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The Distribution of Technological Activities in Europe: A Regional Perspective

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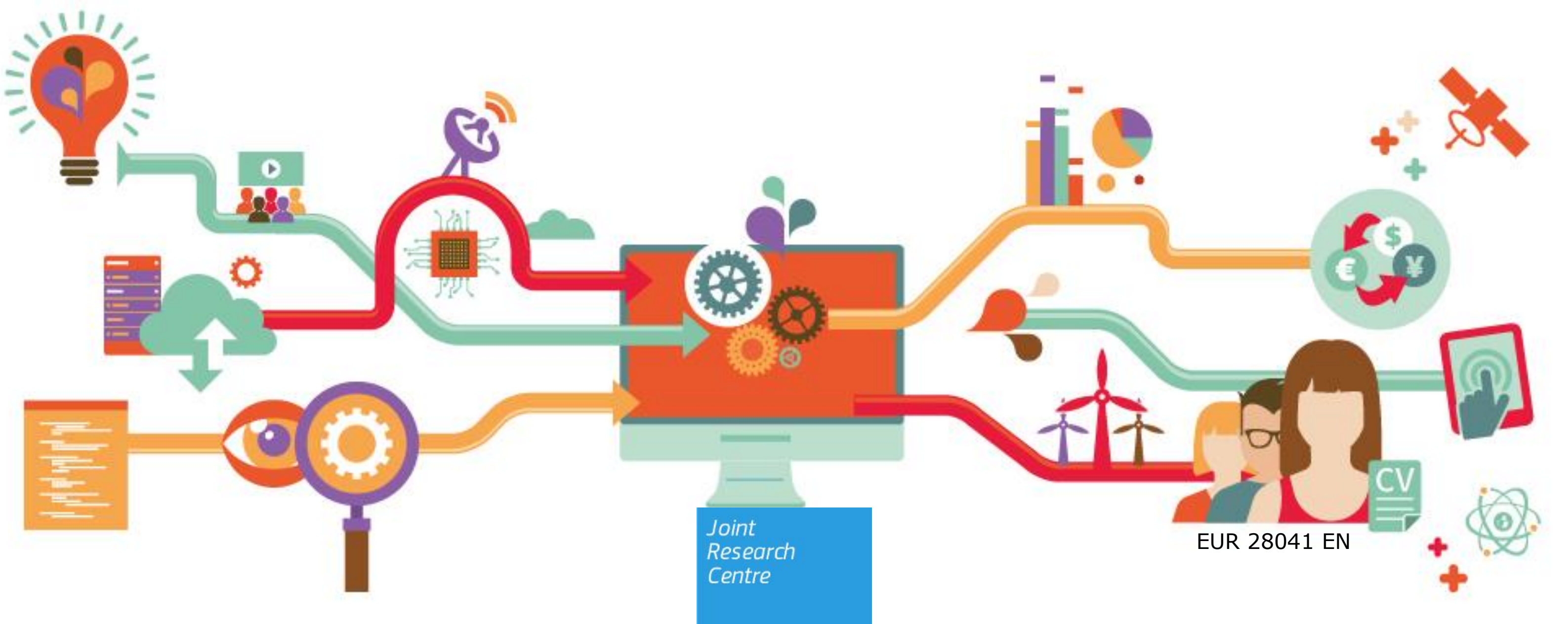

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Abstract

This study analyses the major patterns and trends in the spatial distribution of technological capacities in the EU area over the 1996-2011 period, adopting a regional perspective. More specifically, the study aims at: a) assessing the level of technological polarization in the EU area and its dynamics; b) highlighting major changes in the patterns of technological specialization of EU regions; c) identifying the technological trajectories that have been more effective, that is able to sustain long-term economic growth and facilitate catching-up processes of EU laggard regions.

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1. Introduction

Building a cohesive and competitive Europe has represented for several decades now one of the most challenging and ambitious goal of our continental policy institutions, and one which is still far from being reached. Since the release of the Lisbon strategy innovation and human capital have been considered as key ingredients and leverages of any strategy pursuing such a goal. Regions, rather than countries, have progressively increased their relevance as key spatial and socio-economic domains as well as policy targets of cohesion policies (European Commission, 2010, 2011; Boschma and Frenken, 2011). In the most recent years regional innovation strategies for smart specialization (RIS3) have become a key component of the EU Cohesion Policy 2014-2020, supporting the thematic concentration of available resources and the reinforcement of the strategic programming and performance orientation of policy action (European Commission, 2011, 2014a). More precisely, the Cohesion Policy initiative encourages regions and cities from different EU Member States to strengthen their technological bases and to collaborate on joint programmes, projects and networks. This approach aims at increasing mutual learning processes that can have a concrete impact on every aspect of economic life including innovation, accessibility, education, business, employment or the environment. Regions are also encouraged to be outward looking and at the same time identify their strength and weaknesses in order to strategically positioning themselves in the European and global value chains, improve their connections and cooperation with other regions, clusters and innovation players. This is deemed to be of crucial importance in order to favour the internationalisation of their companies, to achieve a critical potential of cluster activities and to generate inflows of knowledge relevant to the region's existing knowledge base (European Commission, 2012).

In this context, investigating and mapping the distinctive competitive advantages, and identifying viable and qualitative patterns of structural change able to sustain long term economic growth, represents a very relevant informative base for orientating industrial and technological policies. This study aims at providing an empirical contribution in this direction. The report is structured as follows. Section 2 provides a survey of the relevant literature. Section 3 contains a brief description of the data-set used and other methodological notes. Section 4 presents a descriptive analysis of the spatial distribution of technological activities in the EU area. Key questions addressed in this section are the following:

- What is the level of spatial concentration of technological activities in the EU area and how has the level of technological polarization changed over the 1996-2011 period?
- What are the technological fields where competencies and innovation capacities are more concentrated and what are the technological areas where innovation capacities are more evenly distributed across EU regions?
- Are laggard and peripheral EU regions catching-up (in terms of technological performances) with regard to the core and more advanced EU areas?
- How heterogeneous are the long-term technological performances of regions located in different geographical areas or moving from different technological stages of development?

The aim of Section 5 is to analyse differences and similarities in the technological specialization of EU regions as well as highlighting the long-terms changes in their technological profiles and performances. More in particular the descriptive evidence presented in this section aims at:

- ❖ Exploring the variety of the patterns of technological specialization of EU regions and their long term changes.
- ❖ Verifying if technological gaps across the main EU regional areas, and differences in their long term technological performances, are associated to specific patterns of technological specialization and to the extent to which regions have changed their specialization profile over the last 15 years.
- ❖ Investigating the role played by the level of technological development of EU regions in influencing the spectrum of technological competencies of regions, the areas of technological specialization and the technological trajectory regions have undertaken.

