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Missing Convergence in Innovation Capacity in the EU: Facts and Policy Implications

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Missing Convergence in Innovation Capacity in the EU

Facts and Policy Implications

Reinhilde Veugelers

Abstract

Over the medium- to longer term, trends in total factor productivity growth and innovation will determine the growth and convergence trajectories of the EU economies. However, already before the crisis, Europe has suffered from disappointing innovation performance and productivity growth, and developments since then have only reinforced this trend.

Persistent innovation and productivity growth divergences among EU countries, and in particular euro area countries, raise concerns of rising income differentials and long-term cohesion across countries.

In this contribution we will start with describing the major trends of total factor productivity growth in the EU and EURO member countries and compared to its major global competitors. As the creation and adoption of innovations is seen as a major driver of TFP, we will describe the major trends and convergence/divergence in innovation capacity and its components directly. How big are the differences and they diminishing over time, establishing convergence? Are the laggards catching up? Or the leaders forging ahead? The analysis finds that there is substantial heterogeneity in innovation capacity among EU Member States. This heterogeneity is very stable, avoiding strong divergence, but also no consistent convergence signs. The divide between the Innovation Leaders in the North and the Innovation Laggards from the South and the East proves to be difficult to address.

JEL Classification: O33.

Keywords: σ-convergence, catching up, heterogeneity, innovation capacity.

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1. HETEROGENEITY IN INNOVATION CAPACITY FROM DIFFERENCES IN ECONOMIC DEVELOPMENT

What can we expect in terms of heterogeneity in innovative capacity in Europe and convergence in innovative capacity, using insight from economic theory?

A virtuous innovation-growth link requires a set of factors to be present within a country. Which factors will be most important depends on the level of initial development and a country's initial position relative to the technology frontier, as particularly the endogeneous growth theory framework predicts (Aghion & Howitt (1998)).

For countries still far from the technology frontier, the contribution of technology to growth runs through the country's ability to access and effectively absorb (foreign) new technologies (eg World Bank, 2008; Lall 1992). This requires openness through trade, foreign direct investment (FDI) and other forms of international cooperation. This openness needs to be combined with indigenous 'absorptive capacity' (Cohen and Levinthal, 1990) or 'social capability' (Abramovitz, 1986) in order for the foreign technologies to be effectively absorbed into productivity growth. This absorptive capacity depends on many factors, including the extent to which a country has a technologically-literate workforce and promotes a pro-investment climate; permitting the creation and expansion of firms using higher-technology processes (eg World Bank, 2008).

For countries at higher levels of development, closer to the technology frontier, another factor comes into play, namely countries' own indigenous innovative capacity (eg Hoekman et al, 2005). First, a country's own R&D complements the take-up of existing technology because it is a component of absorptive capacity. But, at higher levels of development, a country's own R&D can increasingly substitute adoption of existing technologies, allowing the generation of new technologies, pushing the technology frontier. At this stage, countries require technological know-how, reflected in public and private R&D resources. They also need to have a system that rewards innovation (Nelson (1993)). Using the insights from both macro and micro models, applied economic theorists (e.g., Furman, Porter & Stern 2002) have synthesized what determines an economy's "**innovation capacity**" defined as the ability of a nation to not only produce new ideas, but also to commercialize a flow of innovative technologies over the longer term. From this perspective a range of factors are deemed to be important. In well-functioning product markets, that are sufficiently open to enable competition between incumbent firms and the entry of new firms, incumbent firms will have incentives to innovate to improve their competitive position, while new firms can flow into the market, embodying new ideas. This also requires a large base of local and/or foreign customers willing to pay for innovative products, and effective intellectual property rights (IPR) schemes. Furthermore, new business opportunities can only be taken advantage of if appropriately educated and skilled workers can be hired under the right conditions. This requires the presence of skills and well-functioning labour markets that give innovators access to researchers and skilled human capital. Similarly, well-functioning risk capital markets give innovators access to capital to finance their risky projects.

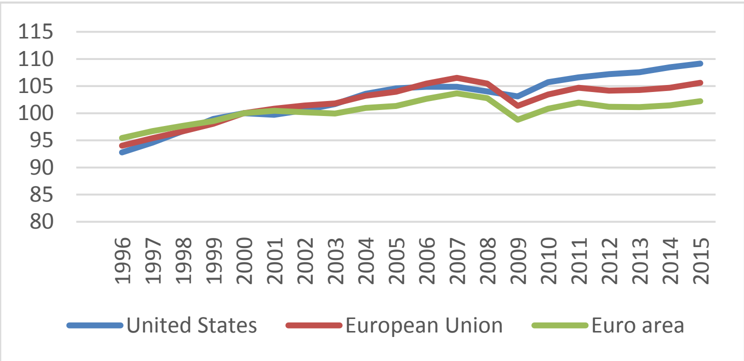
To summarise, the set of factors shaping a country's capacity for a virtuous innovation-growth link, depends on the level of initial development and a country's initial position relative to the technology frontier. We can therefore expect substantial heterogeneity among European countries, because of different capacities to put in place a virtuous innovation-growth system, but also because of differences in initial conditions requiring differently composed innovation systems. At the same time, we can expect the ongoing process of market integration in the EU, including the integration of product & services markets, but also the integration of capital and labour markets and the consequent economic convergence to also push convergence in innovative capacity. We would thus expect that the heterogeneity in innovation capacity among EU countries reflecting differences in initial positions should diminish over time along a process of further economic integration.

In section 2 we describe the major trends of total factor productivity growth in the EU and EURO member countries and compared to its major global competitors. As the creation and adoption of innovations is seen as a major driver of TFP, we will describe in sections 3-8 the major trends and convergence/divergence in innovation capacity and its component drivers directly. Section 4 looks at how much heterogeneity there is in innovation capacity within the EU and how that heterogeneity has evolved since the crisis? Are the differences diminishing over time, establishing convergence? Are the laggards catching up? Are the leaders forging ahead? Section 5 looks at the (trends in) heterogeneity in business sector innovation performance. Section 6 at the trends in (heterogeneity in) innovation enabling factors, more particularly public R&D investements (section 6.1) and education levels of the work force (section 6.2). Section 7 compares the convergence processes among the different components of innovation capacity, while section 8 looks at the EURO area in particular. Section 9 summarizes the main findings, while section 10 discusses policy implications.

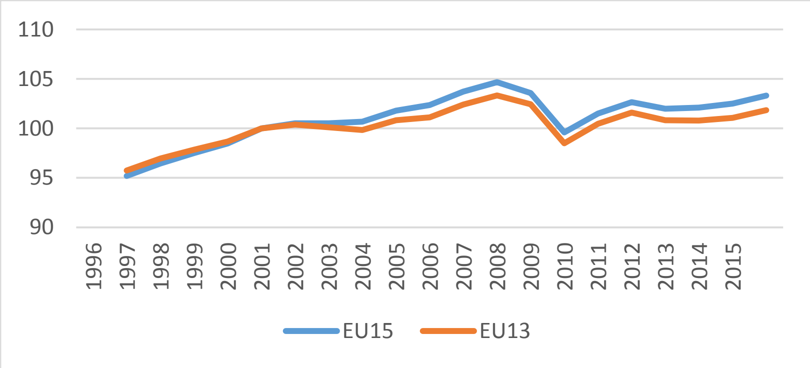
2. TRENDS IN TFP GROWTH

A first look at trends in innovation in the EU is provided by the numbers on TFP growth (Source: AMECO). TFP is a 'residual' growth factor not caused by capital and labour, commonly interpreted as reflecting technological progress [1].

