NEW TRENDS IN R&D DISPARITIES AMONG EU COUNTRIES. A SIGMA CONVERGENCE APPROACH

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Abstract: *The recent economic crisis brought about new challenges and disrupted the previous convergence process in R&D systems of EU member countries. The new developments in the configuration of the European Research Area require the use of adequate methods for measuring disparities between EU countries and monitoring of the convergence process. In this context, our paper aims to explore the new trends in R&D disparities among different groups of EU countries by means of a specific method for assessing the convergence/divergence process, namely the "sigma convergence" indicator introduced by Barro and Sala-i-Martin (1995). Considering the sizeable heterogeneity that exists within the EU-28 and candidate countries, we performed separate analyses on two groups of countries that are likely to be more homogenous: old and new EU member countries. Our main finding is a convergence trend for both EU-28 and candidate countries and old EU members over 2006-2013, while the new EU countries seem to diverge in terms of the research and development activity as captured by the Summary Innovation Index. The existence of a systematic trend of convergence / divergence was further tested based on both Augmented Dickey - Fuller (ADF) and DF-GLS stationarity tests.*

Keywords: R&D, disparities, sigma convergence, EU
JEL classification: O31, O32

Introduction

The monitoring of the convergence in R&D systems is being addressed for a long time within the framework of European Research Area. The new challenges induced by the current configuration of the European Research Area (ERA), by the Innovation Union commandments and by the new European research program Horizon 2000 - ERA, require the use of adequate methods for measuring disparities between EU countries. These can substantiate integrated strategies able to insert the objective of reducing disparities between R&D systems of EU member states.

As a result of the actions of building ERA, a certain degree of similarity and convergence appeared between the objectives and aspirations enshrined in national policies on R&D (Reding, 2005). It is due to better coordination and communication at EU level (Commission of European Communities, 2002, 2003, 2005), the implementation of the Open Method of Coordination and enlarged interactions between the old and new Member States, on the one hand and European institutions on the other, and by transferring best practices between countries or by imitating the priorities set out in the framework R&D Programmes.

The 2012 picture of the degree of convergence in the EU on innovation, considered the most important pillar of sustainable economic growth and competitiveness is however pessimistic. For the first time in 13 years, it was mentioned in a document prepared under

the aegis of the European Commission that there has started a divergence process in innovation, after more than 10 years of efforts to achieve convergence. Innovation Union Scoreboard 2013 states that “Less innovative countries as a group are no longer catching up with the most innovative countries. This means that difference in innovation performance in the European Union have started to increase signalling a possible start of a process divergence in Member State’s innovation performance” (IUS 2013, p. 6). To the old factors involved in emergence of the European Research Area, such as economic globalization and communications, accelerating technological progress and its social implications (Council of the European Union, 2003; Sandu and Paun, 2009), new ones have been added in recent years, owing especially to the economic crisis which have disrupted the previous convergence process.

Nevertheless, new data in Innovation Union Scoreboard 2014 indicate that “there are again positive signs in Member States as the innovation performance improves and the catching up process of less innovative countries resumes” (IUS 2014, p.4). Despite overall improvements in R&D activity, proven by the annual average growth rate of 1.7% for the 2006-2013 interval (IUS 2014, p.6) significant differences in innovation performance persist among EU countries.

While acknowledging the weaknesses of R&D systems in the EU, compared to those of competitors in the U.S. or Asia, EU Horizon 2020 presents an optimistic view, tracing the lines of overcoming the current situation and facing current challenges such as slow economic growth, insufficient innovation, worsening environmental and social problems. The European R&D program is structured into a new vision, focusing on three key priorities (Excellent Science, Industrial Leadership and Societal Challenges) and the policies and strategies to support entrepreneurs and innovative companies to develop new technologies and to promote the kind of research that have marketable results. The six priorities established for the research aim to stimulate innovation, to offer solutions for solving problems of the today world, namely: health, population growth, food security and clean energy and also address climate change, the need to increase efficiency in using resources, to achieving an innovative, inclusive and safe society.