Section 6 investigates, on an econometric ground, whether the economic performances of EU regions are associated to their overall technological dynamism, to specific patterns of technological specialization and type technological trajectory. The concluding section (Section 7) contains a synthesis of the main findings of this study and some final remarks.

2. Relevant streams of literature

2.1 The level and dynamics of technological polarization in the EU area

As shown and empirically documented by numerous contributions, technological capacities are far from being evenly distributed across industries, firms and even more at a spatial level. This is due to various factors, the most important being the cumulative nature of innovation and learning processes, the localized character of spillovers, externalities and systemic interactions in the process of generation and economic exploitation of technology (Jaffe et al., 1993; Jaffe et al., 1999; Evangelista et al., 2002; Maurseth and Verspagen, 2002; Moreno et al., 2005; Rodriguez-Pose and Crescenzi, 2008; Di Cagno et al., 2016). Furthermore, spatial proximity matters also at a broader and macro-regional level accelerating and strengthening cross-regional agglomeration effects and clustering processes between neighbour regional areas. These features produce long-lasting spatial technological asymmetries that can, in absence of cohesion industrial and innovation policies, produce not-reversible processes of technological polarization.

Systematic and up-dated analyses of the level and dynamics of technological polarization in the EU area and studies looking at this issue from a regional perspective are still limited. At an empirical level, and with reference to the European context, Paci and Usai (2000) have found a high level of spatial (regional) technological concentration although in presence of a declining trend in the regional dispersion of innovative activity over the 1980-90 decade, mainly due to changes in the distribution of technological capacities between southern and northern European regions. Some convergence is detected at country level but not at regional level. The same study analyses main regional differences (in a restricted number of EU countries) in labour productivity and technological intensity (patents per employee) finding that the dispersion of labour productivity is remarkably lower than that of innovative activities; moreover, signs of convergence in labour productivity are found across EU regions. Moreno et al. (2006) have shown that innovation activities have been spreading from the centre Europe to an increasing number of regions in the south (especially in Spain and the South of Italy) and in the Scandinavian countries, but also that this process has not been homogenous across European regions and countries.

2.2 The sectoral dimension of technological polarization

The spatially uneven distribution of technological activities and competences has also a sectoral dimension. Several contributions have highlighted that innovative activities tend not only to agglomerate within specific locations but that the intensity of the geographical concentration and the spatial organization of the innovative processes differ significantly across sectors and technological fields (Breschi 2000, Paci and Usai 2000, Moreno et al 2006, Usai 2008). Paci and Usai have shown that the spatial dependence in technological activities and performances is a phenomenon characterizing European regions, but that it also presents some spatial and sectoral specificities leading to the generation of different types of specialized clusters in the different EU regions. In some sectors, such as machinery, transport equipment and energy technological competencies have been found to be particularly spatially concentrated and that this in contrast with a more even spatial distribution of industrial activities and performances.

Breschi (2000) has attempted to link (in an evolutionary perspective) the characteristics of technological regimes and the geographical and sectoral (technological classes) distribution of patent activities using several types of indicators for technological concentration. The paper shows that "while innovative activities tend in general to agglomerate within specific locations, the intensity of the geographical concentration and the spatial organization of the innovative processes may differ remarkably across sectors" and identifies 4 main sectoral and spatial patterns of technological change: deepening/widening & diffused /concentrated.

2.3 Technological specialization of EU regions

The way and the extent to which economic systems concentrate and distribute their competencies, resources and innovative efforts among the different technological areas is the object of investigation of a consolidated stream of literature. The bulk of this literature has traditionally adopted a country level perspective. The sub-national relevance of the technological specialization issue has been still recently almost completely neglected both on a theoretical and on an empirical ground.

Patent data have been commonly used also to measure the technological performance of regions with a sectoral/technological field focus. Analyses using patent data for analysing the technological specialization of EU regions include Paci and Usai (2000), Moreno et al. (2006), Usai (2008), European Commission (2014b). Most of these studies are mainly descriptive and rather heterogeneous regarding the spatial coverage, the time span considered, the type of data and technological classifications of patent activities used. The key issue regarding the extent to which the "level" and "type" of technological specialization is linked to the economic performance of regions is usually not investigated.

Over the last few years there has been an increased interest on the regional dimension of technological specialization with the emergence of the concept of "Smart Specialisation". Originally, the concept of smart specialization lacked a spatial perspective and was designed as a tool for Europe to respond to the transatlantic productivity gap (Ortega-Argiles, 2012). It was recognised that Europe was behind the USA especially in the ability to exploit Information and Communication Technologies (ICT) in using sectors. This was due to the fact that, despite the Single Market, the linkages between sectors, institutions and places were limited (also because of market segmentation), thus limiting knowledge flows, technology spillovers and innovation networks. In this framework the European Research Area (ERA) was established aiming at promoting knowledge spillovers within the EU through the creation of networks of researchers, innovators and firms. In this context the "Knowledge for Growth" (K4G) expert group advising the DG for Research and Innovation developed a policy-prioritization logic termed "smart specialization" (Foray et al. 2009, 2011; David et al. 2009).

The smart specialization concept is strictly related to competitiveness and industrial specialization, where entrepreneurs look for innovation opportunities within their distinctive domain. The key ideas behind the smart specialization concept are those of "embeddedness", "relatedness" and "connectedness". Embeddedness refers to the fact that the potential development of an innovation system strongly depends on the inherited structures and existing dynamics; relatedness refers to the importance of the size of the "domain" intended as the range of the relevant sectors or activities in which new technological adaptations can most likely to be applied and which can best benefit from knowledge spillovers. Finally, connectedness is important since domains that are highly connected with other domains will offer greater possibilities for knowledge flows and learning than less connected domains.

When translated to a spatial context (McCann and Ortega Argiles, 2013) and taking the region as the unit of analysis, a smart specialization strategy can be linked to the achievement of higher levels of technological embeddedness, related variety and connectivity among close domains (Frenken et al. 2007; Frenken and Boschma, 2007; Boschma and Frenken, 2011; Boschma and Iammarino, 2009). Starting from the observation that regions have different comparative advantages, policies should be devoted to deepening the linkages within regions in their relevant fields of specialization, helping to foster a related diversification process, and developing interregional networks on a region's most connected activities while at the same time maximising local knowledge diffusion and learning networks. Overall the smart specialisation strategy does not aim at "picking winners", but rather at favouring a searching and learning process involving local actors and allowing regions to exploit potential unexploited opportunities in particularly promising areas.

