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Sigma convergence testing across selected European countries

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Abstract: *In the article σ-convergence for the period of 1996 - 2015 is tested. For testing of σ-convergence various characteristics of real GDP per capita recalculated according to Purchasing Power Parity (real GDP per capita in PPP) are calculated, namely: cross-sectional variance, cross-sectional standard deviation and cross-sectional coefficient of variation. In case of σ-convergence these characteristics decreases over time. Analyzed data base consists of thirty-one observation - thirty countries of Europe and one integration group EU 28. The results are demonstrated graphically and indicated a convergence process between years 1996 - 2008, because of decrease of coefficient of variation. In 2009 there is an increase of this coefficient, which is seen as oscillation. Based on these results, the evidence does not support the statement of continuous σ-convergence during the entire period 1996 - 2015.*

Keywords: *σ-convergence, the real GDP per capita in PPP, Coefficient of Variation*

1. Introduction

The aim of the article is to test σ-convergence between 1996 and 2015 based on the analysis of generally known variation measures. Theoretical background of our research is the study Barro and Sala-i-Martin, (2004). The indicator σ shows the convergence and divergence tendency depending on the value of sample variance. Variation measurements for real GDP per capita in PPP in the sense of σ-convergence slowly decrease and there is an inverse relationship between the rate of economic growth for real GDP per capita in PPP and the initial level of real GDP per capita in PPP. This phenomenon is known as β-convergence, which is a necessary condition of σ-convergence. The most commonly used characteristics for application of σ-convergence testing are cross variation indicators: variance, standard deviation and coefficient of variation. These measures are also the subject of our research.

Similar methodology was used by more authors, for example by Young, Higgins and Levy (2007), Iancu (2009), Mihut and Lutas (2013), Crespo-Cuaresma and Fernández-Amandor (2013), Simionescu (2014) or by Dvoroková (2014).

First trinity of authors Young, Higgins and Levy (2007) discussed difference between β and σ-convergence for USA data and demonstrated, that σ-convergence has not occurred at the county-level across the USA. Iancu (2009) tested σ-convergence between the EU countries on three groups: EU 10, EU 15 and EU 25. In his research, the coefficient of variation indicated a divergence growth since 1995 to 2006. Later Mihut and Lutas (2013) were

measuring σ-convergence across the new members of EU. Crespo-Cuaresma and Fernández-Amandor (2013) followed the dynamics of the standard deviation for European area business cycles. Following this, Simionescu (2014), the Romanian researcher of Institute for Economic Forecasting of the Romanian Academy tested σ-convergence between countries of EU since 2000 to 2012. Further authors Beyaert and García-Solanes (2014) evaluated the effect of economic conditions on long-term convergence since 1953 to 2010. A popular research from this area is also the work of Dvoroková (2014). Author analyzed and evaluated the impact of financial crisis on the convergence among EU member states in the period 2001 to 2012 by use of β-convergence and σ-convergence testing.

Econometric testing of σ-convergence by using of unit root test was applied by authors Beyaert and García-Solanes (2014). In their thesis was used a Multivariate Threshold Autoregressive Model with bootstrapping simulations to assess the influence of short-run economic conditions on long-run economic convergence.

Because the theory is background of every research, except definitions and explanations from Barro and Sala-i-Martin (2004), who analyzed σ-convergence for USA, European countries and Japan, we follow discussion of diversity and convergence processes in Southeast Asia by Severino (2000). Severino theoretically explained geographical, economical, cultural and political view of convergence, what develop theoretical application of σ-convergence for Southeast Asia countries.

To sum up, the aim of the article is the testing of σ-convergence by using variation measures for 30 chosen European countries for time period from 1996 to 2015. These results may help to better understand how European countries approach approximately the same steady state. EU tries to create one strong group, where is possible to impose one currency politics, and similar law and political framework. It is our opinion that only case of homogeneous countries it is possible to build strong society with high level of living standard. We believe, our research may help to determine differences between countries, which may said with decision making of the EU Committee.