Figure 1. **Trends in TFP Growth**



1 As a 'residual', TFP basically accounts for effects in total output growth not caused by capital and labour. TFP is commonly interpreted as a measure of the technology of production and its rate of growth as a measure of technical progress (World Bank, 2008, p.54). Being a residual concept, TFP calculations are plagued by substantial measurement errors. Nevertheless, the concept is widely used for measuring the contribution of innovation to growth.



Source: AMECO; 2000=100

The upper panel shows the EU's struggle to catch up with the US on TFP growth. EU TFP growth got a bigger dip from the 2008 crisis than the US and the US recovered better after the crisis.

When looking within the EU, the lower panel show that the slow catching up process by the EU13 countries before 2000, stopped after 2000 and even reversed.

In the remainder of the analysis, we investigate directly the innovation dimensions for which TFP proxies.

3. MEASURING HETEROGENEITY AND CONVERGENCE IN INNOVATION CAPACITY

To capture the position of European countries (and the trends therein) on the different dimensions of innovation capacity needed to transfer know-how into growth, we revert to the summary assessment of the EC's Innovation Union Scoreboard (IUS). IUS assesses a broad range of factors of relevance for assessing innovative capacity, in line with the concept of Innovation Capacity, as developed by Furman et al 2002 (cf. supra). The IUS indicator is a composite that captures the following dimensions of Innovation Capacity: Human Resources, Research Systems, Finance, Firm Investment, Linkages& Entrepreneurship, IPR, Innovations, Economic Effects. (See Annex I for the empirical proxies that go into the UIS indicator).

The IUS indicator has the advantage that it is broad, capturing the various dimensions of innovation capacity. It is much broader than the more classic R&D or innovation expenditures data often used to proxy for innovation capacity. But as the IUS is a composite indicator, being an average of about 25 indicators, it will have less variance over time than a single indicator would have. In sections 5&6 we will look at some individual indicators of the compositie indicator.

To assess heterogeneity in innovation capacity, we will look at the scoring of individual countries within the EU on the IUS composite indicator. The **Coefficient of Variation (CV=√VAR/MEAN)** is our proxy for heterogeneity.

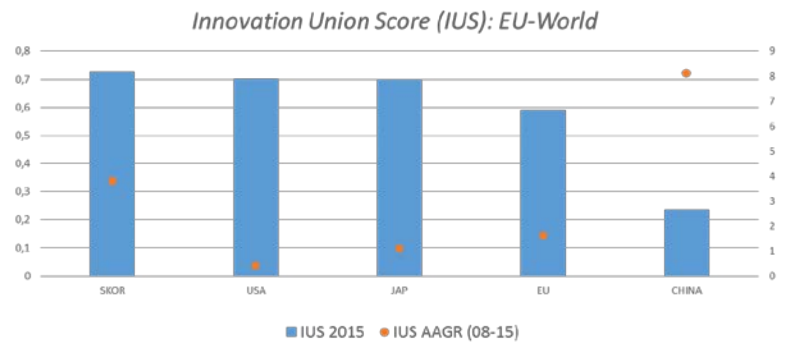
To measure how heterogeneity evolves over time, as part of a convergence or divergence trend, we use the σ-convergence concept. **σ-convergence** occurs when the dispersion across a group of economies decreases over time, as measured by the Coefficient of Variation decreasing over time. (Quah, 1996).

Within the EU, we will look at different groups of member countries, reflecting different (initial) conditions and capacities. We will look at Innovation Leaders versus Innovation Laggards (resp above and below the EU average on IUS scor); the EU15 versus the EU13, with the EU15 further split into the EU15-NORTH vs EU15-SOUTH. We will disentangle overall EU heterogeneity (and its trend) into gaps between these groups (and their trend) and within group heterogeneity (and its trend).

4. (CHANGES IN) HETEROGENEITY IN INNOVATION CAPACITY AMONG EU COUNTRIES

Figure 2 shows that the EU displays a lower Innovation Capacity as measured by its IUS score compared to the US, Japan or South Korea, and it is only very slowly catching up, in line with the data on TFP growth as shown in Figure 1. While China is still far behind on Innovation Capacity, it is much faster catching up.

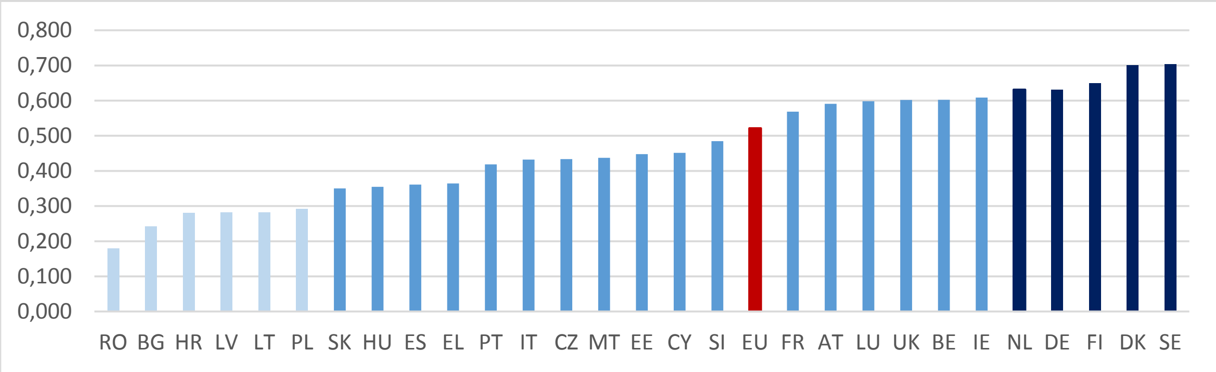
Figure 2. **Trends in Innovation Capacity in the EU and the World**



Source: EC, Innovation Union Scoreboard, 2016

Figure 3 show the heterogeneity among EU member states on innovation capacity. The countries that are leading are all in the North: Sweden, Denmark, Finland, Germany and the Netherlands. Most other EU15 countries are also above the EU average, like Belgium, UK, Austria and France. However, not all of the EU15 are above EU average. Particularly noteworthy is the weak score of Italy and the former cohesion countries: Portugal, Spain and Greece. Among the former cohesion countries, Ireland stands out with a strong IUS performance. At the bottom we find EU13 countries: Romania, Bulgaria, Croatia, Latvia, Lithuania and Poland. But some of the EU13 countries score close to the EU average: Slovenia, Estonia, Czech Republic. The divide in innovation capacity seems therefore not a straightforward initial positions and economic development as expected along the EU15 versus EU13 distinction. There is plenty of heterogeneity within the EU15 and EU13. The North-South divide seems to be equally telling as the East-West.

