

Structural Convergence in European Union^{*}

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Abstract: *Estimating structural convergence is a relatively recent topic in specialised literature. Based on the Solow theory of economic growth by stages and on empirical data for European Union we estimated a model to simulate structural changes. Using a set of selected indicators, we analyse the convergence process in the period 2000-2011 at the EU level (EU-27), but also inside of Eastern group of countries (EU-10) and inside of Western group of countries (EU-15). As general conclusion, at the EU level a general tendency of structural convergence was demonstrated. However, between the two groups of countries, there were some different trends in matter of structural convergence.*

Keywords: structural convergence, Lorenz curve, divergence

JEL Classification: C8, E20, F02, O11, O47

Introduction

Convergence theory is suggestively expressed in Solow model (Solow, 1956). This can be shown in line with the fact that while economic development is advancing (expressed by the income per capita growth), there is a general convergence process between countries. Generally, empirical evidences confirmed this process. In specialised literature last time emerged some studies trying to estimate the so-called structural convergence. In our study, based on empirical evidences in spatial distribution of GDP per capita in EU we estimated a model to describe and simulate structural changes concomitant with the general process of economic development. Using a set of adequate indicators we analyse the convergence process at the EU level, but also inside of Eastern group of countries and inside of Western group of countries.

1. Growth theory and empirical evidences

One of the consequences of the neoclassical growth model, often used as the Solow model, is the stadial development of a national economy. It also involves long-term convergence of nations in terms of per capita income. Moreover, the model, supplemented by empirical studies, served to analyze economic development on a historical scale structures and to estimate future dynamics of economic systems.

Empirical substantiation of the theory was made through two procedures: either starting from data on past changes over long periods of economic structure on the three sectors (primary, secondary and tertiary respectively) for a country or group of countries which is currently in high stages of development or by analyzing, at a given moment, the distribution among sectors of employment for a large number of countries at different stages of development. Among the conclusions drawn from the analysis of the stages of economic development, the general process of structural changes include: continuing decline in the share of the primary sector, while increasing to a peak followed by a decline in the secondary sector and a continued growth of the service sector.

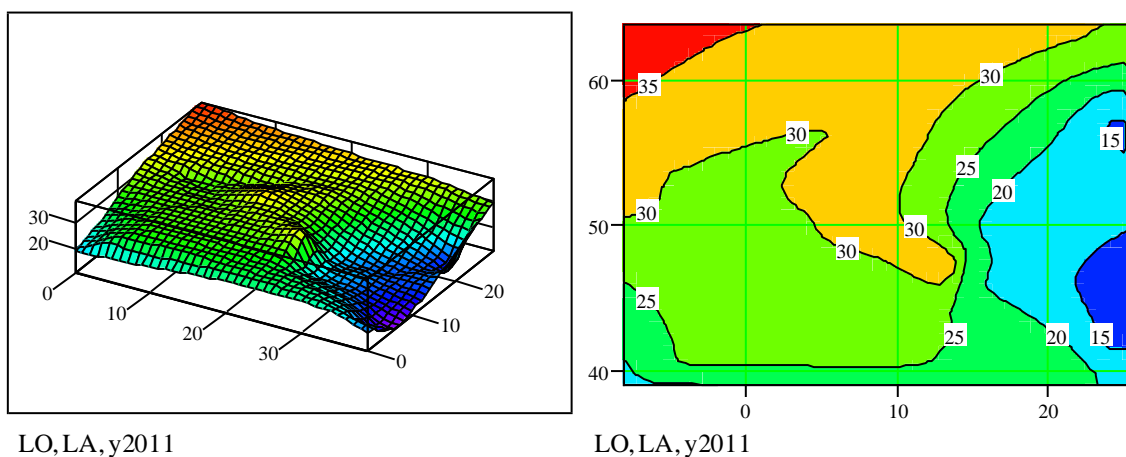
This explanation of structural changes in the economic growth still relies only on empirical findings, not resulting clear whether and to what values will stabilize the values of variables represented by shares in total employment in agriculture, industry and services respectively. A first simulation of the dynamics of long-term economic structure can be achieved by using a theoretical model, starting from a consistent set of empirical data. The model requires the existence of some limit values, to which the trajectories will converge in the long run. Advancing in the economic development is expressed by per capita income growth.

^{*} The paper is partially based on the research performed for two studies “Prospects of labor market in Romania in the context of Europe 2020 strategy” and respectively “Increasing the contribution of foreign trade to achieving real convergence”, *Strengthening the institutional capacity for evaluation and formulation of macroeconomic policies for economic convergence with EU within the National Commission for Prognosis* - SMIS code 27153 - project co-financed by the European Social Fund thru PODCA - Operational Programme for Administrative Capacity Development.