RIS3 strategies can target different priority areas with the aim of generating one (or more) pattern(s) of economic development; four distinct patterns can be identified. The first pattern involves the transition of existing activities to new ones by extending the range of application of given engineering and manufacturing capabilities to other, technologically related domains. This is the case when, for instance, textile firms that have hitherto produced textiles for apparel move into high-tech textile production for industrial applications. The second pattern involves the modernisation of existing capabilities by combining them, for instance, with general-purpose technologies (GPTs) such as information technology or nanotechnology thereby boosting productivity and extending the potential range of applications. The third pattern involves classical diversification processes exploiting economies of scope such as the development of new lines of productive activities. Finally, the fourth pattern implies the radical formation of entirely new domains of enterprises in a region or country by combining local expertise with R&D or management experience from outside.

As already pointed out, a general critical point regarding the smart specialization literature is that it has remained rather conceptual in nature, rarely supported by empirical evidence and difficult to be operationalized in terms of clear-cut policy prescriptions and guidelines (Foray et al., 2011).

2.4 Technological specialization and economic performances

The relationship between the "level" and "type" of technological specialization and the economic and innovation performances has been empirically studied by a limited number of studies and exclusively at a country level. Pianta and Meliciani (1996) have examined the correlation between the level of distribution/concentration of patent activities (Chi2 indexes), the national share in electronics, GDP per capita, Gross fixed capital formation and R&D. This study finds a positive relation between the Chi2 index (measuring the level of specialization) and the growth rates (but not levels) of economic variables (reverse results for patent share in electronics) as well as some evidence of technological and economic convergence. Other studies have followed the technological gap approach to explain country trade performances (export data or trade balance) (Amendola et al 1998, Carlin et al 2001, Laursen and Meliciani 2010).

Most of the literature on the relationship between technological specialization and economic performances has focussed on the role played by specific technologies. ICTs, fast growing technological classes, General purpose technologies (GPT) and Knowledge enabling technologies have been identified as the technological areas able to qualify the technological profile of countries and exert a positive economic impact (Pianta and Meliciani, 1996, Meliciani, 2001, Vertova, 2001; Huang and Miozzo, 2004; Nesta and Patel, 2004). However, empirical analyses that have tested the economic effects of these technologies have not provided univocal results.

At a sub-national level the empirical literature has been largely focussed on the search of a positive relationship between the level of the aggregate technological performances of regions and their economic performances. Crescenzi (2005) shows that R&D expenditures and personnel (but not high-tech patents) have a positive and significant impact on GDP per capita. Their paper tests also a more sophisticated model that includes as regressors the education levels of labour force and population and proxies for technological accessibility. The results show that an increase in innovative efforts yields a higher increase in the average growth rate (of GDP per capita) in regions that benefit from better accessibility or more educated labour. Verspagen (2010) uses Moran coefficient of spatial correlation for all combination of 30 variables reflecting the Education levels of the population, the level of economic development and patents-related variables (Per capita EPO patents and Herfindahl indexes for 11 manufacturing ISIC sectors) and finds evidence of the existence of positive spatial correlations. Basile et al. (2012) use a semi-parametric spatial lag model to estimate the effects on labour productivity growth rate of physical and human capital, employment growth rate, latitude-longitude, geographical, relational, social and technological proximities and the interaction term between them finding that knowledge spillovers, channelled by different forms of proximities, are jointly at work in affecting European regions' economic growth. Vogel (2013) tests the presence and significance of direct (or innovation) effects (total patents over employment in manufacturing and Population with 3rd education) and indirect (or imitation) effects of R&D on TFP growth. The study finds a positive direct effect of human capital and a positive indirect effect of R&D activity on TFP growth for the EU 15 regions.

2.5 Taxonomies of regional innovation systems

Relevant for this study are also a few taxonomic exercises mapping the main technological profiles of EU regions. These studies use a wide array of technological indicators reflecting the overall technological performances of regions, their stage of technological development, and some basic features of their economic structure.

Navarro et al. (2008) propose a regional taxonomy defining 7 different types of regions based on the use of 21 indicators for 186 EU-25 regions. The indicators used include measures for the socio-economic characteristics of regions (such as employment rates and other production-structural features), population density, human resources on science and technology, R&D expenditures and patents. [1] The regional taxonomy elaborated by Verspagen (2010), based on 30 indicators and referring to 154 (mixed NUTS 0/1/2) regions of the EU-25 countries, identifies 4 main regional clusters. (1) Southern regions, (2) New Member States, (3) Central European regions (with UK and Ireland and few Northern), (4) Regions with highest per capita GDP and patenting activity (German-Dutch regions, sub-clusters of Danish and Swedish regions and few isolated urbanized regions such as Paris and London). The Wintjes and Hollanders taxonomy (2011) uses data for 253 NUTS2 regions and, as in the case of the Navarro taxonomy identify seven types of regions, but with a characterization more related to their knowledge capabilities.[2]

The most recent regional taxonomic exercise is the one proposed by European Commission (2014b) and contained in the Regional Innovation Scoreboard. It uses data for 190 EU regions from 22 EU Member state countries plus Norway and Switzerland. This taxonomy is based on the use of a very large number of indicators (from Eurostat and the Community Innovation Survey, CIS) covering a variety of technological and economic dimensions categorized as Enabling factors (Population with tertiary education, R&D/GDP), Firm activities (firms investments, Innovation and collaboration SMEs, Pat/billion GDP) and Output measures (SMEs with innovations, employment in medium and high technology manufacturing sectors and Knowledge intensive services). Four main regional innovation groups are identified: LEADERS, FOLLOWERS, MODERATE, and MODEST Innovators.

[1] The types of regions identified are: (1) Restructuring industrial regions with strong weaknesses, (2) Regions with a weak economic and technological performance; (3) Regions with average economic and technological performance, (4) Advanced regions, with a certain industrial specialisation, (5) Innovative regions, with a high level of economic and technological development, (6) Capital-regions, with a certain specialisation in high value-added services and (7) Innovative capital-regions, specialised in high value-added services.

