Marginal Vertical Convergence:
New Approach in Real Convergence Analysis

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Abstract:

Purpose: *The main aim of this paper is to present a concept of marginal vertical income convergence. This method allows to determine the individual contribution of the objects (countries, regions) to the observed general process of real convergence.*

Design/Methodology/Approach: *Proposed methodology allows to avoid the limitations of the classical analysis of income convergence. To check the cross-country stability of the parameters and to assess an individual contribution to convergence process, separate regressions for all EU member states was provided. The differences between coefficients of the model based on full sample and coefficients specific for a particular country indicate this individual effect.*

Findings: *The empirical results show that in 1993-2018 we can observe an absolute β income convergence within the European Union, accelerated after 2008-2009's crisis period. However, the main conclusion is that the contribution to the overall process of levelling out GDP per capita within the EU was different from one member state to another. Received results confirmed that outliers removing allows to increase the quality of used models and the reliability of formulated interpretations.*

Practical Implications: *Different values of marginal vertical income convergence are caused by differences in the dynamics of economic growth of individual countries, their different resistance to economic shocks, as well as different levels of inequality and distribution of income and wealth. Recognition of such differences is the first step in developing policies aimed at reducing discrepancies among national behaviours that could be observed as a background of a general convergence process.*

Originality/value: *This research presents new concept of cross-sectional real convergence analysis built on the long period sample covering pre- and post-crisis time for all EU member countries. Additional contribution of the undergone study is robustness analysis that make allowances of outlier's impact.*

Keywords: *Marginal income convergence, cross-sectional models, outliers, EU, crisis.*
JEL classification: *O47, C01, O52.*
Paper Type: *Research study.*

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1. Introduction

International and regional convergence of income levels has important consequences for economies and societies. For this reason, the term of income convergence is reflected in most economic growth models. From a neoclassical perspective, capital flows from richer to poorer countries are considered to be the main cause of income convergence, allowing above-average profits to be made through the use of new technologies and labour productivity growth, under conditions of low labour costs (Aghion and Howitt, 1999; Barro and Sala-i-Martin, 2004). The literature lists many more factors that foster income convergence, such as differences in: capital accumulation rates, the degree of openness of economies and the dynamics of total factor productivity or changes in the sectoral structure of economies, different quality and stock of human and social capital, processes of diffusion of knowledge and technology (Chapsa, Athanasenas, and Tabakis, 2019; Caselli and Tenreyro, 2005; Giertz and Mehta, 1996; Islam, 2004).

The long-term income convergence requires the fulfilment of certain conditions, such as for example an expansion of demand, as well as the existence of fully developed banking sector (Forgó and Jevčák, 2015). In most endogenous growth models, only a conditional real convergence is possible, due to the existence of positive diffusion effects related to investment in physical and human capital, as well as well-developed R&D activities (Carlaw and Lipsey, 2004). Table 1 shows which growth models assume the occurrence of income convergence.

Table 1. *Type of economic growth model and existence of real convergence*

Convergence	Economic growth model
Yes	Solow-Swan, Solow-Swan with labour-intensive technical progress, Mankiw-Romer-Weil, Ramsey-Cass-Koopmans, AK augmented, Diffusion of technology, Solow-Swan with migration, Ramsey with migration, Labour/Leisure choice
No	AK Romer, Learning by doing, Knowledge spillovers, Public services

Source: Batóg (2010).

Many studies has been dedicated to income convergence. This study is focused on the presentation of the author's concept of marginal vertical real convergence. It will be applied to determine the individual contribution of the members of the European Union to the observed process of income convergence occurring in the group of these countries (Thalassinos *et al.,* 2015).

The analysis carried out realize of a postulate formulated by Barro and Sala-i-Martin (2004), who noted that "If we want to understand what the known differences in quality of life between countries are caused by, we need to explain the mechanism of differentiation of long-term growth rates". An important part of this study is also an assessment of the impact of outliers on the results of income convergence modelling.

Statistical data cover the period 1993-2018, and comes from Total Economy Database April 2019 created by The Conference Board Inc.

The rest of the paper is organized as follows. First part presents review of current works on real convergence. The second section presents standard approach to analysis of β-convergence used further as the framework in part three, where the new concept of marginal vertical convergence was described. Part four contains empirical results. The paper ends conclusions, discussion and the proposals of prospect's research.