As empirical evidence, we are presenting in Figure 1 the spatial distribution by countries of GDP per inhabitant in EU in 2011, in which LO means longitude (on its left side relating to the origin, 0 meridian, the Western longitude, as it is marked usually on geographical maps, was changed in negative values), LA – latitude, and y – GDP per inhabitant in purchasing power standard). The purchasing power standard, denoted as PPS, is an artificial currency unit (PPS is the technical term used by Eurostat for the common currency in which national accounts aggregates are expressed when adjusted for price level differences using PPPs; PPP being Purchasing power parity). Aside the 3D representation is presented its attached “geodesic” map (or the so-called contour plot). In Figure 1 we excluded from the graphical representation two island states (Malta and Cyprus), and Luxembourg due to high level of GDP per inhabitant (273% comparing to the EU average level).

We can see on the EU stylised map an increasing tendency going from Eastern European countries (blue colour on the right side of the map) toward Western countries (red colour on the left side of the map).

Based on Lorenz curve for the distribution of EU GDP in 2011, it is shown that 20% of the EU population (the most poor 9 countries with a GDP per capita of less than 19,400 PPS) have covered only 12.4% of the total EU GDP (Albu, 2012). However, referring to the period 2000-2011, at the level of EU, it was found a significant convergence, the value of Gini coefficient decreasing from 18.0% to 12.0%. At the same time, GDP per capita increased by 32.0%, from 19,4 PPS in 2000 to 25,5 PPS in 2011.



LO, LA, y2011

Source: Own calculations based on Eurostat data

Figure 1.

Usually, there are considered two groups of countries in EU (excluding the two island states, Cyprus and Malta): old EU countries, denoted as EU-15 (Austria, Belgium, Denmark, Germany, Greece, Finland, France, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and UK) and former communist countries, denoted as EU-10 (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia). In this case, we can see large discrepancies between the two groups of countries related to the level of per capita GDP in PPS. In 2000 this indicator for the EU-10 represented only 44.5% of the EU average, compared with 115.5% for the EU-15. However, in the last decade, it was registered a significant process of convergence between the two groups of countries, so that in 2011 the GDP per capita in the EU-10 has grown up to 59.9% of overall EU average, compared to 109.9% for the EU-15.

Moreover, a deeper analysis highlights difference between the two groups of countries, in matter of real convergence. Thus, while within the group less developed countries (EU-10) was registered a significant growth in concentration and hence the existence of an intense convergence process, in case of the developed countries (EU-15) it was registered an accentuated decrease of concentration, and hence a divergence process.

Generally, it is expected that convergence in EU in terms of per capita income to be followed by structural convergence. Moreover, the structural convergence even could be conceived as foundation of the convergence in matter of GDP per capita.

To estimate changes in economic structure, we used a model in which the share of employment in agriculture in total employment, na , and respectively the share of employment in services in total employment, ns , as functions of GDP per capita, y , are expressed by the following relationships:

$$na(y) = (k1*y + k2) / (k3*y + k4) \quad (1)$$

$$ns(y) = k5*y / (k6 + y) \quad (2)$$

where $k1, \dots, k6$ are parameters.

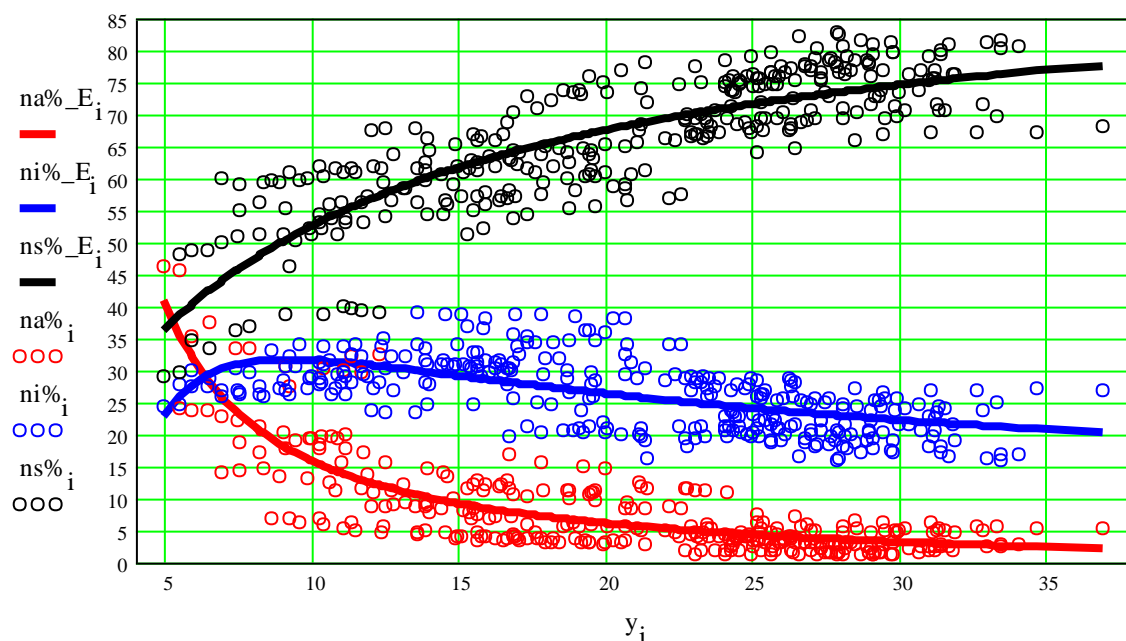
Thus the resulting equation for the share of employment in industry in total employment, ni , is as follows:

$$ni(y) = 1 - \{[(k1*y + k2) / (k3*y + k4)] + [k5*y / (k6 + y)]\} \quad (3)$$

To simulate the model in case of EU, we used Eurostat data for all member countries in the period 2000-2011. The results of the simulation model (excluding Luxembourg) are presented in Figure 2 (where share of the three sectors in total employment is in percents and GDP per capita is in thousand PPS).

