of the world; Cuñado and Pérez de Gracia[12] for African countries; Bernard and Durlauf[13] and Christopoulos and León-Ledesma[14] for the OECD countries; Cunado[15] for the OPEC countries; Evans and Kim[16] for the Asian countries. Stochastic convergence was also examined in the

---

7 In the earlier study (M. Próchniak, B. Witkowski, *On the Use of Panel…*, op.cit.), we also analyzed a different approach of stochastic convergence by testing stationarity of the series of GDP gaps in each possible pair of countries, in line with the method adopted by Pesaran (M.H. Pesaran, *A Pair-wise Approach to Testing for Output and Growth Convergence*, "Journal of Econometrics" 2007, vol. 138, pp. 312–355).

8 M. Abreu, H. de Groot, R. Florax, *A Meta-Analysis of β-Convergence: The Legendary 2%*, "Journal of Economic Surveys" 2005, vol. 19, pp. 389–420.

9 Z. Matkowski, M. Próchniak, R. Rapacki, *Nowe i stare kraje Unii Europejskiej: konwergencja czy dywergencja?*, "Prace i Materiały" Instytutu Rozwoju Gospodarczego SGH, z. 91, Warszawa 2013, pp. 63–98.

10 Ł. Goczek, *Metody ekonometryczne w modelach wzrostu gospodarczego*, „Gospodarka Narodowa" 2012, nr 10, pp. 49–71.

11 M.H. Pesaran, op.cit.

12 J. Cuñado, F. Pérez de Gracia, *Real Convergence in Africa in the Second-half of the 20th Century*, "Journal of Economics and Business" 2006, vol. 58, pp. 153–167.

13 A.B. Bernard, S.N. Durlauf, *Convergence…*, op.cit.

14 D.K. Christopoulos, M.A. León-Ledesma, *Time-series Output Convergence Tests and Stationary Covariates*, "Economics Letters" 2008, vol. 101, pp. 297–299.

15 J. Cunado, *Structural Breaks and Real Convergence in OPEC Countries*, "Journal of Applied Economics" 2011, vol. 14, pp. 101–117.

16 P. Evans, J.U. Kim, *Stochastic Convergence of the Catch-up Rate and Multiple Structural Breaks in Asian Countries*, "Economics Letters" 2011, vol. 111, pp. 260–263.

regional context by: Kane[17] for the U.S. regions; Lau[18] for Chinese regions; and Le Pen[19] for European regions.

The paper is composed of four sections. The next section discusses the research methodology by presenting the concept of absolute and conditional stochastic convergence, and describes the data used. The further section presents and discusses the results. The last section concludes.

2. Methodology of the research

The stochastic convergence was defined in the literature in early 90's of 20th century. Following, for example, Bernard and Durlauf[20] one can state the following. Let $lnGDP_{i,t}$ represent the logarithm of the GDP of country *i* in period (year) *t*. Then countries *i* and *j* converge stochastically if

$$\lim_{k\to\infty}\left(lnGDP_{i,t+k} - lnGDP_{j,t+k} \mid I_t\right) = 0, \quad (1)$$

where I_t represents the set of information available at time *t*, and the $lnGDP_{i,t}$ is the natural logarithm of the *i*th country's GDP per capita (at purchasing power parity at constant US$) in year *t*. The econometric way to see and test for the above is to notice that for the formula (1) to be fulfilled, a cointegrating vector [1, –1] is required for the series $lnGDP_{i,t}$ and $lnGDP_{j,t}$. Thus testing for convergence in the bivariate case of countries *i* and *j* requires computing the gap series

$$dGDP_{ij,t} = lnGDP_{i,t} - lnGDP_{j,t} \quad (2)$$

and testing for the stationarity of the $dGDP_{ij,t}$ series. Usually a variation of the ADF test would be used here, though Pesaran[21] among others discusses also the KPSS-type tests as the power of ADF tests is questionable especially in the case of short series.

[17] R. Kane, *Investigating Convergence of the U.S. Regions: A Time-Series Analysis*, U.S. Department of Commerce, Bureau of Economic Analysis Working Paper no. 2001-02.

[18] C.K.M. Lau, *New Evidence about Regional Income Divergence in China*, "China Economic Review" 2010, vol. 21, pp. 293–309.