2. Literature Review

The subject of income convergence, which began to be present in the broader economic literature in the late 1990s (de la Fuente, 1997; Durlauf and Quah, 1999; Florax, de Groot, and Heijungs, 2002; Rey and Janikas, 2005) a great deal of attention is still given to its importance in the construction and implementation of economic policy.

Most empirical studies confirm an income convergence pattern within the EU (Batóg and Batóg, 2006; Młynarzewska-Borowiec, 2018) and indicate that huge capital inflows, its sectoral structure, TFP growth as well as the EU accession were the most important factors behind this phenomenon. For instance Forgó and Jevčák (2015) found no significant difference in the speed of real income convergence in twelve CEE countries between these with fix and float exchange rate regimes in 2004-2014. They noticed however a large degree of heterogeneity within both groups and the real convergence path smoother for the latter. Grela *et al.* (2017) shows that during the last 20 years GDP *per capita* of the CEE countries has been converging towards the level observed in the EU-15, in line with the neoclassical growth theory, although relatively fast convergence observed in 2001-2008 was interrupted by the financial crisis (Siljak, 2015). Some authors underline the lack of sustainability in the process of real convergence within EU even before this crisis due to institutional conditions that did not support business innovation and productivity growth, structural rigidities and a lack of effective competition contributed to a mis-allocation of capital and sudden decrease of real interest rates pushed up credit growth and demand, and in consequence the accumulation of very large external imbalances (Borio, 2012).

The „2008" economic crisis is also the main reason of the disturbances of regional convergence pro-cesses (Dapena, Rubiera-Morollon, and Paredes, 2018). The general pattern of convergence in the analysed period changed over time and depended on the specific set of countries. When the sample was split into the 'old' and new EU member states, absolute convergence could only be confirmed for the latter group. This evidence was confirmed for 23 EU members in 1990-2009 by Monfort *et al.* (2013) and for 26 EU member countries in 1999-2016 by Gros (2019), while the existence of subgroups that converge to different steady states among the New Member States was pointed out by Borsi and Metiu (2015). When analysing the convergence of income levels more broadly, we must be aware that although we

observe real convergence in a such homogeneous group of countries like the European Union, we cannot prove that it has been occurring in the world in the last decades (Gomes, 2015; Thalassinos and Stamatopoulos, 2015). This phenomenon is also usually not visible on a regional scale or occurs only within specific groups of regions (Hamit-Haggar, 2013; Goda and Torres García, 2017).

3. Classical Approach to Analysis of Absolute *β*-Convergence

One of the most popular ways of identifying whether we are dealing with the equalization of GDP *per capita* levels is *β*-convergence analysis. The evaluation of its absolute type occurrence is based on the use of the regression equation derived from the Solow-Swan model, in which the rate of change of product *per capita* is explained variable, and the explanatory variable is the initial level of GDP *per capita* (Aghion and Howitt, 1999):

$$\frac{1}{T} \cdot ln\left(\frac{Y_{iT}}{Y_{i0}}\right) = \alpha_0 + \alpha_1 \cdot ln\, Y_{i0} + \varepsilon_{iT}, \qquad (1)$$

where:
$\frac{1}{T} \cdot ln\left(\frac{Y_{iT}}{Y_{i0}}\right)$ – annual growth rate of real GDP *per capita* in country i,
Y_{i0} – initial level of real GDP *per capita* in country i.

Many authors underline difficulties in application of the classical approach to income convergence analysis including: the dynamic nature of the data-generating process, endogenous regressors, measurement errors, omitted variable bias, and a small number of time periods (Cojocaru *et al*., 2015). Important limitations of the standard approach to income convergence also include the assumption of equal rates of technological and environmental progress and the failure to take into account the differences in business cycles, especially in panel studies using short term growth rates (Aghion and Howitt, 1999).

The reasons for obtaining inconsistent results on an international scale may also be the appreciation of the national currency and an increase in prices and wages due to the inflow of foreign capital and aid funds. The impact of these factors is lower if these funds are allocated to the growth of domestic investment, and increases with the allocation of domestic savings to consumption (Czyżewski, Orłowski, and Zienkowski, 2003; Hübner, 2004). The contradictory results are caused by chosen different periods of analysis, data sets and methodological approaches, leading to incoherent conclusions among the different analyses about the speed or even existence of convergence within EU (see the meta-analysis of Abreu, De Groot, and Florax 2005).

