Sigma Versus Beta-convergence in EU28: do they lead to different results?

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Abstract: The process of economic convergence has been undoubtedly marked by the financial crisis. The paper focuses on analysis and evaluation of the impact of financial crisis on the real convergence among EU member states. The beta-convergence approach is verified by econometric modelling techniques, namely with the use of cross-sectional linear regression analysis. The next focus is given on the examining of the sigma-convergence which is tested by standard deviation of real GDP per capita. The aim is to verify the hypothesis that the approach of beta-convergence and the concept of sigma-convergence lead to a different results for the EU member states in the period 2001-2012.

Key-Words: sigma-convergence, beta-convergence, cross-sectional analysis, EU, financial crisis

1 Introduction

Economic convergence has been in the center of professionals´ attention for many years. In the EU environment the convergence among member economies is one of the basic conditions for strengthening the EU competitiveness externally, but also a prerequisite for increasing cohesion within the EU. The actual convergence is being affected by many factors then, either positively or negatively. This paper is therefore driven by efforts to evaluate the impact of the global financial crisis as an exogenous factor of the convergence process between EU member economies.

The paper is thematically focused on the analysis of real convergence at the national level, which represents the convergence of all member economies of the EU in terms of GDP per capita converted to PPP and PPS. Methods chosen to evaluate the process of real convergence approaches were beta- and sigma-convergence. Economic convergence in general can be seen from different points of view, depending on the analysis of economic phenomena, therefore the very definition of methodological convergence is placed in the second chapter of this scientific paper. The following parts of the paper are devoted to the actual empirical analysis which leads to economic verification of the findings.

This paper aims to evaluate the impact of the global financial crisis on the process of real convergence of the economies within the EU. The operational objective is to determine whether these approaches for the study of real convergence beta- and sigma-convergence (β- and σ-convergence) lead to the same or different conclusions. All EU28 member states were selected to assure a representative sample. Outliers such as Luxembourg were included in order to maintain the most realistic picture of the EU economy. Economy of Croatia was also included into observation, although it has become a member country only in 2013, but has spent many years trying to come closer to the EU in not only the economic but also the political and legal aspects. As the reference period was selected period 2001-2012. Here the research alludes to the unavailability of longer time series in official statistical databases of Eurostat and the World Bank. Nevertheless, this chosen period represents the period in which the EU economy has been hit by the global financial crisis.

2 Definition and Concept of Convergence

The term convergence is in comparative economy primarily distinguished by a character of explored variables to nominal and real convergence. Although the real convergence is inseparably connected to nominal and therefore both approaches have to be evaluate as parallel processes, it is crucial to stress out that the very understanding of nominal and real convergence is not unite among particular

authors. Nominal convergence is viewed as economies closing to each other from the perspective of price characteristics, thus as economies tendency to achieve the same level of nominal variables, such as inflation rate, interest rates or exchange rate. In broader view, nominal convergence is being understood to as a fulfilment of Maastricht convergence criteria. On the contrary measurement of real convergence is made with a use of chosen real macroeconomic aggregate. The aggregate most often used in empirical studies is GDP in real terms in conversion per capita or per worker.

Convergence as one of macroeconomic theories is closely connected to the issue of long term economic growth (economic growth theory). This theory has the solid purpose to study factors which influence the economic growth in particular countries and to explain the differences in their real income per capita. Chronologically speaking, the beginnings of studying convergence can be seen as studying absolute convergence, which can be defined as a process in which economies with lower capital per worker grow faster than economies with higher capital per worker. However, when we take into account empirical observations, the hypothesis of absolute convergence is in breach of reality for the high capital per worker economies also achieve faster GDP growth per worker. Based on these observations a condition of homogeneity was set up. If we measure convergence among homogeneous sample with the same institutional parameters we speak of conditional convergence. Typical sample to measure conditional convergence is OECD countries. On contrary it is impossible to measure convergence of for example Germany and Mozambique.

Absolute or conditional convergence can be verified by β-convergence and σ-convergence. An application of these approaches is depended on methodological framework for research of listed types of convergence. The β-convergence, which can be found in studies of Furceri and Karras (2008), Michelacci and Zaffaroni (2000) or Pfaffermayr (2009), is based on neoclassical theory of economic growth which postulates that initially poorer countries evince more dynamic growth. This means, poorer countries convergence to initially richer countries because those do not have such dynamic growth. GDP growth per capita is negatively dependent on initial economic level and β-convergence is characterized by negative slope of linear function. The σ-convergence concept is applied by for example Dalgaard and Vastrup (2001), Lucke (2008) or Miller and Upadhyay

(2002) and it is also based on neoclassical theory of economic growth. The idea is that all countries converge to the same level of advancement or in other words to the same economic output. The σ-convergence is defined as lowering of variance of real GDP per capita logarithm among economies in time.