[19] Y. Le Pen, *A Pair-wise Approach to Output Convergence between European Regions*, "Economic Modelling" 2011, vol. 28, pp. 955–964.

[20] A.B. Bernard, S.N. Durlauf, *Convergence…*, op.cit.

[21] M.H. Pesaran, op.cit.

The natural extension to the group of $N > 2$ countries is to test for convergence replacing the series of gaps between two countries output (2) with the series of gap between the $lnGDP_{i,t}$ and its mean in a group of considered countries:

$$dGDP_{i,t} = lnGDP_{i,t} - \overline{lnGDP_t} \,. \tag{3}$$

Again, a popular approach is to test for stationarity of $dGDP_{i,t}$ with a variation of ADF test.

Our own study[22] referred to the issue of the absolute versus relative stochastic convergence in the group of the EU countries. In this paper, we analyze the convergence of the group of the 28 EU countries, treating the weighted EU15 per capita income level as the reference point, on the basis of the annual series of data that start in 1994 and finish in 2013. An ADF test is used with a single lag in each of the equations (we check that it is sufficient to eliminate the – in most cases slight – autocorrelation of $dGDP_{ij,t}$ and $dGDP_{i,t}$ respectively). However, we modify the approach of Bernard and Durlauf (and most others) since we are interested in the convergence of particular EU countries (mostly the "new" EU countries, that is – the 13 recent EU countries) to the old EU15. Thus the $\overline{lnGDP_t}$ in (3) represents the population weighted average EU15 logarithm of GDP. The weights used to construct the $\overline{lnGDP_t}$ vary from one year to another, reflecting a varying number of population of the individual countries.

In the analyses of the β convergence it is common to consider two types of it: the absolute and the conditional convergence. We use a similar approach in the field of stochastic convergence. There is a possibility that the series of $lnGDP$ of certain country would not be converging due to other than autonomous reasons, such as i.e. highly supportive (or highly discouraging) government policy which makes the country flourish (or get into recession) thus preventing convergence which otherwise would take place. In order to overcome this issue we propose analyzing the convergence of the series of adjusted $lnGDP$. The proper correction that should be applied consists in eliminating the influence of the (non-homogeneous across countries) growth factors that distort the series. However, it is subjective which of the growth factors do and which of them do not play a role and what is their strength of influence. It could be attained from the parallel beta-convergence equation, however, depending on the set of control variables in the Barro beta-convergence regression, the results would differ – sometimes even very strongly. In order to overcome this issue, we apply Bayesian Model Averaging (BMA) to assess the influence of the considered growth factors without the

[22] M. Próchniak, B. Witkowski, *On the Use of Panel…*, op.cit.

necessity to preselect the growth factor independent variables. The whole procedure that we suggest is the following.

As the first step, we apply BMA algorithm to estimate a Barro-type model of GDP convergence as in Próchniak and Witkowski[23]. The functional form of the estimated model is

$$\Delta lnGDP_{it} = \alpha_i + \beta_0 lnGDP_{i,t-1} + x_{it}^{'}\beta + \varepsilon_{it}, \tag{4}$$

where α_i is the individual effect of *i*-th country, β_0 is the β-convergence parameter, x_{it} is the vector of the growth factors while β is the vector that covers their influence on the GDP growth and finally ε_{it} represents the error term. The model itself is estimated as such while cross-sectional data are used, while a minor transformation is applied in the case of panel-data-based analysis, as described, for instance, in the paper by Próchniak and Witkowski[24]. As in the Frequentist Model Averaging (FMA) logic, we use the pseudo-*t* statistic in order to eliminate the variable (s) whose influence on the rate of growth is not supported by the data and average the estimates of parameters on the remaining variables. Since in this paper the convergence of the EU28 group is considered in the 1994–2013 period, we thus have a panel with annual observations and the Blundell and Bond's system GMM estimator is used (Blundell and Bond[25]).