4. The Concept of Marginal Vertical Absolute *β*-Convergence

However, many authors point out that the classical research approach can only be an indirect measure of income convergence, because very often we observe significant

dissimilarities between the growth patterns among individual countries (Siljak, 2015; Svoboda and Klementova, 2014). The catching up benefits achieved by a group of countries usually mean negative effects in another group of countries. Baldwin (2016) lists the countries that have benefited from globalisation in the period 1990-2010: China, Korea, India, Brazil, Poland, Nigeria, Australia, Mexico, Venezuela, Turkey, Indonesia, and Thailand, indicates that the main factors of their success were exports and industrial agglomeration that fostered innovation and boosted competitiveness. The key role of innovation performance for productivity and economic growth was also pointed out by Guellec and Pilat (2009).

When the speed of convergence and the steady state of each territory depend on the group to which it belongs, standard measurements of convergence, with only one convergence coefficient, would fail to identify this type of heterogeneity (Postiglione, Andreano, and Benedetti 2013; Castellacci, Los, and de Vries 2014).

If the examined group of objects includes countries with convergence of GDP *per capita* levels and countries for which this phenomenon does not occur, then on the basis of the model (1) it is possible to draw wrong conclusions about the occurrence of convergence between all analysed economies (Nowak, 2007). An additional disadvantage of the classical absolute convergence model is that it is impossible to assess whether individual countries have a different "contribution" to the overall process of income convergence (divergence).

In most empirical studies it is assumed that the relation captured by the estimated equation is stable over time. Grela *et al.* (2017) release this assumption and check the time stability of the parameters by either dividing the full sample period into three non-overlapping sub-periods or by performing the growth regression on five-year rolling windows. The similar concept was previously described in Batóg (2010) and called "marginal horizontal convergence". Among others it allows to assess the influence of economic downturns on the process of income convergence. In the same study of Grela *et al.* (2017), year-by-year cross section estimates was performed in the case of absolute convergence. To check the cross-country stability of the parameters and to assess an individual contribution to convergence process, separate regressions for the old and new EU member states as well as regressions with skipping one country at a time was provided.

The latter approach is similar to this proposed in the current study (see also Batóg, 2010). We can find alternative concepts used to catch the individual contribution of the country into the overall convergence process. For example Güreşçi and Utkulu (2015) proposed unconditional convergence model with implied parameter λ, that allows to show country-specific unconditional convergence behaviour. According to their results Sweden had the fastest unconditional convergence, and United Kingdom has the lowest. The other countries with low unconditional convergence were Malta, Spain, Lithuania and Bulgaria, while France, Germany, Slovenia and Belgium were characterized by high unconditional convergence speed. It is worth to mention that

indicated half-times were in the range from 21 to 60 years. Another way to identify the individual nature of convergence for individual countries is to apply stochastic convergence with a reference object, the disadvantage of which is the problems associated with the ambiguous results obtained for the various cointegration tests. An alternative may also be quartile regression or analysis of full distributions of variables characterizing the level of economic development (Wójcik, 2018).

Processes of agglomeration and spillover effects could operate differently depending on the level of spatial disaggregation. The research on this phenomenon was provided by Bartkowska and Riedl (2012) and Monfort, Cuestas, and Ordonez (2013). For instance, the lack of catch-up or even divergence of a lagging region (country) could be explained by the fact that it is surrounded by other lagging regions (countries) with similar convergence rates (Bourdin, 2015). To capture the differences among spatial scales, Dapena, Rubiera-Morollon and Paredes (2018) built a multilevel and spatial effects extension of the Solow-Swan growth model. For 2000-2014 they found that a general process of convergence in the EU coexists with intranational processes of divergence. For example, countries such as France, Ireland, and Slovenia had an internal process of significant divergence, whereas others, such as Spain, Greece, and Portugal, have an internal process of significant convergence. Countries that are near to (far from) their steady state could increase (decrease) inequalities within their territory. Obtained results confirmed also that the economic crisis strongly reinforced the weakness of the EU convergence.