Monitoring the convergence is achieved, since 2000, through a system of indicators that develops and refines every year, in order to adapt to new trends and requirements, to express the most relevant and systemic progress in research, development and innovation, both in terms of inputs and outputs and the contribution of R&D, as a determining factor, in the growth of national and European competitiveness.

In this context, our paper aims to explore the trends in R&D disparities among EU countries by means of specific statistical methods used for assessing the convergence/divergence process.

The Method

Time trends in R&D inequalities among countries can be interpreted using the methods of convergence analysis. We will employ a standard indicator of convergence proposed by Barro and Sala-i-Martin (1995) – called "sigma convergence". Sigma convergence means the decrease in the dispersion of the variable of interest in cross-sectional data context. On the other hand, if less developed countries grow faster than the developed ones, it is considered that a β convergence process occurs.

In order to measure sigma convergence the common choice is the coefficient of territorial variation. The coefficient of variation for each year t is measured as the standard deviation of the variable y under consideration divided by its mean:

$$\sigma = \frac{\sqrt{\frac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n}}}{\bar{y}} \quad (1)$$

The reduction of this coefficient of variation calculated for EU counties for a certain time interval T: $\sigma_{to+T} < \sigma_{to}$ would indicate the presence of a convergence trend. On the opposite, the increasing value of the sigma coefficient: $\sigma_{to+T} > \sigma_{to}$ is corresponding to a divergence process.
The existence of a systematic trend of convergence / divergence can be tested using the following regression equation:

$$\sigma_t = a + bt + \varepsilon_t \quad (2)$$

where the dependent variable σ_t represents annual values of the coefficient of variation and ***bt*** reflects the trend in sigma values. If the regression coefficient b is statistically significant and negative it indicates a convergence process. On the opposite, if positive it signals divergence among the group of countries in the sample.
In order to capture the persistence in the R&D dispersion among countries, an autoregressive process of first order is introduced in the model, resulting the following extended equation:

$$\sigma_t = a + bt + \rho\sigma_{t-1} + \varepsilon_t \quad (3)$$

The last regression equation is useful for testing the non-stationarity of the sigma time series based on Augmented Dickey - Fuller (ADF) test (Dickey and Fuller, 1981). ADF test estimates the equation that results by subtracting σ_{t-1} from both sides of relation (3):

$$\Delta\sigma_t = a + bt + c\sigma_{t-1} + \varepsilon_t \quad (4)$$

where $\Delta\sigma_t$ is the first-order difference in sigma values, ***bt*** captures the trend, and c = ρ -1. ADF tests the presence of unit root (H_0: ρ = 1). Failing to reject the null hypothesis confirms the existence of a convergence/divergence process, depending on the sign of the trend variable (Drennan, 2004). We are also going to use a second stationarity test, namely the DF- GLS test (Elliott et al., 1996) which is a stronger version of ADF and applies the method of generalized least squares (GLS).

Results and Discussion
According to Barro and Sala-i-Martin (1995) classical σ indicator, we consider that there is sigma convergence in the EU research and development system if the coefficient of variation for the relevant R&D variables analyzed in a territorial perspective decreases over time.

