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R&D AND INNOVATION CONVERGENCE WITHIN THE EUROPEAN UNION

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Abstract

The configuration and consolidation of the European Research Area have facilitated the development and implementation of similar objectives and policy measures, at national level, regarding research, development and innovation. Sharing priorities and best practices, the EU Member States entered a slow but steady convergence trend in innovation performance which, nevertheless, has been disrupted by the recent economic crisis. This paper investigates the current convergence / divergence process, applying the "sigma" and "beta" convergence methods on the latest available data on innovation performance within EU, between 2007 and 2014. For higher homogeneity, we separated the older and the newly integrated Member States and carried our analysis on each group. Our results do not validate any systematic convergence trend in R&D.

Keywords: RDI convergence, innovation performance, economic convergence, the European Research Area, the European Innovation System.

JEL Classification: O31, O38

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1. Introduction

The issue of economic convergence in the European Union (EU) has been increasingly in the focus of researchers and policy makers as one of the main objectives on medium and long-term. This goal has been included in various EU documents, such as the Lisbon 2010 Strategy or the more recent Europe 2020.

The enlargement brought forth greater disparities and differences that slowed down and challenged the cohesion and integration processes. The catching-up pace of the lagging new member states could either hinder or foster the economic development of the European Union. Moreover, the EU position on the global economic map depends on the economic convergence of its member states which, in turn, relies, at a great extent, on the convergence in technological capabilities and innovation performance. On the long run, the divide within the member states in research, development and innovation (RDI) is considered to hamper the EU heading towards sustainable socio-economic and environmental development.

The integration processes dragged along a wider variety in technological competence, industrial structures and innovation performance, jeopardizing the challenging goal of RDI convergence. Therefore, the evolution of RDI disparities within EU has been systematically approached and monitored at national and regional levels, having in view trends, causalities, country level historical, contextual and institutional particularities, regional socio-economic gaps etc. Moreover, it has been pursued through the design and construction of the European Research Area and through key strategic instruments, such as the Framework Programmes for Research and Technological Development.

Yet, despite efforts at both the EU and the member countries level, the convergence process has moved slowly, and, more recently, the evolution of relevant indicators for RDI performance has outlined the setting up of a divergence process.

In this context, our paper looks into current trends regarding the divide in innovation performance among the EU Member States, processing last available data with specific statistical instruments, and investigating available literature. The last section resumes some of the main implications for policy makers at EU and national levels.

2. RDI Convergence in the literature. Conceptual framework and main findings

The convergence in RDI within EU has been systematically approached, in the literature, with respect to the national systems of innovation, to the policy framework, as well as to the innovation performance.

The debate on the convergence or divergence between the *national innovation systems*, in both normative and positive approaches, has lately grown in importance (Lundvall and Tomlinson, 2014). Assumed to be “extended competence building systems”, the national innovation systems do differ regarding performance levels, the innovative process, the system structure and configuration. According to experts, particularities are due to multiple various historical, institutional, cultural and contextual factors: social capital, education systems, financial infrastructure, labour markets, political and economic institutions, external linkages etc. These dimensions have been considered to predetermine the national capacity to absorb new technology and improved management techniques and, further on, the catching up pace.

At political level, under the ERA and Innovation Union flagship, the literature has underlined that there is a growing convergence between the EU member states regarding the main policy instruments and measures for stimulating research and innovation. (EC, 2013; Filippetti and Archibugi, 2011; Veugelers, 2016). There are still authors that reason for tailoring the core political principles to the particularities of the national innovation system and its mechanisms, according to the development level of the specific innovation capacity (Veugelers, 2016).

Regarding the discrepancies in the *innovation performance and technological capabilities*, the empirical and theoretical studies have emphasized the divergent forces derived from globalisation and integration processes, that have concomitantly worked in favour and against innovation convergence (Boldrin, Casanova, et al., 2001; Leonardi, 1995).

On one hand, some studies argue that the economic and political integration facilitate the diffusion of technologies and of innovative infrastructure, scientific exchanges, cooperation between scientific communities and foreign investment, which represent opportunities for the laggards to catch up and capitalize upon – according to available absorptive capacity – existing technological advancements and knowledge (Sandu and Anghel, 2011; Castellaci, 2008; Cohen and Levinthal, 1990).

