Sigma Versus Beta-convergence in EU28 in Financial Crisis and Post-crisis Period

KATEŘINA DVOROKOVÁ
Department of European Integration
VSB – Technical University of Ostrava
Sokolskátřída 33, 701 21 Ostrava
CZECH REPUBLIC
katerina.dvorokova@vsb.cz

Abstract: This paper focuses on evaluation of the impact of the global financial crisis on the process of real convergence within the EU28 economies. The beta-convergence approach is verified by the use of cross-sectional linear regression analysis. The sigma-convergence is tested by standard deviation of real GDP per capita. The aim is to verify the hypothesis that the beta- and sigma-convergence (β- and σ-convergence) approaches for the study of real convergence lead to different conclusions 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 Croatiawas 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 used in a variety of semantic modifications. Therefore its definition is dependent on a type of observed issue. The term convergence can be found in various natural sciences; then it has a specific meaning in the language of economists. Economic convergence is understood as a process where there is a reduction of differences in the economic level and efficiency of individual countries (eventually regions) as well. Providing that there is an opposite case, that is an

increase of differences in the economic level and economics efficiency, it is a *divergence* then. However the focus is not only whether the differences are decreasing or increasing, but it is also important to examine how quickly these changes are done.

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 understoodto as a fulfilment of Maastricht convergence criteria. Legal conditions for adopting a common currency are informally called the Maastricht convergence criteria. Their name is directly linked to the Maastricht Treaty, for details, where the criteria was for the first time taxatively defined. This treaty represents the completion of decade of efforts to achieve the monetary union within countries of existing European community (EC). The major changes of this treaty include mainly the name transformation from European community to European Union, moreover supplementation of existing economic pillar with two more pillars and already mentioned definition of the criteria which is necessary to meet for the Euro area entry. Especially Germany has warned that the monetary union cannot be entered by any state, but only by the state which is sufficiently prepared to adopt the common currency to avoid later distortions of the monetary union stability.

The convergence criteria then represent the nominal convergence which creates economic conditions expressed by measurable indicators. In case of meeting these criteria the particular state can enter the Euro area. Compliance of the Maastricht criteria should be long-lasting, not nonrecurring. Then the Maastricht treaty has established that the condition for the common currency adoption is not only the meeting of the convergence criteria, but also the compatibility condition of statutes of the national central bank with ECB and the European system of central banks.

The convergence criteria consist of fiscal criteria (government finance deficit, government debt) and the monetary criteria (price stability, exchange rate stability, stability of long-term nominal interest rates). In the current legislation the convergence criteria are anchored in Article 140 of Treaty on the functioning of the European Union and further in the additional protocols to the Treaty on European Union and Treaty on the functioning of the European Union as amended by the Lisbon Treaty (further only the Treaty):

- protocol No. 13 on the convergence criteria and
- protocol No. 12 on the excessive deficit procedure.

Comparing these criteria mainly macroeconomic stabilization of a particular country and economic development convergence of countries that form the monetary union is monitored. The macroeconomic stabilization achievement is in the interest of every country regardless of its involvement in integration groupings. It can be highlighted that the convergence of economic development of countries forming the monetary union is mainly related to the loss of independent national currency, monetary policy and exchange rate.

The main reason for establishing the convergence criteria has been an apprehension that the future monetary union would have adverse inflationary impacts on engaged economies. This idea comes from a thesis that if the monetary union has been entered by countries with different preferences regarding inflation rate, then probably countries with lower inflation would lose when entering the monetary union, particularly in the sense that the monetary policy of ECB would reflect an idea of the inflation level of all monetary union countries (not only countries with low inflation). Due to this fact an increase would probably occur in the entire monetary union (in countries with lower inflation as well).

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.As stated above, in the broadest sense, the real convergence is understood as the convergence of economic level of a compared country to a reference country or group of countries. The real convergence is then a process of reducing the gap in the economic level of compared countries. If there is a reversal process, i.e. expansion of the gap, it can be stated that a process of divergence emerges. In the context of growth theories we can talk about narrowing a technological gap and adjustment of producing structure. The real convergence can be realized via

two channels. The first one is a growth of labour productivity which will outstrip growth in reference countries. The second channel is the growth rate of economic activity and employment rates of population that may occur as a result of demographic changes of economically active population. The main factor of the real convergence is the labour productivity growth which is measured via the development of GDP per worker or per hours worked. The real convergence is expressed via economic indicators, such as convergence of economic level (GDP/capita), convergence of price levels, business cycles harmonization and structural similarity of economies.

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:

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

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:

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

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

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

convergence is then described as catching up effect. 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:

$$\sigma^2{}_t > \sigma^2{}_{t+1}. \quad (3)$$

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:

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

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 $\Delta\left(\frac{GDP_{i,2012}}{GDP_{i,2001}}\right)$ during the reporting period from 2001-2012 at 65%, see Table 1.

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 (see Table 2), 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.

Table 2: Model Estimation

Variab.	Coef.	Std. Error	t-Statistic	Prob.
C	0.056	0.007	7.546	0.000
X	-0.027	0.004	-7.062	0.000

R-squared	0.657	Meandependent var	0.004
Adjusted R-squared	0.644	S.D. dependent var	0.008
S.E. ofregression	0.005	kaikeinfocriterion	-7.885
Sum squaredresid	0.001	Schwarz criterion	-7.789
Log likelihood	112.391	Hannan-Quinncriter.	-7.856
F-statistic	49.867	Durbin-Watson stat	1.702
Prob(F-statistic)	0.000		

Source: authors ‘calculations

Heteroskedasticity was tested using the White Heteroskedasticity test, see Table 3. On the selected level of significance the model can be considered homoscedastic.