Given the economic sense and data availability, the following variables are considered as economic growth determinants: (1) log of lagged GDP per capita (at purchasing power parity at constant US$); (2) inflation rate (*infl*); (3) investment rate (*inv*); (4) openness rate ((exports + imports)/GDP) (*open*); (5) general government consumption expenditure (% of GDP) (*gov_cons*); (6) the share of population ages 15–64 (*pop_15_64*); (7) population growth (*pop_gr*); (8) log of fertility rate (births per woman) (*fert*); (9) log of life expectancy at birth (*life*); (10) current account balance (% of GDP) (*cab*). However, the *cab* variable is eliminated in the FMA process and only the remaining variables are left.

The choice of control variables is based on our earlier studies on β convergence and economic growth determinants. The set of variables includes typical and – as most studies prove – relevant factors of economic growth, but of course not all the possible

---

[23] M. Próchniak, B. Witkowski, *Time Stability of the Beta Convergence among EU Countries: Bayesian Model Averaging Perspective*, "Economic Modelling" 2013, vol. 30, pp. 322–333.

[24] M. Próchniak, B. Witkowski, *On the Stability of the Catching-Up Process among Old and New EU Member States. Implications from Bayesian Model Averaging*, "Eastern European Economics" 2014, vol. 52, pp. 5–27.

[25] R. Blundell, S. Bond, *Initial Conditions and Moment Restrictions in Dynamic Panel Data Models*, "Journal of Econometrics" 1998, vol. 87, pp. 115–143.

ones. The variables that represent population aspects – mainly responsible for human capital – (*fert*, *pop_gr*, *pop_15_64*, *life*) are treated as exogenous while all the remaining are allowed to be endogeneous, which is based on the economic knowledge and/or intuition in this manner: the variables assumed to be exogeneous are not likely to be dependent on the economic growth in short time horizon themselves, which is why we do not decrease efficiency of the estimator by allowing their endogeneity.

Once the model (4) is estimated, the Bayesian averaged values of $\hat{\beta}$ are attained (these are attained as in Próchniak and Witkowski[26]). In the second step, the vector of $\Delta lnGDP_{it}$ for each $i = 1,\ldots,N$ can be modified so as to constitute

$$\widetilde{\Delta lnGDP_{it}} = \Delta lnGDP_{it} - (x_{it}' - \overline{x}_{.t}')\hat{\beta}, \tag{5}$$

where the $\overline{x}_{.t}$ represent average values of all the considered growth factors throughout the sample in period *t*. In the third step, the modified $lnGDP$ series are created for each of the considered countries. In each of the cases, the modified series is defined as

$$\widetilde{lnGDP_{it}} = \begin{cases} lnGDP_{it} & t = 1 \\ \widetilde{lnGDP_{i,t-1}} + \Delta lnGDP_{it} & t = 2,\ldots,T. \end{cases} \tag{6}$$

In the last step we apply the same ADF test with a single lag as applied to series (3) in order to test for stationarity of the series of

$$d\widetilde{GDP}_{i,t} = ln\widetilde{GDP}_{i,t} - \overline{ln\widetilde{GDP}_{t}}. \tag{7}$$

Rejecting the null hypothesis of non-stationarity of the series (7) would suggest that the considered economies converge stochastically in the conditional sense, while the stronger case of rejection the non-stationarity hypothesis of (3) would suggest the existence of absolute stochastic convergence. The empirical results of the above described procedures are given in the next section.

3. Empirical results

The results of the analysis are presented in Tables 1–2 and Figure 1. Table 1 refers to both absolute and relative stochastic convergence. It displays *p*-values in testing the

[26] M. Próchniak, B. Witkowski, *Time Stability*…, op.cit.

hypothesis regarding the staionarity of the differences between GDP per capita of the individual country and the weighted EU15 average GDP per capita level. Series (3) is used to test for the absolute stochastic convergence while series (7) is used to test for the relative one. According to the null hypothesis in the ADF test the considered series is non-stationary; hence, the stochastic convergence occurs when the null hypothesis is rejected – in the analysis we arbitrarily use the 0.1 significance level.

The results of testing the absolute stochastic convergence are given in the second column of Table 1. It turns out that the studied countries did not reveal – in general – very strong stochastic convergence tendencies. As regards absolute convergence, only three countries converged toward the EU15 average income level: Finland, Ireland, and Netherlands (*p*-values are equal to 0.0990, 0.0469, and 0.0673 respectively). For the other 25 countries, the null hypothesis in the stationarity test cannot be rejected at the 10% significance level. In the case of Finland, Ireland and Netherlands, the null hypothesis was rejected, meaning that the deviations of these three countries' GDP from the weighted average EU15 per capita income are stationary, which confirms the existence of convergence.