To solve the limitations of the classical approach to the study of the adolescent convergence we propose a concept of marginal vertical income convergence of β type, which allows to determine the role of individual objects (countries, regions) in the convergence process characterizing the whole set of objects. To indicate this individual contribution it is necessary to estimate the convergence equation (1) taking into account all examined objects and its modifications, in which we use corrected data. The correction for a country i consists in eliminating the observation that applies to it from the full data set. The value of marginal vertical convergence of β type is obtained from the following formula (Batóg, 2010):

$$\Delta\beta_i = \hat{\beta} - \hat{\beta}_i^{N-1} \tag{2}$$

where:
 $\Delta\beta_i$ – marginal vertical convergence specific for country i,
 $\hat{\beta}$ – general convergence speed,
 $\hat{\beta}_i^{N-1}$ – convergence speed for N - 1 objects (without country i),
and the value of parameter $\hat{\beta}$ (and respectively $\hat{\beta}_i^{N-1}$) is calculated using the formula:

$$\hat{\beta} = -\frac{1}{T} \cdot ln(1 + \hat{\alpha}_1 \cdot T). \tag{3}$$

Positive values of $\Delta\beta_i$ are evidence of a country's positive contribution to the overall process of income convergence. The same procedure can be applied to the length of half-time of convergence:

$$\Delta T_{1/2,i} = T_{1/2} - T_{1/2,i}^{N-1} \tag{4}$$

where:
$T_{1/2} = \frac{ln2}{\hat{\beta}}$ and $T_{1/2,i}^{N-1} = \frac{ln2}{\hat{\beta}_i^{N-1}}$.

Negative value of $\Delta T_{1/2}$ inform by how many years the half-time of convergence is shortened due to the inclusion of the country i in the group of surveyed objects.

5. Empirical Results

The data used in the study comes from *The Conference Board Total Economy Database April 2019* and include real values of GDP *per capita* expressed in USD, using the 2010 prices and updated values of EKS PPP 2005. The methodology of calculating the value of GDP expressed in PPP using the EKS method, whose name derives from the first letters of the names of its authors, Èltetö, Köves and Szulc, is described, among others, in the paper Eurostat-OECD… (2005), and the characteristics of its use in determining the real values of GDP are presented in the Methodological Notes on the website http://www.conference-board.org/economics/database.cfm#12.

The dynamic of the economic growth in the European Union in the years 1994-2018 is presented in the Figure 1.

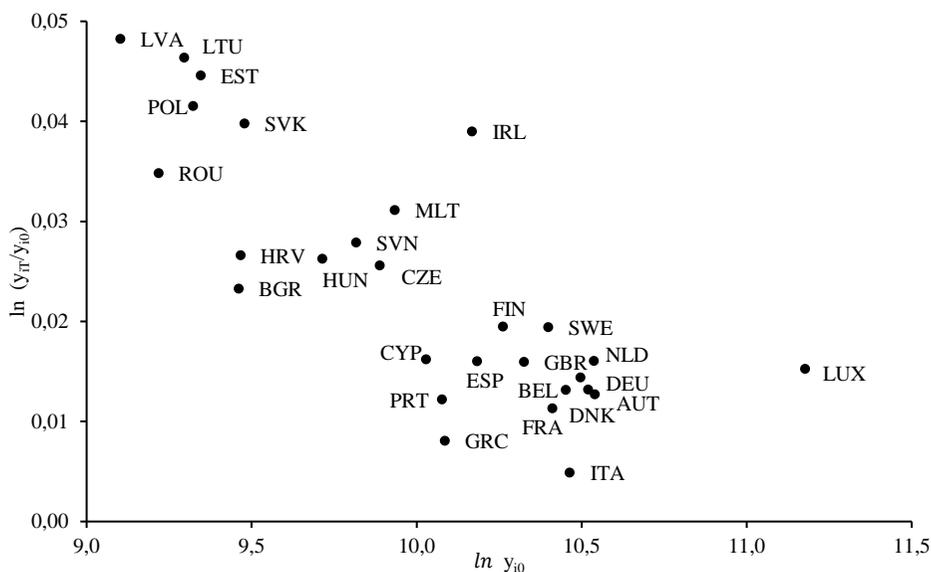**Figure 1.** *Average growth of real GDP in the European Union in 1994-2018*
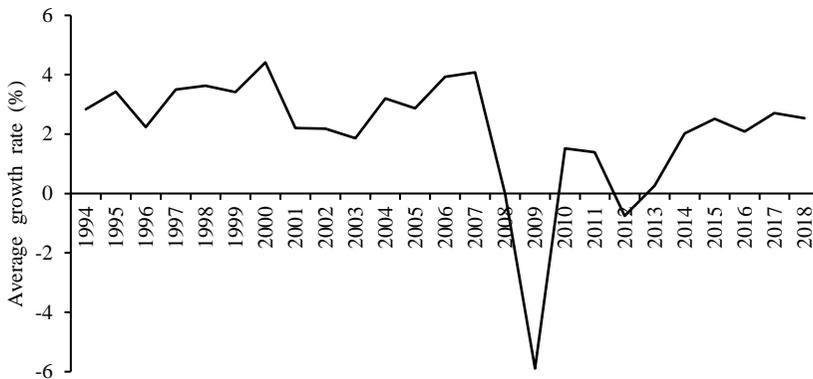
Source: *Own calculations on the base of The Conference Board Total Economy Database, April 2019, http://www.conference-board.org/data/economydatabase/.*