[2] The types of regions identified are: (1) Metropolitan knowledge-intensive services (KIS) regions, (2) Knowledge absorbing regions, (3) Public knowledge centres, (4) Skilled industrial Eastern EU regions, (4) High-tech regions, (5) Skilled technology regions, (6) Traditional Southern regions.

All in all, these regional taxonomies represent a useful tool in order to map the technological performance and profile of EU regions and to assess and monitor the level and dynamics of technological and economic cohesion in the EU area from a regional perspective. In this study we make use of the taxonomy elaborated by the European Commission (European Commission, 2014b). Most of our descriptive patent statistics will be presented also broken down according the four typologies of regions identified in this study and based on data provided by the Regional Innovation Scoreboard.

3. Data & Methodology

Patent data provide unique insights about quantitative and qualitative dimensions of inventive activities.

In this study, the technological activities and performances of EU regions will be analysed using REGPAT, a patent database developed by the OECD where patents are linked to regions according to the addresses of the applicants and inventors. In the present report we will focus on the inventor localization to analyse the technological capabilities of European regions as we assume that this choice is the most appropriate in order to localize the area where technological activities are carried out and knowledge and competences accumulated.

Patent data allow identifying the technological fields where a region is active and can be used to build several types of indicators measuring the technological specialization and performances of regions (Acs and Audretsch, 1989; Acs et. al., 2002). To this end, in this report, the concordance between International Patent Classification (IPC) and technologies, originally developed by Schmoch (WIPO, 2013), is used. The technological classification proposed by Schmoch has been designed in order to allow country comparisons. The classification has a hierarchical structure. The first level identifies 5 main technological sectors: Electrical engineering; Instruments; Chemistry; Mechanical engineering; Other fields. The second level of this classification defines 35 technological fields (subgroups) allowing for a more detailed analysis of the technological activities and performances of regions (see the Appendix). In this report we will use both these two classification levels.

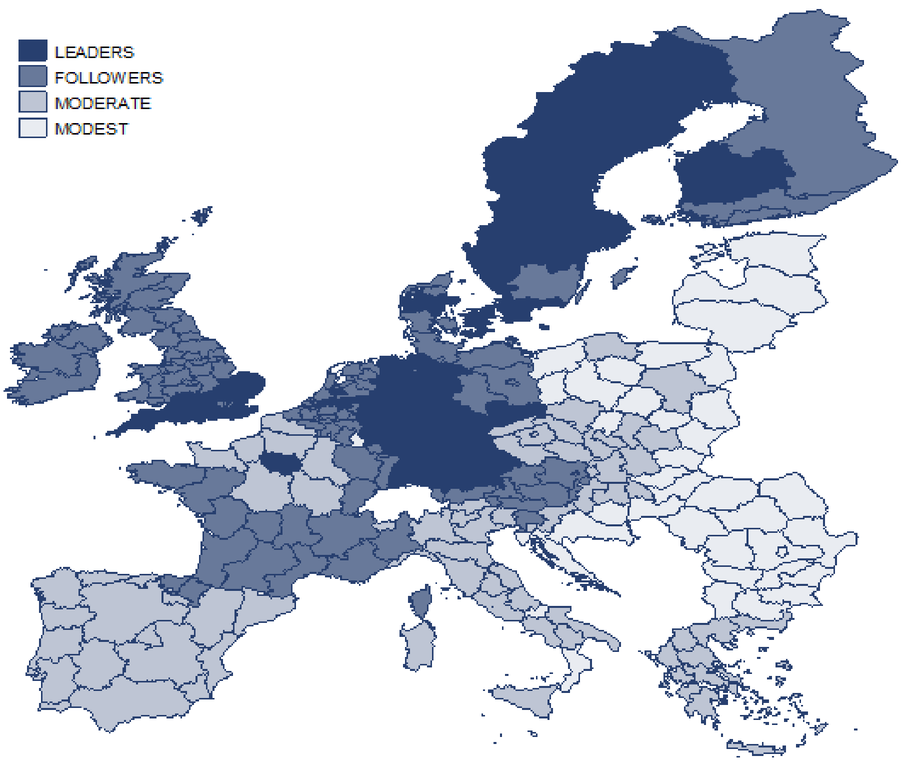
Although in principle REGPAT provides patent information at the NUTS3 spatial level, in this Report the statistical analysis will be carried out manly at the NUTS1 (and NUTS0 for some countries) level.[3] This approach is motivated by the following reasons. On the one hand, for a few small countries the regional breakdown is not available for most economic variables provided by Eurostat, therefore limiting the analysis of the link between technological characteristics and economic performance at a regional level. On the other hand, the characterization of the regional technological profiles requires a minimum number of patents per period considered in order to provide consistent and robust results and many NUTS2 regions have very few or even no patents at all for many years and in many technological areas and fields. For this reason, Cyprus has not been included in the analysis.

[3] For illustrative purposes maps have been computed at the NUTS2 level.

The analysis is carried out on the 1996-2011 period and all data are aggregated (for the data constrains discussed above) by four sub-periods: 1996-1999, 2000-2003, 2004-2007, 2008-2011. This choice also allows us to reduce to the minimum the annual variability of the underlying data (particularly strong for patent data in the smallest unit of analysis) and to better highlight the overall (long term) changes occurred during the period considered.

Finally, consistently with other works and for presentation purposes, a series of statistics will be presented aggregating data at the level of macro regional groups. In particular, two types of macro-regional aggregations will be considered. The first one is based on the geographical location of regions: North Europe (Sweden, Norway, Finland and Denmark), Mittle-Europe (Austria, Belgium, Germany, France, Ireland, Luxembourg, Netherlands, UK), South Europe (Greece, Italy, Malta, Portugal, Spain) and East Europe (Bulgaria, Czech Republic, Croatia, Estonia, Hungary, Lithuania, Poland, Romania, Slovakia, Slovenia); the second criteria is based on the level similar of technological development of the regions and the advancement of their regional innovation systems. For this purpose we have used the regional classification proposed by the Regional Innovation Scoreboard (European Commission, 2014) that, on the base of 11 indicators, identifies four groups of EU regions: LEADERS, FOLLOWERS, MODERATE and MODEST Innovators (see Figure 1).

Figure 1: Level of innovativeness of EU-NUTS2 regions (2004-10)
Based on the Regional Innovation Scoreboard (EU, 2014)



Although useful for many purposes, this taxonomy provides a rather static picture of technological gaps in Europe and, most importantly, does not take into account the technological specialization of regions. This report aims precisely at analysing the long term dynamics of the spatial distribution of technological activities in the EU area and at identifying whether, and the extent to which, technological gaps and long term innovation performances of EU regions are associated to specific patterns of technological specialization.

