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The legendary 2% convergence parameter: flexible or fixed?[1]

Summary

The study analyzes the time stability of the beta convergence coefficient for the EU28 countries over the 1992–2012 period which is divided into seventeen 5-year overlapping subperiods. The basic convergence model is estimated with the use of GMM system estimator and a variety of control variables which are typical growth factors. It turns out that the average value of β-coefficient is 6.10% which indicates quite a rapid pace of convergence. However, it is not appropriate to claim about a constant rate of convergence over time among the EU countries as β-parameter was changing over time. After some trough in the second half of the 1990s, it was observed a gradual acceleration of the pace of the catching-up process in the 2000s and 2010s.

Keywords: economic growth, convergence, catching-up, European Union, GMM

1. Introduction

The hypothesis of β-convergence has been widely verified in the literature by numerous empirical studies[2] made a review of empirical studies on convergence

[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. 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.

published in English in journals listed in the EconLit database and found an enormous number of 1650 articles devoted to this topic). The common conclusion from empirical evidence is a varying pace of convergence for different countries and regions and that is why the studies focused on club convergence at a regional or national level appear more frequently in the literature[3].

Fewer studies refer to the problem whether the convergence parameter is constant or varying over time for the given group of countries. The assumption of the constancy of convergence parameter over time is made in most of the models, but this assumption should be examined in greater detail. Macroeconomic, political and institutional environment for all the countries of the world varies from one year to another (sometimes very rapidly) and the pure speed of convergence is unlikely to be constant over time. The studies in which time stability of the convergence parameter is verified and the structural breaks are introduced appear quite rarely in the literature. For example, Crespo Cuaresma, Havettová, Lábaj[4] analyze unconditional convergence among EU28 countries during 1995–2009 based on cross-sectional data and find that the speed of income convergence was highest in the period 2000–2005. Serranito[5] uses a model with endogenous breaks for the analysis of convergence of 8 MENA (Middle East and North Africa) countries towards the European per capita income level during 1960–2008 finding that the process of β-convergence is not constant over time and that periods of divergence outnumber periods of convergence.

This paper tries to fill the literature gap by adding new insights into the problem of the stability of the catching-up process. The main research hypothesis refers to the analysis of stability of the β-convergence coefficient over time. The parameter that measures the speed of the catching-up process is allowed not to

[3] See e.g. M. Bartkowska, A. Riedl, *Regional Convergence Clubs in Europe: Identification and Conditioning Factors*, "Economic Modelling" 2012, vol. 29, pp. 22–31; M.J. Herrerias, J. Ordoñez, *New Evidence on the Role of Regional Clusters and Convergence in China (1952–2008)*, "China Economic Review" 2012, vol. 23, pp. 1120–1133; M. Battisti, Ch.F. Parmeter, *Clustering and Polarization in the Distribution of Output: A Multivariate Perspective*, "Journal of Macroeconomics" 2013, vol. 35, pp. 144–162; M. Ghosh, A. Ghoshray, I. Malki, *Regional Divergence and Club Convergence in India*, "Economic Modelling" 2013, vol. 30, pp. 733–742; M. Monfort, J.C. Cuestas, J. Ordóñez, *Real Convergence in Europe: A Cluster Analysis*, "Economic Modelling" 2013, vol. 33, pp. 689–694.

[4] J. Crespo Cuaresma, M. Havettová, M. Lábaj, *Income Convergence Prospects in Europe: Assessing the Role of Human Capital Dynamics*, "Economic Systems" 2013, vol. 37, pp. 493–507.

[5] F. Serranito, *Heterogeneous Technology and the Technological Catching-up Hypothesis: Theory and Assessment in the Case of MENA Countries*, "Economic Modelling" 2013, vol. 30, pp. 685–697.

be constant over time. The econometric model is then estimated to verify this view.

The analyzed sample consists of 28 current European Union member countries (EU28). The analysis covers the 1992–2012 period, converted into 5-year overlapping observations.

The paper is composed of four sections. Econometric methodology and the data both are described in section 2. Section 3 presents and discusses the results. Section 4 concludes.