In Figure 1 a clear division into two sub-periods of moderate economic growth is visible. In the first one (1994-2007), the annual real GDP growth rate oscillating around 3% was observed, with a slight breakdown in 2001-2002. The second one (2010-2018) was characterized by lower GDP dynamics, which gradually increased to the level observed in the first sub-period, but has not yet reached it.

It is also worth noting that the average GDP growth rate in the European Union countries decreased significantly in 2012. The indicated sub-periods are separated by a short period of recession resulting from the crisis that started in 2007 in the USA.

Figure 2 presents the relationship between the initial level of real GDP observed in the European Union countries in 1993 and the average growth rate over the entire period under examination.

Figure 2. *Initial GDP per capita [$\ln y_{i0}$] versus an average growth rate [$\ln\left(\frac{y_{iT}}{y_{i0}}\right)$] in the UE in 1993-2018*

Source: Own calculations on the base of The Conference Board Total Economy Database, April 2019, http://www.conference-board.org/data/economydatabase/.

The scatter of points forms the shape of an ellipse, which suggests the existence of a linear relationship between these variables. At the same time, we can see that the correlation is negative, which indicates the existence of income convergence.

The structural parameters of the convergence equation (1) were estimated using the ordinary least squares method. Some authors point out that the parameters of the models in the convergence analysis should be estimated with a non-linear least square method, because OLS does not guarantee that the estimate of the parameter α_1 will take negative value, which makes it impossible to determine the value of β (Quah, 1996). In turn, Durlauf, Johnson and Temple (2004) believe that the OLS estimate of the parameter β may indicate only statistical convergence, not income convergence in the economic sense, and lead to an overestimation of the speed of convergence. However, previous analyses carried out by the Authors allow to conclude that the results obtained by means of various estimation methods are similar. Table 2 presents the results of the estimation for all countries.

Table 2. *Results of estimation of absolute β convergence in EU (all countries) in 1993-2018*

Coefficient	Estimate	t	p	$\hat{\beta}$ (%)	$T_{1/2}$ (years)
$\hat{\alpha}_0$	0.216	7.536	0.000	2.62	26.45
$\hat{\alpha}_1$	-0.019	-6.718	0.000		
$R^2 = 0.634$, $s = 0.008$, $F(1, 26) = 45.129$, $p = 0.000$					

Source: *Own calculations on the base of The Conference Board Total Economy Database, April 2019, http://www.conference-board.org/data/economydatabase/.*

The obtained results confirm the existence of absolute income convergence of type β in the European Union countries in the years 1993-2018. The speed of convergence for all countries is 2.62% and half-time convergence period is 26.45 years. The parameters of the model are statistically significant and goodness-of-fit of the model is at the level observed in most of the works on the analysed topic.

Table 3 shows the results of estimation for the sample from which two outliers were removed: Ireland – outlier identified according to an abnormal standardized residual (2.386) and Luxembourg – outlier identified on the base of the high value of Cook distance (0.623). Both outliers could be easily recognized in the Figure 2. A comprehensive description of the methodology of an outlier identification and applied measures can be found in Barnett and Lewis (1994), while previous studies on outlier's impact on the income convergence modelling results can be found in Batóg (2015).

Table 3. *Results of estimation of absolute β convergence in EU without Ireland and Luxembourg in 1993-2018*

Coefficient	Estimate	t	p	$\hat{\beta}$ (%)	$T_{1/2}$ (years)
$\hat{\alpha}_0$	0.251	9.951	0.000	3.39	20.43
$\hat{\alpha}_1$	-0.023	-9.033	0.000		
$R^2 = 0.772$, $s = 0.006$, $F(1, 24) = 81.596$, $p = 0.000$					

Source: *Own calculations on the base of The Conference Board Total Economy Database, April 2019, http://www.conference-board.org/data/economydatabase/.*

The results of estimation for the reduced sample indicate a better quality of the model and, in line with expectations, a much faster process of income convergence in the European Union countries.