The simulation model seem to demonstrate a general process of structural convergence in EU during the analysed period, as the economic development process is advancing. Discrepancies among countries can now be interpreted

not only as differences between levels of income per capita, but also as the structural differences (structural gap). Moreover, as we can see from the 3D representations and their attached “geodesic” maps (or contour plot) in Annex 1, there is a strong positive impact of services’ share on economic growth (correlation coefficient = +0.816), but a negative impact of those of agriculture (correlation coefficient = -0.699) and industry (correlation coefficient = -0.580).



Source: Own calculations based on Eurostat data

Figure 2.

2. Trends in structural convergence

High degree of economic development and efficiency in general are a direct consequence of modern structures. Although attempts to achieve a structural convergence within it, in the European Union still exist numerous structural differences. In this section of the study we are trying estimating some appropriate indicators for evaluating the so-called structural convergence.

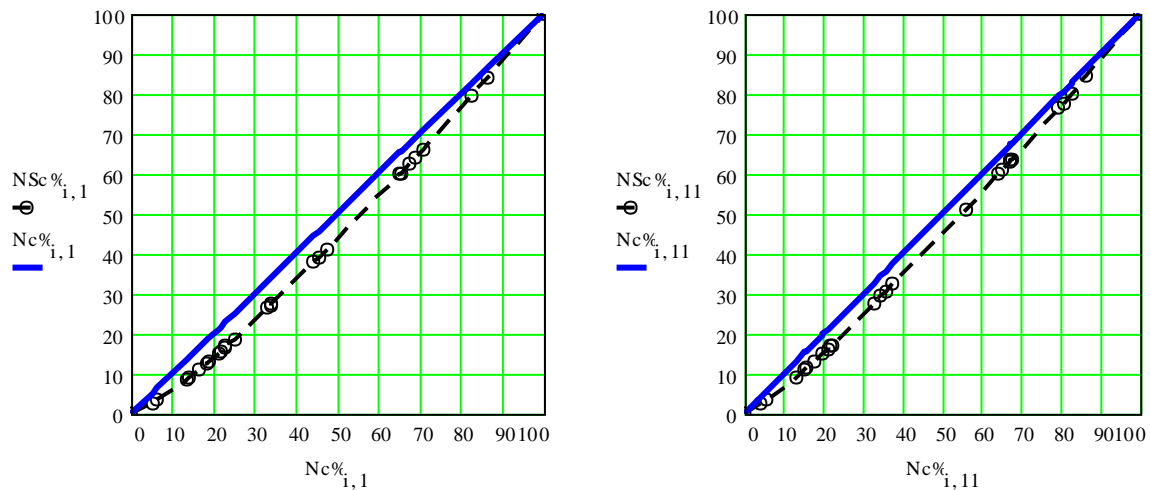
In the current period, with achieving high efficiency in industry and agriculture, it is considered that in a modern economy must prevail services. In fact, economic history shows transition, with increasing the general level of development, from a predominantly agrarian society, to an industrial society, and finally to one of services. At the level of EU, the share of services in employment increased between 2000-2011 from 65.4% to 71.8%. However, among member countries still there are considerable differences in this matter.

As a tool to analyse structural differences we used the Lorenz curve (Lorenz, 1905). It can be useful to study the concentration in a group of countries, as EU is.

Changes in time in concentration is an indicator of convergence. The Lorenz curve expresses the distribution of a certain indicator of interest, as is employment in services, NS, for instance, within a certain population of employment. Thus, on abscissa is marked the cumulative share of countries in total EU employment, $N_c\%$, from lowest to highest share of services in total employment, and on the ordinate the corresponding cumulative share of countries in total EU employment in services, $N_{Sc}\%$. The line passing through all points $(N_c\%, N_{Sc}\%)$ in plan is the Lorenz curve.

The diagonal of the unit square thus formed means the average share of services in employment, while the area delimited by the Lorenz curve and this diagonal, denoted by A, represents an aggregate measure of the disparities or the concentration degree. The diagonal is corresponding to the so-called the line of perfect equality (all levels of services share are equal; by contrast, the line of perfect inequality is represented by the horizontal line, $N_{Sc}\%=0$ for all $N_c\%$ less than 100%, continuing with the vertical line $N_{Sc}\%=100\%$ when $N_c\%=100\%$).