3 Methodology and Goal

3.1 Methodological Solutions of Beta- and Sigma-convergence

Methodology to study β-convergence comes from original Baumol (1986) study of real convergence between economies. Baumol has developed so called conventional approach to convergence analysis. Through graphical projection of statistical data and through observed dependencies he has constructed an original growth equation:

$$\frac{1}{T}\left[\ln\left(y_{i,T}\right) - \ln\left(y_{i,t_0}\right)\right] = \beta_1 + \beta_2 \ln\left(y_{i,t_0}\right) + \varepsilon_t, \qquad (1)$$

where T is the end of time period, y_T is real GDP per worker at the end of time period, t_0 is the initial time period, y_{t_0} is real GDP per worker at the beginning of time period, β_1 is the intercept, β_2 slope parameter, ε is statistical error term and i is index marking each country.

Baumol did not use analytical procedure to create original growth equation but instead he began to study graphical data. Regression dependence from theoretical framework of economic growth was then developed by Barro and Sala-iMartin (1992) and Mankiw, Romer and Weil (1992). Mankiw, Romer and Weil originated from theoretical concept of Solow and Swan model. On the other hand Barro and Sala-iMartin deduced the equation from model of Ramseyho, Casse and Koopmanse.

For the purpose of the paper the Baumol equation was modified as follows:

$$\frac{1}{T}\log\left(\frac{y_{i,T}}{y_{i,0}}\right) = \alpha + \beta \log\left(y_{i,0}\right) + \varepsilon_i, \qquad (2)$$

where α is level constant.

The concept of σ-convergence[1] also comes from neoclassical growth theory. The σ-convergence is defined as lowering of variance of real GDP per capita logarithm among economies in time. Sigma convergence is then described as catching up effect.

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[1] Dalgaard and Vastrup (2001), Lucke (2008), Miller and Upadhyay (2002)

If the variance of real GDP per capita logarithm is denoted as σ_t^2 in group of countries in time t then σ-convergence among t and $t+1$ period means:

$$\sigma_t^2 > \sigma_{t+1}^2. \tag{3}$$

Disadvantage of variance is the fact, that its results are expressed in squares of measured unit. With respect to the fact that input data are listed in US dollars the result has to be recalculated on square root of variance.

3.2 Input Data

Statistical input data for measuring real convergence among EU countries is made up of national data of each member state. Data for the purpose of verifying β-convergence were obtained from Eurostat database (Eurostat, 2013). In case of σ-convergence, the model uses data from UNCTADStat database (2013).

For the analyzed economies were used annual time series of two macroeconomic indicators. Gross domestic product per capita in PPS (EU28=100) is important when studying β-convergence. Gross domestic product per capita in PPP (constant prices of 2005, in US dollars) is used when verifying σ-convergence.

The subject of analysis is all of EU member states including Croatia which entered the EU in 2013. Reference time period includes years from 2001 to 2012. This time period represents pre-crisis, crisis and post-crisis years. The data before 2001 are not available.

3.3 Specification of the Cross-Section Data Model for the EU Economy

Cross-sectional regression is not drawn by an effort to find model which could predict future development of convergence process. The goal is to find out whether among EU economies is the convergence process present or there are more divergence tendencies.

Mathematically, the estimate of a regression model of cross-section data for the EU countries can be written as follows:

$$\frac{1}{T}\log\left(\frac{GDP_{i,T}}{GDP_{i,0}}\right) = \alpha + \beta \log\left(GDP_{i,0}\right) + \varepsilon_i, \tag{4}$$

where:

$\log GDP$ logarithm of gross domestic product per capita in PPS,

α constant level,

β slope parameter,

ε_i random component,

i index indicating the country (total of 28 countries monitored in the reference period 2001-2012)

$0,T$ index indicating the time (0 = 2001, T = 2012).

The dependent variable is average economic growth. Explanatory variable is macroeconomic indicator GDP per capita used in other studies which deal with economic convergence, such as Barro et al. (1992), Czech National Bank (2012) or Slavík (2005). The specified model allows us to determine whether the EU countries are converging or diverging. With respect to the fact that GDP per capita in PPS time series include merely short time period, the timelines were not fit to divide on partial time series.

4 Estimation of the Econometric Model of β-convergence and Interpretation of Results

Parameters of linear regression model of cross-section data are estimated using least-squares method (OLS). The model will be verified statistically at 5% significance level and for the calculations will be used the eViews program.

Before performing the economic verification and interpretation of the model, the model will be subjected to statistical and econometric verification. Statistical significance of the model was tested using the F-test. Individual model parameters were tested by the t-test. Model as a whole is statistically significant at 5% level of significance. The value of the correlation coefficient R indicates that GDP per capita in PPS in each country is 81% dependent on the development of explanatory variable, ie initial levels of GDP per capita in PPS surveyed economies. The coefficient of determination (R Square - multiple R) says that the explanatory variable (initial GDP per capita in 1995) explains

$\Delta\left(\dfrac{GDP_{i,2012}}{GDP_{i,2001}}\right)$ during the reporting period from

2001-2012 at 65%.