2. The empirical method and the data

A wide variety of panel data-based research on GDP convergence implies a large number of different methods of the analysis although these can basically be divided into a few main categories. Most authors as a starting point make use of Barro regression:

$$\Delta \ln GDP_{it} = \beta_0 + \beta_1 \ln GDP_{i,t-1} + x'_{it}\gamma + \alpha_i + \varepsilon_{it}, \tag{1}$$

where $\Delta \ln GDP_{it}$ is the change of log GDP for i-th country over t-th period, β_0 is the constant, $\Delta \ln GDP_{i,t-1}$ is the one period lagged log GDP, x_{it} is a vector of the considered growth factors for i-th country over t-th period (β is the associated coefficient), α_i is the individual effect of the i-th country and ε_{it} is the error term. Convergence exists if β_1 is statistically significantly negative. In such a case, it is possible to calculate the β-coefficient, that measures the speed of convergence, from the equation:

$$\beta = -\frac{1}{T}\ln(1+\beta_1 T), \tag{2}$$

where T is the length of a single period in (1).[6]

[6] Barro and Sala-i-Martin (R.J. Barro, X. Sala-i-Martin, *Economic Growth*, The MIT Press, Cambridge–London 2003, p. 467) analyze β convergence based on the neoclassical model and they derive the equation showing the relationship between the average annual GDP growth rate and the initial income level: $(1/T)\ln(y_{iT}/y_{i0}) = a - [(1-e^{-\beta T})/T]\ln(y_{i0}) + w_{i0,T}$, where y_{iT} and y_{i0} – GDP per capita of country i in the final and initial year, T – the length of period, β – the convergence parameter, a – a constant term, $w_{i0,T}$ – a random factor. The coefficient on initial

In very old research some authors would estimate (1) with the use of OLS – a solution which might be useful in the case where cross-sectional rather than panel data are available (but linear regression models are still used and are being expanded[7]. Slightly later a one-way fixed or random effects approach used to be popular: while random effects estimator is never recommended here due to its inconsistency in the context of the dynamics of the model, the fixed effects approach is acceptable as long as the length of the considered time series is very high and the independent variables in x_{it} can be treated as strictly exogeneous. The latter is highly questionable (and it also is required to perform consistent OLS estimation with the use of cross-section). The GMM approach is the one that most researchers would use nowadays: initially in the 1990's the Arellano and Bond[8] approach (AB hereafter) was dominating, but ever since the paper of Blundell and Bond[9] (BB hereafter) their system-GMM estimator is certainly the most popular tool. This is due to its relatively high efficiency and ability to avoid such pitfalls as massive small sample bias, which was one of the properties of the AB estimator. Indeed, high downward bias of AB resulted in a number of papers with the conclusion of surprisingly high rate of convergence published in the 1990's, which – as it is known now – was due to the downward bias of the AB estimator in small samples while the true value of autoregressive parameter was close to one[10].

The data shortage is always a serious problem when GMM is applied: that is because at least the first two waves of observations are lost since they are used only as instruments and the requirements that regard the number of observations needed for the GMM estimator to have any of its good properties are difficult to fulfill. Additionally, in the context of growth empirics, one cannot use high frequency data. That is because the phenomenon of growth should – macroeconomically – be observed in longer time horizon. Economic cycles as

income, i.e. $-[(1-e^{-\beta T})/T]$, equals β_1 in equation (1). Thus, from $\beta_1 = -[(1-e^{-\beta T})/T]$ we get (2). For a small T the regression coefficient β_1 is very similar to the convergence parameter β, because if T tends to zero the expression $(1-e^{-\beta T})/T$ approaches β.

[7] See e.g. M. Bernardelli, *Metoda szybkiej aktualizacji dekompozycji QR dla modeli liniowej regresji*, "Roczniki" Kolegium Analiz Ekonomicznych SGH, z. 27, Oficyna Wydawnicza SGH, Warszawa 2012, pp. 55–68.

[8] M. Arellano, S. Bond, *Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations*, "Review of Economic Studies" 1991, vol. 58, pp. 277–297.