On the other hand, other empirical research papers have highlighted that the proximity and agglomeration effects associated to the economic integration may actually widen the disparities and further disfavour the least developed regions (Moreno, Paci, et al., 2005; Rodriguez-Pose and Crescenzi, 2008).

The convergence process among the European countries has been observed and described along the last decades. Before enlargement, empirical research underlined a convergence trend in innovation performance among the 15 older EU Member States (Archibugi and Coco, 2005). Even following the first accession wave (2004), research conducted by Zizmond and Novak (2007) found significant technology convergence between the EU 15 and the new ex-communist 8 Member States. Also, Johnson (2010) optimistically concluded that, due to considerable potential of Eastern European countries to accelerate technological development, they may catch up with the rest of EU in the following 15 years.

Providing a larger and more general temporal perspective, as their research work covered previous two decades, Filippetti and Peyrache (2010) concluded that the countries that accessed EU in the last two waves had been part of a global tendency of convergence in technological capabilities.

Archibugi and Filippetti (2011) further undertook an empirical research regarding the evolution of the research and innovation divide for all the 27 countries, processing mostly pre-accession data (2004-2008). Even if the last integrated countries were not fully entitled to the membership privileges and responsibilities, the two employed econometric models [1] robustly attested a significant convergence process within Europe regarding innovation. This may support the earlier mentioned hypothesis, that the economic and political integration intrinsically fosters innovative and technological convergence.

It is though worthy to note that the applied β convergence models emphasized some of the innovation performance dimensions – comprised in the IUS Summary Innovation Index (SII, used as an overall indicator of the innovation performance at national level) – where convergence consistently occurred at a slower pace: "Firm Investment", "Human Resources" and "Economic Effects" (Archibugi and Filippetti, 2011). These seemed to have remained the main weaknesses and sources of vulnerability for the EU as a whole (Veugelers, 2016) and the crisis worsened the situation. In all Member States except for Austria, Finland and Sweden, the share of firms cutting their budgets for RDI exceeded the share of companies that increased their investment.

As expected, the crisis hit most of the national RDI sectors, but the magnitude varied within EU, given high heterogeneity of political responses, of budgetary constraints, of socio-economic particularities. Nevertheless, newly integrated countries were amongst the most severely affected countries, where both the public and private expenditure for RDI suffered considerable abatement. Available studies noticed that, what seemed to be a slow catching-up process at the level of lagging EU countries came to a halt. Moreover, some authors argue that divergence superseded convergence (EC, 2013b; Filippetti and Archibugi, 2011).

3. Research methodology

This paper investigates the recent trends in innovation performance variation among the EU member states applying the "sigma" and "beta" convergence methodological frameworks (Barro and Sala-i-Martin, 1995) on the recent data provided by the Innovation Union Scoreboard (IEC, 2015).

For higher relevance, we conducted our analysis separately on the group of the old Member States (EU15) and, respectively, on the group of the newly integrated Member States (NMS – EU13), allowing for increased homogeneity within each group.

[1] B convergence model proposed by Barro and Sala-i-Martin (2005), to be later described in the paper; and a panel data fixed effects regression model, where the dependent variable was log of the SII annual variation at country level and the regressor is the log of the SII value for each country.

The input data is the Summary Innovation Index (SII) (EC, 2015), a valuable indicator that allow for constant and improved monitoring of the innovation performance evolution at the Union and national levels. It covers all major dimensions of innovation capacity, i.e. human resources, national research systems, public and private R&D and innovation finance, linkages and entrepreneurship, intellectual property rights, innovators and economic effects.

Sigma convergence, a concept based on neoclassical economic theories, tests for a downward trend for the dispersion of the variable at stake (SII, in our case), in a cross sectional data set. For measuring Sigma convergence, we calculate the annual coefficient of variation σ_t for SII within the EU:

$$\sigma_t = \frac{\sqrt{\frac{\sum_{i=1}^{n}(SII_i - \overline{SII})^2}{n}}}{\overline{SII}} \tag{1}$$

where *i* represents the country and *t*, the year.

The statistical significance of the convergence process will be confirmed by testing the non-stationarity of the sigma time series based on Augmented Dickey - Fuller (ADF) test (Dickey and Fuller, 1981). The ADF tests the presence of unit root in the sigma series and confirms/invalidates the existence of a convergence process (Drennan, Lobo, et al., 2004).