As illustration, in Figure 3 we present the Lorenz curve for the EU in 2000 and in 2011 (where the cumulated weights of employment in services, $N_{Sc}\%$, on the ordinate and those of total employment, $N_c\%$, on abscissa are expressed as percentage). Countries in EU are noted as $i=1, \dots, 27$ and the years in the considered period from 2000=0 to 2011=11. We can see a diminution of the area bounded by the Lorenz curve and the diagonal line in 2011 compared to 2000, which signifies a process of convergence in this period.



Source: Own calculations based on Eurostat data

Figure 3

A number of indicators can be estimated from the Lorenz curve. Among them, Gini coefficient is defined as the ratio of surface area A (bounded by the Lorenz curve and the diagonal line) and the entire area below the diagonal line, denoted by A+B, where B is the area under the Lorenz curve. Thus, we may estimate the Gini coefficient, G, as follows:

$$G = A / (A + B) \tag{4}$$

Also, taking into account that the denominator is equivalent to half of the unit, the Gini coefficient is by definition twice of A:

$$G = 2 A \tag{5}$$

where A is equal to 0.5 - B.

Gini coefficient can range from 0 (perfect equality) and 1 (perfect inequality). When it is expressed as a percentage, this indicator is called Gini index.

To estimate Gini coefficient we used an econometric approach by considering a continuous function, $ye(x)$, that best approximates the Lorenz curve. Then, by the integration on the interval [0, 1], we can calculate area B, as follows:

$$B := \int_0^1 ye(x) dx \tag{6}$$

As function to estimate the Lorenz curve that usually produces good estimates, we used the following expression

$$ye(x) = x / (a x + b) \tag{7}$$

The estimation result shows a clear trend of convergence in the EU in the period 2000-2011. Thus, the Gini index decreased continuously from 9.5% in 2000 to 7.0% in 2010, after which in 2011 has increased slightly to 7.1%.

Another method to estimate Gini coefficient is one of interpolation, which produce less consistent results, but is less laborious. In this case, the Lorenz curve is estimated for each interval as a line between two consecutive points, the area B being approximated by the so-called method of trapezoids. The relationship for obtaining the Gini coefficient is:

$$G := 1 - \sum_{i=1}^n \left(\frac{X_i - X_{i-1}}{100} \right) \cdot \left(\frac{Y_i + Y_{i-1}}{100} \right) \tag{8}$$

where, X=Nc% and Y=NSc%.

Again there is a clear trend of convergence over the analysed period. Thus, Gini coefficient, estimated by this method, decreased almost continuously (from 9.7% to 7.3%). Minimum value of coefficient was reached in 2010 (7.2%).

Another indicator to evaluate the convergence derived from the Lorenz curve is the maximum vertical distance between the curve and the line of perfect equality (diagonal line). In case of studying the income distribution, it can be considered as the amount to have to be transferred from the richer half of the population to the poorest half of the population, given the idea to achieve equality in the distribution of income among entities (persons, groups fo population, households, regions, countries). Therefore, this indicator is sometimes called Robin Hood coefficient or RH index (when it is expressed as a percentage). Taking into account the case of the employment in services, the relationship for the RH index is as follows:

$$RH = \max (Nc\% - NSc\%) \tag{9}$$

where Nc% is the cumulative share in the EU total employment of countries and NSc% is the cumulative share of countries in the EU total labour force in services.

The estimation results show a strong convergence in the EU demonstrated by a continuous decreasing in RH index from 9.7% in 2000 to 5.2% in 2010, after which in 2011 has increased slightly to 5.3%.

Apart from indicators derived from Lorenz curve, we are using the standard coefficient of variation σ , whose formula for a specific variable of intensity or a structural variable, ns (share of services sector in total employment), in case of EU comprising 27 countries, is for a year as follows:

$$\sigma_{ns} = (\sum Vns N) / \sum N \tag{10}$$

where σ_{ns} is the variation coefficient for each year of the investigated period, Vns is the deviation from the average expressed in module for each country in EU, and N is the total number of employment for each country in EU.

In order to estimate the values of variation coefficient for the period 2000-2011 we used the following relations:

- for the weighted average of the share of services in employment at the level of EU

$$NSm_t := \frac{\sum_{i=1}^n N_{i,t} \cdot N_{i,t}}{\sum_{i=1}^n N_{i,t}} \tag{11}$$

- for the deviation from the EU average level

$$Vns_{i,t} := |N_{i,t} - NSm_t| \tag{12}$$

- for the variation coefficient at the EU level

$$\sigma_{ns_t} := \frac{\sum_{i=1}^n Vns_{i,t} \cdot N_{i,t}}{\sum_{i=1}^n N_{i,t} \cdot NSm_t} \cdot 100 \tag{13}$$

where $i = 1, 2, \dots, n$ ($n=27$) are countries in EU, $t = 1, 2, \dots, T$ ($T=12$) are years of the period 2000-2011,

$$NS_{i,t} := \frac{NS_{i,t}}{N_{i,t}} \tag{14}$$

and NS being the number of employment in services.

The estimation results show again a significant convergence in the EU demonstrated by a continuous decreasing in the variation coefficient from 14.0% in 2000 to 10.4% in 2010, after which in 2011 has increased slightly to 10.5%.