2. Methodology

According to Barro and Sala-i-Martin (2004, β and σ-convergence are new tools for measuring the speed of convergence. The main goal of the article is the testing of σ-convergence by σ indicator which shows the convergence or divergence tendency depending on the value of sample variance. In this section is explained methodology and practice for testing of σ-convergence based on the Economic Growth (Barro and Sala-i-Martin, 2004). Whole testing is realized according to mathematical calculation of variation measurements with graphical expression of their development in time.

2.1. Mathematical analysis

The assumption of β-convergence is that poor economies tend to grow faster than rich ones (as is stated by diminishing yield of the neo-classical theory), Soukiazis (2014). A necessary condition for σ-convergence is to achieve approximately the same steady state of the selected indicator (the most used is the real income per capita).

According to concept of σ-convergence based on study Economic Growth (Barro and Sala-i-Martin, 2004), variation indicators of chosen indicators decrease over time. The most used indicator is coefficient of variation, because it allows making comparisons (coefficient of variation is explained in percentage rate). Coefficient of variation is expressed as a share of the cross standard deviation in the nominator and the cross mean of the real GDP per cap-

ita in PPP between chosen countries in denominator. Variance is computed as the degree of deviations of each country by the mean of the real GDP per capita in PPP between chosen countries (is calculated as the sum of the squares of the differences of the real GDP per capita in PPP for each country and the simple arithmetic average of all countries). The sum of these squares of differences is divided by number of countries. The variance expresses the degree of variation of the values compared to the average. In case of small samples (when the sample of countries does not exceed at least 20 observations), the denominator is reduced by 1 observation instead of origin number of observations, Simionescu (2014). The standard deviation is calculated as the square root of the variance. In our analysis, the denominator is calculated as the value of original sample, which is 31 observations (thirty countries of Europe and one integration group EU 28).

The coefficient of variation is indicated in convergence analysis because it does not depend on the unit of measurement and the measure order of the indicators. The aspect of σ-convergence is known as a decrease of the values of variation measurements in time. We had decided to follow development of cross variance, cross standard deviation and from the reason of simple comparison also cross coefficient of variation for the real GDP per capita in PPP during time period 1996 to 2015. In case, when cross variance of the real GDP per capita in PPP decreases, is possible to state convergence. When cross variance grows or oscillates, divergence is found to exist.

2.2. Graphical analysis

For bringing the issue fully to every reader, obtained results are also represented as graphs. By using the graphs it is shown the time development of the calculated values of the cross-sectional coefficient of variation and cross-sectional standard deviation for period 1996 - 2015. Subsequently, an interpretation of obtained results is presented. Dynamically decreasing development of calculated variation characteristics indicate σ-convergence. Because shocks may disturb verification of σ-convergence, it is necessary to analyze whole sample of the real GDP per capita in PPP since 1996 to 2015.

2.3.Data

To analyze the σ-convergence, data published on-line on the website Eurostat were used. Selected sample consists from thirty-one observations for every country: EU 28, Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Greece, The Netherland, Austria, Poland, Portugal, Romania, Slovak Republic, Slovenia, Finland, Sweden, United Kingdom, Norway and Switzerland. The variation characteristics over the period 1996 – 2015 for the real GDP per capita in PPP are presented both, numerically and graphically.

3. Obtained results

The σ-convergence was tested on the period from 1996 to 2015 by the use of variation characteristics. Obtained results of cross variance, cross standard deviation and cross coefficient of variation are shown in Table 1 for every year. The coefficient of variation is expressed in percentage rate.