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

[10] Econometric methods in economic growth models are described by Goczek: Ł. Goczek, *Przegląd i ocena ekonometrycznych metod używanych w modelach empirycznych wzrostu gospodarczego*, "Gospodarka Narodowa" 2012, t. 10, pp. 49–73.

well as coincidental shocks bring about serious distortions of short term observations. Most authors divide the time series they use into 5-year-long periods of subsequent years. That means that a period of 20 years provides just 4 observations. We propose a different strategy, already described in Próchniak and Witkowski[11]: one can divide the set of yearly panel data on different countries into 5-year-long *overlapping* observations, such that the first "period" covers, say, years 1991–1995, the second – years 1992–1996 etc. At first it seems that the same data are used many times and no additional information is thus obtained, but that is not true: each value of GDP in year t is used only twice: once as the dependent variable (in the role of GDP_t) and once as the independent variable (in the role of GDP_{t-1}). One important issue here is the problem of autocorrelation. An essential condition of consistency of the applied GMM is that there should be no form of the autocorrelation of the error term while this way of using the data makes the risk of autocorrelation very high. It must thus be checked for very carefully before proceeding anywhere further with the model.

In order to use the AB or BB estimator, (1) requires to be transformed to:

$$\ln GDP_{it} = \beta_0 + (\beta_1 + 1)\ln GDP_{i,t-1} + x'_{it}\gamma + \alpha_i + \varepsilon_{it}, \tag{3}$$

which enables finding proper instruments based on lags of the variables in the model. In most research, authors do not consider the fact that the rate of convergence can change over time: the proposed model structures usually assume stability in this respect, although, as it was mentioned in introduction, there are papers in which that is taken into account. We suggest the following approach: at first, a set of time dummies should be included in the model:

$$\ln GDP_{it} = \beta_0 + (\beta_1 + \theta_t v_t + 1)\ln GDP_{i,t-1} + x'_{it}\gamma + \alpha_i + \varepsilon_{it}, \tag{4}$$

where $(v_t, t = 1),...,T$ are the time dummies – constant for all the countries in period t while different over time, while $\theta_t, t = 1,...,T$ are the parameters standing by the respective time dummies which can be thus treated as time effects. For the purpose of estimation, equation (4) can be written with the use of interaction term as

[11] M. Próchniak, B. Witkowski, *The Analysis of the Impact of Regulatory Environment on the Pace of Economic Growth of the World Countries According to the Bayesian Model Averaging*, National Bank of Poland Working Paper no. 165, Warsaw 2013.

$$\ln GDP_{it} = \beta_0 + (\beta_1 + 1)\ln GDP_{i,t-1} + \theta_t(v_t \ln GDP_{i,t-1}) + x'_{it}\gamma + \alpha_i + \varepsilon_{it}, \quad (4a)$$

although it is the equation (4) that shows the true meaning of particular $\theta_t, t = 1,...,T$. The estimates of time effects shall reflect the time-varying but constant for all the countries deviation of the rate of convergence in the given period as compared to the overall rate of convergence. On the operational level, one solution is not to include one of the time dummies for a selected period (say, for $t = 1$) and treat it as a reference period so that the estimates of all the other time dummies should reflect the differences between the given period and the period for which the dummy was skipped.

Each of the θ_t, $t = 1,...,T$, reflects the ceteris paribus difference between the average convergence parameter in period t (understood as t-th 5-year-long time period in the data set) in all countries in the considered sample and the estimated convergence parameter for all the countries in the reference period. The estimated rate of beta convergence in period t can be then derived from the sum of convergence parameter β_1 and its temporary deviation θ_t on the basis of the equation (2). However, they are not only the shocks in the economy but also any sort of distortions in the dataset (including errors of data collection or handling) might thus have a serious influence on θ_t. Thus we suggest computing the values of the $\{\beta_1 + \theta_t\}$, $t = 1, ..., T$ series, converting those into the β-convergence parameters and then smoothing them with the use of one of the algorithms in step two – in this paper we apply double exponential smoothing for this purpose. Step three is optional and consists in finding a function of time that could be used to describe the smoothed β-convergence rate over time and replacing the set of time dummies with that function in (4). The concept behind it is both saving the degrees of freedom of the model and allowing for forecasting, which otherwise requires assuming the value of t for future periods. The appropriate function supposedly shall be cyclical, reflecting the nature of the economy, however, might be difficult or even impossible to find due to both smaller and larger shocks in the market that change the behavior of most economies and make the shape of the function difficult to predict, as well as due to the changing nature of the convergence process – in this paper the shape of the final rate of convergence curve is so untypical that we do not fit any particular curve to it.