4. The spatial distribution of technological activities in the EU area.

In this section we investigate the level and dynamics of technological polarization in the EU area from a regional perspective. We use for this purpose the Gini coefficient, an indicator commonly used to synthesize the level of "concentration" and "inequality" of socio-economic phenomena and variables. This index has been computed on the distribution of patent applications across 98 EU NUTS1 regions and covering the period 1999-2011.

Table 1 shows the values of the Gini coefficients for four distinct sub-periods (1996-99; 2000-03; 2004-07; 2008-11) and taking into account both the all volume of patent activities of EU regions and the number of patent applications in five broad technological areas (Electrical engineering; Instruments; Chemistry; Mechanical engineering; Other technological fields). Table 1 reports also the Gini coefficients computed on regional Gross Domestic Product (GDP) values. The latter can be used as a sort of bench-mark in order to assess the relevance and dynamics of technological polarization in the EU area in comparison to the levels and dynamics of economic gaps.

Table 1: Technological inequality in the EU
(Gini coefficient across EU-NUTS1 regions)

	1996-99	2000-03	2004-07	2008-11
Total patents	0.767	0.765	0.756	0.746
ICT & Electrical Engin.	0.812	0.811	0.793	0.776
Chemistry	0.757	0.750	0.739	0.730
Mechanical Engin.	0.789	0.791	0.786	0.777
Instruments	0.763	0.761	0.756	0.746
Others	0.759	0.750	0.753	0.747
GDP	0.503	0.500	0.491	0.485

The first indication emerging from Table 1 is that the EU area is characterized by a very (spatially) uneven distribution of technological capacities, with all indicators of technological concentration being much higher than the ones computed on GDP. The highest levels of technological concentration are found in the area of ICT and Electrical Engineering. Table 1 also shows that the level of technological concentration has decreased over time but only at a very slow pace.

Table 2 provides a more detailed picture of the level and dynamics of technological polarization in Europe presenting Gini coefficient indexes (for the 1996-99 and 2008-11 periods only) for each of the 35 (two digit) technological fields examined in this study. The table shows the presence of significant differences across technological fields in the spatial distribution of technological capacities across EU (NUTS1) regions. Table 2 confirms that the most polarized technological fields are those broadly related to the broad ICT area (Semiconductors, Basic communications, Digital communications, Audio-visual, Telecommunications). Among the least polarized technological fields we find the Pharmaceutical and Bio-technology areas (Pharmaceutical, Bio-materials, Bio-technologies and Medical technologies).

Table 2: Technological inequality in the EU at technological field level
(Gini coefficient across EU-NUTS1 regions)

	1996-99 (1)	2008-11 (4)	Change (4-1)
Semiconductors	0.858	0.823	-0.035
Microstructural and nano tech.	0.865	0.820	-0.045
Basic communications	0.866	0.820	-0.046
Digital communications	0.851	0.818	-0.034
Audio-visual tech.	0.815	0.814	-0.001
Engines, pumps, turbines	0.807	0.813	0.005
Mechanical elements	0.805	0.807	0.002
Telecommunications	0.823	0.800	-0.023
Transport	0.813	0.799	-0.014
Machine tools	0.830	0.796	-0.033
Textile/paper machines	0.832	0.793	-0.039
Optics	0.835	0.791	-0.044
Computer	0.816	0.788	-0.028
Macromol. chemistry	0.818	0.786	-0.032
Electrical machinery	0.806	0.784	-0.022
Organic fine chemistry	0.775	0.782	0.007
Basic materials chemistry	0.771	0.776	0.006
IT methods for management	0.766	0.776	0.010
Thermal processes and apparatus	0.780	0.775	-0.004
Control	0.795	0.775	-0.020
Measurement	0.816	0.773	-0.043
Other consumer goods	0.791	0.771	-0.020
Surface technology, coating	0.791	0.768	-0.022
Furniture, games	0.776	0.766	-0.010
Materials, metallurgy	0.789	0.766	-0.023
Environmental technology	0.798	0.761	-0.037
Handling	0.774	0.758	-0.017
Chemical engineering	0.759	0.757	-0.003
Other special machines	0.774	0.757	-0.017
Civil engineering	0.764	0.744	-0.021
Food chemistry	0.747	0.742	-0.004
Analysis of biological materials	0.744	0.742	-0.002
Biotechnology	0.753	0.722	-0.031
Medical technology	0.765	0.720	-0.045
Pharmaceuticals	0.751	0.715	-0.036

It is interesting to note that the already mentioned process of spatial re-balancing of technological capacities is a rather widespread phenomenon across the technological fields reported in Table 2. Over the 1996-2011 period the level of technological polarization has decreased in most of the technological fields, with only 5 technological areas showing an increase of the Gini coefficient (Engines pumps, Mechanical elements, Organic and Basic chemicals, IT methods for management). Also worth mentioning is the fact that the long-run decrease of technological concentration is particularly significant in the technological fields where the spatial distribution of technological capacities is more uneven.

Table 3 provides a more detailed picture of the level of concentration of technological activities in the EU area presenting, for each of the 35 technological fields, the shares of patents accounted by the 4 leading NUTS1 EU regions. For each technological field, the share of patents invented in the four leading regions (CR4 index) and their respective shares are reported. Table 3 confirms the presence of a high level of spatial technological concentration in Europe with the first four regions accounting for, in most technological fields, between one third and a half of total EU patents.

Table 3: CR4 indexes by technological sector and top 4 patenting Regions, 2008-11.