Table 1. Results of calculated variation characteristics

Year	Cross Variance	Cross Standard Deviation	Cross Coefficient of Variation (%)
1996	0,5507	0,7421	14,72
1997	0,5434	0,7371	14,53
1998	0,5387	0,7339	14,41
1999	0,5389	0,7341	14,35
2000	0,5340	0,7308	14,18
2001	0,5307	0,7285	14,08
2002	0,5227	0,7230	13,92
2003	0,5128	0,7161	13,75
2004	0,5072	0,7122	13,60
2005	0,4971	0,7051	13,40
2006	0,4920	0,7014	13,25
2007	0,4827	0,6948	13,05
2008	0,4777	0,6911	12,96
2009	0,4853	0,6966	13,13
2010	0,4843	0,6959	13,07
2011	0,4803	0,6931	12,98
2012	0,4787	0,6919	12,94
2013	0,4783	0,6916	12,92
2014	0,4758	0,6898	12,85
2015	0,4740	0,6884	12,77

Source: Own calculation based on Eurostat data

The values of calculated variation characteristics are in most of the period from 1996 to 2015 decreasing, but with slight increases in 1999 and 2009. In 1999, the value of cross variance and cross standard deviation little increased and in 2009 the value increased more significantly. Below the level of 2008 values fell again in 2014. However, the most important indicator for our research is coefficient of variation expressed in percentage rate. The development of this characteristic is decreasing since 1996 until 2008, and then in 2009 also as in the case of others variation characteristics is recorded a sudden increase. Since 2009, the value of the coefficient of variation decreases until 2015. Below the level of 2008 values fell in 2012.

In the article is presented also the development of selected cross variation characteristics graphically. Figure 1 shows the development of the cross standard deviation for the real GDP per capita in PPP.

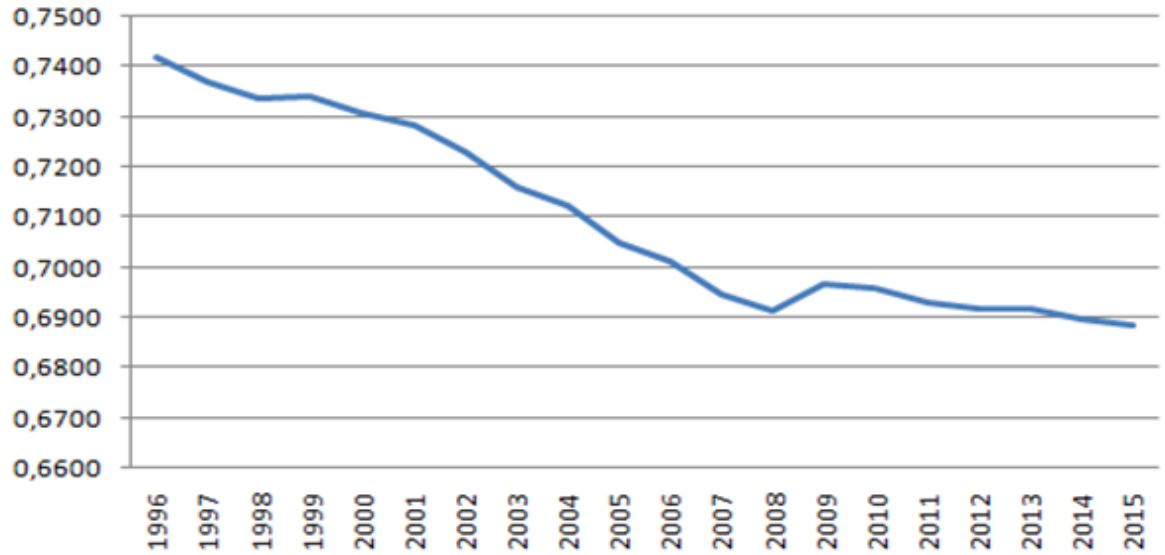

Figure 1. The cross-sectional standard deviation of the real GDP per capita in PPP
Source: Own calculation based on Eurostat data

The main determinant for analysis of σ-convergence is the coefficient of variation. Because of this reason, Figure 2 shows the development of the cross coefficient of variation in percentage rate.