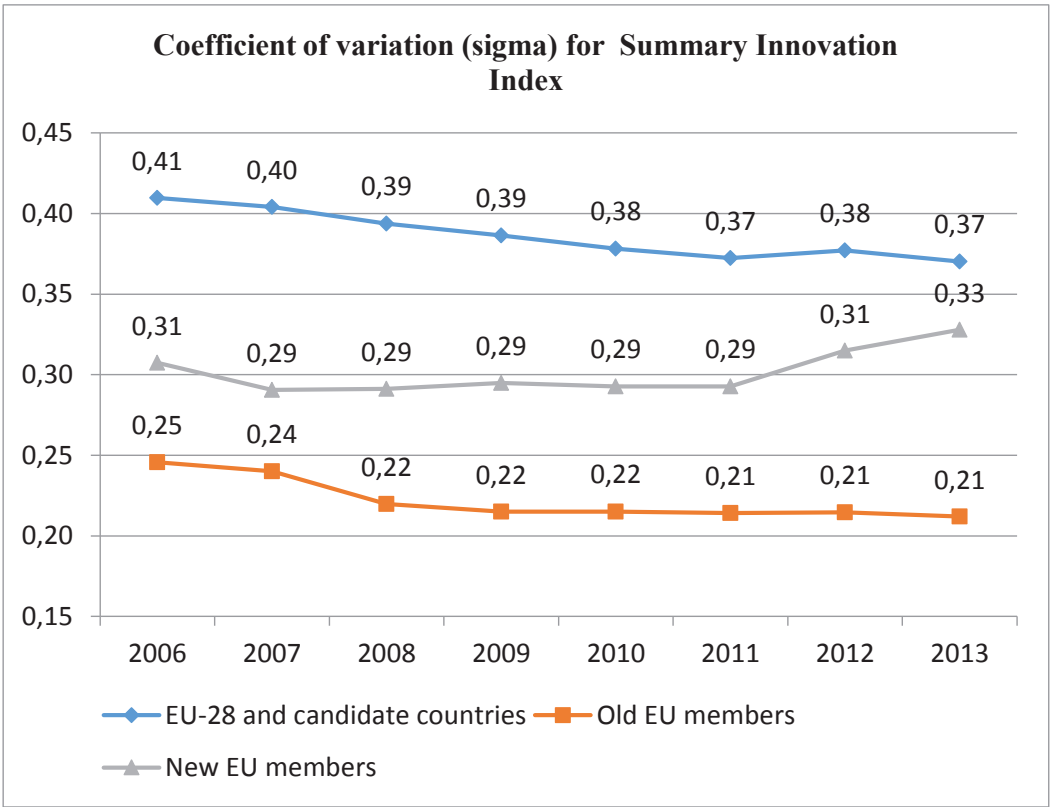

Fig.1. Sigma convergence/divergence for different groups of countries based on Summary Innovation Index
Source: processed by authors based on Eurostat data

The annual values computed for the coefficient of variation (sigma) based on the level of Summary Innovation Index indicate a significant declining trend over the period 2006-2013 (Figure 1) suggesting a process of convergence in R&D. Considering the sizeable heterogeneity that exists within the EU-28 and candidate countries and the subsequent loss of statistical significance in the results, we further defined two groups of countries that are likely to be more homogenous:

- old EU member countries: Belgium, Denmark, Germany, Ireland, Greece, Spain, France, Italy, Netherlands, Austria, Portugal, Finland, Sweden, United Kingdom;
- new EU member countries: Bulgaria, Croatia, Czech Republic, Estonia, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia, Slovakia.

As expected, the calculations for the two groups of countries show important differences between them in terms of both sigma coefficient levels and their trends (Figure 1). R&D systems are more homogenous across old EU member countries, as the dispersion of Summary Innovation Index values is relatively moderate and tends to decline, leveling at about 0.21 in the last few years, while the new EU members are more diverse in their R&D potential and performance and the distance between them increased following the recent economic crisis that impacted strongly (but unevenly) their R&D funding. For instance, the crisis changed the investment behavior and diminished companies' propensity for credits. Surveys indicate that companies' investments dedicated to innovation projects in 2011 were founded from internal rather than external sources (Eurobarometer, 2013)
In sum, only old EU countries converge, while the new members seem to diverge in terms of the research and development activity as captured by Summary Innovation Index.

Table 1. The results of the ADF test equation (dependent variable Δσ).

Variable/ statistic	EU-28 and candidate countries		Old EU Countries		New EU Countries	
	Coeficient	Std. Error	Coeficient	Std. Error	Coeficient	Std. Error
Sigma (-1)	-0.5032	0.4596	-0.8977***	0.0796	-0.3944	0.3336
Constant	0.1987	0.1903	0.1979***	0.0198	0.1003	0.0981
Trend	-0.0021	0.0030	-0.0010	0.0005	0.0050**	0.0014
R-Squared	0.379296		0.993468		0.747205	

Significance: *** p<0.01; ** p<0.05; * p<0.1

ADF and DF-GLS tests on sigma series

Test critical values		t-Statistic (Prob.[1)])		
		EU-28 and candidate countries	Old EU Countries	New EU Countries
Augmented Dickey-Fuller test		-1.094883	-2.684558	-1.182227
1% level	-6.292057			
5% level	-4.450425			
10% level	-3.701534			
Elliott-Rothenberg-Stock DF-GLS test		-2.187864	-2.270814	-1.273446
1% level	-3.770000			
5% level	-3.190000			
10% level	-2.890000			

[1)] MacKinnon (1996) one-sided p-values.

