



The economic convergence in European Union based on concentration and entropy approach

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Abstract. The main objective of this study is to assess the economic convergence in European Union (EU-28) using a frequent approach in literature based on Gini coefficients, Lorenz curve and Theil's index. On the other hand, the entropy approach is quite new in the convergence field, but the results are relevant. The assumption of economic convergence is confirmed for EU-28 in 2003-2012. According to Gini coefficient values the degree of concentration has decreased on the analyzed period, but there is an insignificant decrease in 2012 compared to 2003. The value of Theil's index also confirmed the convergence. In the convergence analysis the increase in entropy translates into an emphasis of divergence process. In 2012 the entropy is lower than the value of entropy in 2003, the convergence being more relevant in 2012 compared to 2003.

Keywords: economic convergence, Gini coefficient, Theil's index, Lorenz curve .

1 Introduction

The interest for economic convergence analysis increased in the last year mainly in the context of new integrations in the European Union. There are many ways to assess the degree of convergence, the approach based on Lorenz curve being considered relevant for many researchers, even if there is not a unique indicator to express the convergence intensity.

This paper brings us novelty the use of entropy indicators for evaluating the degree of convergence. Moreover, the convergence process refers to the countries of European Union in its extended form (EU-28). The studies elaborated till now refer to EU-27 or to other reduced forms from the European territory.

The structure of the paper follows a rational demarche: after the brief introduction, a short retrospective in the literature is made, giving also some theoretical basis. The application refers to the convergence in EU-28 and the methods used for measuring the economic convergence are based on Lorenz curve, Gini coefficients, Theil's index and entropy indicators.

2 The measurement of economic convergence in literature

The economic convergence is characterized by the decrease of the development gap between less



developed economies compared to developed countries. The process is very well analyzed in the economic literature, the interest for convergence becoming higher in the context of the extension of the European Union in the last 10 years (Angeloni, Flad, Mongelli, 2005).

There is not still a unique indicator for measuring the degree of convergence process, but there are indicators that reflect the disparities between regions or countries: variance, coefficient of variance, Gini coefficient, Theil index, etc. (Castro, 2004). Theil index is an extensive indicator used to measure the inequality, being decomposable, but also additive.

(Barro & Sala-i-Martin, 1995) considered the theoretical background for studying the convergence of contributions to inequality. This approach was developed by (Islam, 1995) and (Nerlove, 1999) for panel analysis. The convergence test of inequalities based on the variation of Gini index was proposed by Bénabou (1996) and developed by Ravallion (2003). (Antonescu, 2012) used the spatial methods to measure the regional convergence in European Union and Romania, among the methods being the computation of Lorenz curve and Gini coefficients.

(Geppert & Stephan, 2008) assessed the overall convergence and the spatial concentration in the European Union using methods like Markov chain, cross-sectional regressions and Kernel density estimation. The concentration of economic activities increased the disparities between the EU countries. (El ouardighi & Somun-Kapetanovic, 2009) obtained a weak convergence of contributions to inequality when they analyzed the international income inequality of 32 countries from Europe during 1989-2002.

(Albu, 2012a) proved that there is a general tendency of structural convergence in the EU during 2000-2011 using the Lorenz curve. Even if the actual economic crisis has a negative effect on convergence process, (Albu, 2012b) used the Lorenz curve and Gini coefficients to show that there is still significant convergence across EU countries.

(Ville, 2013) linked the convergence with the evolution in income distribution measured by Gini coefficient. In general, there was not found a correlation between convergence and changes in income repartition during 2000–2011.

(Buturac, 2013) confirmed the economic convergence in South-Eastern European countries during 2000-2010. The author used Theil's index as inequality measure to analyze the macroeconomic convergence.

(Weatherspoon et al., 2003) used the Theil's index to assess the economic convergence in OECD and then the computed indices for industrial employment, GDP per capita, government and investment expenditures were made dynamic by using pairwise cointegration and Johansen's I(2) multi-cointegration tests.

(Maasoumi & Wang, 2008) proposed a new concept of convergence that takes into account the entropy measure described by (Granger et al., 2004) for assessing economic convergence in China.