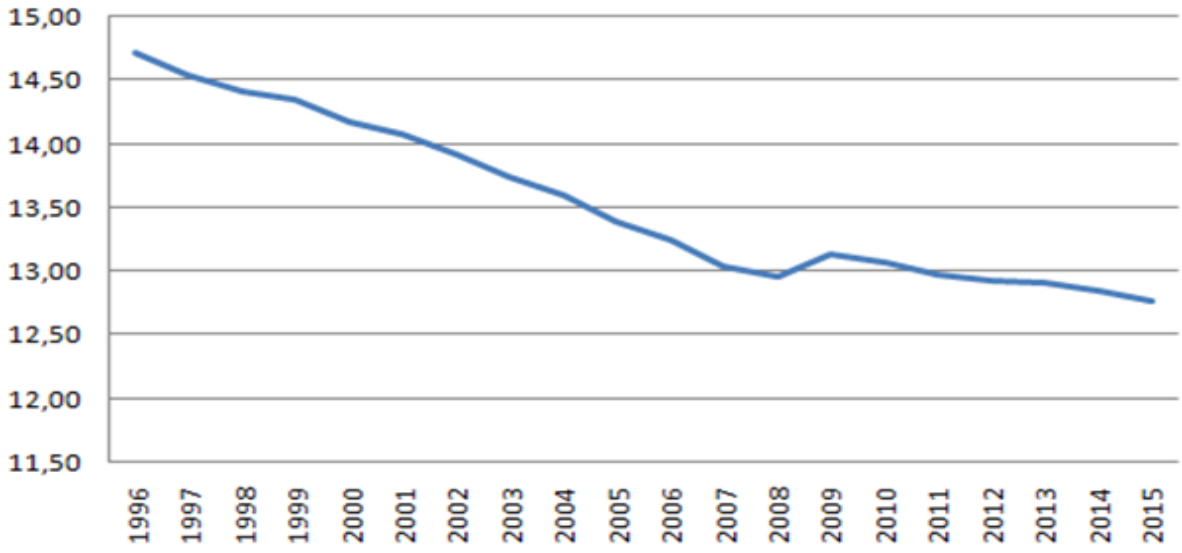

Figure 2. The cross-sectional coefficient of variation for the real GDP per capita in PPP
Source: Own calculation based on Eurostat data

The analysis together with graphical explanation shows a downward trend in the coefficient of variation since 1996 to 2008. Is possible to state that σ-convergence between chosen European countries is apparent within this period. Because of increase in 2009, there is an increase in the value of the coefficient of variation, and we reject σ-convergence for the period 1996 - 2015.

Based on decreasing coefficient of variation, we state σ-convergence was present only from 1996 to 2008. In this period there are no changes in monotonicity of development of values of this coefficient.

4. Conclusion

In the paper σ-convergence is analyzed by selected variation characteristics, which are expressed also graphically. Cross-sectional variance, cross-sectional standard deviation and cross-sectional coefficient of variation are calculated from the real GDP per capita in PPP for thirty chosen European countries and one integration group EU 28. Selected time period is 1996 - 2015.

Time development of cross coefficient of variation is decreasing without oscillations within the period from 1996 to 2008. In 2009 this coefficient suddenly increases and in further years the coefficient of variation decreases until end of 2015. Value of coefficient of variation fell below level in 2008 later after 2012, so it is not possible to state σ-convergence occurred within the entire period 1996 - 2015.