The “Beta convergence” methodology, inspired, as well, from the neoclassical theories of economic growth (Solow-Cass-Koopmans) investigates the hypothesis that the initially poorer countries experience an accelerated growth rate which allow them to catch up and close the gaps with the well positioned countries (Karras, 2008; Pfaffermayr, 2009).

The beta convergence method implies the existence of an inverse relationship between the initial level and the relative growth over time of the variable of interest. The model of ***absolute convergence*** for the Summary Innovation Index (SII) is presented below (eq. 2):

$$\frac{1}{T}\log\left(\frac{SII_{t_0+T}}{SII_{t_0}}\right) = a + b\log(SII_{t_0}) + \varepsilon, \tag{2}$$

where *a* is a constant, *t* represents the year, *ε* is the error term. A negative value of the regression coefficient *b* signifies convergence.

The *absolute β convergence* model assumes structural homogeneity, suggesting that all variation is due to the differences at initial stages, as well as faster growth rates for the laggards.

As this model does not control for the institutional or technological particularities at country or regional level, we would add *GDP/capita* as a control variable that accounts for the economic differences between countries. The new model, a *conditional β convergence* model is expressed in the equation 3:

$$\frac{1}{T}\log\left(\frac{SII_{t_0+T}}{SII_{t_0}}\right) = a + b\log(SII_{t_0}) + \log(GDP_{t_0}) + \varepsilon\,. \qquad (3)$$

The new ***b*** coefficient captures the different equilibrium levels at country level, associated to specific national conditions.

4. Results and discussions

According to Barro and Sala-i-Martin (1995), sigma convergence occurs when the coefficient of variation declines over time. We calculated the coefficient of variation (sigma) for the Summary Innovation Index (SII), and our results (see Table 1) indicate a slow declining trend over the period 2007-2014, suggesting a slight convergence in R&D. The Summary Innovation Index composite indicator, yearly calculated by the European Union experts in the “European Innovation Scoreboard” report, assess the innovation performance at EU and country level, based on 25 individuals indicators selected for the main innovation dimensions.

Given high heterogeneity within EU-28 countries, we considered it more relevant to perform the analysis using more homogenous groups of countries, as follows:

- EU-15 (old EU member countries): Belgium, Denmark, Germany, Ireland, Greece, Luxembourg, Spain, France, Italy, Netherlands, Austria, Portugal, Finland, Sweden, United Kingdom;
- EU-13 (new EU member countries): Bulgaria, Croatia, Czech Republic, Cyprus, Estonia, Latvia, Lithuania, Malta, Hungary, Poland, Romania, Slovenia, Slovakia.

Table 1. Sigma convergence/divergence of SII by groups of countries

	EU-28	EU-15	EU-13
2007	34.52	20.62	25.95
2008	33.36	19.95	26.56
2009	32.62	19.43	25.92
2010	32.76	19.59	26.37
2011	31.69	19.73	25.97
2012	33.54	19.83	28.49
2013	33.43	19.80	29.22
2014	32.95	20.67	27.13

Source: processed by authors based on European Innovation Scoreboard data (EC, 2015)

The results present differences among the three groups of countries. R&D systems are more homogenous and stable across old EU member countries, as the dispersion of SII values is relatively moderate, levelling at about 0.20. The new EU members are more diverse in their R&D potential and performance and the distance between them tends to grow, suggesting divergence.

In order to test the existence of a systematic trend of convergence/divergence for these three groups of countries, we applied the Augmented Dickey - Fuller (ADF) test that verifies the “unit root” hypothesis. Once the null hypothesis is validated, a process of convergence / divergence – according to the sign of the trend variable – is confirmed (Goschin, 2015). Although the test fails to reject the null hypothesis of unit root (Table 2), the results in Table 3 show no systematic trend for any group of countries.