The appearance of stochastic absolute convergence for Netherlands and Ireland may be caused, on the one hand, by the fact that they are relatively small open economies, influenced by a lot of external factors. Finland also fits to these characteristics. As the result, these countries exhibited stochastic convergence toward the average GDP per capita in the EU15 group, as it is the EU15 economies that might influence them mostly, considering their openness.

Obviously to some extent the fact that the converging countries are Western European economies may result from the fact that the convergence is tested toward the weighted average income of the EU15 group. In the case of an unweighted average, each country has the same contribution in influencing the group's average. In contrast, in the case of a weighted average, main contributors to the reference value are big Western European countries, mainly Germany, France, and the UK. It is likely that the behavior of some other smaller Western European economies will be similar to that of the biggest Western European countries, confirming the existence of convergence.

The latter finding is reinforced when comparing *p*-values for Western and Central-Eastern European countries, given in the second column of Table 1. In general, *p*-values for Western European countries are lower than those for Central and Eastern European (CEE) countries meaning that the former economies are more likely to catch up stochastically toward the EU15 GDP per capita level.

Table 1. Stochastic convergence of the individual EU countries toward the EU15 weighted GDP per capita

Country	Absolute stochastic convergence	Conditional stochastic convergence
Austria	0.9955	0.5543
Belgium	0.4701	0.9312
Bulgaria	0.8601	0.9918
Croatia	0.6298	0.9687
Cyprus	0.9828	0.7667
Czech Republic	0.8173	0.7315
Denmark	0.5177	0.8375
Estonia	0.4819	0.9830
Finland	0.0990*	0.0029*
France	0.2544	0.0250*
Germany	0.7451	0.0028*
Greece	0.3675	0.9939
Hungary	0.7331	0.6930
Ireland	0.0469*	0.2518
Italy	0.9877	0.9958
Latvia	0.6758	0.9718
Lithuania	0.9062	0.6422
Luxembourg	0.2152	1.0000
Malta	0.9164	0.5148
Netherlands	0.0673*	0.4935
Poland	0.9504	0.6626
Portugal	0.5706	0.7521
Romania	0.8548	0.9040
Slovakia	0.9394	0.0000*
Slovenia	0.4254	0.9780
Spain	0.5465	0.8050
Sweden	0.9591	0.7545
United Kingdom	0.3423	0.9968

A star (*) means a confirmation of convergence – a rejection (at a 10-percent significance level) of the null hypothesis in the ADF test with a single lag and a constant.

Source: own calculations.

Figure 1 shows a graphical representation of selected results. It displays deviations of a given country's GDP per capita against the weighted EU15 average. The countries displayed on the figure are only those which were converging in absolute terms, namely Finland, Ireland, and Netherlands.

The figure demonstrates that in these three cases GDP deviations are stationary or trend-stationary. GDP differences between a given country and the group's average tend to diminish, confirming the existence of stochastic convergence. The most evident is the situation of Ireland where GDP deviations were relatively large prior to the global crisis and after that they clearly diminished.

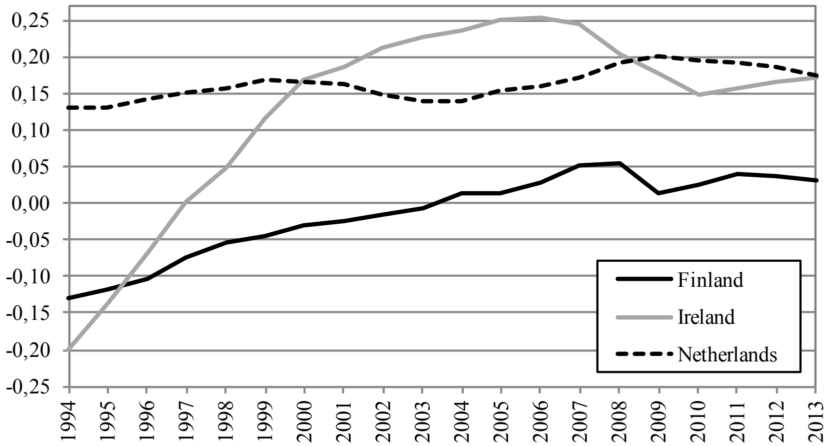

Figure 1. Deviations of GDP per capita between the three converging EU countries (in absolute terms) and the weighted EU15 average

Source: own calculations.