In order to test the existence of a systematic trend of convergence/divergence for the different groups of countries, we used Augmented Dickey - Fuller (ADF) and DF- GLS tests. The results from the ADF test equation on sigma series (Table 1) confirm the convergence trend for both EU-28 and candidate countries and old EU members, while new EU countries diverge. Both ADF and DF-GLS tests fail to reject the null hypothesis of unit root, indicating that sigma series does not display stationarity. This supports our hypotheses on sigma convergence/divergence in SII. Given the rather small sample size the results from these tests may however not be accurate.

We need to be aware that the Summary Innovation Index is a composite indicator that hides important inequalities between the countries as regards the groups of indicators (the eight innovation dimensions), as well as the underlying individual indicators. Consequently, we further calculated the sigma coefficient for each innovation dimension, annually. The results (Figure 2) reveal that despite the overall downturn trend in R&D dispersion (i.e. convergence trend), there are also divergence trends, especially in Finance and support dimension, since 2011.

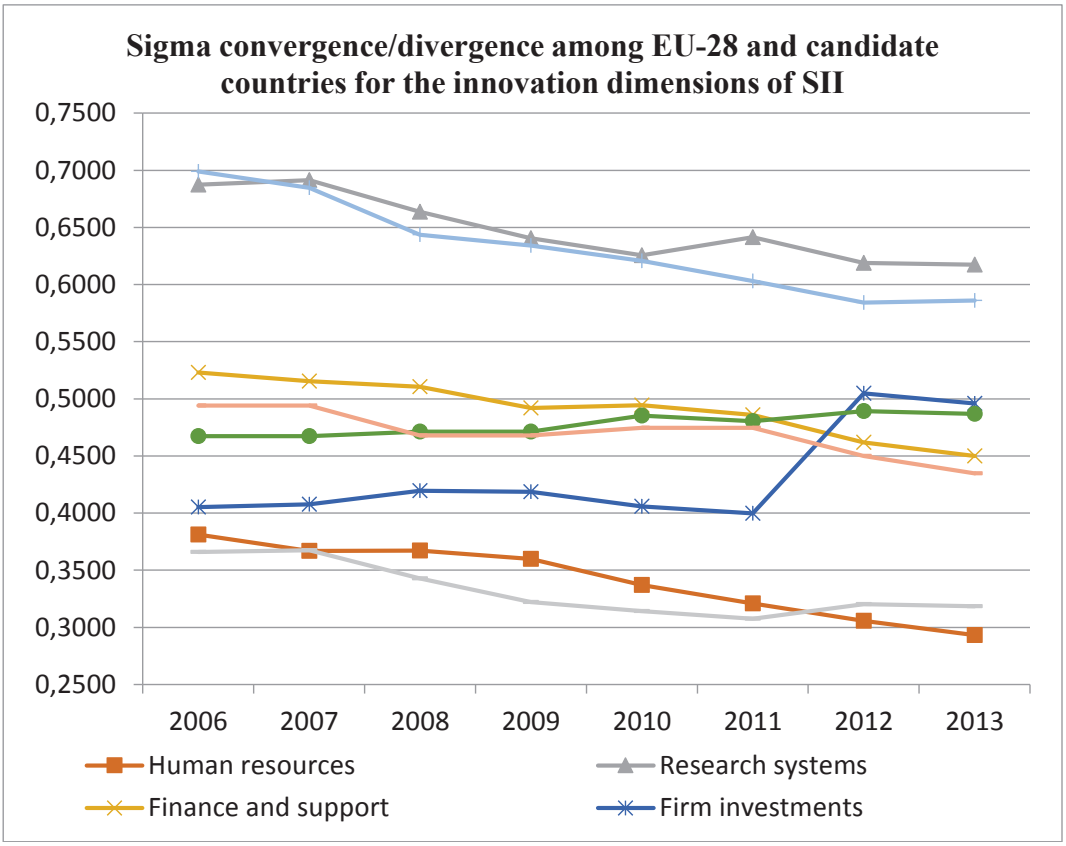

Figure 2. Sigma convergence/divergence trend among EU-28 and candidate countries for the eight innovation dimensions of the Summary Innovation Index (SII), 2006-2013
Source: processed by authors based on Eurostat data