Concentration is actually perceived as an accumulation more and more significant of means (incomes, real estate etc.) for a small number of holders, expressing an inequality state, a divergence. In the convergence economic approach, in a group of countries a convergence process in relation to income (GDP, output), if the proportion of each country in the population group has a closer and closer correspondent as measure in outcome proportion of that country in the overall outcomes of group. The concentration indicators close to zero show the equilibrium state or the proportionality between resources (population, surface, number of organizations etc.) and results (income, production, access to funds etc.) registered by group's components. A simple indicator is the Gini indicator:

Equation 1 Formula for Gini coefficient

$$C_G = \sqrt{\sum_{i=1}^n g_i^2}$$

g_i - element's weight (country, region i)

Equation 2 Formula for the weight

$$g_i = \frac{x_i}{\sum_{i=1}^n x_i}$$

The maximal value of this coefficient is 1; the minimum value of the coefficient is $\sqrt{\frac{1}{n}}$ which is obviously different from zero. The Gini-Struck coefficient is between 0 and 1:

Equation 3 Formula for Gini-Struck coefficient

$$C_{G-S} = \sqrt{\frac{n \sum_{i=1}^n g_i^2 - 1}{n - 1}}$$

Onicescu informational energy that is also known as Herfindahl coefficient is computed as:

Equation 4 Formula for Herfindahl coefficient

$$E_o = \sum_{i=1}^n g_i^2$$

$$\frac{1}{n} \leq E_o \leq 1$$

Each coefficient indicates a higher concentration if the value increases towards the superior limit. Lorenz curve refers to concentration and it is a useful tool in the economic analysis, showing the process intensity, but also a possibility of measuring the concentration degree. The procedure supposes the parallel analysis of the weights' location regarding the two correlated variables.

In the convergence analysis, the concentration indicators provide limited information, these being defined to express states that are complementary to convergence. A comparative analysis of concentration coefficients calculated for successive periods could show indirectly a closer situation of convergence. This kind of situation could be confirmed by the slow diminish of the concentration level towards zero. In a direct way, the concentration indicators show how far we are of equality situation, of a proportional distribution of the economic results in the analyzed countries.

The convergence process in a group of spatial units (regions, countries) has a correspondent in physics, given by the entropy. It tends to increase all the time (it converges towards an equilibrium state, according to the second law of thermodynamics). The convergence measurement is somehow related to the way of getting a numerical measure of the indetermination degree (entropy). The level of development, synthetically measured by GDP per capita in each country from EU is assimilated to the independent realizations of a random variable y_i . The Theils' index is based on the additive entropy and on the reference unit given by the decimal logarithm base.

Equation 5 Formula for Theil's index

$$T = \frac{1}{n} \sum_{i=1}^n \frac{x_i}{\bar{x}} \log \frac{x_i}{\bar{x}}$$

(Dickey, 2001) proposed another version that takes into account the existence of more groups of spatial units that compose the entire region:

Equation 6 Formula for modified Theil's index

$$T_{(d)} = \sum_{k=1}^K s_k T_k + \sum_{k=1}^K s_k \log \frac{x_k}{\bar{x}}$$

T_k - the Theil's index for group k

s_k - share of variable x (GDP per capita) to group k in the overall groups

If Theil's index decreases towards zero, the divergence degree in the sense of diversity decreases, too. So, the countries converge to close values regarding the analyzed variable. This index expresses in a synthetic way a state of the system that could be correlated with the convergence process development. Moreover, the Theil's index allows us to assess the divergence (differences in levels) in the case of a structured entire on groups of countries, regions etc. There are few limits of this indicator like: the all elements are considered as a closed system, the countries are independent from the economic point of view, the finish of the convergence process conducts to a "out of stock" system if the energy transfer is not possible any more.

3 The measurement of economic convergence in EU-28

For measuring the degree of concentration and its evolution in time in a first stage the countries of EU-28 were grouped according to GDP per capita in 2003 (reference base). These groups were maintained in 2012 for ensuring the comparability and for the lack of significant change in homogeneity in each group. Only the intervals' limits changed. In the following table we mention the group number for the interval' limits represented in 2003 the values (GDP per capita). The number of countries, weights for GDP, but also population in 2003 and 2012 are included in the table columns. The weights of GDP/capita for 2003 were kept.