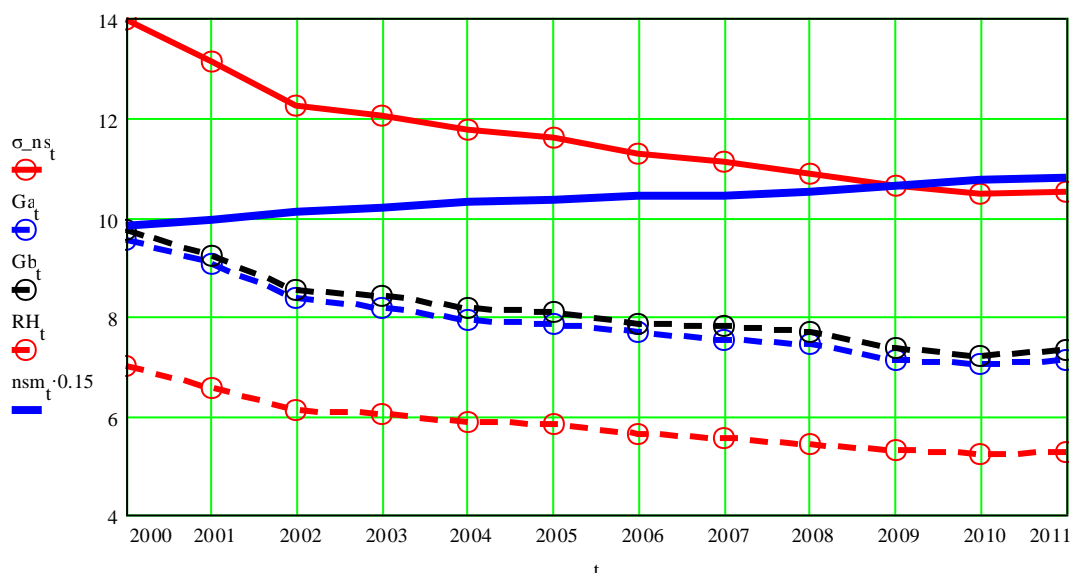
In Table 1 we are presenting the estimates for the four indicators of convergence, in the period 2000-2011, and the average level of the services share in total employment at the level of EU. We denoted Gini coefficients corresponding to the two estimation methods by Ga (first method) and Gb (second method). Also in Figure 4 is shown, on the same graph, dynamics of indicators used to evaluate the convergence in the EU in the considered period and levels of the services share in employment, nsm (it is equal to NSm expressed as percentage and multiplied by 0.15 to fit in the same area of the graph like convergence indicators).

Table 1

- % -

Year	Ga Coefficient	Gb Coefficient	RH Coefficient	Variation Coefficient	Share of Services
2000	9.506	9.725	6.981	13.961	65.396
2001	9.022	9.210	6.548	13.095	66.209
2002	8.369	8.502	6.105	12.210	67.298
2003	8.171	8.399	6.015	12.030	67.895
2004	7.927	8.164	5.868	11.736	68.495
2005	7.814	8.054	5.795	11.591	68.888
2006	7.672	7.833	5.619	11.239	69.328
2007	7.496	7.777	5.543	11.085	69.526
2008	7.432	7.681	5.420	10.839	69.896
2009	7.097	7.339	5.306	10.612	70.839
2010	7.024	7.197	5.221	10.442	71.509
2011	7.123	7.298	5.252	10.504	71.798

Source: Own calculations based on Eurostat data



Source: Own calculations based on Eurostat data

Figure 4

Based on the same methodology for estimating the convergence indicators, we evaluated for the period 2000-2011 the convergence process in case of industry share in total employment and respectively in that of agriculture share in total employment. The results are different. Thus, within the EU, in first case a divergence proces was registered in the considered period, but in the second case a convergence proces was demonstrated.

3. Differences in structural convergence between EU-10 and EU-15

The absolute value of the estimated indicators that we used shows for a group of countries the degree of concentration inside it. Only its trend is a measure of convergence (when the value is decreasing) or divergence (when the value is growing).

Applying the same methodology as at the level of EU, we estimated the value of the four indicators for two groups of countries, EU-10 and respectively EU-15. Here we report synthetically the main results based only on the coefficient of variation.