Table 1: Summary of Beta Convergence Model

R	R square	Sig. F change	Durbin-Watson
0,810	0,657	.000*	1,702

Note: * 5% significance level
Source: authors 'calculations

The statistical verification is followed by econometric verification, which includes autocorrelation, heteroskedasticity, normality test and test of randomness of explanatory variable. Autocorrelation was tested using the Durbin-Watson (D-W) test and graphically using the autocorrelation (ACF) and partial autocorrelation function (PACF). On the selected level of significance the model can be considered without autocorrelation. Heteroskedasticity was tested using the White Heteroskedasticity test. On the selected level of significance the model can be considered homoscedastic. Residuals normality was tested using Jarque-Bera test. On the selected level of significance normal distribution of residuals can be observed. Randomness of explanatory variable was tested using t-test. On the selected level of significance explanatory variable can be considered as random.

Subsequently, an econometric model can be verified economically and its results can be interpreted. Table 2 lists estimates of the level constants α and parameter β.

Table 2: Estimates of the Parameters α and β

Period	α	Sig.	β	Sig.
2001-2012	0,056	.000 *	-.0027	.000 *

Note: * 5% significance level
Source: authors 'calculations

All presented results of the econometric model are a reflection of cross-section effect in 28 studied economies in period covering the years 2001-2012. In the second column the table contains values of level constant α, which corresponds to the average economic level in particular periods assuming that explanatory variable has got zero value. Modeling of the economic level of EU economies in the period 2001 to 2012 was led effort to identify whether these economic levels converge or not. Convergence or divergence indicates a calculated parameter β. Modeling input variables in eViews was detected this functional dependence:

$$\frac{1}{T}\log\left(\frac{GDP_{i,T}}{GDP_{i,0}}\right) = 0,056 - 0,027 \cdot \log\left(GDP_{i,2001}\right), \qquad (5)$$

which suggests that the economic level of the tested countries converged, because of the negative value of the parameter β (-0.027). The model of beta convergence can be used to analyze the development of economic levels only retrospectively (i.e. in the past). The model did not include the future values of the explanatory variables. Therefore this model can be applied only ex post.

Fig. 1: β-convergence in EU in 2001-2012

Source: authors 'calculations

As seen from Fig. 1 the slope of regression line is negative and therefore there is a convergence among EU28 in time period 2001-2012. For better information ability a graph of real observed values in reference economies was computed (see Fig. 2). Positions of particular countries confirm theoretical basis of beta convergence that initially poorer countries have tendencies to grow faster than countries initially richer. A higher growth rates were observed in reference time period in countries with initially lower economic level – Romania, Bulgaria, Latvia and Lithuania. These countries are to be found in upper left hand part of the graph. On contrary, countries which evinced in default year 2001 higher economic level, such as Ireland, Netherlands, Italy, France and Belgium have in time period 2001-2012 low or even negative economic growth. These economies can be found in bottom right hand quadrant.

Fig. 2: Beta-convergence in EU28 in 2001-2012

Note: AU – Austria, BE – Belgium, BU – Bulgaria, CR – Croatia, CY – Cyprus, CZ – Czech Republic, DE – Denmark, ES – Estonia, FI – Finland, FR – France, GE – Germany, GR – Greece, HU – Hungary, IR – Ireland, SP – Spain, IT – Italy, LA – Latvia, LI – Lithuania, LU –

Luxembourg, MA – Malta, NE – Netherland, PL – Poland, PT – Portugal, RO – Romania, SL – Slovenia, SK – Slovakia, SW – Sweden, UK – United Kingdom.
Source: self-elaboration

When analyzing economic convergence among EU28 it is important to ask whether they convergence because the initially poorer countries have tendency to grow faster when economic growth in richer countries is getting slower. Tab. 3 gives us the answer to this question. First, we must accept the hypothesis that a steady state, to which EU economies convergence, is GDP per capita in PPS average. This average is dynamic in time because it is recalculated annually using the PPS method depending on macroeconomic data of GDP per capita in particular countries. The average value however is year to year 100. As seen from Tab. 3 it is obvious that some economies convergence to the EU28 average from below, others from above. As a consequence it means that in some countries the economic level is decreasing in time. It is mostly the most advanced EU economies, such as Belgium, Denmark, Ireland, France, Netherlands, Finland and the United Kingdom. Some economies are even diverging from EU28 average, such as Austria, Germany, Greece, Spain, Luxembourg and Sweden. Of course even among these economies we can find some differences. Austria, Germany, Luxembourg and Sweden evince such great economic growth thanks to which they diverge from EU28 average. On contrary, an economic downturn was detected in Greece and Spain causing even greater deviation from EU28 average.