Table 1 Weights for population and GDP per capita in 2003 and 2012

No. of group	Number of countries	GDP per capita weights in 2003	Population weights in 2003	GDP per capita cumulative weights in 2003	Population cumulative weights in 2003	GDP per capita weights in 2012	Population weights in 2012	GDP per capita cumulative weights in 2012	Population cumulative weights in 2012
1: Less than 9001	2	2.46%	6.02%	2.46%	6.02%	3.55%	5.46%	3.55%	5.46%
2: 9001-	7	14.06%	13.31%	16.53%	19.34%	17.47%	12.84%	21.01%	18.29%



No. of group	Number of countries	GDP per capita weights in 2003	Population weights in 2003	GDP per capita cumulative weights in 2003	Population cumulative weights in 2003	GDP per capita weights in 2012	Population weights in 2012	GDP per capita cumulative weights in 2012	Population cumulative weights in 2012
13000 3: 13001 -	3	9.05%	4.30%	25.57%	23.64%	8.87%	4.27%	29.88%	22.56%
17000 4: More than 17000	16	74.43%	76.37%	100%	100%	70.11%	77.43%	100%	100%

2.46% of the GDP/capita is produced by only 6.02% of the EU28 population. but this situation is compensated by the fact that 76.37% of the EU population in 2012 produced 74.43% of the total production. In 3.55% of the GDP/capita was obtained by 5.46% of the EU28 inhabitants. while 77.43% of the population produced 70.11% of the GDP/capita.

The Gini coefficient in weighted variant was computed. The computations for concentration and entropy indicators were made in Wessa free statistical software.

Table 2 Concentration and entropy indicators in 2003 and 2012

Indicator	2003	2012
Entropy	2.691537	2.686573
Maximum Entropy	3.332205	3.332205
Normalized Entropy	0.807735	0.806245
Exponential Index	0.067777	0.068114
Herfindahl	0.092268	0.092292
Normalized Herfindahl	0.058648	0.058673
Gini Coefficient	0.600281	0.601846
Concentration Coefficient	0.622514	0.624137

The entropy is a measure of information uncertainty, a higher value of it implying a higher degree of uncertainty. In the convergence analysis this increase in uncertainty translates into an emphasis of divergence process. In 2012 the entropy is 2.6865, which is lower than the value of entropy in 2003 (2.6915). This means that the convergence process is a little more obvious in 2012 compared to 2003. For Gini coefficient a higher value was registered in 2012, even if the differences between indicator values are insignificant. The concentration coefficient indicates a slow increase in the degree of concentration in 2012 with respect to the situation presented in 2003.

The study of the absolute and relative indicators of convergence and entropy for each country does not allow us to draw a conclusion regarding the convergence for overall European Union.

Table 3 Absolute and relative indicators for concentration and entropy in 2003 and 2012

Category	2003				2012			
	Elements (Absolute)	Elements (Relative)	Entropy (Absolute)	Entropy (Relative)	Elements (Absolute)	Elements (Relative)	Entropy (Absolute)	Entropy (Relative)
1	1.035584e+7	0.021168	0.081607	0.030320	1.109485e+7	0.022070	0.084165	0.031328
2	7.845841e+6	0.016037	0.066279	0.024625	7.327224e+6	0.014575	0.061631	0.022940