Table 2. ADF Unit Root test on sigma series

	t-Statistic	Prob.
EU-28	-2.309942	0.3785
EU-15	-1.609918	0.6750
EU-13	-2.474852	0.3337

Source: calculated by authors

Table 3. Augmented Dickey-Fuller Test Equation on sigma series

All EU countries				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
SIGMA_EU28(-1)	-0.863340	0.373750	-2.309942	0.0820
C	28.13701	12.60393	2.232400	0.0894
TREND	0.060851	0.153094	0.397475	0.7113
Old EU countries				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
SIGMA_EU15(-1)	-1.186968	0.737284	-1.609918	0.2487
C	22.23262	14.39288	1.544695	0.2624
TREND	0.273004	0.109161	2.500929	0.1295
New EU countries				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
SIGMA_EU13(-1)	-1.993396	0.805461	-2.474852	0.1318
C	49.81819	20.03469	2.486597	0.1307
TREND	0.843932	0.471844	1.788582	0.2156

Source: calculated by authors

Although the coefficient of variation (sigma) for the Summary Innovation Index seems to indicate a slight R&D convergence trend for EU-28 countries and a divergence trend for the new EU countries, the ADF tests performed on sigma series couldn’t confirm that. Given the rather small sample size the results from the tests may not be entirely accurate.

The data in Table 4, where SII stands for the Summary Innovation Index and GDP is the Gross Domestic Product, indicate that the results from estimating the beta convergence models by group of EU countries are inconclusive, as well, failing to validate any R&D convergence process in the EU (Table 4). Separate analyses for the two groups of countries (EU 15 and EU 13) failed, also, to render statistically significant results.

Table 4. Results from the beta convergence models

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Model 1: EU-28				
SII_initial	-0.012285	0.016983	-0.723393	0.4762
GDP	0.002096	0.008560	0.244870	0.8086
C	-0.018879	0.097566	-0.193495	0.8481
Model 1: EU-15				
SII_initial	0.003810	0.011680	0.326236	0.7499
GDP	-9.61E-08	2.13E-07	-0.451485	0.6597
C	0.014401	0.012972	1.110163	0.2887
Model 1: EU-13				
SII_initial	-0.019930	0.032812	-0.607411	0.5571
GDP	1.19E-06	2.08E-06	0.573565	0.5789
C	-0.018724	0.057137	-0.327694	0.7499

Source: calculated by authors

There are significant differences in R&D performance not only between the old and new Member States, but also inside each of the two groups. The R&D systems are more homogenous among the old EU member states, while the new EU members are more diverse in their R&D potential and performance and the disparities between them continued to increase in the aftermath of the economic crisis that affected severely but unevenly their R&D systems.

Our results are congruent with other research conducted with different statistical tools (Veugelers, 2016). The convergence process expressed through the evolution of the coefficient of variation of the SII among the EU member states has stopped in 2010.

The impact of the economic crisis on the previous convergence trend is evident in the figure bellow (Figure 1), where we plotted the SII performance in the initial year against the interval SII variation rate for both the preceding period (2004-2008) and, respectively, the following interval (2009-2014), when the crisis started to cast shadow on the RDI systems and performance.

The slope that had indicated relatively substantial convergence before crisis has been almost completely abated. The countries with the previous fastest catching up pace experienced the most severe downfalls. The highest annual average growth rates (i.e Romania,7.3%, Greece 7.4%, and Cyprus, 6.22%) became the highest negative annual growth rates, after crisis (Romania (-5.03%), Greece, (-1.06%) and Cyprus (-1.21%)). It is also apparent that the best performers, despite small or even slightly below zero growth rates, kept their leading positions.

Moreover, the hardest hit are the countries which also were the farthest laggards, considerably contributing, thus, to the convergence trend, such as Poland, Slovakia, Bulgaria, Romania, Slovenia, but also Greece. The least affected by economic recession are some of the most economically dynamic and advanced countries, such as Austria, Finland and Sweden. As the innovation leaders are responding better to the crisis than the followers or the lagging behind member states, the process that set in reversed the convergence tendency observed prior to the crisis (Archibugi and Filippetti, 2011; EC, 2013).