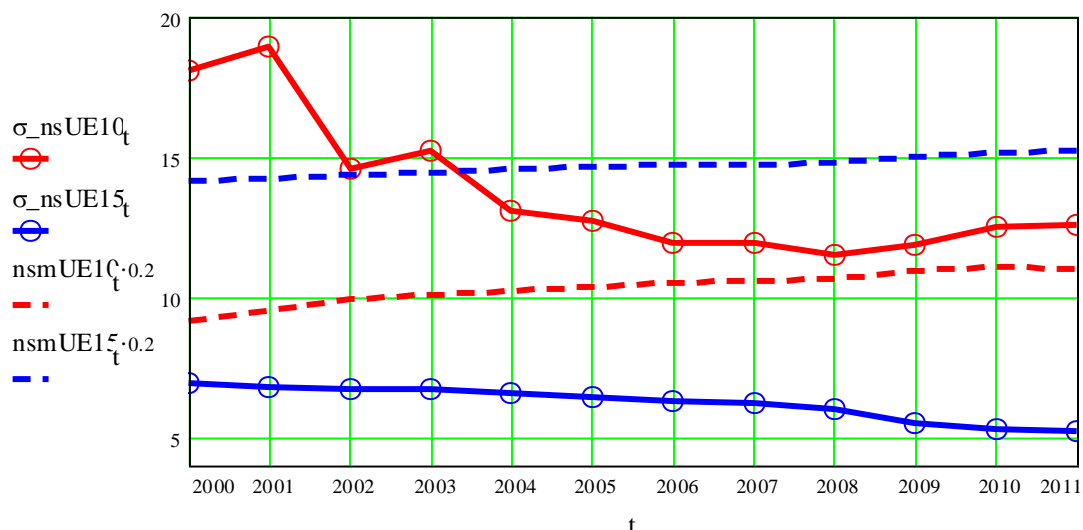
In case of the services share in employment, we can see, from data in Table 2, a higher level of concentration inside UE-15 than inside UE-10, expressed by smaller values of the variation coefficient (more than double in UE-10 than in UE-15). Also in Figure 5 it is shown on the same graph the trajectory of the coefficient of variation in the considered period together with that of the average share of services in employment, for the two groups of countries (average share, nsm , was multiplied by 0.2 in order to fit in the same area of the graph like the convergence indicator).

During last decade it was a tendency of rapprochement between the two groups of countries, the gap in terms of the average share of services in employment comparing to the EU average level decreased significantly. Thus, while the share of services in employment inside the EU-10 increased in the period by almost ten percentage points (from 45.6% in 2000 to 55.1% in 2011) inside the EU-15 it increased only slightly over five percentage points (from 70.6% in 2000 to 75.9% in 2011). We can conclude that in the period 2000-2011 in both groups of contries was registered a clear convergence process.

Table 2

Year	Variation Coefficient		Share of services in employment	
	UE-10	UE-15	UE-10	UE-15
2000	18.057	6.896	45.582	70.644
2001	18.916	6.791	47.331	71.088
2002	14.577	6.736	49.694	71.680
2003	15.186	6.698	50.259	72.198
2004	13.078	6.561	51.126	72.722
2005	12.712	6.438	51.642	73.080
2006	11.926	6.275	52.564	73.433
2007	11.923	6.217	52.893	73.634
2008	11.482	5.966	53.175	74.060
2009	11.857	5.500	54.504	74.914
2010	12.471	5.263	55.275	75.539
2011	12.580	5.203	55.122	75.932

Source: Own calculations based on Eurostat data



Source: Own calculations based on Eurostat data

Figure 5

We can also note a strong correlation between the share of service sector growth and convergence for both groups of countries (correlation coefficient values between the average share of services and coefficient of variation, signifying the degree of concentration or degree of convergence in groups, was -0.891 for the EU-10 and -0.970 respectively for EU-15).

Regarding convergence for share in total employment of the other two major sectors of the economy, industry and agriculture respectively, the results of our estimates for the period 2000-2011, are synthetically presented in Tables 3 and 4. These include data on the dynamics of the coefficient of variation as a measure of concentration, and that the average weights across the EU (EU-27) and in the two groups of countries (EU-10 and EU-15 respectively).

Table 3

- % -

Year	Variation Coefficient			Share of industry in employment		
	UE-27	UE-10	UE-15	UE-27	UE-10	UE-15
2000	14.662	13.772	15.798	26.082	28.547	25.432
2001	15.376	11.272	15.649	26.147	30.060	25.139
2002	15.765	8.770	16.018	25.866	30.727	24.660
2003	16.130	9.191	16.344	25.432	30.423	24.218
2004	16.915	8.024	16.741	25.212	30.960	23.817
2005	17.224	7.650	16.937	24.980	30.975	23.527
2006	17.499	6.445	16.874	24.886	31.411	23.291
2007	17.692	5.832	16.849	24.893	31.838	23.182
2008	17.692	5.469	16.418	24.677	32.110	22.830
2009	17.934	4.992	15.595	23.744	30.855	21.973
2010	18.506	6.196	15.894	23.054	29.833	21.375
2011	19.863	6.261	17.327	22.841	30.029	21.064