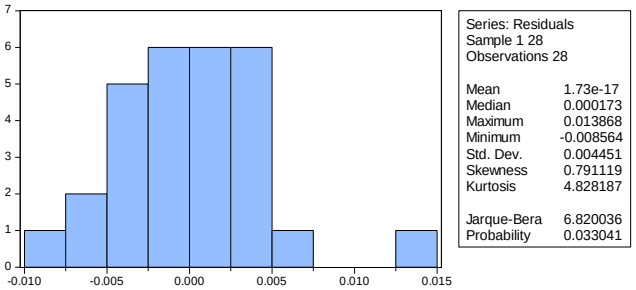
Table 3: Heteroskedasticity Test: White

F-statistic	8.143	Prob. F(2,25)	0.002
Obs*R-squared	11.045	Prob. Chi-quare	0.004
Scaledexplained SS	18.229		

Source: authors ‘calculations

Residuals normality was tested using Jarque-Bera test. On the selected level of significance normal distribution of residuals can be observed (see Figure 1).

Figure 1: Normality test



Source: authors ‘calculations

Randomness of explanatory variable was tested using t-test (see Table 4). On the selected level of significance explanatory variable can be considered as random.

Table 4: Normality test

log(GDPi), 2001	Residuals	(log(GDPi), 2001) * (Residuals)
2,093	0,000	-0,001
1,477	0,000	0,001
1,863	-0,002	-0,004
2,107	0,001	0,001
2,064	0,002	0,004
1,672	0,003	0,006
2,127	0,001	0,002
1,940	-0,009	-0,017
1,991	-0,002	-0,004
2,064	-0,002	-0,005
1,708	-0,003	-0,005
2,076	-0,006	-0,013
1,959	-0,003	-0,005
1,591	0,004	0,006
1,623	0,007	0,011
2,371	0,014	0,033
1,763	-0,003	-0,006
1,914	-0,002	-0,004
2,127	0,001	0,001
2,100	0,003	0,005
1,681	0,001	0,002
1,908	-0,007	-0,013
1,447	0,004	0,005
1,903	-0,003	-0,006
1,724	0,004	0,006
2,064	0,000	0,000
2,090	0,003	0,006
2,079	-0,003	-0,005
Average		5,1E-18
Tcounted		5,6E-16
Tcritical		2,1E+00

Source: authors ‘calculations

Subsequently, an econometric model can be verified economically and its results can be interpreted. Table 5 lists estimates of the level constants α and parameter β.

Table 5: Estimates of the Parameters α and β

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

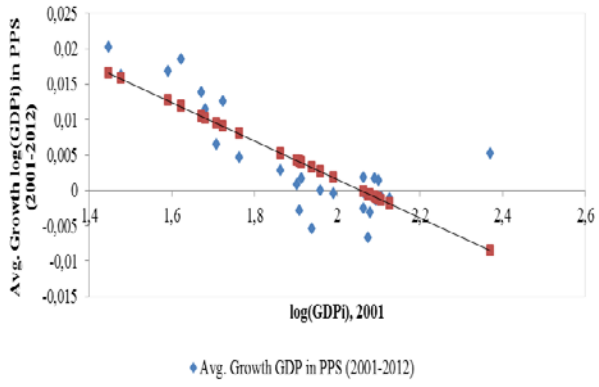
Note: * 5% significance level
Source: authors 'calculations

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. Modelling 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.

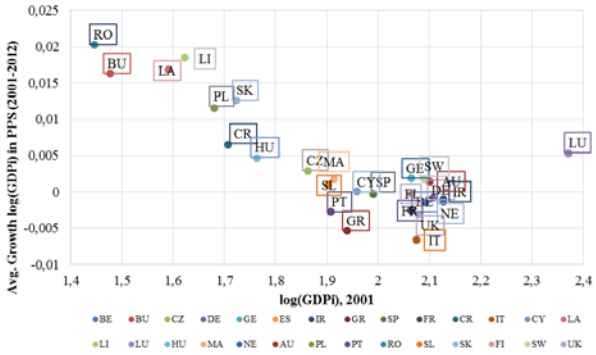
Figure 2: β-convergence in EU in 2001-2012



Source: authors 'calculations

As seen from Figure 2 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 Figure 3). 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.

Figure 3: Beta-convergence in EU28in 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. 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 Table 6it 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 6: Convergence process in EU28

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

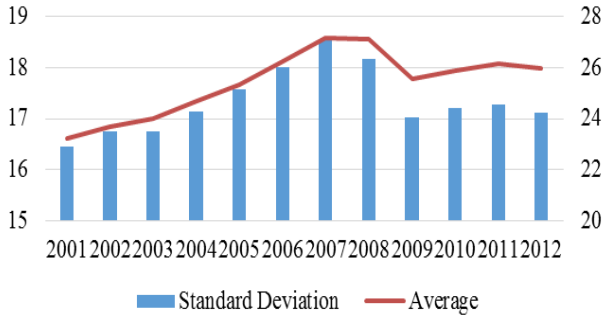
Source: self-elaboration

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. 4 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 4: 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).

In comparison with the beta convergence approach that indicates the convergence among EU countries to the average value of EU28 economy and corresponds to the theoretical basis of the neoclassical growth economics, the sigma convergence approach does not indicate a clear downward trend in the standard deviation over the time– its evolution was volatile. We can detect the visibly impact of the financial crisis due to this approach. Generally speaking both approaches are important for the analysis of economic convergence.

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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