Category	2003				2012			
3	1.019265e+7	0.020834	0.080652	0.029965	1.050544e+7	0.020898	0.080834	0.030088
4	5.383507e+6	0.011004	0.049623	0.018437	5.580516e+6	0.011101	0.049962	0.018597
5	8.253668e+7	0.168708	0.300230	0.111546	8.032790e+7	0.159789	0.293037	0.109075
6	1.364678e+6	0.002789	0.016407	0.006096	1.333788e+6	0.002653	0.015739	0.005858
7	3.964191e+6	0.008103	0.039020	0.014497	4.582707e+6	0.009116	0.042824	0.015940
8	1.100638e+7	0.022497	0.085363	0.031715	1.112303e+7	0.022126	0.084322	0.031387
9	4.182784e+7	0.085497	0.210261	0.078119	4.681822e+7	0.093131	0.221070	0.082287
10	6.010184e+7	0.122850	0.257591	0.095704	6.340919e+7	0.126134	0.261149	0.097205
11	4.305384e+6	0.008800	0.041652	0.015475	4.275984e+6	0.008506	0.040547	0.015093
12	5.732107e+7	0.117166	0.251223	0.093338	5.939421e+7	0.118147	0.252342	0.093927
13	713720.000000	0.001459	0.009527	0.003539	862011.000000 0	0.001715	0.010920	0.004065
14	2.299390e+6	0.004700	0.025193	0.009360	2.044813e+6	0.004068	0.022391	0.008334
15	3.431497e+6	0.007014	0.034789	0.012925	3.003641e+6	0.005975	0.030592	0.011387
16	448300.000000	0.000916	0.006410	0.002382	524853.000000 0	0.001044	0.007167	0.002668
17	1.014236e+7	0.020731	0.080357	0.029855	9.931925e+6	0.019757	0.077530	0.028858
18	397296.000000	0.000812	0.005779	0.002147	417546.000000 0	0.000831	0.005892	0.002193
19	1.619257e+7	0.033098	0.112808	0.041912	1.673035e+7	0.033280	0.113246	0.042152
20	8.100273e+6	0.016557	0.067900	0.025227	8.408121e+6	0.016726	0.068421	0.025468
21	3.821853e+7	0.078120	0.199168	0.073998	3.853845e+7	0.076661	0.196893	0.073288
22	1.044459e+7	0.021349	0.082125	0.030512	1.054240e+7	0.020971	0.081045	0.030167
23	2.162751e+7	0.044207	0.137877	0.051226	2.009600e+7	0.039975	0.128700	0.047905
24	1.995033e+6	0.004078	0.022437	0.008336	2.055496e+6	0.004089	0.022486	0.008370
25	5.374873e+6	0.010986	0.049561	0.018414	5.404322e+6	0.010750	0.048729	0.018138
26	5.206295e+6	0.010642	0.048345	0.017962	5.401267e+6	0.010744	0.048708	0.018130
27	8.940788e+6	0.018275	0.073141	0.027175	9.482855e+6	0.018863	0.074898	0.027879
28	5.949020e+7	0.121600	0.256213	0.095192	6.349535e+7	0.126306	0.261333	0.097274



The cumulated indicators for concentration and entropy show that in general the convergence process emphasized as tendency in 2012 compared to 2003. However, for few countries an obvious regression of the convergence was observed during 2003-2012.

Table 4 Absolute and relative cumulated indicators for concentration and entropy in 2003 and 2012

Category	2003				2012			
	Elements (Absolute Cumulated)	Elements (Relative Cumulated)	Entropy (Absolute Cumulated)	Entropy (Relative Cumulated)	Elements (Absolute Cumulated)	Elements (Relative Cumulated)	Entropy (Absolute Cumulated)	Entropy (Relative Cumulated)
1	1.035584e+7	0.021168	0.081607	0.030320	1.109485e+7	0.022070	0.084165	0.031328
2	1.820168e+7	0.037205	0.147886	0.054945	1.842207e+7	0.036645	0.145796	0.054268
3	2.839433e+7	0.058039	0.228539	0.084910	2.892752e+7	0.057543	0.226630	0.084356
4	3.377784e+7	0.069043	0.278161	0.103347	3.450804e+7	0.068644	0.276592	0.102953
5	1.163145e+8	0.237751	0.578391	0.214893	1.148359e+8	0.228433	0.569629	0.212028
6	1.176792e+8	0.240540	0.594799	0.220988	1.161697e+8	0.231086	0.585367	0.217886
7	1.216434e+8	0.248643	0.633819	0.235486	1.207524e+8	0.240202	0.628192	0.233826
8	1.326498e+8	0.271140	0.719182	0.267201	1.318755e+8	0.262328	0.712514	0.265213
9	1.744776e+8	0.356638	0.929443	0.345320	1.786937e+8	0.355459	0.933584	0.347500
10	2.345794e+8	0.479488	1.187034	0.441025	2.421029e+8	0.481593	1.194733	0.444705
11	2.388848e+8	0.488288	1.228685	0.456500	2.463789e+8	0.490099	1.235280	0.459798
12	2.962059e+8	0.605454	1.479909	0.549838	3.057731e+8	0.608246	1.487622	0.553725
13	2.969196e+8	0.606913	1.489435	0.553377	3.066351e+8	0.609961	1.498543	0.557790
14	2.992190e+8	0.611613	1.514628	0.562737	3.086799e+8	0.614029	1.520933	0.566124
15	3.026505e+8	0.618627	1.549417	0.575663	3.116835e+8	0.620004	1.551526	0.577511
16	3.030988e+8	0.619544	1.555827	0.578044	3.122084e+8	0.621048	1.558693	0.580179
17	3.132412e+8	0.640275	1.636184	0.607899	3.221403e+8	0.640804	1.636223	0.609037
18	3.136385e+8	0.641087	1.641962	0.610046	3.225579e+8	0.641635	1.642115	0.611230
19	3.298310e+8	0.674185	1.754770	0.651958	3.392882e+8	0.674915	1.755360	0.653383
20	3.379313e+8	0.690742	1.822670	0.677186	3.476963e+8	0.691641	1.823781	0.678850
21	3.761498e+8	0.768862	2.021838	0.751183	3.862348e+8	0.768302	2.020675	0.752138
22	3.865944e+8	0.790211	2.103962	0.781695	3.967772e+8	0.789273	2.101720	0.782305
23	4.082219e+8	0.834419	2.241839	0.832921	4.168732e+8	0.829248	2.230419	0.830210