Figure 3 shows the values of the marginal vertical convergence for each country ($\Delta\beta_i$) and their tolerance areas, calculated using the concept of a control card. These tolerance areas are determined on the base of average and standard deviation of all $\Delta\beta_i$.

We can see the division of the examined countries into two groups almost equal in number. In the first one, which is characterized by a negative contribution to the overall income convergence in the EU, there are among others Netherlands, Croatia,

Romania. Bulgaria has the highest negative contribution to the convergence. Among the countries that strengthen the process of income convergence, an important role is played by the countries: Italy, Estonia, Latvia and Lithuania. Next calculations were made for two sub-periods determined on the base of Figure 1, excluding the years in which the influence of the last world economic crisis was observed. Table 4 presents the results of the estimation of convergence models for the 1993-2007 sub-period and Figure 4 shows obtained values $\Delta\beta_i$ for the same period.

Figure 3. *Values of $\Delta\beta_i$ for period 1993-2018*
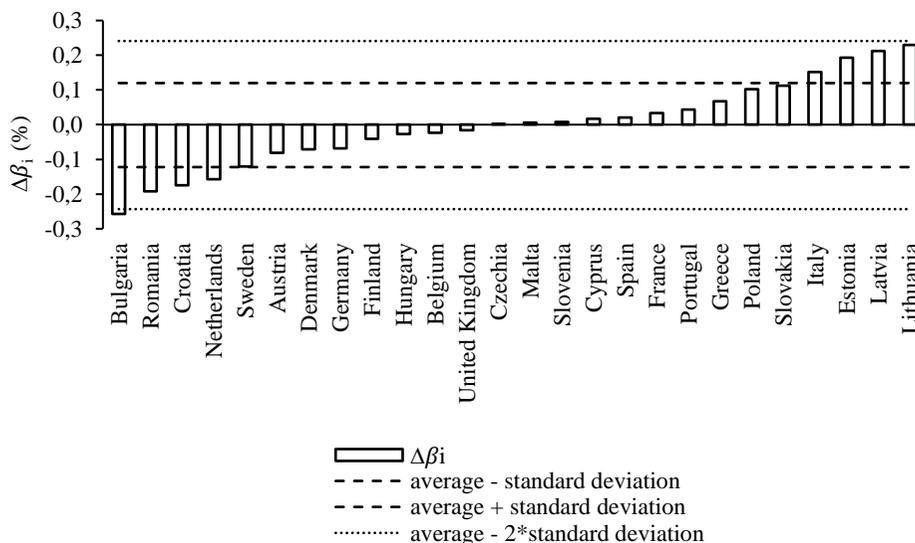
Table 4. *Results of estimation of absolute β convergence in EU in EU without Ireland and Luxembourg in 1993-2007*

Coefficient	Estimate	t	p	$\hat{\beta}$ (%)	$T_{1/2}$ (years)
$\hat{\alpha}_0$	0.303	7.625	0.000	3.39	20.47
$\hat{\alpha}_1$	-0.027	-6.772	0.000		
$R^2 = 0.656$, $s = 0.010$, $F(1, 24) = 45.856$, $p = 0.000$					

Again, the quite good quality of the model is visible, while at the same time we observe in this sub-period a similar speed of convergence as that obtained for a full sample with no outliers. This speed is at a higher level of 2%, which is shown in a significant part of the hitherto analyses of the income convergence phenomenon. In a period of stronger growth compared to the full period, we notice a significant flattening of values $\Delta\beta_i$ obtained for individual countries. The extreme values of this measure occur for two countries with negative vertical marginal contribution to

convergence – Bulgaria and Romania, and for two countries with positive vertical marginal contribution to convergence –Estonia and Latvia.

The results obtained for the post-crisis period are presented in Table 4 and Figure 4. In comparison with the previous sub-period, an additional outlier was identified – Greece.