In the main analysis, the conditional convergence hypothesis is tested. This means that the regression equation (1) should include control variables that are typical growth factors. The theory of economics is highly inconclusive here and there are a lot of variables that – from the theoretical point of view – affect GDP growth from both the demand and supply-side perspective. Hence, for

practical reasons, in any macroeconomic research the author has to reduce the set of control variables to a reasonable size, constrained inter alia by data availability. In this study, 14 variables are tested as growth factors. They are listed in Table 1. The variables chosen are those that are frequently used in the other studies on economic growth and convergence[12] and for which sufficiently large time series are available.

Table 1. Summary statistics of control variables, EU28 countries

Name	Variable description	Mean	Min.	Max.
Endogenous variables				
inv	Investment (% of GDP)	22.5	11.8	35.5
human_cap	Index of human capital[a]	2.9	2.3	3.5
edu_exp	Education expenditure (% of GNI)	5.0	2.7	8.1
gov_cons	General government consumption expenditure (% of GDP)	20.9	11.3	36.8
infl	Inflation (annual %)	8.4	0.5	283.0
cred	Annual change (in % points) of domestic credit/GDP ratio	3.5	–23.6	24.9
econfree_fi	Index of economic freedom[b]	7.2	4.0	8.4
dem_fh	Index of democracy[c]	6.7	4.5	7.0
Exogenous variables				
life	Log of life expectancy at birth (years)[d]	76.4	67.4	81.7
fert	Log of fertility rate (births per woman)[d]	1.5	1.1	2.2
pop_15_64	Population ages 15–64 (% of total)	67.5	63.8	72.3
pop_den	Log of population density (people/km^2)[d]	107	17	1296
pop_gr	Population growth (annual %)	0.3	–2.2	2.6
pop	Log of population, total[d,e]	8.3	0.4	82.5

[a] Index of human capital per person, based on years of schooling and returns to education, taken from PWT.
[b] Fraser Institute index of economic freedom, ranging from 0 = lowest to 10 = highest.
[c] Average of civil liberties and political rights according to Freedom House, converted to the scale from 1 = lowest to 7 = highest.
[d] Not logarithmized data are reported.
[e] Data reported are in million.

Source: R.C. Feenstra, R. Inklaar, M.P. Timmer, *The Next Generation of the Penn World Table*, 2013, www.ggdc.net/pwt [Penn World Table 8.0 – PWT]; World Bank, *World Development Indicators*, 2014, databank.worldbank.org; IMF, *World Economic Outlook Database October 2013*, updated: January 2014, www.imf.org; Fraser Institute, *Economic Freedom of the World*, 2014, www.freetheworld.com; Freedom House, *Freedom in the World*, 2014, www.freedomhouse.org.

[12] See e.g. R.J. Barro, X. Sala-i-Martin, op.cit.; K. Sum, *The Integration of the Financial Markets and Growth Evidence from a Global Cross-Country Analysis*, "Bank i Kredyt" 2012, nr 43, pp. 47–70.

The required methodology (system GMM) requires the variables to be divided into three subgroups: endogenous, predetermined, and strictly exogenous variables. Based on the literature review[13], institutional variables are treated as endogenous. The same applies to macroeconomic variables, while population variables are treated as exogenous.

3. Results

The results of the analysis are presented in Table 2. The basic convergence model refers to the conditional convergence hypothesis and is estimated with the use of GMM system estimator.