Figure 3: **Innovation Capacity within the EU**

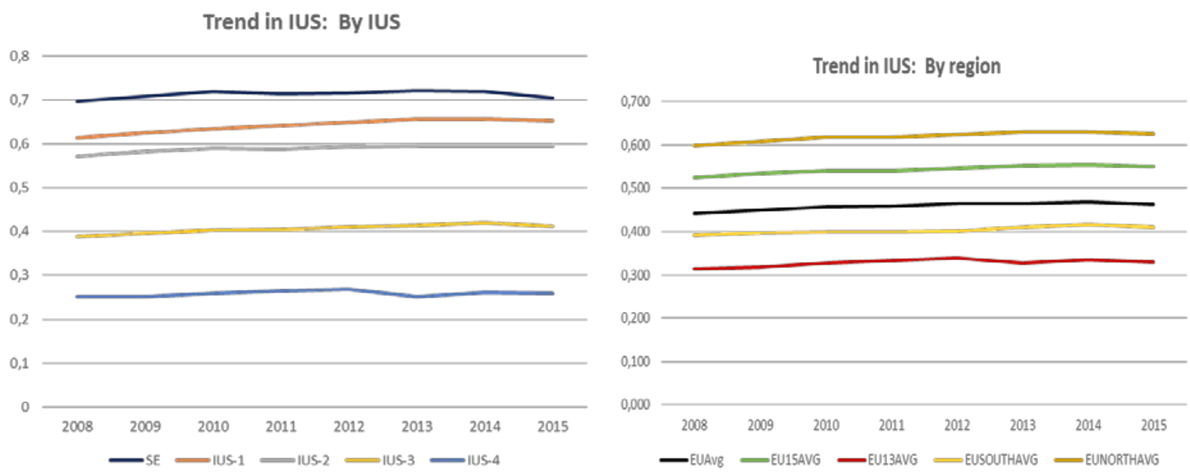


Source: EC, Innovation Union Scoreboard, 2016

Following Figure 3 we will classify EU28 countries in IUS groups as follows: countries above the EU average are classified as Innovation Leaders (IUS12), with NL,DE, FI, DK, SE (in dark) belonging to IUS1 and the others to IUS2. Countries below the EU average are classified as Innovation Laggards (IUS34) with RO, BG, HR, LV, LT, PL (in light) belonging to IUS 4 and the others to IUS3, which includes Italy.

Figure 4 shows the serious divide between EU countries at the top of the IUS ranking and the countries at the bottom. The leading country Sweden stands out very clearly. But most striking is the high degree of stability in the innovation capacity positions over the considered period (2008-2015). Overall there is a slow growth in all IUS groups. The growth is mostly coming from the innovation leading countries (IUS 1&2) forging ahead rather than from the innovation laggards catching up, particularly the bottom laggards (IUS4). Among the leaders, especially the Netherlands is a strong riser, while Finland is losing momentum. Among the EU13, Estonia is a catching-up example, while Romania is an example of further falling. (see Annex II for individual countries).

Figure 4: **Trends in Innovation Capacity within EU**



Source: Own calculation on basis of EC, Innovation Union Scoreboard, 2016

The Coefficient of Variation numbers in Table 1 confirm the high variance in innovation capacity among EU countries and the lack of σ-convergence over the time period 2009-2015. This holds even stronger in the most recent period.

Table 1: **Convergence in Innovation Capacity within EU**

	2009	2012	2015
EU28	0,502	0,519	0,521
CV EU28	0,333	0,325	0,327
Innovation Leaders (IUS12) and Innovation Laggards (IUS34)			
IUS12/EU28	1,357	1,344	1,351
IUS34/EU28	0,769	0,777	0,773
CV IUS12	0,089	0,083	0,070
CV IUS34	0,240	0,244	0,243
EU15 versus EU13			
EU15/EU28	1,190	1,175	1,187
EU13/EU28	0,706	0,730	0,711
CV EU15	0,216	0,222	0,206
CV EU13	0,276	0,287	0,285
EU15 South and EU15 North			
EU15NORTH/EU28	1,357	1,344	1,351
EU15SOUTH/EU28	0,884	0,864	0,886
CV EU15NORTH	0,089	0,083	0,070
CV EU15SOUTH	0,107	0,130	0,094

Note: CV= Coefficient of Variation; IUS Scores of groups are unweighted averages. EU15 South includes CY, EL, ES, IT, MT and PT.

Source: Own calculation on basis of EC, Innovation Union Scoreboard, 2016

When we zoom in the different groups within the EU, we can decompose the trends into within and between group patterns. Splitting the EU countries into Innovation Leaders and Laggers (ie with above or below EU average IUS score, see Figure 3), shows that the difference between the two groups is considerable and very persistent: although the leading countries loose a bit and the lagging ones catch up somewhat relative to the EU average, both the average lead and the average lag have remained very stable after the crisis. When looking within the group of innovation laggards, the variance is substantial and very persistent, with no signs of σ-convergence within this group, which would be the case if the most lagging countries are catching up faster.

The same persistent divide and lack of catching up can be found between EU15 and EU13 countries. The variation in innovation capacity within both blocks is considerable and persistent. This holds for the EU13, reflecting a high heterogeneity in innovation capacity development. But also in the EU15 block there is a high variance in innovation capacity. This high variance in the EU15 is foremost a North-South divide, as the last rows in table 1 identify. The gap between North and South is considerable and fails to close, especially in the most recent period.

5. (LACK OF) CONVERGENCE IN THE EU IN PRIVATE SECTOR INNOVATION CAPACITY

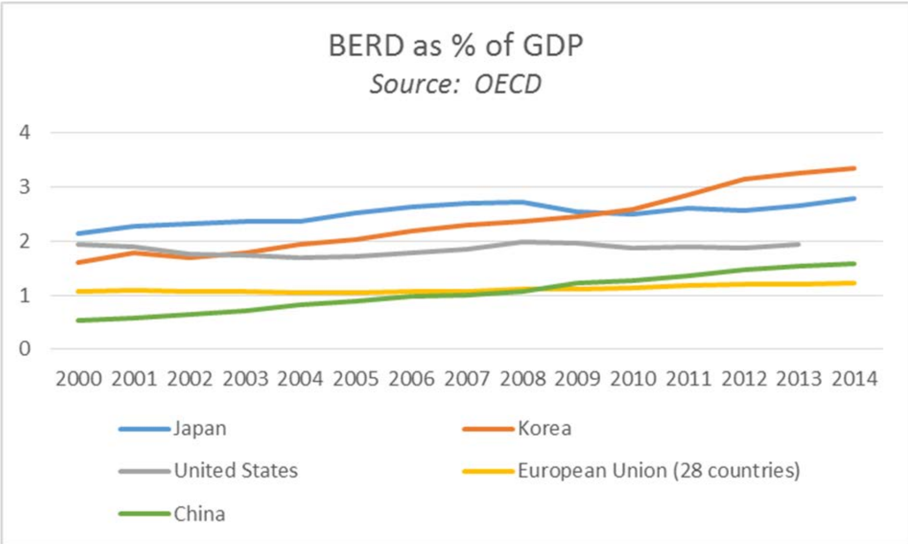
In this section we move away from the IUS composite indicator to zoom in on key individual innovation indicators, which measure business sector investments.

5.1 BUSINESS SECTOR R&D EXPENDITURES

The most pivotal indicator in the IUS composite are the business sector expenditures on R&D (BERD). These expenditures reflect at the same time the capacity as well as the incentives of the private sector to use scientific and technological opportunities to launch own created innovations that will improve their profitability and competitiveness. Low scores on this indicator may identify deficits in R&D capabilities in the business sector, together with deficits in the framework conditions for R&D, shaping the incentives and costs of investing in R&D. It is therefore a major indicator for EU innovation policy to monitor. It is often targeted as part of an overall 3% target for a country's R&D-to-GDP-ratio to be around 2%.