Since results for the whole group of EU-28 and candidate countries can be misleading due to significant heterogeneity, we further performed separate analyses for old and new EU countries (Table 2). It is noteworthy that significant differences still persist within the two groups of EU members, but their amplitude is however considerably smaller inside each group of countries.
Old EU countries display significant lower dispersion than new EU members in all innovation dimensions, except for Human resources. The differences between the two country groups are very marked in the case of Linkages & entrepreneurship and Innovators (dispersion was more than double for the new members in 2013), as well as for Research systems and Intellectual assets.

Table 2. Sigma convergence/divergence for old and new EU countries
Coefficient of variation among old EU members for Summary Innovation Index (SII) and innovation dimensions

year	SII	Human resources	Research systems	Finance and support	Firm investments	Linkages & entrepreneurship	Intellectual assets	Innovators	Econ. effects
2006	0.246	0.295	0.329	0.343	0.295	0.314	0.404	0.288	0.250
2007	0.240	0.280	0.323	0.336	0.290	0.314	0.402	0.288	0.242
2008	0.220	0.276	0.306	0.327	0.310	0.302	0.371	0.261	0.204
2009	0.215	0.274	0.290	0.305	0.309	0.302	0.370	0.261	0.200
2010	0.215	0.274	0.283	0.321	0.327	0.282	0.364	0.250	0.199
2011	0.214	0.263	0.274	0.342	0.323	0.280	0.356	0.250	0.209
2012	0.215	0.244	0.270	0.349	0.356	0.277	0.355	0.254	0.188

2013	0.212	0.244	0.275	0.331	0.352	0.274	0.367	0.256	0.188

Coefficient of variation among new EU members for Summary Innovation Index and innovation dimensions

year	SII	Human resources	Research systems	Finance and support	Firm investments	Linkages & entrepreneurship	Intellectual assets	Innovators	Econ. effects
2006	0.307	0.252	0.436	0.395	0.432	0.521	0.552	0.588	0.330
2007	0.291	0.214	0.402	0.384	0.432	0.521	0.454	0.588	0.328
2008	0.291	0.214	0.439	0.342	0.492	0.548	0.420	0.557	0.334
2009	0.295	0.195	0.437	0.380	0.489	0.548	0.440	0.557	0.310
2010	0.293	0.183	0.431	0.463	0.352	0.620	0.448	0.590	0.317
2011	0.293	0.175	0.490	0.442	0.351	0.614	0.504	0.590	0.308
2012	0.315	0.194	0.472	0.448	0.551	0.623	0.500	0.577	0.342
2013	0.328	0.150	0.509	0.492	0.544	0.626	0.522	0.548	0.340

Source: processed by authors based on Eurostat data

Important differences between the two groups of countries also emerge as regards the trend of the sigma coefficients (Figures 3 and 4).

The group of developed EU countries display a stable downturn trend in sigma values, indicating persistent convergence (Figure 3). One notable exception is Firm investments that reversed the declining trend in 2010, in the context of the economic crisis that hit the national R&D systems with different intensity, depending on the specific R&D policies of the countries.