Table 2. GMM estimates of the convergence model for the EU28 countries

Variable	Period	Coef-ficient[a]	*p*-value[b]	Total $\beta_1 + \theta_t$ (untransformed)[a,c]	Smoothed β convergence[d]
$\Delta \ln GDP_{i,t-1}$	92–96	0.7043	0.000	–0.0591	6.02%
dummies for the respective periods θ_t	93–97	0.0038	0.000	–0.0584	6.02%
	94–98	0.0052	0.000	–0.0581	6.02%
	95–99	0.0044	0.000	–0.0583	6.02%
	96–00	0.0041	0.000	–0.0583	6.01%
	97–01	0.0037	0.044	–0.0584	6.01%
	98–02	0.0011	0.296	–0.0589	6.02%
	99–03	–0.0006	0.041	–0.0593	6.04%
	00–04	–0.0011	0.000	–0.0594	6.06%
	01–05	–0.0028	0.002	–0.0597	6.09%
	02–06	–0.0018	0.034	–0.0595	6.10%
	03–07	–0.0013	0.000	–0.0594	6.11%
	04–08	–0.0030	0.000	–0.0598	6.12%
	05–09	–0.0120	0.000	–0.0616	6.17%
	06–10	–0.0128	0.000	–0.0617	6.22%
	07–11	–0.0142	0.000	–0.0620	6.27%
	08–12	–0.0168	0.020	–0.0625	6.32%

[13] See e.g. D. Acemoglu, S. Johnson, J.A. Robinson, *The Colonial Origins of Comparative Development: An Empirical Investigation,* "American Economic Review" 2001, vol. 91, pp. 1369–1401.

Variable	Period	Coef-ficient[a]	*p*-value[b]	Total $\beta_1 + \theta_t$ (untransformed)[a,c]	Smoothed β convergence[d]
inv		0.0033	0.000	Average beta	6.10%
human_cap		0.1328	0.417		
edu_exp		–0.0145	0.000		
gov_cons		–0.0005	0.000		
infl		–0.0005	0.000		
cred		0.0014	0.000		
econfree_fi		0.0887	0.000		
dem_fh		0.0491	0.000		
life		1.2312	0.000		
fert		0.0608	0.005		
pop_15_64		–0.0024	0.000		
pop_den		–0.0044	0.000		
pop_gr		–0.0261	0.000		
pop		–0.0099	0.000		
Constant		–3.2699	0.000		

[a] The 1992–1996 is treated as the reference period, hence the respective θ_t for that period is treated as equal to zero.
[b] For the initial period the *p*-value refers to the $\ln GDP_{i,t-1}$, while for the other periods – to the respective θ_t.
[c] Calculated as [the coefficient for $\ln GDP_{i,t-1}$ plus the respective θ_t given in the 3rd column minus 1] divided by 5.
[d] Obtained by replacing the β_1 with the estimate of $\beta_1 + \theta_t$ in equation (2), computing the β in (2) with $T = 1$ (to be in accordance with equation (2) and footnote 4), and smoothing it with double exponential algorithm; AB test of autocorrelation of order 2: *p*-value = 0.1385.

Source: own calculations.

The results first demonstrate that the EU28 countries grew in line with the conditional convergence hypothesis. For the 1992–2012 period as a whole, the average convergence coefficient amounted to 6.10%. This result points to a more rapid pace of income level equalization observed in the enlarged European Union as compared to a 2% rate, widely-cited in the literature. This effect comes from two basic reasons. First, from the economic point of view, a more rapid pace of catching-up process is a consequence of the institutional framework of the countries under study. Economic policy performed by the EU aims at reducing income disparities between countries and regions of the enlarged EU. Structural and market-oriented reforms in the CEE countries (including privatization of state-owned enterprises, price liberalization, enterprise restructuring, liberalization of foreign trade and exchange rates), the liquidation of barriers in the flows of inputs (labor and capital) between countries, as well as the large amount of

EU funds, all were important factors that led to a more rapid growth of initially less developed regions and counties. As a result, a reduction in development differences in the enlarged EU was observed. These results show that the EU policy aimed at reducing income differences satisfied its goal in terms of accelerating economic growth of less developed regions and countries. It may be expected that the outcomes are likely to confirm a significant role of EU funds in fostering economic growth of the CEE countries. Various EU structural and aid funds, flown to the CEE countries under a variety of EU programs, stimulated – at least in the short run – output growth in the CEE countries and a catching-up process towards Western Europe.