Category	2003				2012			
	Elements (Absolute Cumulated)	Elements (Relative Cumulated)	Entropy (Absolute Cumulated)	Entropy (Relative Cumulated)	Elements (Absolute Cumulated)	Elements (Relative Cumulated)	Entropy (Absolute Cumulated)	Entropy (Relative Cumulated)
24	4.102170e+8	0.838497	2.264276	0.841258	4.189287e+8	0.833337	2.252906	0.838580
25	4.155918e+8	0.849483	2.313837	0.859671	4.243330e+8	0.844087	2.301635	0.856718
26	4.207981e+8	0.860125	2.362182	0.877633	4.297342e+8	0.854831	2.350343	0.874848
27	4.297389e+8	0.878400	2.435324	0.904808	4.392171e+8	0.873694	2.425241	0.902726
28	4.892291e+8	1.000000	2.691537	1.000000	5.027125e+8	1.000000	2.686573	1.000000

According to Gini coefficient values the degree of concentration has decreased but with an insignificant decrease in 2012 compared to 2003 (a value of 0.601846 in 2012 compared to 0.600281 in 2003). Lorenz curve indicates a lower inequality of the wealth distribution in 2012 compared to 2003.

Table 5 Lorenz curve in 2003 and 2012

Cumulative % of population	Cumulative % of variable (2003)		Cumulative % of variable (2012)	
	Expected	Observed	Expected	Observed
0%	0.000000	0.000010	0.000000	0.000010
4%	0.035714	0.000812	0.035714	0.000831
7%	0.071429	0.001728	0.071429	0.001875
11%	0.107143	0.003187	0.107143	0.003589
14%	0.142857	0.005977	0.142857	0.006243
18%	0.178571	0.010055	0.178571	0.010310
21%	0.214286	0.014755	0.214286	0.014399
25%	0.250000	0.021769	0.250000	0.020374
29%	0.285714	0.029872	0.285714	0.028880
32%	0.321429	0.038672	0.321429	0.037996
36%	0.357143	0.049314	0.357143	0.048740
39%	0.392857	0.060300	0.392857	0.059490
43%	0.428571	0.071304	0.428571	0.070591
46%	0.464286	0.087341	0.464286	0.085166
50%	0.500000	0.103899	0.500000	0.101892
54%	0.535714	0.122174	0.535714	0.120755
57%	0.571429	0.142905	0.571429	0.140512
61%	0.607143	0.163739	0.607143	0.161409
64%	0.642857	0.184907	0.642857	0.182380
68%	0.678571	0.206256	0.678571	0.204450
71%	0.714286	0.228754	0.714286	0.226576
75%	0.750000	0.261852	0.750000	0.259857
79%	0.785714	0.306059	0.785714	0.299832
82%	0.821429	0.384179	0.821429	0.376493
86%	0.857143	0.469676	0.857143	0.469624
89%	0.892857	0.586842	0.892857	0.587771
93%	0.928571	0.708442	0.928571	0.713906
96%	0.964286	0.831292	0.964286	0.840211
100%	1.000000	1.000000	1.000000	1.000000