Table 3: Estimates of the Parameters α and β

| COUNTRY	GDP PER CAPITA IN PPS (EU28=100)		CHANGE	CONVERGENCE PROCESS
	2001	2012		
Austria	126	131	+5	Diverged
Belgium	124	119	-5	Converged from above
Bulgaria	30	47	+17	Converged from below
Czech Republic	73	79	+6	Converged from below
Denmark	128	125	-3	Converged from above
Germany	116	122	+6	Diverged
Estonia	47	69	+22	Converged from below
Ireland	134	130	-4	Converged from above
Greece	87	75	-12	Diverged
Spain	98	97	-1	Diverged
France	116	108	-8	Converged from above
Croatia	51	61	+10	Converged from below
Italy	119	99	-20	Converged from above
Cyprus	91	91	0	Status quo
Latvia	39	62	+23	Converged from below
Lithuania	42	70	+28	Converged from below
Luxembourg	235	272	+37	Diverged
Hungary	58	66	+8	Converged from below
Malta	82	86	+4	Converged from below
Netherland	134	129	-5	Converged from above
Poland	48	66	+18	Converged from below
Portugal	81	75	-6	Diverged
Romania	28	49	+21	Converged from below
Slovenia	80	82	+2	Converged from below
Slovakia	53	75	+22	Converged from below
Finland	116	115	-1	Converged from above
Sweden	123	129	+6	Diverged
United Kingdom	120	110	-10	Converged from above

Source: self-elaboration

5 Does σ-convergence Lead to Different Results?

Real convergence analysis through beta convergence concept has one weakness. It only focuses on average values in reference time period. The results tell us whether the economies converge or diverge from steady state in time. It serves us little when we try to measure the convergence process in particular years. To analyze this, a sigma convergence approach is much more suitable.

Fig. 3 shows the evolution of the simple average of real GDP per capita in the EU28 and its standard deviation for each year. The figure shows that the differences in economic levels between EU member states during the financial crisis widened and then decreased slightly. The reason for reducing the variance was the relatively larger decline in real GDP in rich countries in 2009. The variance between 2010 and 2011, increased slightly again after some states quickly recover from the crisis decline, while the performance of other countries (especially those most affected by the debt crisis) further decreased.

Figure 3: Real GDP per capita in PPP (in thousands of US Dollars)
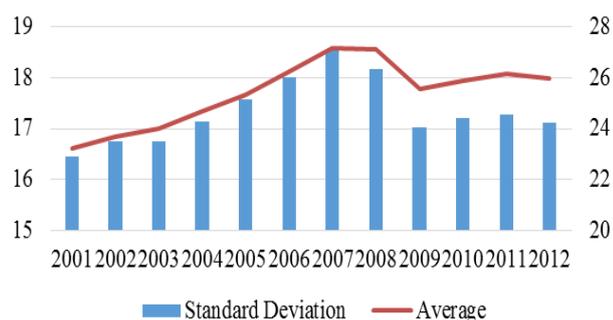
Source: self-elaboration

We can see an increase of the variance in 2008-2009 when economies has been hit by the recession. A similar increase occurred in the second half of the year 2010, which reflects the above-mentioned differences in the post-crisis economic development. The sigma convergence concept offers following conclusions. Crisis period has definitely negative impact on EU28 which suffered from economic downturn in 2007-2009 and their GDP per capita in PPS standard deviations have increased. In 2010 some EU countries experienced a recovery, however not all of them. Countries which kept struggling with the impacts of world financial crisis have continuously suffered from poor or even negative economic growth (mostly PIIGS states). The impacts of financial crisis have caused different economic development in studied economic which lead on one side to divergence from EU28 average (Austria), but on other side to convergence (Slovakia).

4 Conclusion

The aim of the article was to evaluate the impact of the financial crisis on the convergence process among EU countries. For the assessment of this external factor concepts of beta- and sigma-convergence were selected. Results are as follows. In the reference period 2001-2012 beta-convergence between EU Member States can be confirmed. It means that initially poorer countries showed a higher average rate of economic growth than initially richer states. This fact demonstrates the high economic growth in Latvia, Lithuania, Bulgaria and Romania. Conversely, weak economic growth rate was typical for PIIGS countries - Portugal, Ireland, Italy, Greece and Spain. Thanks to the economic development it can be said that beta-convergence among EU countries occurred.

In contrast, the analysis that was done through the concept of sigma-convergence revealed the different convergence development in individual years. From the graphical analysis, it was evident that before the financial crisis there was more divergent development between the EU states. Only in financial crisis and post-financial crisis period, the correction of these differences emerged. Thus in the reference period 2001-2012 a trend in reducing disparities in economic performance of EU countries cannot be monitored.

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