Second, a relatively rapid income-level convergence evidenced in this study results from the applied econometric methodology and the set of explanatory variables included in the growth equation. Some of the studies[14] indicate that system GMM estimators lead to higher β-coefficients as compared with standard estimators (e.g. OLS), however the simulation studies demonstrate that it no longer is the problem of small sample bias as demonstrated formerly by the AB estimator. That is why the results indicating the pace of convergence at the level of about 6% throughout the whole period are by no way strange. A rapid pace of income-level convergence may also be explained taking into account a large set of explanatory variables. Unconditional convergence parameters tend to be rather lower (in absolute terms) than corresponding conditional convergence parameters due to the fact that the latter ones better extract the pure catching-up mechanism. Controlling for the impact of some growth factors, it turns out that the role of initial conditions in subsequent economic growth is higher than in the case of unconditional convergence regressions where the convergence parameters reflect also the impact of all the factors affecting output dynamics[15].

As the major aim of the study is the analysis of time stability of the convergence parameter, it is worth to examine in details how the convergence coefficient evolved over time.

β-coefficients for different subperiods are presented in Table 2. These have been smoothed with the use of double exponential algorithm in order to avoid previously described effects of short term shocks, errors in the data and any other types of distortions. The results suggest that the pace of the catching-up

[14] See e.g. B. Bayraktar-Sağlam, H. Yetkiner, *A Romerian Contribution to the Empirics of Economic Growth*, "Journal of Policy Modeling" 2014, vol. 36, pp. 257–272.

[15] See e.g. M.S. Andreano, L. Laureti, P. Postiglione, *Economic Growth in MENA Countries: Is There Convergence of Per-Capita GDPs?*, "Journal of Policy Modeling" 2013, vol. 35, pp. 669–683.

process was not constant over time although the differences between the respective subperiods are not very large. Nevertheless, all except one subperiod dummies are statistically significant (at a 5% significance level) meaning that it is proper to argue that convergence was not stable over time.

Throughout the entire period, one may observe a gradual acceleration of the pace of convergence. This finding may be explained by several reasons. First of all, EU enlargement and the "integration anchor" both reduced the income gap between the old and new EU member states and they accelerated the income-level convergence between the individual countries. The biggest EU enlargement on Central and Eastern Europe took place in 2004 – the year which places approximately in a middle of the analyzed period. We may expect a more rapid pace of the catching-up process inside the enlarged EU due to economic and political factors. After EU enlargement, a lot of barriers in capital and labor flows between countries were abandoned. Large migration of workers from poorer to richer countries of the EU was an important factor in stimulating the process of convergence. Another factor was a massive transfer of EU aid to poorer regions and countries of the Union. Aid and structural funds devoted for the CEE region exploded after the EU enlargement. Although their basic effect is the long-term increase in potential output and the impact on the supply-side of the economy, their immediate effect is an increase in aggregate demand and the demand-side influence on output dynamics. Moreover, along with the EU accession, the CEE countries were forced to make some progress in institutional reforms such as privatization, enterprise restructuring, increasing the scope of economic freedom, price and exchange rate liberalization etc. All these factors were likely to fuel a gradual acceleration of the pace of convergence over the analyzed period.

Another (undesirable) source of the accelerating pace of convergence is the global economic and financial crisis. The crisis started in 2009 and the resulting recession touched all the EU countries except Poland which noted only a slowdown in the growth of output. However, the depth of recession was different in various EU countries, being the largest one in the Baltic states and in Western European countries (notably, Mediterranean economies). Since the fall in output – in average terms – was higher in Western Europe than in CEE, it means that the latter countries reduced their distance towards the former ones in terms of the development gap. Hence, economic crisis was another factor that can explain a gradual acceleration in the pace of convergence throughout the entire period – this time in result of a sudden fall of the higher developed countries rather than in result of speeding up of the less developed ones.