Technological Field	CR4	Top 4 Regions in terms of patenting activity (2008-2011)			
Mechanical engineering	41.0				
Machine tools	48	Baden-Württemberg-DE (21.3)	North Rhine-Westphalia-DE (11.1)	Bavaria-DE (11)	North East-IT (4.8)
Mechanical elem.	47	Baden-Württemberg-DE (17.7)	Bavaria-DE (16)	North Rhine-Westphalia-DE (9.3)	North West-IT (4.4)
Engines, pumps, turbines	43	Baden-Württemberg-DE (16.3)	Bavaria-DE (9.4)	North Rhine-Westphalia-DE (9.3)	Île-de-France-FR (7.6)
Transport	41	Baden-Württemberg-DE (14.2)	Bavaria-DE (12)	Île-de-France-FR (8.2)	North Rhine-Westphalia-DE (7.1)
Textile/Paper machines	40	Baden-Württemberg-DE (13)	Bavaria-DE (11.6)	North Rhine-Westphalia-DE (10.7)	North West-IT (5.2)
Thermal proc. Appar.	40	Bavaria-DE (12.4)	Baden-Württemberg-DE (12.3)	North Rhine-Westphalia-DE (9.7)	North East-IT (5.3)
Handling	36	Bavaria-DE (11.6)	Baden-Württemberg-DE (8.5)	North Rhine-Westphalia-DE (8.3)	North East-IT (7.5)
Other_special_machines	32	Bavaria-DE (11.1)	North Rhine-Westphalia-DE (8)	Baden-Württemberg-DE (7.3)	Lower Saxony-DE (5.5)
Electrical engineering	37.8				
Semiconductors	46	Bavaria-DE (17.7)	Centre East-FR (11.8)	Baden-Württemberg-DE (9.2)	South Netherlands-NL (7.3)
Electrical machinery	41	Baden-Württemberg-DE (13.2)	Bavaria-DE (12.7)	North Rhine-Westphalia-DE (9.7)	South Netherlands-NL (5.7)
Digital communications	40	East Sweden-SE (12.8)	Mainland Finland-FI (10.3)	Île-de-France-FR (9.6)	Bavaria-DE (7.7)
Basic communications	40	Bavaria-DE (11.1)	Baden-Württemberg-DE (10.5)	South East England-GB (9.9)	Centre East-FR (8.4)
Audio-visual tech.	36	Bavaria-DE (12.4)	Baden-Württemberg-DE (9.5)	South Netherlands-NL (7.5)	Île-de-France-FR (6.3)
Computer	35	Bavaria-DE (11.5)	Île-de-France-FR (9.5)	South Netherlands-NL (7)	Baden-Württemberg-DE (6.6)
Telecommunications	34	Bavaria-DE (10.5)	Île-de-France-FR (9.5)	East Sweden-SE (7.1)	Baden-Württemberg-DE (6.5)
IT methods for manag.	31	Île-de-France-FR (9.3)	Baden-Württemberg-DE (8.5)	Bavaria-DE (6.4)	Mediterranean-FR (6.4)
Other fields	35.5				
Furniture, games	37	North Rhine-Westphalia-DE (11.2)	Bavaria-DE (10)	Baden-Württemberg-DE (8.8)	North West-IT (6.7)
Other consumer goods	36	Bavaria-DE (11.8)	North East-IT (9.2)	Baden-Württemberg-DE (8.7)	North Rhine-Westphalia-DE (6.8)
Civil engineering	33	North Rhine-Westphalia-DE (13.5)	Bavaria-DE (7.6)	Baden-Württemberg-DE (7.2)	North East-IT (5.1)
Instruments	34.1				
Control	40	Bavaria-DE (14.3)	Baden-Württemberg-DE (11)	North Rhine-Westphalia-DE (8.5)	Île-de-France-FR (6.2)
Optics	40	Île-de-France-FR (10.6)	Baden-Württemberg-DE (10.4)	South Netherlands-NL (10)	Bavaria-DE (8.8)
Measurement	36	Baden-Württemberg-DE (14.2)	Bavaria-DE (10.9)	Île-de-France-FR (5.8)	North Rhine-Westphalia-DE (4.9)
Medical tech.	30	Baden-Württemberg-DE (10.5)	Bavaria-DE (8.1)	South Netherlands-NL (6.5)	Hessen-DE (4.9)
Analysis of bio-material	25	Bavaria-DE (6.4)	Île-de-France-FR (6.4)	Baden-Württemberg-DE (6.2)	South East England-GB (5.9)
Chemistry	33.2				
Microstr. & nano tech.	47	Centre East-FR (19.8)	Baden-Württemberg-DE (15.4)	South East England-GB (7.4)	Île-de-France-FR (4.8)
Environmental tech.	37	Baden-Württemberg-DE (11.4)	North Rhine-Westphalia-DE (11)	Bavaria-DE (7.5)	Île-de-France-FR (6.7)
Surface techn., coating	36	North Rhine-Westphalia-DE (14.1)	Bavaria-DE (9.5)	Baden-Württemberg-DE (8.4)	Hessen-DE (4.4)
Macromole chemistry	36	North Rhine-Westphalia-DE (17.5)	Baden-Württemberg-DE (6.5)	Bavaria-DE (6.1)	Rhineland-Palatinate-DE (5.8)
Materials, metallurgy	35	North Rhine-Westphalia-DE (13.4)	Bavaria-DE (9.5)	Île-de-France-FR (6.3)	Baden-Württemberg-DE (5.6)
Basic materials chemistry	34	North Rhine-Westphalia-DE (15.6)	Hessen-DE (6.9)	Rhineland-Palatinate-DE (6.1)	Bavaria-DE (5.9)
Organic fine chemistry	34	North Rhine-Westphalia-DE (11.1)	Île-de-France-FR (10.6)	Hessen-DE (7)	Rhineland-Palatinate-DE (5.7)
Chemical engineering	33	Baden-Württemberg-DE (11.8)	North Rhine-Westphalia-DE (9.3)	Bavaria-DE (8.5)	Centre East-FR (3.9)
Food chemistry	25	West Netherlands-NL (9.1)	Denmark-DK (6.2)	Bavaria-DE (5.2)	North Rhine-Westphalia-DE (4.8)
Biotechnology	24	Bavaria-DE (6.5)	North Rhine-Westphalia-DE (6)	Île-de-France-FR (5.9)	Denmark-DK (5.9)
Pharmaceuticals	22	Île-de-France-FR (7.8)	South East England-GB (4.8)	Baden-Württemberg-DE (4.7)	North Rhine-Westphalia-DE (4.7)

Once again the highest CR4 indexes are found in the ICT and Electrical engineering technological fields, while among the least spatially polarized fields we find the residual (and less innovative) area of "Other technological fields" (Furniture and games, Other consumer technologies, Civil engineering) and in the areas of Chemistry, Pharmaceutical and Bio-tech technologies.

Table 3 shows that three German regions (namely Baden-Württemberg, Bavaria, North Rhine-Westphalia) play an absolute hegemonic role in a large number of technological fields. 92 out of the 140 cells contained in Table 3 are occupied by German regions confirming the absolute relevance of the German technological potential in the EU zone. Other leading regions include Île-de-France-FR, Denmark (considered as a single NUTS0 regional area), the two northern Italian NUTS1 regions (North-west and North-east Italy), South East England-GB, East Sweden-SE.