Looking at the results of the absolute stochastic convergence some questions arise. Firstly, why Finland, Ireland, and Netherlands are the only countries that exhibited stochastic convergence toward the EU15 average per capita income level? Secondly, why was convergence not evidenced in the case of Central and Eastern European countries which should catch up due to the so-called "integration anchor" and further EU accession? To address these questions, it is worth to extend the analysis for conditional convergence.

Cross-sectional studies on β convergence indicate that absolute convergence does not show the full picture of economic growth paths of the examined countries. The main argument is that the countries tend to different steady-states because the process of economic growth is multidimensional and there are numerous factors affecting the rate of growth that need not be equally distributed among the considered countries. It is thus worth to verify the idea of conditional stochastic convergence, introduced by Próchniak and Witkowski[27].

In the case of stochastic conditional convergence, we adjust the GDP time series for each country from the impact of the given country's economic growth determinants.

[27] M. Próchniak, B. Witkowski, *On the Use of Panel…*, op.cit.

The adjustment is made based on the empirical model of economic growth. Initially, as described in the previous section, nine variables were considered as economic growth determinants (and the initial GDP per capita level being the 10th variable). After applying the BMA approach, one variable (current account balance) was eliminated due to statistical insignificance (basing on the pseudo *t*-statistics). As a result, the final model of economic growth encompasses 9 explanatory variables (including lagged GDP).

Table 2 shows the estimation results of the final model of economic growth obtained based on the BMA procedure, which is used to adjust GDP per capita time series for the analysis of conditional stochastic convergence. Individual regression equations constituting (after averaging) the model given in Table 2 are estimated with the use of the Blundell and Bond[28] GMM system estimator with the volume of GDP per capita in the current period being the explained variable.

Table 2. The Bayesian Model Averaging estimates used to adjust GDP growth rates for the stochastic conditional convergence*

Regressor	Estimated coefficient	Standard error	Pseudo t-statistics
Lagged GDP per capita	0.9654	0.0059	186.23
infl	–0.0001	0.0000	–6.32
inv	0.0060	0.0003	20.52
open	0.0002	0.0000	6.77
gov_cons	–0.0034	0.0005	–6.08
pop_15_64	–0.0043	0.0010	–4.57
pop_gr	–0.0078	0.0016	–5.02
fert	–0.0434	0.0150	–2.95
life	–0.2012	0.0727	–2.59
Variables excluded due to statistical insignificance (small pseudo t)			
cab	0.0001	0.0003	–0.73

Dependent variable: GDP per capita in the current period. Estimator: Blundell and Bond GMM system estimator. * Lagged GDP is introduced in order to avoid the omitted variable bias in view of the existence of the beta convergence, but it is not used to adjust the GDP growth series as it is not a growth factor by itself.

Source: own calculations.

The model is generally correct from the economic and statistical point of view. All the variables used to adjust GDP time series are statistically significant on any reasonable significance level. The coefficient standing on lagged GDP per capita is less than 1 meaning that in the standard untransformed economic growth model with the change in output as the dependent variable, the coefficient on initial income would be

[28] R. Blundell, S. Bond, op.cit.

less than zero. Hence, the model confirms the existence of cross-sectional conditional β convergence (i.e. a negative relationship between the initial income level and the subsequent growth rate). Investments and trade openness are the variables that have a positive impact on GDP growth while inflation, government consumption, population growth, and fertility rate have a negative impact on the dynamics of output. These results are in line with the theoretical structural model. In the case of both the share of population aging 15–64 and life expectancy, the estimated coefficients are negative and this outcome has weaker economic background.

The results of testing conditional stochastic convergence hypothesis are presented in the last column of Table 1. As in the case of absolute convergence, *p*-values less than 0.1 indicate the rejection of null hypothesis, confirmining the existence of convergence.