Looking at the results in greater detail, one may observe a small trough in the values of β-coefficient in the 1996–2000 and 1997–2001 subperiods (betas were equal to 6.01% in that time). It is likely that a slight slowdown in the catching-up process in this period was caused by the Russian crisis. Russia is one of the major trading partners for many examined countries. Deterioration of the economic climate in Russia could negatively affect the process of income-level convergence in Europe.

A gradual increase in the value of β-coefficient over time has strong economic consequences. Namely, if these trends are maintained, one may expect a continuation of a rapid catching-up process in the enlarged EU and a relatively fast reduction of income gap between the old and new EU member states. Of course, these optimistic growth prospects for the CEE region in terms of the catching-up process should not be treated as the only possible future growth paths. Some studies suggest the possibility of reversing past convergence trends, pointing to the appearance of divergence tendencies in Europe[16].

The obtained results are reinforced by the correctness of the model from both econometric and economic point of view referring to the estimated parameters standing for control variables. Among 14 explanatory variables included in the model as growth factors (except initial GDP, time dummies etc.), only one variable (*human_cap*) is statistically insignificant (with *p*-value of 0.417).

This study confirms the important role of investments in accelerating economic growth of the EU countries. The estimated coefficient of the *inv* variable is positive and statistically significant (with *p*-value of 0.000). This outcome corresponds to the theoretical and logical relationship that high investment rate is an important growth driver. It is also in line with, among others, neoclassical growth models according to which the CEE countries which are far away from the steady-state could increase its investment rate to accelerate output growth. Such a positive relationship between investment rate and economic growth is consistent with the assumed 5-year time spans. Such an approach, representing medium-run relationships, is between the typical short-run and long-run time intervals. Hence, it can be expected that the positive impact of investment on economic growth reveals both demand-side and supply-side effects. The former ones are rather of the short-run nature where high investments mean high spending and in this way they influence economic growth while the latter ones

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

represent rather long-run relationships where higher investment means higher accumulation of physical capital leading to a more rapid growth of potential output.

The results strongly demonstrate a negative impact of inflation on economic growth. The model implies that accelerating inflation hampers output growth. To achieve sustainable economic development it is necessary to perform economic policy aimed at reducing inflation rate.

Last but not least, the model shows a statistically significantly positive impact of good institutional environment and democratic society on economic growth. The two variables representing institutions (*econfree_fi* that shows the scope of economic freedom and the regulatory framework as well as *dem_fh* that represents political rights and civil liberties) both have positive and statistically significantly different than zero values of the estimated coefficients.

We check for the robustness of the results by comparing the outcomes of the basic model with the conditional convergence model estimated with the use of OLS. Second, the analysis of absolute convergence is examined with the use of system GMM. These imply different model specifications: the OLS-estimated model requires dropping the individual effects in (4), which is equivalent to assuming equal steady states for the considered economies[17]. On the other hand, the absolute convergence model estimated with system-GMM assumes that the steady states are different, but the convergence process is not conditional upon the growth factors, thus implies dropping the $x'_{it}\gamma$ in (4). Both alternative specifications yield significantly lower convergence parameters (given in Table 3). In the conditional OLS approach, the average β-coefficient amounts to 4.51% while in the case of absolute convergence it equals 3.12%. These differences are in line with the other empirical studies that suggest that the application of dynamic panel data estimators as well as the introduction of additional control variables both lead to the discovering the "faster" catching-up process[18].

[17] See e.g. M. Próchniak, B. Witkowski, *Real β Convergence of Transition Countries. Robust Approach*, "Eastern European Economics" 2013, vol. 51, pp. 6–26.