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Appendix: Data used for σ-convergence testing

GEO/TIME	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
EU 28	6,8885	6,9127	6,9324	6,9535	6,9845	7,0020	7,0174	7,0241	7,0453	7,0641	7,0883	7,1134	7,1158	7,0898	7,1078	7,1203	7,1287	7,1322	7,1461	7,1675
Belgium	5,3012	5,3253	5,3362	5,3599	5,4012	5,4108	5,4337	5,4339	5,4479	5,4620	5,4787	5,4988	5,5006	5,4852	5,5174	5,5334	5,5477	5,5496	5,5601	5,5789
Bulgaria	4,5722	4,5843	4,6361	4,6128	4,6537	4,6741	4,7149	4,7409	4,7756	4,8140	4,8533	4,9080	4,9395	4,9214	4,9356	4,9405	4,9518	4,9498	4,9662	4,9923
Czech Republic	5,1076	5,1176	5,1201	5,1359	5,1616	5,1892	5,2028	5,2266	5,2556	5,2797	5,3082	5,3482	5,3423	5,3268	5,3349	5,3563	5,3606	5,3698	5,3932	5,4206
Denmark	5,0273	5,0558	5,0732	5,0924	5,1273	5,1366	5,1506	5,1485	5,1775	5,1966	5,2249	5,2441	5,2534	5,2292	5,2613	5,2708	5,2771	5,2849	5,2968	5,3177
Germany	6,2267	6,2418	6,2555	6,2759	6,2936	6,3086	6,3175	6,3221	6,3411	6,3503	6,3682	6,3930	6,3923	6,3632	6,3895	6,4124	6,4228	6,4280	6,4468	6,4664
Estonia	3,9162	3,9765	4,0010	4,0063	4,0618	4,0938	4,1376	4,1815	4,2207	4,2791	4,3318	4,3851	4,3793	4,3184	4,3421	4,3905	4,4151	4,4242	4,4401	4,4537
Ireland	4,8032	4,8558	4,9055	4,9468	5,0026	5,0382	5,0751	5,0893	5,1244	5,1552	5,1943	5,2295	5,1961	5,1562	5,1776	5,1959	5,2077	5,2126	5,2400	5,3753
Greece	5,1584	5,1916	5,2090	5,2300	5,2578	5,2892	5,3253	5,3411	5,3701	5,3683	5,4042	5,4195	5,4308	5,4085	5,3906	5,3484	5,3365	5,3361	5,3377	5,3418
Spain	5,7603	5,7909	5,8206	5,8458	5,8838	5,9097	5,9379	5,9526	5,9781	6,0118	6,0540	6,0846	6,0847	6,0578	6,0560	6,0533	6,0532	6,0478	6,0602	6,0803
France	6,0389	6,0635	6,0868	6,1103	6,1457	6,1675	6,1818	6,1737	6,1894	6,2156	6,2337	6,2559	6,2525	6,2329	6,2526	6,2663	6,2713	6,2819	6,2904	6,3087
Croatia	4,5406	4,5793	4,5947	4,5993	4,6285	4,6522	4,6840	4,7082	4,7381	4,7615	4,7887	4,8332	4,8506	4,8104	4,8058	4,8224	4,8314	4,8283	4,8336	4,8473
Italy	6,0471	6,0680	6,0889	6,1029	6,1297	6,1402	6,1471	6,1504	6,1575	6,1704	6,1920	6,2142	6,2164	6,1908	6,2008	6,2116	6,2122	6,2037	6,2091	6,2268
Cyprus	3,9895	4,0125	4,0418	4,0710	4,1121	4,1438	4,1569	4,1696	4,2032	4,2411	4,2704	4,3175	4,3355	4,3187	4,3241	4,3284	4,3182	4,2869	4,2802	4,2998
Latvia	4,0848	4,1341	4,1685	4,1886	4,2209	4,2631	4,3005	4,3304	4,3690	4,4207	4,4612	4,5169	4,5243	4,4392	4,4499	4,4867	4,5133	4,5250	4,5432	4,5650