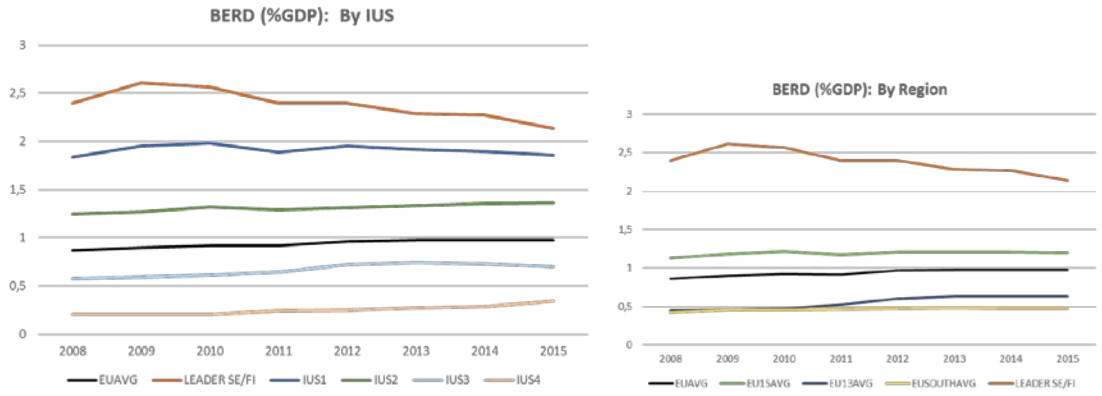
Figure 5 shows that the EU Business R&D share of GDP continues to hover around 1%, which is consistently below other countries like the US, Japan and Korea and since 2008, also below the score for China and far below a 2% target.

Figure 5: **Trends in Business R&D in the EU and the World**



Looking within the EU area, Figure 6 shows important differences in business R&D investments across EU28 countries. Sweden and Finland, top IUS scoring countries in the EU, are by far the leaders on this crown-indicator, scoring around 2.5%, which is even higher than the US. While they forged ahead on this indicator immediately after the crisis, they are now gradually losing edge. This holds most notably for Finland (cf Nokia), but also for Sweden. The countries lagging behind on the IUS (IUS3&4) are also lagging behind considerably on this crown indicator, with an average score of around only 0.5%. But in the more recent years there is some catching up. The right panel shows that the catching up by lagging countries is mostly an EU13 story. The EU15 South countries have a flat 0.5% scoring.

Figure 6: **Trends in Business R&D in the EU**



Source: Own calculation on basis of EC, Innovation Union Scoreboard, 2016

Table 2 confirms the high variance among EU countries on Business R&D, as the large CV numbers demonstrate. This variance is especially high within the group of innovation lagging countries. This variance reduced over time, signaling σ-convergence. This σ-convergence is a combination of (i) a reduced variance both within the group of innovation leading countries as well as within the group of lagging countries as well as (ii) a reduction in the gap between the leading and lagging countries, due to a catching up of the lagging countries, but also because the top lost lead. The catching up by the lagging countries is a EU13 story. The EU15 South has lost further position.

Table 2: **Convergence in" Business R&D to GDP" in EU**

	2008-09	2010-11	2012-15
Avg Score EU28	0,881	0,919	0,973
Coefficient of Variation EU28	0,822	0,793	0,723
Coefficient of Variation EU-Innovation Leaders (IUS12)	0,376	0,369	0,337
Coefficient of Variation EU-Innovation Laggards (IUS34)	0,912	0,855	0,809
Lead by Innovation Leaders (IUS12/EU28)	1,757	1,731	1,642
Gap by Innovation Laggards (IUS34/EU28)	0,510	0,527	0,584
Coefficient of Variation EU15	0.629	0.622	0.596
Coefficient of Variation EU13	1.070	0.977	0.876
GAP by EU13 (EU13/EU28)	0,515	0,542	0,639
GAP by EU15-SOUTH (EU15SOUTH/EU28)	0,501	0,500	0,484

Note: Score is Business R&D expenditures as % of GDP. Averages are unweighted country average scores.

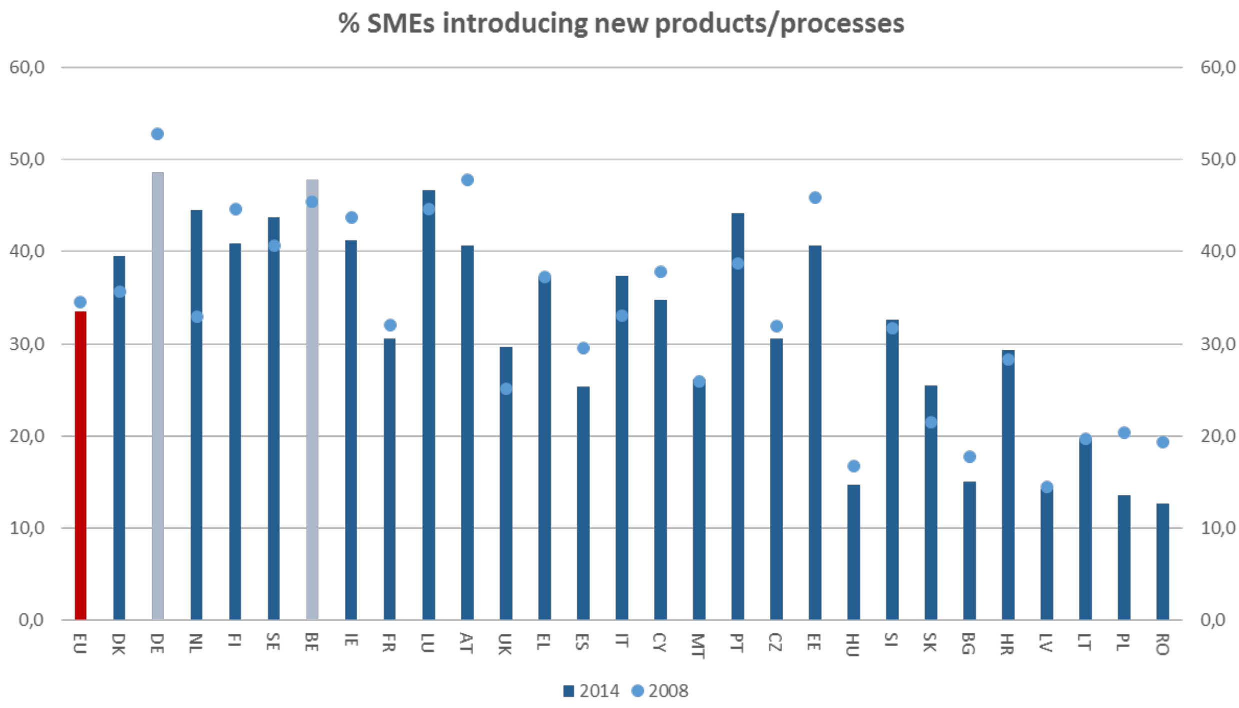
Source: Own calculation on basis of EC, Innovation Union Scoreboard, 2016

Overall, the numbers show that there is some convergence on private sector R&D within the EU, a combination of the top losing its lead and some timid catching up by lagging EU13 countries. But overall, the heterogeneity on this crown innovation indicator remains substantial within the EU as a whole, but also within the group of Innovation Laggards, where the EU15-South is missing any catching-up potential.

5.2 SMES INNOVATING

While the business R&D numbers are driven by the expenditures for own research and development activities from leading big corporates[2], what also matters for innovation capacity, and particularly for countries in catching up mode, further from the technology frontier, is whether companies are adopting the latest available innovations, not necessarily developed inhouse. This holds most notably for SMEs. OECD recent work (see Andrews, Criscuolo & Gal (2015)) has highlighted that the problem of productivity growth in the West is a problem of too slow adoption by non-frontier firms. To look at this adoption process more closely, we look at the % SMEs that are introducing new products or processes (new to the firm, not necessarily new to the market). This indicator is included in the IUS composite (cf Annex I) using data from several waves of the EUROSTAT-Community Innovation Surveys[3].