Table 4 shows that an overwhelming share of the EU technological capacity is concentrated in Mittle-European regions. Once again Germany emerges as the country where most of EU technological capacities are concentrated. In all periods German regions account for more than 40% of total EU patent applications while French and UK regions account respectively for around 15% and 10% of total patent applications. Regions located in the southern EU countries account all together for around one tenth of total EU patents while regions belonging to new EU member states play a very negligible role (less than 1% in the first two periods and less than 2% in the last one).

Table 4: The level and dynamics of patent shares in the EU

	1996-99	2000-03	2004-07	2008-11
Geographical groups				
NORTH_EU	0.091	0.089	0.089	0.095
SE	0.049	0.044	0.045	0.048
FI	0.025	0.027	0.024	0.023
DK	0.017	0.018	0.021	0.023
MITTLE_EU	0.809	0.805	0.787	0.780
DE	0.428	0.428	0.417	0.414
GB	0.114	0.111	0.099	0.094
FR	0.155	0.144	0.147	0.152
SOUTH_EU	0.095	0.098	0.111	0.107
IT	0.079	0.079	0.085	0.078
ES	0.014	0.017	0.022	0.026
EAST_EU	0.005	0.008	0.012	0.017
Regional innovation groups				
LEADERS	0.623	0.626	0.603	0.590
FOLLOWERS	0.267	0.262	0.271	0.281
MODERATE	0.108	0.110	0.122	0.123
MODEST	0.002	0.002	0.004	0.005

Along with showing the presence of a very asymmetric distribution of technological capacities in the EU area Table 4 confirms the presence of some degree of technological convergence of the most peripheral and less innovative regions of Europe. Since the end of '90 the share of patents of Southern EU countries, and even more the share of Eastern new-member state regions, have in fact increased. The convergence process is even more clear-cut taking into account the shares of Southern and Eastern EU regions in the ICT related patents (figures not shown). If we look at the long-term dynamics of patents shares the following indications can be drawn: a) the convergence process of southern EU regions is due almost exclusively to the dynamics of patent activities of Spanish regions (in fact, the share of patents of Italian regions increase till the 2004-2007 period and then start to decrease in the following period); b) somewhat unexpectedly the share of patents of German regions has diminished over the 1996-2001 period. This dynamics might partly be due to the increasing international delocalization (off-shoring) of production and technological capacities of German firms, especially towards neighbour East-European regions; c) the same decreasing trend applies to the UK patent shares, but this does not appear as an unexpected dynamics taking into account the increasing tertiarization of the UK economic structure; d) most of Eastern-EU regions increase their patent shares. As already mentioned this might be (at least partly) the beneficial outcome of the increasing integration of these regions within the German productive and technological area of influence.

Table 5 confirms that the technological convergence discussed above is the result of a relatively high technological dynamism of regions located in Eastern and Southern European countries as well as of firms/inventors located in the most technological backward EU areas. The result is that technological gaps (measured by difference in the patent per capita index) - as well as economic gaps (GDP per capita) - between the four main EU macro-regional areas, and between most and least innovative regional groups have progressively decreased. Even in this case some qualifications regarding the extent and nature of these convergence processes are needed. First, the overall process of technological and economic convergence has been rather slow, and below the expectations and the EU cohesion policy targets. Technological and economic gaps remain at the end of the period (2008-11) very large. Second, the process of economic convergence (GDP per capita) has been weaker than the process of technological convergence raising a series of issues regarding possible causes and remedies of this asymmetric dynamics. This asymmetry might be related to the way value chains have been restructured on a EU continental scale with centripetal and centrifugal forces jointly at work. One hypothesis is that while manufacturing and technological capacities have been relocated on a wider spatial scale, the financial and strategic governance of the value chains and the extraction of revenues, incomes and profits have been increasing centralized in core regions.

Table 5: Patents and GDP per capita in the main EU regional areas

	Patents per capita								GDP per capita							
	1996-99		2000-03		2004-07		2008-11		1996-99		2000-03		2004-07		2008-11	
NORTH_EU	0.734	100.0	0.946	100.0	1.029	100.0	1.066	100.0	28.0	100.0	31.2	100.0	34.3	100.0	34.4	100.0
MITTLE_EU	0.529	72.0	0.687	72.7	0.729	70.8	0.710	66.6	25.2	90.0	27.5	88.0	29.3	85.4	29.7	86.4
SOUTH_EU	0.124	16.9	0.168	17.8	0.202	19.6	0.188	17.6	19.2	68.6	21.0	67.4	22.0	64.1	21.3	62.0
EAST_EU	0.008	11	0.015	16	0.027	2.6	0.039	3.6	4.7	16.8	5.4	17.3	6.6	19.4	7.5	218
LEADERS	0.862	100.0	1.136	100.0	1.196	100.0	1.160	100.0	27.0	100.0	29.3	100.0	31.1	100.0	31.8	100.0
FOLLOWERS	0.277	32.2	0.354	312	0.389	32.5	0.389	33.5	24.6	911	27.2	92.8	29.4	94.6	29.6	92.9
MODERATE	0.131	15.2	0.172	15.2	0.205	17.1	0.206	17.8	16.6	617	18.3	62.5	19.5	62.8	19.4	60.9
MODEST	0.007	0.8	0.012	11	0.021	17	0.023	2.0	4.2	15.6	4.9	16.8	6.0	19.4	6.6	20.8

*: For each period the second column reports the relative distance from leading regional groups (Nortern regions: 100; Leader regions: 100)

*: For each period the second column reports the relative distance from leading regional groups (Nortern regions: 100; Leader regions: 100)

The evidence produced so far has shown that technological gaps and in particular the patent propensity of regions have a clear spatial dimension. In fact, both the level and dynamics of patent activities can be broadly associated to the geographical location of regions and to their overall technological profile (type of regional system of innovation). There is no need to say that we expect a great deal of heterogeneity in the technological performances of regions within the broad macro-regional areas and type of regional innovation groups considered in this study. A way to explore and start qualifying this heterogeneity is to decompose the total variance of patent performances of EU NUTS1 regions in two parts: a "within (regional-groups) component" and a "between (regional-groups) component". This has been done carrying out an ANOVA analysis and using as "regional groups" the four macro EU regional areas (NORTH, MITTLE, SOUTH and EAST EU regions) and four groups of regional innovation systems (LEADERS, FOLLOWERS, MODERATE, MODEST).