Lithuania	4,2924	4,3388	4,3769	4,3809	4,4138	4,4544	4,4917	4,5435	4,5710	4,6129	4,6495	4,7064	4,7196	4,6401	4,6777	4,7177	4,7456	4,7633	4,7826	4,7973
Luxembourg	4,1641	4,1898	4,2122	4,2782	4,3277	4,3263	4,3468	4,3565	4,3906	4,4265	4,4790	4,5166	4,5193	4,4852	4,5187	4,5528	4,5633	4,5801	4,6129	4,6371
Hungary	4,9137	4,9397	4,9646	4,9871	5,0254	5,0671	5,1025	5,1221	5,1412	5,1639	5,1815	5,1959	5,2130	5,1951	5,2147	5,2329	5,2365	5,2481	5,2664	5,2884
Malta	3,6803	3,7146	3,7391	3,7669	3,8105	3,8054	3,8322	3,8457	3,8582	3,8804	3,8922	3,9152	3,9317	3,9263	3,9558	3,9561	3,9693	3,9865	4,0210	4,0620
Netherlands	5,5066	5,5399	5,5699	5,6011	5,6442	5,6602	5,6733	5,6664	5,6883	5,7133	5,7398	5,7687	5,7751	5,7434	5,7526	5,7634	5,7718	5,7786	5,7831	5,7970
Austria	5,2189	5,2403	5,2613	5,2825	5,3134	5,3136	5,3339	5,3433	5,3664	5,3781	5,4035	5,4218	5,4273	5,4065	5,4268	5,4451	5,4660	5,4719	5,4832	5,5001
Poland	5,4347	5,4737	5,5004	5,5288	5,5527	5,5665	5,5874	5,5990	5,6345	5,6538	5,6794	5,7222	5,7417	5,7471	5,7872	5,8169	5,8359	5,8392	5,8558	5,8814
Portugal	5,1072	5,1392	5,1661	5,1985	5,2311	5,2449	5,2606	5,2669	5,2799	5,3074	5,3319	5,3491	5,3468	5,3280	5,3442	5,3289	5,3225	5,3310	5,3424	5,3610
Romania	5,0473	5,0379	5,0358	5,0429	5,0628	5,1013	5,1270	5,1557	5,2194	5,2459	5,3118	5,3645	5,4226	5,3942	5,4243	5,4393	5,4589	5,4646	5,4825	5,5135
Slovenia	4,3842	4,4179	4,4389	4,4701	4,4976	4,5155	4,5413	4,5536	4,5853	4,6096	4,6314	4,6620	4,6751	4,6298	4,6383	4,6493	4,6515	4,6501	4,6714	4,6923
Slovakia	4,6327	4,6701	4,6942	4,7021	4,7292	4,7616	4,7880	4,8092	4,8391	4,8800	4,9237	4,9720	5,0031	4,9754	5,0127	5,0220	5,0369	5,0450	5,0624	5,0831
Finland	4,9343	4,9767	5,0113	5,0388	5,0756	5,0881	5,1011	5,1025	5,1361	5,1485	5,1699	5,2067	5,2172	5,1783	5,1952	5,2138	5,2190	5,2159	5,2187	5,2335
Sweden	5,2507	5,2713	5,2903	5,3216	5,3571	5,3594	5,3700	5,3787	5,4068	5,4160	5,4490	5,4857	5,4843	5,4479	5,4748	5,4939	5,5074	5,5079	5,5190	5,5439
United Kingdom	6,0284	6,0582	6,0703	6,0888	6,1284	6,1463	6,1642	6,1798	6,2051	6,2192	6,2375	6,2498	6,2460	6,2117	6,2338	6,2404	6,2562	6,2642	6,2858	6,3072
Norway	5,0008	5,0365	5,0333	5,0752	5,1625	5,1703	5,1700	5,1738	5,2177	5,2734	5,3193	5,3362	5,3663	5,3086	5,3355	5,3652	5,3943	5,3976	5,3938	5,3808
Switzerland	5,2495	5,2726	5,2893	5,3031	5,3331	5,3411	5,3546	5,3528	5,3708	5,3868	5,4217	5,4631	5,4790	5,4635	5,4864	5,5127	5,5388	5,5494	5,5607	5,5863