Figure 7: **Trends in "Innovative SMEs" in the EU**



Source: Own calculation on basis of EC, Innovation Union Scoreboard, 2016

On average about one third of SMEs are introducing new products and processes in the EU, a pattern that has remained fairly stable over the considered period. Overall, there seems to be substantially heterogeneity within the EU on this indicator. Germany and Belgium are leading the ranks on this indicator, with close to 50% of SMEs innovating. In most innovation leading countries, the ratio has

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[2] For example, the EC-IPTS Scoreboard of largest R&D spenders, represents about 80% of the total business R&D numbers in Europe (Veugelers & Cincera (2010).

[3] As the data are based on EC-CIS, the EU cannot be compared to other parts of the world on this indicator.

gone down between 2008 and 2014. The ratio has increased in especially the Netherlands, but also in Belgium, Denmark, Sweden and the UK. The innovation lagging countries typically score lower on this indicator. Portugal and Estonia are within this group the better scoring countries.

Table 3: **Convergence in "Innovative SMEs" in EU**

	2008-09	2010-11	2012-15
Avg Score EU28	32.7	32.7	32.4
Coefficient of Variation EU28	0.328	0.317	0.353
Coefficient of Variation EU-Innovation Leaders	0.201	0.183	0.153
Coefficient of Variation EU-Innovation Laggards	0.330	0.354	0.388
Lead by Innovation Leaders (IUS12/EU28)	1.239	1.199	1.273
Gap by Innovation Laggards (IUS34/EU28)	0.845	0.871	0.823
GAP by EU13 (EU13/EU28)	0.744	0.757	0.697
GAP by EU15-SOUTH (EU15SOUTH/EU28)	1.031	1.080	1.055

Note: Score is share of SMEs that introduced new products/processes

Source: Own calculation on basis of EC, Innovation Union Scoreboard, 2016

On Innovative SMEs the dispersion within the EU28 area is much lower than on Business R&D. Also the lead/gap between innovation leading and lagging countries is smaller. The EU15 South has no lag on this indicator, unlike for BusinessR&D. The trend is however one of increasing divergence, as the higher CV numbers in the latest period show. This is due to an increase in the gap by the innovation laggards, in casu EU13 innovation laggards, and an increase in the variance within this group of lagging countries.

6. (LACK OF) CONVERGENCE IN INNOVATION ENABLERS

We continue the analysis by looking at the dispersion among EU countries in some of the enablers of innovation capacity.

We will look at the dispersion in public funding for R&D in section 6.1. In section 6.2, we will look a the skill level of the work force, measured by their ertiary education levels. This skill level is an important component both of the absorptive capacity as well as of the creative capacity of innovation systems, as discussed in section 2. Education levels are also in most EU countries an important component of public policy. We therefore have two enablers which are also important policy levers.

6.1 PUBLIC R&D EXPENDITURES

The deployment of a country's public budget for innovation will depend on its level of innovation development and its level of key enablers for innovation based development and will be dynamically evolving along with and driving its growth path. In view of the large heterogeneity in innovation capacity positions among EU countries, we should therefore expect across EU countries heterogeneity in public innovation spending, and changes over time.

Table 4 shows Public R&D expenditures as a percentage of GDP for the EU28 compared to other parts of the world. It shows first that public spending on R&D is in general low in Europe, hovering around 0.7% of GDP, considerably below a 1% target, on par with the US, but considerably lower than Korea. While China is still lower, its public R&D spending as share of GDP is rising faster.

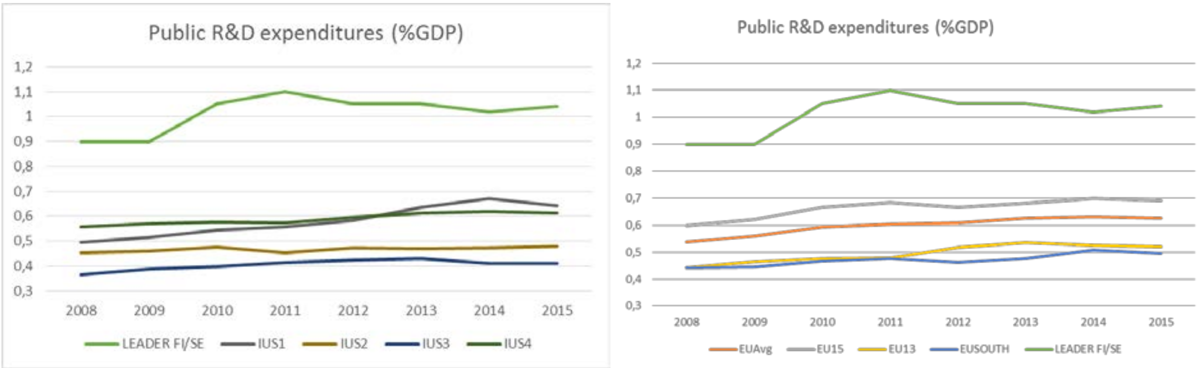
Table 4: **Public R&D in EU and the World**

	EU28	US	KR	JP	CN
Public R&D (%GDP), 2014	0.72	0.72	0.87	0.75	0.46
Relative Score (EU=100), 2014		100	121	104	65
Change in Relative Score (2007-2014)		0.0%	1.8%	-1.0%	0.8%

Note: Relative scores equal 100 * the country's indicator values divided by those of the EU. Growth differences are calculated by subtracting EU growth rates from those of the country ; Source: EC, Innovation Union Scoreboard, 2016

Figure 8 (right panel) shows that Public R&D expenditures as a percentage of GDP have been gradually increasing over time for the EU. This increase was more pronounced in the pre-2008 period (not shown); the increase initially continued after the crisis, be it at a slower pace, but has stopped increasing since 2010.

Figure 8: **Trends in Public R&D spending (as % of GDP)**



Source: Own calculation on basis of EC, Innovation Union Scoreboard, 2016

There are important differences in the amounts spent by EU member states. These differences in public spending (relative to GDP) are closely related to the positions of countries in terms of their innovation capacity (Figure 8 left panel), but not in an expected relationship. *Innovation-leading* countries spend more than *innovation lagging countries*. Viewing public spending as a policy instrument for catching up, one would have expected more of an inverted relationship, with public spending on R&D (as a share of GDP) to be more prominent in the countries that are catching up. The EU innovation leading countries Finland and Sweden are spending the most on public R&D as a share of their GDP and they have even increased this share over time, further forging ahead. The innovation lagging countries show no catching up, with particularly the EU15South continue to lag behind.

Table 5 confirms that the variance in public R&D spending is substantial within the EU28. The variance is higher within the group of innovation lagging countries.

Table 5: **Convergence in "public R&D spending " in EU**

	2008-09	2010-11	2012-15
Avg Score EU28	0,548	0,598	0,622
Coefficient of Variation EU28	0,360	0,388	0,377
Coefficient of Variation EU-Innovation Leaders	0,236	0,253	0,263
Coefficient of Variation EU-Innovation Laggards	0,332	0,335	0,350
Lead by Innovation Leaders (IUS12/EU28)	1,277	1,317	1,276
Gap by Innovation Laggards (IUS34/EU28)	0,738	0,703	0,746
GAP by EU13 (EU13/EU28)	0,828	0,799	0,844
GAP by EU15-SOUTH (EU15SOUTH/EU28)	0,808	0,788	0,780

Note: Score is Public R&D expenditures as % of GDP. Averages are unweighted country average scores.