[18] See e.g. A. De La Fuente, *Convergence Equations and Income Dynamics: The Sources of OECD Convergence, 1970–1995*, "Economica" 2003, vol. 70, pp. 655–671; A. Di Liberto, J. Symons, *Some Econometric Issues in Convergence Regressions*, "The Manchester School" 2003, vol. 71, pp. 293–307; M.S. Andreano, L. Laureti, P. Postiglione, *Economic Growth in MENA Countries: Is There Convergence of Per-Capita GDPs?*, "Journal of Policy Modeling" 2013, vol. 35, pp. 669–683; B. Bayraktar-Sağlam, H. Yetkiner, *A Romerian Contribution to the Empirics of Economic Growth*, "Journal of Policy Modeling" 2014, vol. 36, pp. 257–272.

Table 3. Alternative convergence models

Variable	Period	OLS		System GMM (absolute convergence)	
		smoothed β convergence	p-value[a]	smoothed β convergence	p-value[b]
$\ln GDP_{i,t-1}$	1992–1996	4.47%	0.000	3.20%	0.000
dummies for the respective periods θ_t	1993–1997	4.47%	0.100	3.18%	0.000
	1994–1998	4.46%	0.012	3.14%	0.000
	1995–1999	4.45%	0.023	3.10%	0.000
	1996–2000	4.44%	0.029	3.08%	0.000
	1997–2001	4.44%	0.032	3.07%	0.000
	1998–2002	4.45%	0.253	3.07%	0.000
	1999–2003	4.46%	0.602	3.08%	0.000
	2000–2004	4.48%	0.647	3.09%	0.000
	2001–2005	4.50%	0.833	3.09%	0.000
	2002–2006	4.50%	0.640	3.08%	0.000
	2003–2007	4.50%	0.381	3.05%	0.000
	2004–2008	4.51%	0.753	3.04%	0.000
	2005–2009	4.55%	0.000	3.10%	0.688
	2006–2010	4.60%	0.000	3.16%	0.170
	2007–2011	4.65%	0.000	3.22%	0.000
	2008–2012	4.71%	0.000	3.28%	0.000
Average beta		4.51%	×	3.12%	x

[a, b] For the initial period the *p*-value refers to the $\ln GDP_{i,t-1}$ while for the other periods – to the respective θ_t. Only the convergence-related estimates are provided but in the OLS model the set of variables is the same as in the main model (estimates in Table 2).

Source: own calculations.

The conditional convergence model estimated on the basis of OLS suggests a trough in the values of beta in the two subperiods covering the years 1996–2001 and then a gradual acceleration of the speed of convergence which is the same outcome as in the case of the basic model. In contrast, the results of absolute convergence point to the second trough in time series of beta just before the global crisis took place; however, after that, they similarly indicate an acceleration in the pace of the catching-up process. Nevertheless, these two models are nested in terms of their structure in the main one (by imposing the $\alpha_i = cons$ and the $\gamma - 0$ constraints, respectively), thus the differences between the estimates in Table 3 as compared to the main model should be interpreted as emphasizing the

need to analyze the full relative convergence model with different steady-states among countries rather than one of its "simplified" versions.

4. Conclusions

The study analyzes the time stability of the beta convergence coefficient for the EU28 countries over the 1992–2012 period which is divided into seventeen 5-year overlapping subperiods. The basic convergence model is estimated with the use of GMM system estimator and a variety of control variables which are typical growth factors. It turns out that the average value of β-coefficient is 6.10% which indicates quite a rapid pace of convergence. However, it is not appropriate to claim about a constant rate of convergence over time among the EU countries as β-parameter was changing over time. After some trough in the second half of the 1990s, it was observed a gradual acceleration of the pace of the catching-up process in the 2000s and 2010s.

Interestingly, part of the accelerated convergence is caused by unfavorable outcomes of the richer countries. The global crisis led to a recession in almost all the EU countries. However, if the recession in more developed countries is deeper than that in less developed countries, convergence is evidenced although a poorer country does not become richer. Such a situation was likely to prevail in Europe as evidenced by an increasing value of β-coefficient over time, especially at the end of the analyzed period.

Varying pace of income-level convergence in the EU implies that a rapid reduction in development gap between old and new EU member states, observed till now, needn't be maintained in the future. Moreover, some divergence tendencies cannot be excluded.

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