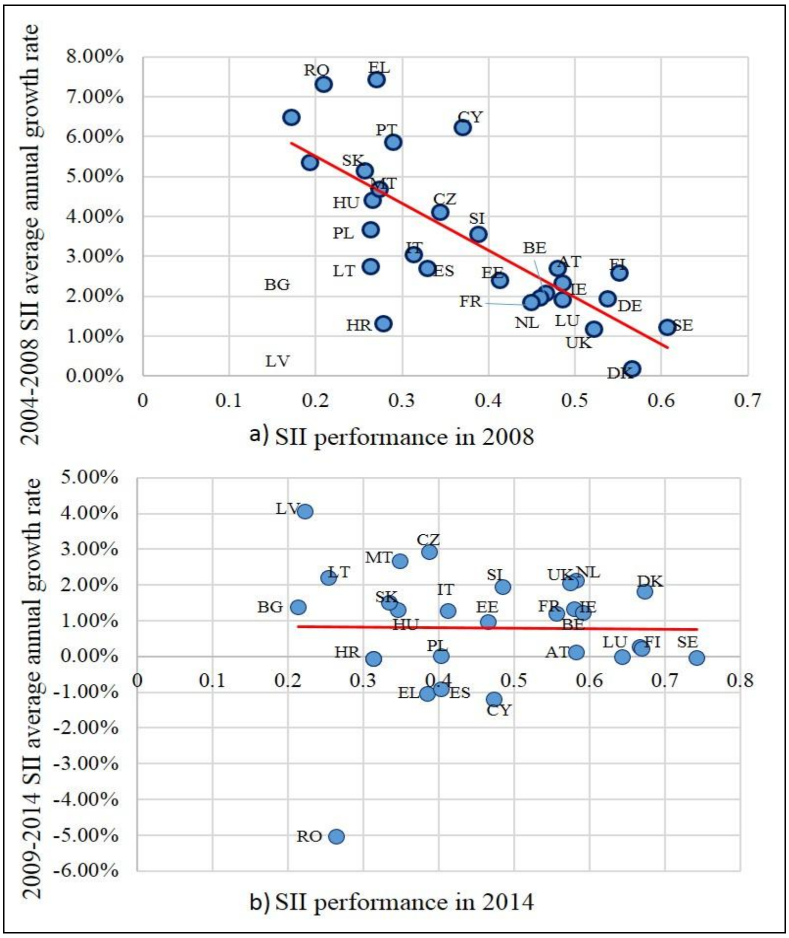

Figure 1. Trends in innovation performance divide within EU, before (a) and after (b) the economic crisis settled in.

Source: Authors' elaboration[2] on European Commission (2011, 2015); SII – Summary Innovation Index.

The economic crisis, thus, worsened the divide within EU. While the innovation leaders kept improving many of their performance indicators as a result of proactive responses to the crisis constraints, the followers and modest innovators lagged further behind. Most of the older EU Member States have relied on their long-term sturdy economies that ensured resilience and stability to shocks, whereas the new Member States have had to cope with inherited weaknesses and vulnerabilities in their search for viable and sustainable answers to increasing challenges at all levels.

However, beyond contextual economic determinants, the current heterogeneity among the EU member states regarding national innovation systems configuration and performances is

[2] We calculated the average annual growth rate for the interval in focus with the mathematic formula employed in IUS 2015, i.e. AAGR = ((end value / start value)^(1/n-1))-1

the outcome of a complex and intricate network of causalities and determinants. (Abramowitz, 1986; Fagerberg, 1994).

The absorptive capacity for already generated knowledge and technology has been largely considered, in the literature, as a critical driver for the innovation performance in the case of catching up countries, as it represents the national capability to take advantage of the technological advancements achieved abroad. A crucial factor for the absorptive capacity is the quality and availability of human resources (an output of the educational system), together with the openness to the outer environment, the quality of innovation infrastructure, the functionality and dynamics of institutions within the national system of RDI and linkages between them, social capital, the congruence and relevance of the political and economic institutions (Krammer, 2009; Apostu, 2009; Archibugi and Filippetti, 2011).

Thus, historical, institutional and contextual factors determined country level particularities that, in interaction with the national economic and RDI strategies and political approaches, have shaped specific institutional frameworks and inter-actor relational patterns, resulting in various levels of technological capabilities, of innovation capacity and performance.

As far as Romania is concerned, the economic crisis brought forth massive cuts in the R&D expenditures both in the public and private sectors. Despite diminished financial resources for research and innovation, there are drivers of convergence towards the EU innovation average performance, acknowledged in the European documents and research papers (EC, 2013a; Goschin, Sandu, et al., 2015), such as increased visibility within the international research community through the quality acquired by Romanian scientific journals, increased co-publishing, the reforms underway in the research institutes and universities, the availability of highly qualified human resources (new PhD and S&T graduates) and growing added value in sectors technology-driven and innovation intensive etc.

Romania may boast with the highest increase in total factor productivity among the EU countries. It is also worth noting that the prior negative trade balance in high-tech and medium-tech products turned positive in 2009 and 2010, suggesting a shift towards high-tech and medium-tech that proved important in counterbalancing the stagnation in the total trade balance (EC, 2013a).