Source: Own calculation on basis of EC, Innovation Union Scoreboard, 2016

The variance in public R&D spending in the EU28 initially further increased after the crisis, but has started to reduce more recently. This is a combination of several trends. The lead by innovation leaders (IUS12) was first increasing, but has been fallen more recently, while innovation lagging countries were immediately after the crisis further falling behind, but have been able to catch up more recently. This catching up is more prevalent in the EU13 laggards rather than in the EU15South which show no catching up. As a consequence, the variance within the group of innovation lagging countries has increased in the more recent period. Also among the innovation leading countries, the variance has increased more recently. The overall drop in variance is therefore mostly because of a closing of the gap between some of the leading and some of the lagging countries, but at the expense of a greater heterogeneity in both leading and lagging countries.

6.2 TERTIARY EDUCATED WORKFORCE

An important enabler of innovation capacity is the quality of a nation's workforce. This matters not only for the creation of new products and processes but also of the adoption of latest available innovations to enable access to skills. A proxy for the quality of human capital is its level of education, particularly the share of workers which finished tertiary education. The tertiary education system is in most EU countries publicly funded and therefore an important policy instrument.

Table 6 shows that about one third of the working age population in the EU28 is tertiary educated. Although this is substantial, it is below the shares in the US, Korea and Japan, but the EU is catching up relative to US and Japan. China is still scoring low on this indicator, but is again catching up fast.

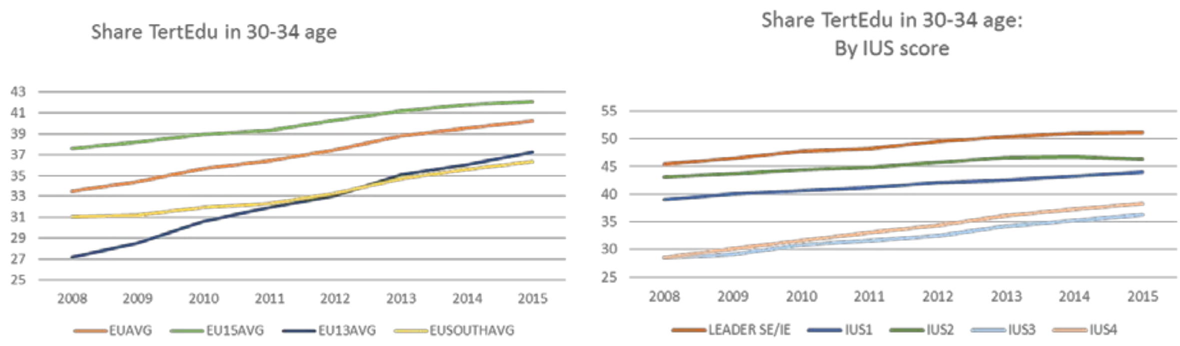
Table 6: **Tertiary Educated Workforce in EU and the World**

	EU28	US	KR	JP	CN
Population completed tertiary education (aged 25-64), 2014	31.7	44.2	44.6	46.6	11.3
Relative Score (EU=100), 2014		140	141	147	31
Change in Relative Score (2007-2014)		-2.1%	0.2%	-1.6%	4.5%

Note: Relative scores equal 100 * the country's indicator values divided by those of the EU. Growth differences are calculated by subtracting EU growth rates from those of the country ; Source: EC, Innovation Union Scoreboard, 2016

Figure 9 displays for the EU area, the "share of people in the 30-34 age group which finished tertiary education", the indicator included in the EU-IUS composite to proxy for human capital skills. It shows that the EU has made important continued improvements in this indicator and this in all parts of the EU: in EU15 as well as in EU13, in E15U North as well as in EU15South. Although there is a gap between the innovation laggards and leaders, this gap has been reduced as the innovation laggards have been catching up faster. This holds particularly for the EU13.

Figure 9: **Trends in Tertiary Educated Workforce**



Source: Own calculation on basis of EC, Innovation Union Scoreboard, 2016

Table 7 shows that although there is heterogeneity in "tertiary educated" among EU28 countries, this has decreased substantially since 2008. This is because of a catching up by the innovation lagging countries, a reduced variance within the group of innovation laggards and a shrinking lead by the leading countries. On the tertiary educated skill level of its workforce, the EU28 can show clear evidence of σ-convergence.

Table 7: **Convergence in "tertiary educated " in EU**

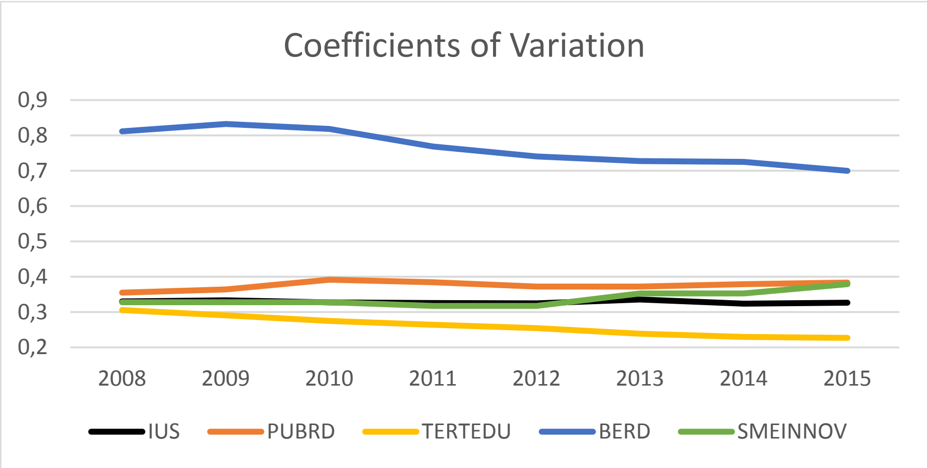
	2008-09	2010-11	2012-15
Avg Score EU28	33,971	36,043	38,992
Coefficient of Variation EU28	0,298	0,270	0,238
Coefficient of Variation EU-Innovation Leaders	0,127	0,120	0,126
Coefficient of Variation EU-Innovation Laggards	0,326	0,298	0,263
Lead by Innovation Leaders (IUS12/EU28)	1,226	1,192	1,150
Gap by Innovation Laggards (IUS34/EU28)	0,854	0,876	0,903
GAP by EU13 (EU13/EU28)	0,820	0,867	0,906
GAP by EU15-SOUTH (EU15SOUTH/EU28)	0,917	0,892	0,897

Note: Score on Share of Tertiary Educated in 30-34 age group. Averages are unweighted country average scores.
Source: Own calculation on basis of EC, Innovation Union Scoreboard, 2016

7. COMPARING TRENDS IN CONVERGENCE IN THE EU ACROSS COMPONENTS OF INNOVATION CAPACITY

Figure 10 compares the variance (as measured by the Coefficient of Variation), and convergence (as measured by the trend in the Coefficient of Variation) for the different components of innovation capacity. By far the highest dispersion is in the Business R&D component. This variance increased immediately after the crisis but has gone down somewhat more recently. It nevertheless remains highly dispersed among EU28 countries. In contrast, the share of SMEs innovating, displays a lower level of dispersion, which is quite stable over time. This indicator has gone up somewhat more recently. Public R&D spending has also increased its dispersion somewhat after the crisis. The tertiary education level is the component that displays the lowest level of dispersion. It has decreased substantially over time, displaying the clearest case of σ-convergence.