Source: Own calculations based on Eurostat data

Table 4

- % -

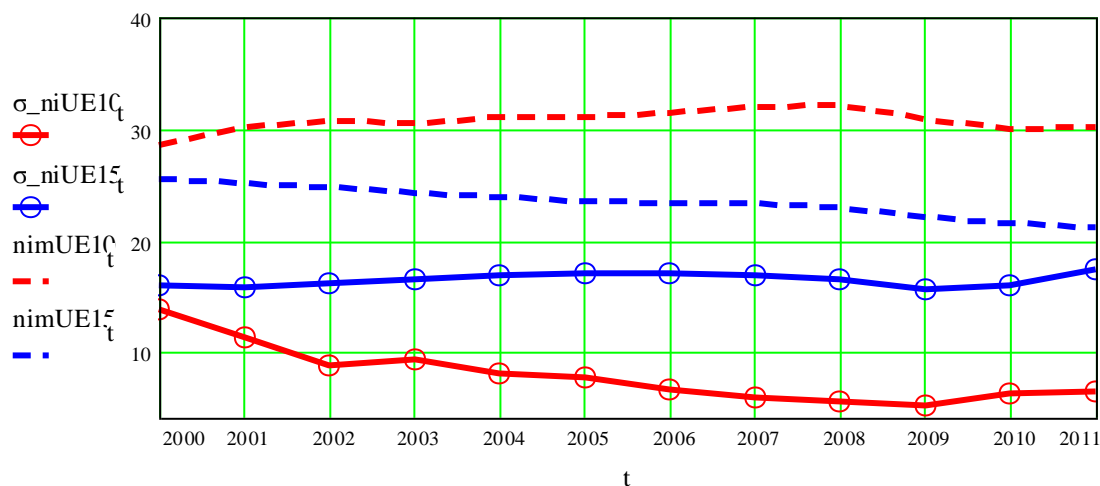
Year	Variation Coefficient			Share of agriculture in employment		
	UE-27	UE-10	UE-15	UE-27	UE-10	UE-15
2000	94.364	43.960	53.286	8.503	25.875	3.899
2001	90.241	52.152	54.187	7.638	22.639	3.757
2002	85.250	40.906	52.845	6.836	19.577	3.660
2003	85.685	45.753	52.004	6.667	19.286	3.584
2004	82.575	41.904	49.800	6.304	17.915	3.474
2005	82.310	43.678	48.199	6.127	17.393	3.385
2006	81.455	43.930	49.207	5.755	16.025	3.237
2007	80.409	46.561	47.692	5.568	15.267	3.170
2008	79.854	48.143	46.618	5.433	14.731	3.114
2009	79.957	49.947	47.219	5.419	14.652	3.112
2010	80.745	54.277	48.319	5.467	14.890	3.123
2011	82.186	55.113	48.920	5.365	14.868	3.005

Source: Own calculations based on Eurostat data

In the period 2000-2011, at the EU level has been a collapse in the share of the population employed in industry in total employment (from 26.1% to 22.8%) and as the proportion of people employed in agriculture in total employment (from 8.5% to 5.4%). However, in the EU-10 the share of employment in industry in total employment increased (+1.5 percentage points), unlike the EU-15 in which there was a decline (-4.4 percentage points).

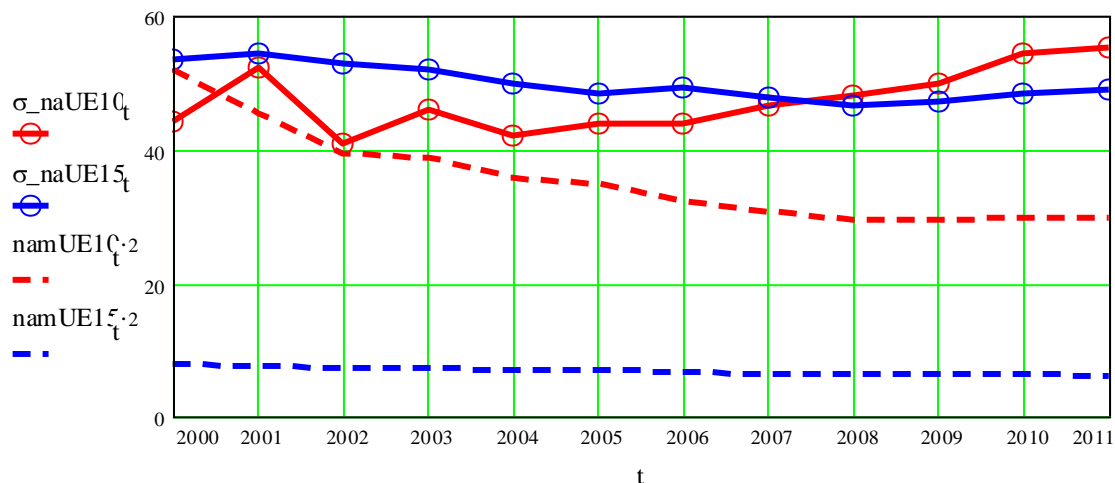
At the EU level, there is still a very high degree of scattering in matter of the share of agriculture in employment, although over the period analysed there was some tendency to concentrate. Inside the EU-10 group of countries even has been a process of divergence in the period under review, although the share of agriculture has declined significantly (from 25.9% in 2000 to 14.9% in 2011).

To illustrate the convergence trends within the two groups of countries, we present graphically in Figures 6 and 7 for the period analysed the dynamics in case of industry and in case of agriculture, respectively. In Figure 7, to fit in the same area of the graph, the average share of employment in agriculture in total employment, respectively $namUE10$ and $namUE15$, was multiplied by 2.