The results indicate that four countries converged conditionally toward the EU15 average, namely: Finland, France, Germany, and Slovakia. As compared with the results of absolute convergence, the list of countries has slightly changed. In conditional terms, the converging countries are both small countries (like Finland and the Slovak Republic) and also biggest EU economies (France and Germany). In the case of Germany and France, the results can be easily explained. As these are the countries that highly contribute to the EU15 weighted average income level, they also reveal a high degree of convergence toward the EU15 average and those – *ceteris paribus* – are the main contributors to the global EU tendencies. It is worth noting that in contrast to the absolute convergence, in the case of conditional convergence the CEE countries do not display generally poorer outcomes in terms of *p*-value. It can be interpreted as the fact that the considered group of countries is not fully homogenous and after controlling for some growth factors the results become different than in the case of absolute convergence.

In summation, our findings give new light on the catching-up process of the EU countries and should be treated as complementary to the other studies on convergence, based on different concepts and methods. Namely, while most cross-sectional studies on β and σ convergence confirm the existence of the catching-up process inside the enlarged European Union, in the case of stochastic convergence the results are less evident.

This difference constitutes the value added of this analysis and can be explained as follows. On the one hand, the lack of stochastic convergence toward the EU15 average income may result from the fact that the EU group's average GDP is created by a number of countries which are homogenous in the long-run perspective but in the short run they may reveal different economic growth paths. Hence, due to a differentiated influence of EU members on the current pace of economic growth of the whole group, the average GDP per capita for the EU15 group does not match well that for the individual countries. On the other hand, the lack of stochastic convergence may result from the fact that the individual countries tend toward the best performers (like

Luxembourg) or the biggest individual economies (like France, Germany, Italy, or UK) and not toward the EU15 average. Still, stochastic convergence is not as strong as the "traditional" β and σ convergence. Even if we extend the analysis to examine conditional stochastic convergence (the original approach proposed by the authors of this study), the number of converging economies rises but not as much as it could be expected from the cross-sectional studies. These results also confirm the theoretical Bernard's and Durlauf's[29] view that time series tests are based on a stricter notion of convergence than cross-section tests and one should bare in mind that the current state of the art – as viewed in the case of the β and σ convergence analyses – need not be the clear indication of the infinite future, at least theoretically considered in the stochastic convergence approach.

4. Conclusions

In this paper, the concept of stochastic convergence of the individual EU28 countries toward the weighted average GDP per capita level of the EU15 group is examined. The study covers the 1994–2013 period. The stochastic convergence means that the expected value of future differences between the GDP per capita levels in a given country and the reference group of EU15 is zero in the infinite time horizon. Additionally to the standard Bernard's and Durlauf's[30] approach, we introduce our own concept of conditional stochastic convergence which is based on adjusted GDP per capita series to account the impact of the other growth factors on GDP. ADF tests are used to test for stationarity of the series of differences between the GDP of a considered country and mean GDP of the EU15 group.

The study demonstrates that the process of stochastic convergence in the EU28 countries is not so widespread as the cross-sectional studies on β or σ convergence indicate. Even if we extend the analysis to examine conditional stochastic convergence, the number of converging economies toward the EU15 group's weighted mean GDP per capita is small (4 countries). This is still not as much as it could be expected from the cross-sectional studies.

Nevertheless, this analysis gives new insights into the nature of economic growth paths of the examined countries. The results indicate that our concept of conditional stochastic convergence is a good idea because it shows a broader picture of economic

29 A.B. Bernard, S.N. Durlauf, *Interpreting Tests*…, op.cit.

30 A.B. Bernard, S.N. Durlauf, *Convergence*…, op.cit.

growth tendencies than the absolute convergence hypothesis and it has been worth to examine it. However, the methods of analyzing conditional stochastic convergence require further theoretical developments and empirical applications to check the robustness of the results.

References

Abreu M., de Groot H., Florax R., *A Meta-Analysis of β-Convergence: The Legendary 2%*, "Journal of Economic Surveys" 2005, vol. 19, pp. 389–420.

Barro R.J., Sala-i-Martin X., *Economic Growth*, The MIT Press, Cambridge–London 2003.

Bernard A.B., Durlauf S.N., *Convergence in International Output*, "Journal of Applied Econometrics" 1995, vol. 10, pp. 97–108.