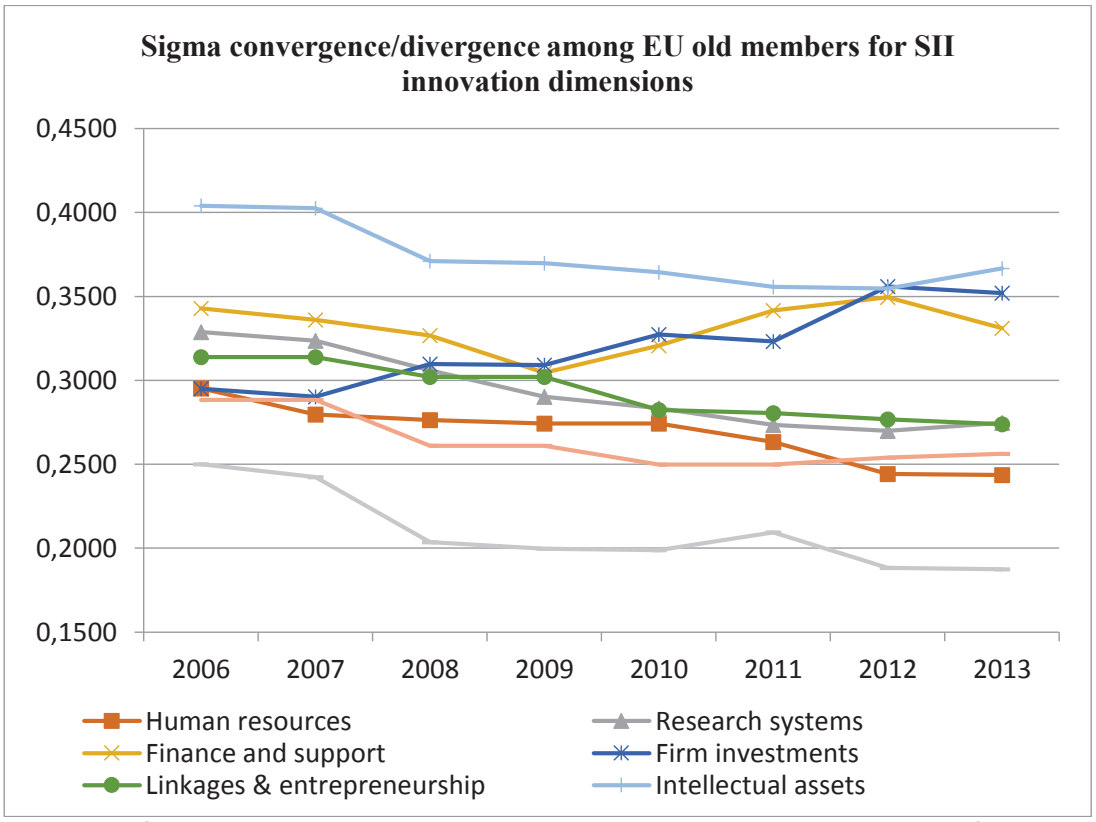

Figure 3. Sigma convergence/divergence trend among EU-old countries for the eight innovation dimensions of the Summary Innovation Index (SII), 2006-2013
Source: processed by authors based on Eurostat data

The new EU members provide more diverse results (Figure 4). Differences among them are rather moderate and rapidly declining as concerns Human resources, but high for all

other innovation dimensions, reaching values above 0.5 for Linkages & entrepreneurship, Innovators, Intellectual assets, Firm investments and Research systems. Moreover, many innovation dimensions display a pronounced rising trend indicating that a divergence process is taking place.
In conclusion there are many differences and divides between old and new member states in the R&D area. These inequalities arise from the larger economic environment. There are specific socio-economic characteristics which influence the innovative capacity and performance in each group.
Old EU countries represent developed, mature economies, owning important economic resources and being more stable, more resilient to shocks such as the recent crisis. They already achieved a certain level of convergence and therefore display lower dispersion than new EU members in all innovation dimensions.