Figure 10: **Comparing trends in convergence across components of Innovation Capacity**

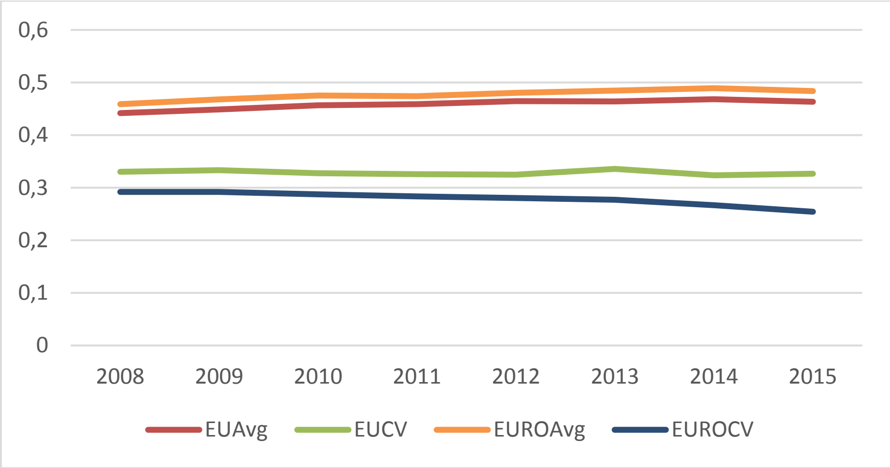


Source: Own calculation on basis of EC, Innovation Union Scoreboard, 2016

8. TRENDS IN CONVERGENCE IN INNOVATION CAPACITY IN THE EURO AREA

We close the analysis with a focus on the EURO area. Convergence (or lack thereof) is more critical for countries joined by a common currency. As the EURO area is not including countries which are at the bottom of the IUS ranking (Roumania, Bulgaria, Poland and Croatia), the average score of the EURO area on Innovation Capacity is higher than the average for the EU. But only slightly so, as Figure 11 shows. Although the variance in IUS scoring is smaller in the EURO area than in the EU area, it is still substantial: it has 8 member countries which are innovation leaders (ie above the EU average), missing 2 top innovation leaders (SE & DK). It has 11 member countries which are innovation laggards (ie below the EU average) (including 2 countries which belong to the bottom IUS4 group (Latvia and Lithuania). In contrast to the EU area, the EURO area group has managed to somewhat reduce its heterogeneity in innovation capacity performance over time, particularly in the later period, showing some signs of σ-convergence around an improving overall IUS scoring.

Figure 11: **Trends in convergence in IUS in the EURO area**



Source: Own calculation on basis of EC, Innovation Union Scoreboard, 2016

Table 87 zooms in on the components of Innovation Capacity. Like for the EU28, the highest variance is found for "Business R&D". The trend of a timid σ-convergence in the EURO area in the overall IUS score, can be witnessed in all of the components.

Table 8: **Convergence in components of Innovation Capacity in the EURO area**

	2008	2009	2010	2011	2012	2013	2014	2015
EURO CV								
IUS	0,292	0,292	0,287	0,284	0,280	0,277	0,267	0,254
BERD	0,758	0,775	0,765	0,735	0,706	0,713	0,721	0,715
SME NNOV	0,292	0,292	0,292	0,284	0,284	0,277	0,277	0,287
PUBRD	0,358	0,360	0,396	0,363	0,339	0,312	0,309	0,306
TERTEDU	0,306	0,287	0,266	0,254	0,244	0,229	0,225	0,223
EU28 CV								
IUS	0,330	0,333	0,328	0,326	0,325	0,336	0,324	0,327
BERD	0,812	0,832	0,818	0,768	0,741	0,728	0,725	0,700
SMEINNOV	0,328	0,328	0,328	0,317	0,317	0,353	0,353	0,379
PUBRD	0,355	0,364	0,392	0,385	0,372	0,372	0,379	0,384
TERTEDU	0,306	0,291	0,275	0,264	0,254	0,239	0,230	0,227

Source: Own calculation on basis of EC, Innovation Union Scoreboard, 2016

Unlike for the EU28, the variance in "public R&D expenditures" in the EURO area, after an increase immediately after the crisis, has been going down since. This is because the EURO area does not include some of the lagging countries that decreased their public R&D to GDP ratio (Bulgaria, Roumania and Croatia) and some of the leading countries that increased their public R&D to GDP ratio (Denmark and Sweden). This σ-convergence in public R&D expenditures takes place along a gradual increase in the "public R&D to GDP" ratio (from 0.54% in 2008 to 0.64% in 2015).

9. HETEROGENEITY AND (LACK OF) CONVERGENCE IN INNOVATION CAPACITY: TAKING STOCK OF THE EVIDENCE

- The EU is only very slowly catching up in innovation capacity performance with its major world competitors.
- The EU displays a large heterogeneity in innovation capacity among its member countries. The divide in innovation capacity is not a straightforward divide along initial positions of economic development as expected along the EU15 versus EU13 distinction. There is plenty of heterogeneity within the EU15 and the EU13, where the North-South divide seems to be equally telling as the East-West.
- This substantial heterogeneity on innovation capacity within the EU proves to be very persistent over time, disappointing those that would expect convergence on innovation capacity based on convergence in economic development and catching up by the innovation laggards, Although the innovation lagging countries catch up somewhat relative to the EU average, the average lag has remained very stable after the crisis. Within the group of innovation laggards, the variance is substantial and very persistent, with no evidence of the most lagging countries to catch up faster.
- The EURO area group has managed to somewhat reduce its heterogeneity in innovation capacity performance over time, particularly in the later period, showing some signs of σ-convergence. This σ-convergence in takes place along a gradual improvement in innovation capacity.
- The heterogeneity among EU countries holds across all components of innovation capacity, but is the most outspoken for the intensity of business R&D, a key components of innovation capacity reflecting the capabilities and the incentives of the business sector to invest in innovation. There is some convergence on business sector R&D within the EU, a combination of the top countries losing their grip and some timid catching up in some lagging EU13 countries.
- On the tertiary educated skill level of its workforce, an important enabler of innovation, both for the adoption of latest innovations and the own creation of innovations, the EU28 is catching up relative to the US and Japan, displays lower heterogeneity among its members and can show clear evidence of σ-convergence, with the lagging EU13 countries catching up.
- Public R&D expenditures as a percentage of GDP have been gradually increasing over time for the EU, but has stopped increasing since 2010. There are important differences in the amounts spent by EU member states. The EU innovation leading countries are spending the most on public R&D as a share of their GDP and they have even increased this share over time, further forging ahead. The innovation lagging countries show no catching up, with particularly the EU15South continue to lag behind.
- The variance in public R&D spending initially further increased after the crisis, but has started to reduce more recently. This is a combination of several trends. The overall drop in variance is mostly because of a closing of the gap between some of the leading and some of the lagging countries, but at the expense of a greater heterogeneity in both leading and lagging countries
- Within the EURO area, after an increase immediately after the crisis, dispersion has been going down since. This σ-convergence in public R&D expenditures takes place along a gradual increase in the “public R&D to GDP” ratio.

10. HETEROGENEITY AND (LACK OF) CONVERGENCE IN INNOVATION CAPACITY: POLICY IMPLICATIONS

The analysis raises two important policy challenges: (i) why is EUs overall innovation capacity so slow in catching up and (ii) why is there so slow catching up within the EU by innovation lagging countries?

The continued business R&D deficit is central in Europe's innovation deficit. It is a symptom of the overall weakness in Europe's capacity to innovate and its low capacity for structural change and shifting towards new growth areas. *What explains this continued business R&D deficit? Why does Europe's business sector continues to have less innovative capacity on average when compared to the US, despite its top performing countries?* Europe's persistent business innovation gap can be correlated with its industrial structure (O'Sullivan (2008) Bartelsman et al. (2004), Aghion et al. (2008), Veugelers & Cincera (2010; 2015), Bravo-biosca et al (2016), and others). New firms fail to play a significant role in the dynamics of European industry, especially in new high-growth sectors. This is illustrated by their inability to enter, and more importantly, for the most efficient innovative entrants, to grow to world leadership. The churning that characterizes the creative destruction process in a knowledge based economy encounters significant obstacles in the EU, suggesting barriers to growth for new innovating firms that ultimately weaken Europe's growth potential. This inability for new European firms to grow large seems to manifest itself particularly in the new high-tech, high-growth sectors, like digital and health sectors. This correlates with a lower specialization of the European economy in R&D intensive, high growth sectors of the nineties, again most notably digital sectors (O'Mahoney & van Ark (2003), Denis et al. (2005), Moncada et al. (2009)).