Source: Own calculations based on Eurostat data

Figure 6



Source: Own calculations based on Eurostat data

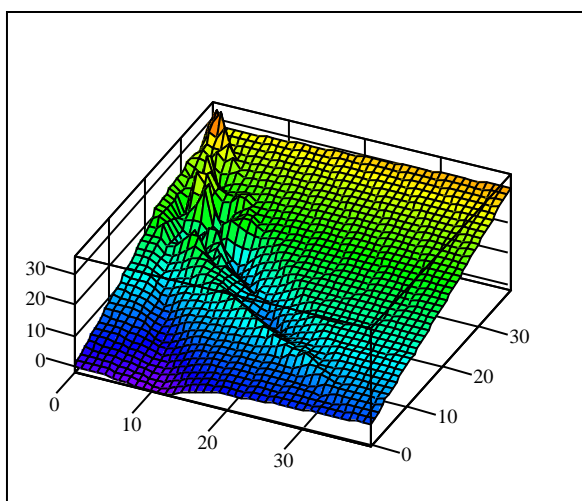
Figure 7

Conclusions

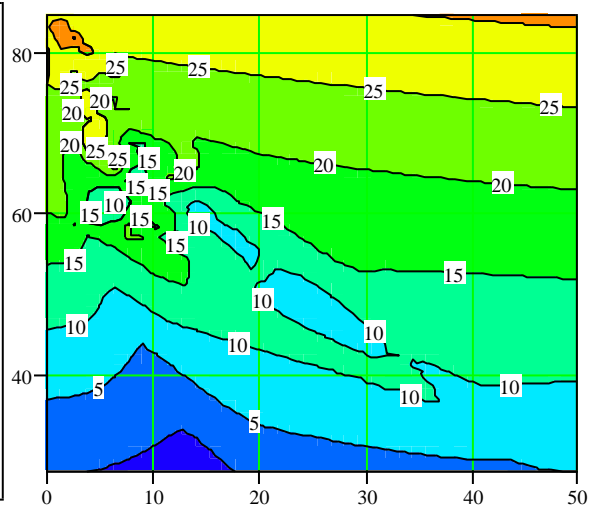
At the EU level during last decade a general tendency of structural convergence was manifested. However, regarding the share of industry in employment, it was registered a divergence process. Between the two group of countries, EU-10, Eastern countries, and EU-15, Western countries, there were some different trends in matter of structural convergence. Thus, in case of the share of industry in employment, in Eastern group of countries it was a strong convergence process, but in Western group of countries a slight divergence. Contrary, in case of the share of agriculture in employment, in Eastern group it was a divergence process unlike a convergence process in Western group.

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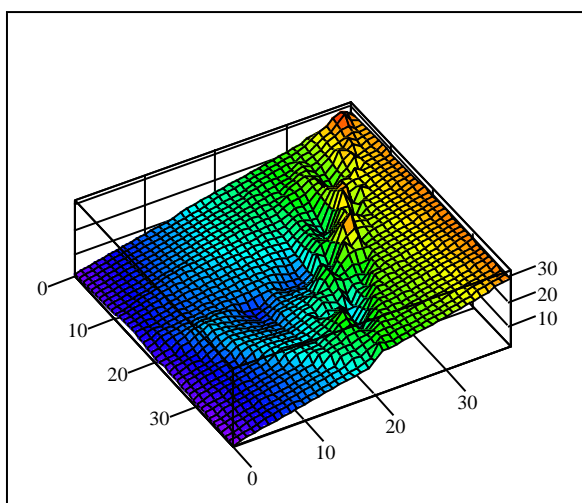
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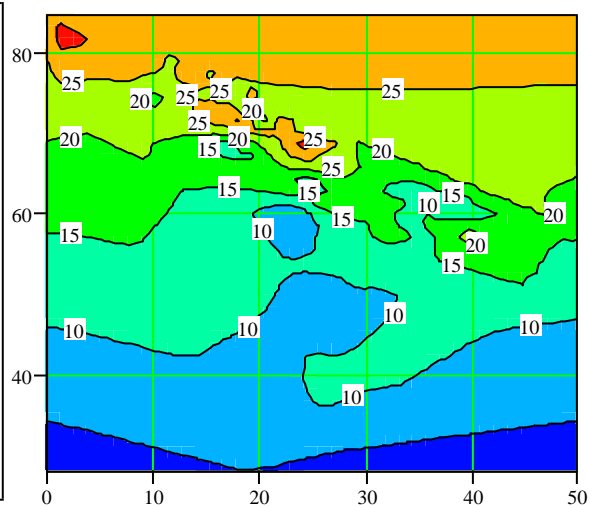
na% , ns% , y



na% , ns% , y



ni% , ns% , y



ni% , ns% , y

$\min(na\%) = 1.2$

$\max(na\%) = 46.3$

$\min(ni\%) = 15.8$

$\max(ni\%) = 39.0$

$\min(ns\%) = 29.2$

$\max(ns\%) = 82.9$

$\min(y) = 5.0$

$\max(y) = 36.9$

$\text{corr}(y, na\%) = -0.699$

$\text{corr}(y, ni\%) = -0.580$

$\text{corr}(y, ns\%) = 0.816$