Figure 4. *Values of $\Delta\beta_i$ for period 1993-2007*
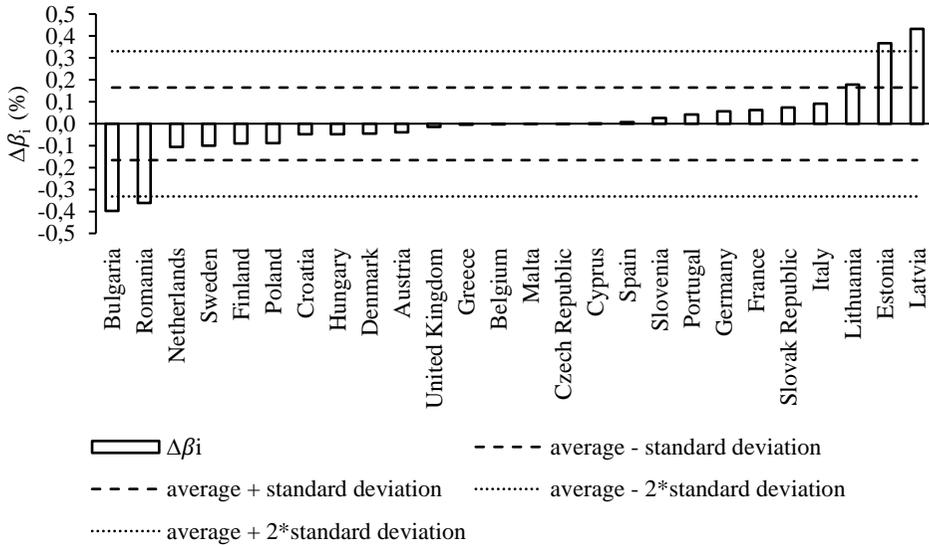
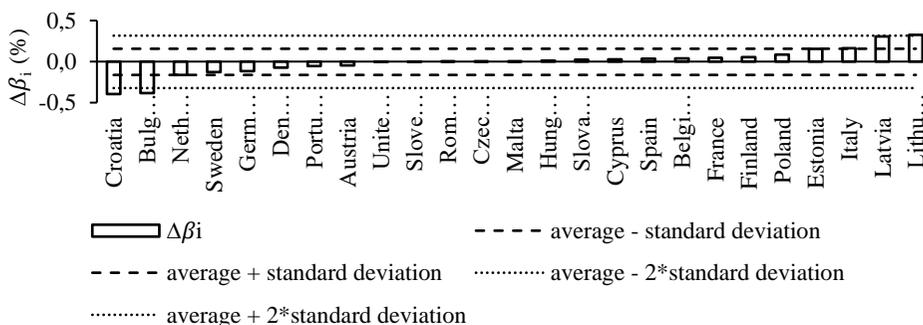**Source:** *Own calculations on the base of The Conference Board Total Economy Database, April 2019, http://www.conference-board.org/data/economydatabase/.*

Table 5. *Results of estimation of absolute β convergence in EU in EU without Ireland, Greece and Luxembourg in 2010-2018*

Coefficient	Estimate	t	p	$\hat{\beta}$ (%)	$T_{1/2}$ (years)
$\hat{\alpha}_0$	0.367	5.609	0.000	3.89	17.82
$\hat{\alpha}_1$	-0.033	-5.314	0.000		
$R^2 = 0.551$, $s = 0.010$, $F(1, 23) = 28.242$, $p = 0.000$					

Source: *Own calculations on the base of The Conference Board Total Economy Database, April 2019, http://www.conference-board.org/data/economydatabase/.*

The quality of the model for the second subperiod is the lowest of all proposed models. Although we observe the statistical significance of structural parameters, the goodness of fit, characterized by a coefficient of determination, is relatively moderate. Compared to the 1993-2007 sub-period, the countries with a negative contribution to the income convergence included Bulgaria and Croatia. The latter country replaced Romania. Lithuania and Latvia were once again the countries with a positive contribution to the income convergence.

Figure 5. *Values of $\Delta\beta_i$ in 2010-2018*

This sub-period is characterized by the highest speed of convergence, close to 4%, and the shortest half-time of the convergence of less than 18 years. It is worth noted that values of $\Delta\beta_i$ are generally smaller in 1993-2018 than in both sub-periods, while the level of heterogeneity of marginal vertical convergence is higher.

The analysis of individual contribution of countries to income convergence using the differences in parameters describing the speed of convergence is complemented by the evaluation of differences of the half-times of the convergence $\Delta T_{1/2,i}$. Table 6 presents the values of the latter differences for all examined periods.