Yet, many other drawbacks hamper the convergence process: prevalence of low / medium technology industrial sectors, immature innovation culture, lowest R&D intensity within EU, lack of political continuity and coordination regarding the RDI sector, outflows of qualified RDI personnel, underperforming higher education institutions, peripheral position to the international knowledge flows, weak linkages between private and public sectors, very low number of patent application.

5. Conclusions and policy implications

Analysing the divide trends within EU, this paper concluded that, in terms of sigma convergence, there is an almost stable variance of R&D performance, as captured by the Summary Innovation Index, among the old EU members, while the new EU countries seem to slightly diverge. The hypothesis of a systematic trend of convergence / divergence was further tested using the standard statistic stationarity tests. The Augmented Dickey-Fuller Unit Root test and the results from the beta convergence models couldn't validate any systematic convergence or divergence process in R&D within EU.

Prior to the economic crisis, there has been a slow process of catching up in the EU, with the followers achieving the highest recovery. Yet, after 2010, while moderate innovators and innovation followers have narrowed gaps with the innovation leaders, the performance of the modest innovators (Romania included) relative to innovation leaders decreased.

After a relatively sustained process of slow improvement and convergence in the European R&D area, there is currently significant divide in innovation performance and technological capabilities, jeopardizing the desiderate of socio-economic sustainable development. Closing the innovation performance gaps between the more and less advanced EU economies is a strategic instrument for the EU catching up with world leading competitors such US and Japan.

To this end, adequate and coordinated programmes, innovation infrastructure and policy tools are further needed at regional, national and EU levels that would foster cooperation and transfer of best practice.

The differences between innovation performance and capabilities among countries may be explained not only by the intensity of R&D expenditure, but also by other particularities, such as the level of capital accumulation and innovation infrastructure, the quality of human capital and the level of investment in education, by the coherence and linkages within the innovation system.

Thus, policy makers *at national level* should look beyond the 3% of GDP target and consolidate efforts towards improving knowledge diffusion and absorption capacity, towards building technological capabilities in line with national particularities. While supporting the business sector initiatives and interest for research and innovation, public policy should also target improving efficiency in the use of public funds for RDI. This may require a general shift towards a more competition and performance based funding which could be also linked to collaboration with the private sector, to international visibility and cooperation and scientific excellence.

Public financial resources for R&D need to follow a coherent and consistent prioritisation scheme. Based on fruitful dialogue with the industrial actors, with business sector, with other stakeholder on the main societal challenges and in line with the strategic priorities set in the broader European R&D programmes, the public funds for research and innovation need to be directed towards the most important areas for the national development.

Another important element to address through specific policy measure, in order to increase competitive advantages and innovation performance, lays in the coherence, intensity and dynamics within the inter-firm cooperation networks.

At EU level, policies that enhance the flows of human resources and knowledge across borders would support the catching up efforts and pace of the laggards and increase the overall innovative output. Encouraging the formation of research and innovation clusters as well as the knowledge flows between them may foster the dispersion of knowledge.

For the ultimate goal of building a performant European Innovation System, it is compulsory that, at the EU level, important resources and political measure should be targeted towards better integrating the new member states in the ERA. Strengthening their innovation potential would spur the EU innovation performance and competitiveness in the global economy.

The apparent coexistence between the similarity in the mix of innovation policy instruments and approaches within EU (Veugelers, 2016), on one hand, and divergence in the technological capabilities and innovation performance, on the other, argues in favour of designing specific innovation policy mixes which, while based on shared principles and prioritisation, and correlated to the Community RDI strategy, should be tailored to the specific level of innovation capacity and to the institutional particularities and limitations of the national innovation systems. For higher convergence, therefore, the innovation policies in the lagging countries should not be simple imitations of the practices in innovation-leading countries.

While accommodating the variety between national systems, the European System of Innovation need to rely on effective coordination instruments for science, innovation and technology policies at EU level.

One limitation of our present research may be found in the still considerable heterogeneity within the two analysed groups of countries. An opportunity for future research, thus, may be the testing of the convergence hypothesis on clusters of EU Member States, grouped by other criteria than the point of entrance in the EU. We also consider investigating the divide dynamic within EU by each of the innovation performance dimensions, the SII components. That would provide valuable information for substantiating specific and targeted RDI policies and priorities for increasing performance and convergence.

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