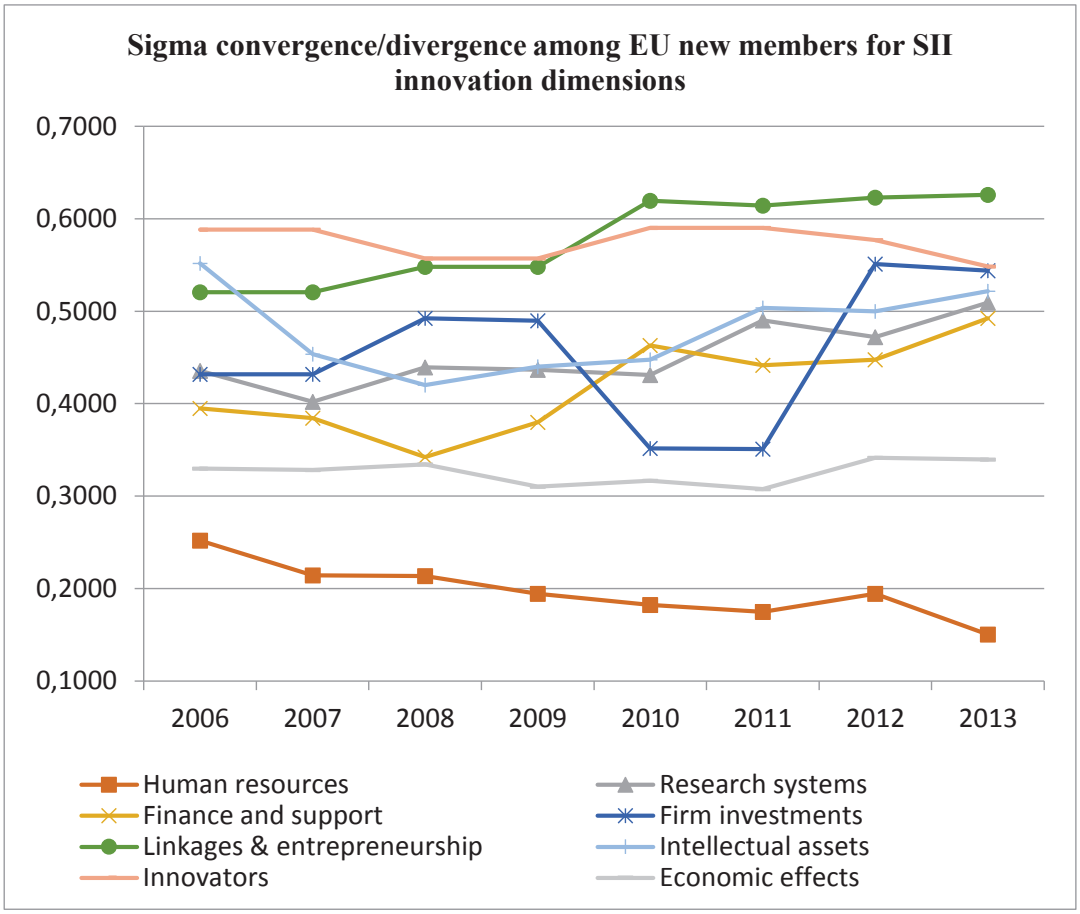

Figure 4. Sigma convergence/divergence trend among EU-new countries for the eight innovation dimensions of the Summary Innovation Index (SII), 2006-2013
Source: processed by authors based on Eurostat data

On the other part, the new EU countries are former socialist countries that only recently concluded the transition to the market economy, and the painful transformations in their economies left many unsolved problems, including a weak and poorly funded research system. Publicly funded research declined sharply in these countries, while most private companies were either not able or not interested to fill the gap by performing more research activities. FDIs in new member countries are not attracted in spending for R&D activity in host countries and were rather medium and low-technology level rarely provided

significant technical progress. Therefore, the R&D systems of these countries are less efficient and more vulnerable to economic crises.

Conclusion

Despite overall improvements in European R&D area and a certain degree of similarity and convergence, significant differences in innovation performance still persist among EU countries. The European research system does not respond adequately to the requirements of sustainable development. There is still need to improve the coordination of the national and regional funding through adequate programmes and infrastructure, to foster cooperation and to transfer best practices between countries.

Our research on the new trends in R&D disparities over 2006-2013, for different groups of EU countries, revealed a convergence process among EU-28 and candidate countries, and for the old EU members as well. On the contrary, the new EU countries seem to diverge in terms of the research and development activity as captured by the Summary Innovation Index. Augmented Dickey - Fuller (ADF) and DF- GLS stationarity tests confirmed that these trends are systematic and statistically significant.

Adequate R&D policies, as well as economic measures to secure recovery and sustainable growth are needed in order to address these differences in R&D systems' performance and to narrow the existing gaps.

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