Bernard A.B., Durlauf S.N., *Interpreting Tests of the Convergence Hypothesis*, "Journal of Econometrics" 1996, vol. 71, pp. 161–173.

Blundell R., Bond S., *Initial Conditions and Moment Restrictions in Dynamic Panel Data Models*, "Journal of Econometrics" 1998, vol. 87, pp. 115–143.

Christopoulos D.K., León-Ledesma M.A., *Time-series Output Convergence Tests and Stationary Covariates*, "Economics Letters" 2008, vol. 101, pp. 297–299.

Cunado J., *Structural Breaks and Real Convergence in OPEC Countries*, "Journal of Applied Economics" 2011, vol. 14, pp. 101–117.

Cuñado J., Pérez de Gracia F., *Real Convergence in Africa in the Second-half of the 20th Century*, "Journal of Economics and Business" 2006, vol. 58, pp. 153–167.

Evans P., Kim J.U., *Stochastic Convergence of the Catch-up Rate and Multiple Structural Breaks in Asian Countries*, "Economics Letters" 2011, vol. 111, pp. 260–263.

Goczek Ł., *Metody ekonometryczne w modelach wzrostu gospodarczego*, „Gospodarka Narodowa" 2012, nr 10, pp. 49–71.

Kane R., *Investigating Convergence of the U.S. Regions: A Time-Series Analysis*, U.S. Department of Commerce, Bureau of Economic Analysis Working Paper no. 2001-02.

Lau C.K.M., *New Evidence about Regional Income Divergence in China*, "China Economic Review" 2010, vol. 21, pp. 293–309.

Le Pen Y., *A Pair-wise Approach to Output Convergence between European Regions*, "Economic Modelling" 2011, vol. 28, pp. 955–964.

Mankiw N.G., Romer D., Weil D.N., *A Contribution to the Empirics of Economic Growth*, "Quarterly Journal of Economics" 1992, vol. 107, pp. 407–437.

Matkowski Z., Próchniak M., Rapacki R., *Nowe i stare kraje Unii Europejskiej: konwergencja czy dywergencja?*, "Prace i Materiały" Instytutu Rozwoju Gospodarczego SGH, vol. 91, Warszawa 2013, pp. 63–98.

Pesaran M.H., *A Pair-wise Approach to Testing for Output and Growth Convergence*, "Journal of Econometrics" 2007, vol. 138, pp. 312–355.

Próchniak M., Witkowski B., *On the Stability of the Catching-Up Process among Old and New EU Member States. Implications from Bayesian Model Averaging*, "Eastern European Economics" 2014, vol. 52, pp. 5–27.

Próchniak M., Witkowski B., *On the Use of Panel Stationarity Tests in Convergence Analysis: Empirical Evidence for the EU Countries*, Institute of Economic Research and Polish Economic Society Branch in Toruń, Institute of Economic Research Working Papers no. 90/2015.

Próchniak M., Witkowski B., *Time Stability of the Beta Convergence among EU Countries: Bayesian Model Averaging Perspective*, "Economic Modelling" 2013, vol. 30, pp. 322–333.

* * *

Konwergencja stochastyczna krajów Unii Europejskiej – podejście warunkowe

Streszczenie

Artykuł jest poświęcony analizie występowania konwergencji stochastycznej krajów Unii Europejskiej do średniej ważonej w grupie krajów UE15. Zostało zbadane występowanie nie tylko konwergencji absolutnej, ale także konwergencji warunkowej. W przypadku analizy konwergencji warunkowej wykorzystano procedurę uśredniania bayesowskiego w celu określenia wpływu poszczególnych czynników wzrostu na faktyczne PKB, a następnie – oczyszczenia szeregów PKB z wpływu tych czynników. Wyniki sugerują, że konwergencja stochastyczna – tak absolutna, jak i względna – występuje w relatywnie nielicznych przypadkach.

Słowa kluczowe: konwergencja stochastyczna, uśrednianie bayesowskie, konwergencja absolutna, konwergencja względna

JEL: C22, C23, O47, O52

Zgodnie z oświadczeniem autorów, ich udział w powstawaniu artykuły był następujący: Mariusz Próchniak – 50%, Bartosz Witkowski – 50%.