Table 6. *Individual and marginal half-time of convergence within EU*

Country	1993-2018 ($T_{1/2} = 20.43$)		1993-2007 ($T_{1/2} = 20.47$)		2010-2018 ($T_{1/2} = 17.82$)	
	$T_{1/2,i}^{N-1}$	$\Delta T_{1/2,i}$	$T_{1/2,i}^{N-1}$	$\Delta T_{1/2,i}$	$T_{1/2,i}^{N-1}$	$\Delta T_{1/2,i}$
Austria	19.95	0.48	20.23	0.24	17.61	0.22
Belgium	20.28	0.14	20.45	0.02	17.99	-0.17
Bulgaria	18.99	**1.44**	18.32	**2.15**	16.23	**1.59**
Croatia	19.43	**1.00**	20.18	**0.29**	16.19	**1.64**
Cyprus	20.53	-0.10	20.48	0.00	17.96	-0.13
Czech Republic	20.44	-0.01	20.46	0.01	17.82	0.00
Denmark	20.01	0.42	20.20	0.27	17.50	0.32
Estonia	21.66	*-1.23*	22.96	*-2.49*	18.56	*-0.74*
Finland	20.19	0.24	19.94	0.53	18.08	-0.25
France	20.63	-0.20	20.86	-0.39	18.04	-0.22
Germany	20.03	0.40	20.82	-0.34	17.31	0.52
Greece	20.84	-0.41	20.45	0.02	-	-
Hungary	20.26	0.16	20.19	0.29	17.88	-0.06
Italy	21.38	*-0.95*	21.04	*-0.57*	18.61	*-0.78*
Latvia	21.79	*-1.37*	23.47	*-2.99*	19.36	*-1.53*
Lithuania	21.91	*-1.48*	21.61	*-1.14*	19.46	*-1.64*
Malta	20.47	-0.04	20.46	0.01	17.84	-0.02

Netherlands	19.52	**0.91**	19.85	**0.62**	17.11	**0.71**
Poland	21.06	-0.64	19.95	0.53	18.22	-0.40
Portugal	20.69	-0.26	20.73	-0.26	17.58	0.25
Romania	19.33	**1.09**	18.50	**1.97**	17.82	0.00
Slovak Republic	21.12	-0.70	20.92	-0.45	17.94	-0.12
Slovenia	20.47	-0.05	20.63	-0.16	17.81	0.01
Spain	20.55	-0.13	20.51	-0.04	17.99	-0.17
Sweden	19.73	**0.70**	19.88	**0.59**	17.25	**0.58**
United Kingdom	20.33	0.10	20.38	0.09	17.81	0.02

Source: *Own calculations on the base of The Conference Board Total Economy Database, April 2019, http://www.conference-board.org/data/economydatabase/.*

The positive and significant contributions to the European convergence in each period were identified for: Estonia, Italy, Latvia and Lithuania (italic). In turn, countries that have significantly slowed down the convergence process are: Bulgaria, Croatia, Netherlands and Sweden (bold). This results are consistent with previous results based on $\Delta\beta_i$.

6. Conclusions

In the European Union countries there was an absolute β income convergence in 1993-2018. Although the prospect of achieving steady-state by all EU countries is quite distant, it can be concluded that this period is constantly shortening. This phenomenon is confirmed by comparing the results obtained for the full sample with the results obtained for the pre and post-crisis sub-periods, which allows us to see the acceleration of income convergence in this second sub-period. However, the contribution to the overall process of levelling out GDP *per capita* was different from one member country to another. To assess these individual differences, an original method of marginal vertical income convergence was used.

Different values of measures of marginal vertical income convergence are a result of differences in the dynamics of economic growth of individual objects, which are, among others, a result of their different resistance to economic shocks, as well as different levels of inequality and distribution of income and wealth (Zandi 2017; Berg, Ostry, and Zettelmeyer, 2012). Identification of the differences between countries is the first step in developing policies aimed at reducing discrepancies among national behaviours that could coexist with a general trend of convergence (compare with regional divergence pattern presented in McCann, 2016). To ensure a real convergence, further actions should be aimed at achieving the macroeconomic stability, the effectivity of the fiscal policy, the flexibility of the labour market and at preventing asset price and credits from high fluctuations. The conducted study allows to notice the important role of outliers in the process of estimation of income convergence models. Elimination of outliers allows also to increase significantly the quality of the analysed models and the reliability of formulated interpretations.

In further research it is worthwhile to try to identify the reasons that cause a given country to belong to a group that "accelerates" or "slows down" the general process of income convergence, and to model changes in this phenomenon including spatial relationships.

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