Policies aimed at raising R&D expenditure across all types of industries and companies will be necessary, but it will not be sufficient, as they do not address the root causes of Europe's innovation deficit. To do this, policies need to address also the specific barriers to development of new high R&D-intensity sectors and companies. While overall innovation policy should further the integration of the European capital, labour, product and services markets, make it easier for players in the innovation system to interact and, at the same time, ensure healthy competition, policy measures are also needed to tackle the specific barriers faced in new sectors by new companies. This includes *inter alia* access to external finance for fast growing highly innovative projects, by public funding and/or by leveraging private risk funding. Beyond furthering the single market for risk financing, a system of grants for high risk taking innovative projects of young companies, during the critical start up and development stages, when financial market barriers are at their highest, cannot be missing in the set of EU instruments.

A second challenge for EU innovation policy making is the slow convergence in innovation capacity between EU member countries and the failure of EU innovation lagging countries to catch up with the EU average. Is the missing catching up signalling a failure of innovation policies in place in these countries to enable catching up? When looking at the size of the public budget for R&D support, although the evidence shows an increase in public spending (as % of GDP), there is substantial heterogeneity in public spending. But this heterogeneity is not supporting convergence, as the innovation leaders have high shares and innovation laggards low shares. Furthermore the heterogeneity even exacerbated further away from catching-up in the aftermath of the crisis, as the leaders increased and the laggards cut public R&D budgets (Veugelers (2015)). Recently the variance in public spending has reduced, but the convergence is because of the leaders no longer forging ahead, while the bottom laggards are still falling further behind on public R&D spending. The public R&D budgets of EU countries are therefore not showing the right type of heterogeneity and convergence to support catching up and convergence on innovation capacity.

National innovation policies for catching up are not only about the size of public funding. It also requires a deployment of policy instruments mix that is adapted to the country's innovation position and trends therein. As an example, more emphasis in innovation policy on supporting the absorption and adaption of existing frontier technologies by industry would make more sense for the EU countries in catching-up mode. Overall the mix of instruments for innovation policy deployed by EU Member States is a rather standard set of instruments, relatively irrespective of their innovation capacity development (Veugelers (2016)).

Innovation policy in the countries of the EU with lower innovation capacity cannot be pursued as imitating a "common practice" (see also Tödtling & Trippl (2005)). The EU2020 strategy and the ERA should not be thought of as a harmonization process: innovative and productive structures' differ across countries and regions. A decentralized policy approach implies more possibilities of adaptation to local specific needs for policy intervention. Nevertheless, coordination among the various policy levels is important. European level policies and national policies should form a coherent mix, in which all policies focus on those capabilities, market and systemic failures best solved at each level and to facilitate diffusion of policy know-how.

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ANNEX I: IUS Components

- *'Human resources'* includes3 indicators and measures the availability of a high skilled and educated workforce. The indicators capture New doctorate graduates, Population aged 30-34 with completed tertiary education and Population aged 20-24 having completed at least upper secondary education.
- '*Open, excellent and attractive research systems*' includes 3 indicators and measures the international competitiveness of the science base by focusing on the International scientific co-publications, Most cited publications and Non-EU doctorate students.
- '*Finance and support*' includes 2 indicators and measures the availability of finance for innovation projects by venture capital investments and the support of governments for research and innovation activities by R&D expenditures by universities and government research organisations
- '*Firm investments*' includes 2 indicators of both R&D and Non-R&D investments that firms make in order to generate innovations. '
- *Linkages* includes 3 indicators measuring innovation capabilities by looking at SMEs that innovate in-house and Collaboration efforts between innovating firms and research collaboration between the Private and public sector.
- '*Intellectual assets*' captures different forms of Intellectual Property Rights (IPR) generated as a throughput in the innovation process including PCT patent applications, Community trademarks and Community designs.
- '*Innovators*' includes 3 indicators measuring the share of firms that have introduced innovations onto the market or within their organisations, covering both technological and non-technological innovations and Employment in fast-growing firms of innovative sectors.
- '*Economic effects*' includes 5 indicators and captures the economic success of innovation in Employment in knowledge-intensive activities, the Contribution of medium and high-tech product exports to the trade balance, Exports of knowledge-intensive services, Sales due to innovation activities and License and patent revenues from selling technologies abroad.

ANNEX II: IUS scoring by EU Member States

	Summary Innovation Index 2008	Summary Innovation Index 2009	Summary Innovation Index 2010	Summary Innovation Index 2011	Summary Innovation Index 2012	Summary Innovation Index 2013	Summary Innovation Index 2014	Summary Innovation Index 2015
EU	0,495	0,502	0,511	0,514	0,519	0,521	0,523	0,521
DE	0,624	0,636	0,654	0,655	0,667	0,661	0,655	0,632
DK	0,624	0,630	0,639	0,678	0,694	0,693	0,675	0,700
FI	0,663	0,668	0,671	0,651	0,651	0,642	0,658	0,649
NL	0,549	0,563	0,573	0,580	0,586	0,631	0,639	0,631
SE	0,697	0,709	0,718	0,714	0,717	0,722	0,719	0,704
AT	0,583	0,598	0,608	0,577	0,581	0,604	0,599	0,591
BE	0,564	0,576	0,578	0,588	0,592	0,596	0,607	0,602
FR	0,539	0,550	0,560	0,562	0,566	0,560	0,556	0,568
IE	0,584	0,596	0,617	0,619	0,627	0,601	0,607	0,609
LU	0,632	0,646	0,632	0,619	0,623	0,646	0,626	0,598
UK	0,525	0,529	0,542	0,560	0,566	0,569	0,580	0,602
CY	0,470	0,474	0,476	0,488	0,491	0,480	0,487	0,451
EL	0,370	0,364	0,368	0,371	0,375	0,386	0,399	0,364
ES	0,381	0,386	0,389	0,386	0,388	0,394	0,387	0,361
IT	0,389	0,400	0,407	0,418	0,416	0,425	0,434	0,432
MT	0,342	0,354	0,351	0,326	0,334	0,379	0,371	0,437
PT	0,393	0,403	0,401	0,404	0,405	0,401	0,418	0,419
CZ	0,413	0,412	0,422	0,440	0,442	0,421	0,433	0,434
EE	0,416	0,441	0,469	0,468	0,505	0,490	0,479	0,448
HU	0,345	0,343	0,354	0,358	0,363	0,355	0,364	0,355
SI	0,446	0,453	0,464	0,479	0,491	0,476	0,498	0,485
SK	0,318	0,329	0,338	0,325	0,313	0,346	0,354	0,350
BG	0,219	0,209	0,230	0,238	0,240	0,210	0,238	0,242
HR	0,299	0,293	0,291	0,302	0,304	0,298	0,292	0,280
LT	0,239	0,238	0,252	0,256	0,268	0,275	0,288	0,282
LV	0,214	0,217	0,224	0,234	0,247	0,215	0,233	0,281
PL	0,290	0,298	0,299	0,291	0,296	0,286	0,291	0,292
RO	0,246	0,255	0,264	0,263	0,261	0,228	0,223	0,180

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