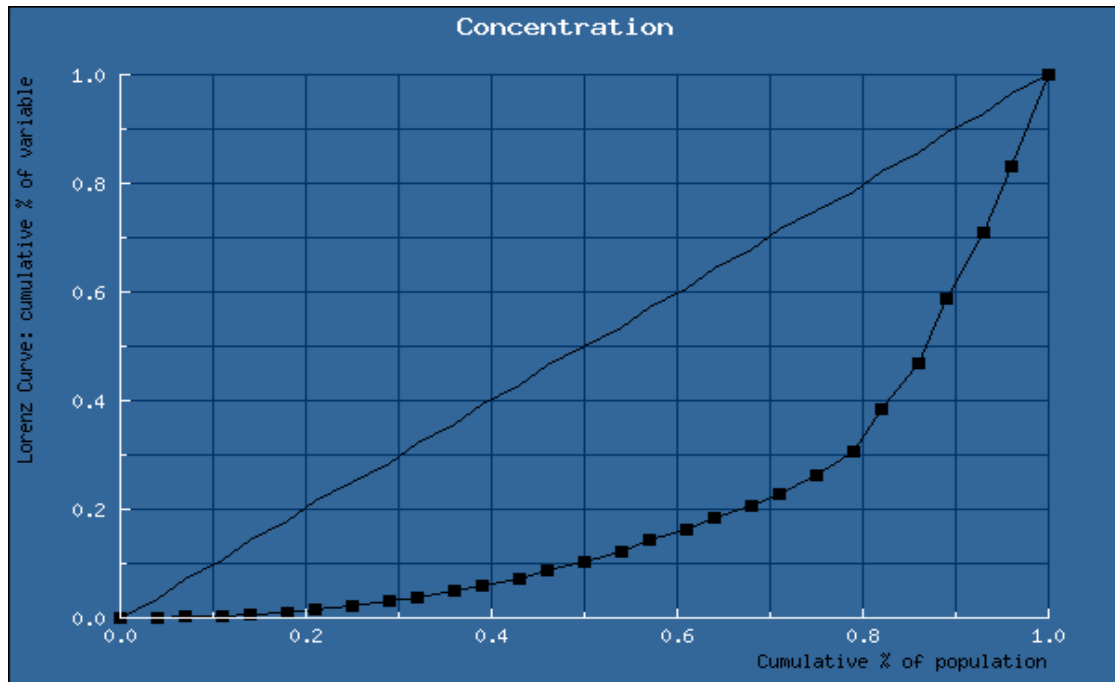


Figure 1 Lorenz curve in EU-28 for 2003

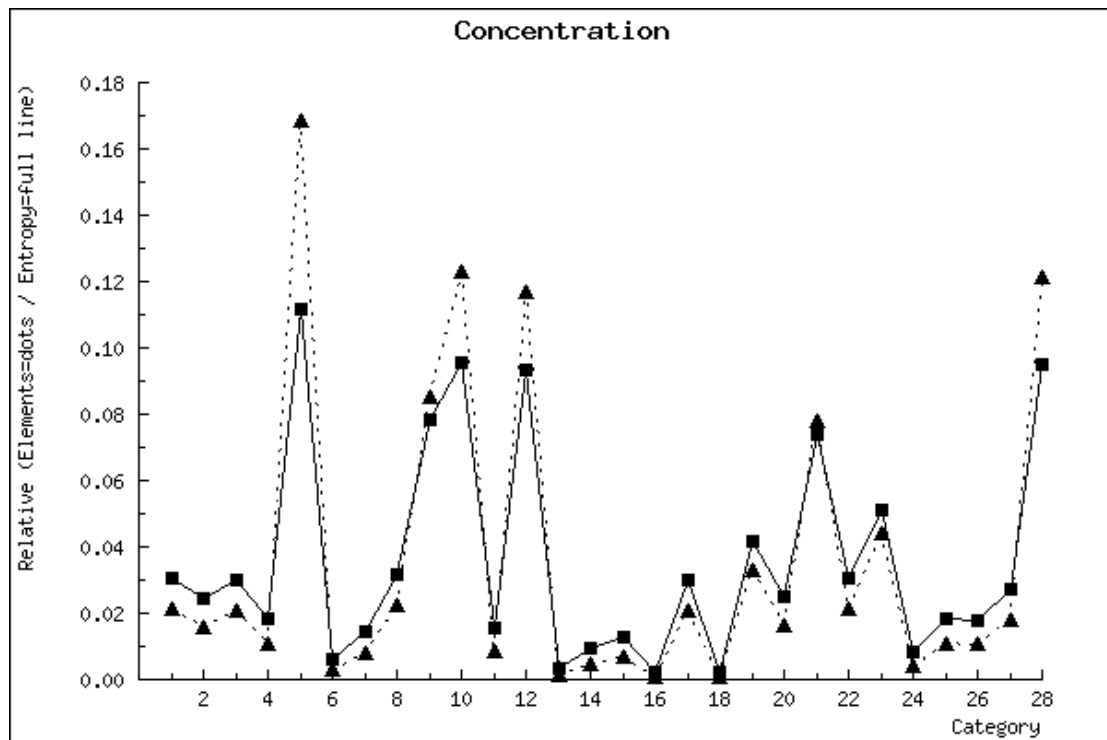


Figure 2 Entropy of GDP per capita in EU-28 in 2003

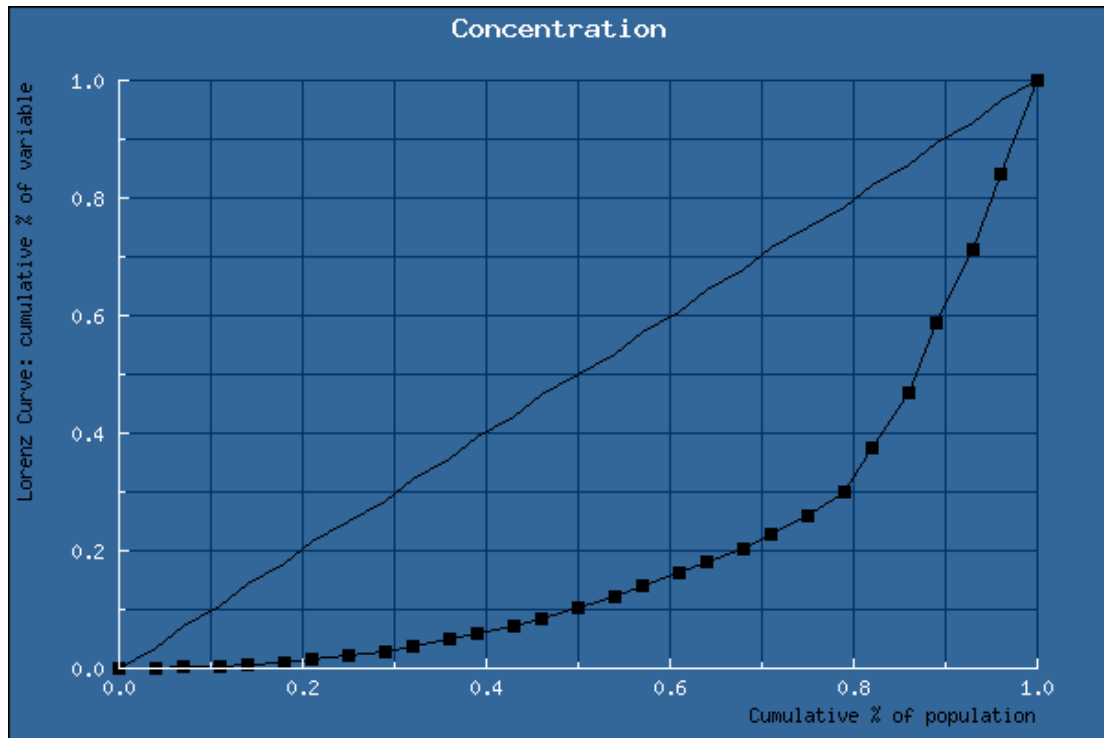


Figure 3 Lorenz curve in EU-28 for 2012

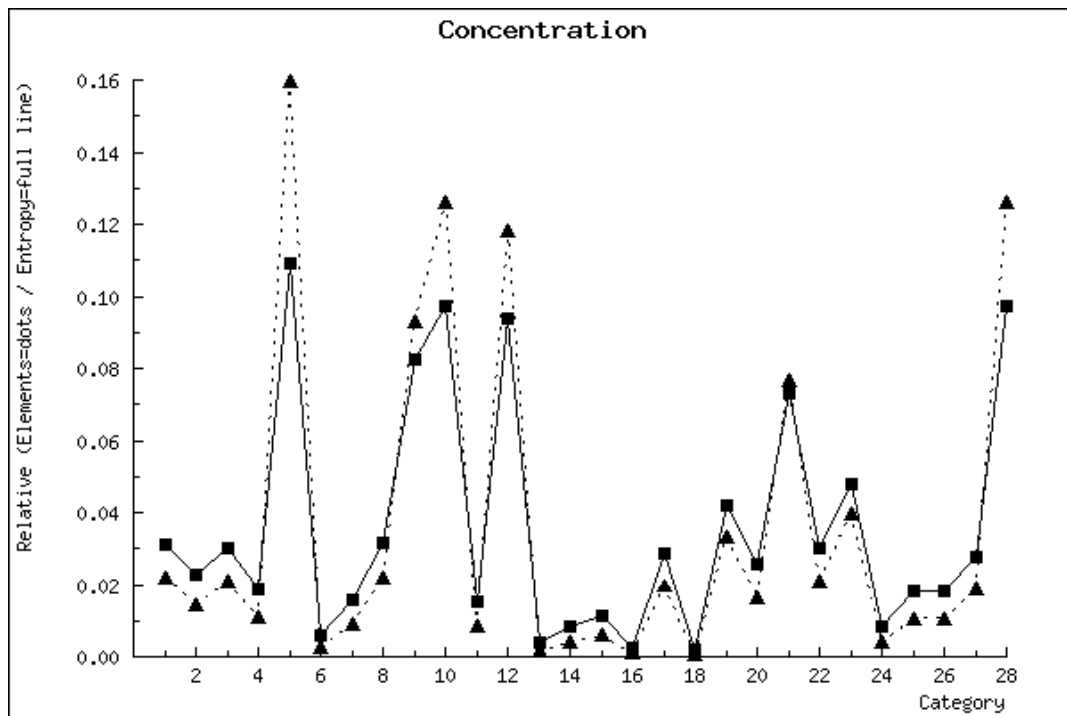


Figure 4 Entropy of GDP per capita in EU-28 in 2012



In order to determine the Theil's index the GDP per capita of EU countries was used. For 2003 we got the value of 175.3 while for 2012 the Theil's index is 181.2. fact that indicates convergence from the point of view given by GDP per capita.

Table 6 Standard deviations and coefficients of variation in 2011 and 2012

Year	Standard deviation	Coefficient of variation
2011	0.047565438	5.30%
2012	0.041368457	4.79%

The standard deviation in 2011 is greater than the value in 2012. Moreover, the degree of variation decreased in 2012 compared to 2011, fact that indicates the economic convergence of the EU countries. A relationship of dependence is considered between the rate of growth in certain interval and the level of development of that particular region. The relationship is observable for more regions at a certain reference time t for a specific degree of development.

The convergence perspective brings that fact that the process of development levels closeness between regions is under hypothesis. According to Solow. the assumption of high rates of growth for the low developed countries is based on statistical data and on the economic theory.

4 Conclusions

The assumption of economic convergence is confirmed for EU-28 when concentration and entropy indicators are used. According to Gini coefficient values the degree of concentration has decreased but with an insignificant decrease in 2012 compared to 2003. The value of Theil's index for GDP per capita shows advancement in convergence process in 2012 with respect to 2003. The research could be continued by analyzing the economic convergence in EU-28 from other perspectives, including the use of tools offered by the spatial econometrics.

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