The issues to be explored are the following: are there statistically significant differences in the technological and economic performances of regions belonging to the four distinct groups? How much variance is explained by the geographical location of regions and by the profile of its innovation system and how much is left "un-explained"?

Table 6 presents the results of the ANOVA referring to four indicators: the patent intensity (number of patents per employee) of regions, the patent growth rates (% growth rate of patents); the level of GDP per capita and GDP growth. For each indicator the table reports the total cross-regional variance (SS: sum of the squared distances from the overall EU median), the "between" and "within" components of total variance with respect to each of the eight "regional groups" (NORTHERN, MITTLE, SOUTHERN and EASTERNS EU regions; four types of regional innovations systems: LEADERS, FOLLOWERS, MODERATE, MODEST); the level of statistical significance regarding the hypothesis that that regional groups do have different mean values.

The results of the ANOVA confirm that the geographical location of the region and its overall technological profile affects all regional technological and economic performances indicators. In all periods, regions located in different EU zones perform differently in terms of patent intensity, patent growth rates, GDP per capita and GDP growth. The same can be said with respect to the role played by the level of technological development of the region. In the latter case, the fact that most and least innovative regions show different propensity to patent and different GDP per capita levels is a rather obvious outcome. Less obvious (and more interesting) is that these different groups of regions differ in terms of patent growth and GDP growth. If combined with the evidence shown in the previous tables the ANOVA results can be interpreted as confirming that despite the existence and permanence of large technological and economic gaps between core and peripheral EU regions some technological and economic convergence has occurred.

Table 6: Analysis of variance on a selected set of technological and economic performance indicators

(Cross-NUTS1 regional variance between/within country groups and regional innovation groups)

	ANOVA - Geographical regional groups					ANOVA - Innovation regional groups				
	Total SS	% between groups	% within groups	F	Prob	Total SS	% between groups	% within groups	F	Prob
Patents per capita1	10.03	0.39	0.61	18.3	0.000	10.05	0.63	0.37	49.4	0.000
Patents per capita2	18.63	0.35	0.65	15.8	0.000	18.64	0.61	0.39	46.3	0.000
Patents per capita3	20.19	0.36	0.64	16.6	0.000	20.21	0.61	0.39	45.2	0.000
Patents per capita4	18.36	0.38	0.62	17.9	0.000	18.37	0.62	0.38	48.2	0.000
GDP per capita1	0.01	0.62	0.38	47.4	0.000	0.01	0.41	0.59	20.2	0.000
GDP per capita2	0.01	0.60	0.40	43.1	0.000	0.01	0.37	0.63	17.5	0.000
GDP per capita3	0.01	0.59	0.41	41.8	0.000	0.01	0.37	0.63	17.1	0.000
GDP per capita4	0.01	0.59	0.41	42.8	0.000	0.01	0.39	0.61	19.0	0.000
Patent growth 1_2	28.91	0.26	0.74	10.4	0.000	28.93	0.24	0.76	9.3	0.000
Patent growth 2_3	43.62	0.46	0.54	24.8	0.000	43.63	0.32	0.68	13.7	0.000
Patent growth 3_4	10.76	0.34	0.66	15.2	0.000	10.77	0.12	0.88	4.1	0.009
GDP growth 1_2	0.36	0.10	0.90	3.1	0.031	0.36	0.09	0.91	2.8	0.045
GDP growth 2_3	0.46	0.44	0.56	22.8	0.000	0.46	0.32	0.68	14.0	0.000
GDP growth 3_4	0.37	0.36	0.64	16.2	0.000	0.37	0.10	0.90	3.4	0.021

Numbers 1 to 4 indicate the reference period of the variable: 1: 1996-99; 2: 2000-2003; 3:2004-7; 4: 2008-11

However, probably the most important message emerging from Table 6 is the presence of a very large intra-group variance in the dynamics (both short and long-term) of technological and economic performance of EU regions. ANOVA results show that regions located in the same broad geographical area and starting from a similar stage of technological development have shown very different capabilities at strengthening their technological competencies and increase their GDP. This means for instance that in the group of MODERATE and MODEST innovative regions one can find regions that have shown very different capacities of catching-up; similarly in the most innovative group of LEADER and FOLLOWER innovative regions one could observe a wide spectrum of technological trajectories, that is regions able to further strengthening their technological leadership as well as exhibiting falling-behind trajectories.

The presence of a high level of heterogeneity in the technological performances of regions belonging to the four geographical areas, and sharing the same (broad) technological profile, is confirmed by Table 7 showing the "within-group" coefficients of variation computed on the patent per capita indicator in the four periods taken into account in this study. What is interesting to note is that the level of variance in the technological performances of regions is decreasing over time and it is higher among less innovative and more peripheral regions, two stylized facts which deserve e deeper investigation.

Table 7: Regional differences in patent intensity and growth
(Coefficient of variations at NUTS1 level)

Reg. groups	Patents per capita 1996-99	2000-03	2004-07	2008-11	Patent Growth (1996-2011-%)
NORTH_EU	0.49	0.44	0.46	0.53	0.92
MITTLE_EU	0.79	0.85	0.80	0.76	0.87
SOUTH_EU	1.53	1.52	1.40	1.31	0.70
EAST_EU	1.82	1.84	1.75	1.43	0.89
LEADERS	0.47	0.52	0.49	0.45	0.72
FOLLOWERS	0.48	0.46	0.48	0.54	0.96
MODERATE	1.59	1.51	1.35	1.33	1.27
MODEST	3.29	3.27	2.80	2.44	1.32
TOTAL EU	1.16	1.20	1.14	1.10	1.81

5. The technological specialization of EU regions

The descriptive analysis presented in section 4 has shown three main pieces of evidences and stylized facts:

- ❖ The persistence in the last 15 years of a very uneven spatial distribution of technological capabilities in the EU area with southern and eastern EU periphery regions accounting for a very marginal share of the overall EU technological potential and still lagging behind (at the end of the period) in terms of technological capacities and performances.
- ❖ The presence of some (although) limited technological convergence (catching-up) of traditional backward/periphery regional areas (especially in the case new EU eastern member states regions).
- ❖ The presence of a high level of heterogeneity in the long-term technological performance of regions within the main EU macro-regional areas, revealing the co-existence in each EU country and macro-regional area (and groups of similar innovation stage) of processes of catching-up and falling-behind processes jointly at work.

The aim of this section is to make a deeper investigation of the spatial distribution of technological activities in the EU area taking into account the differences and similarities in the technological specialization of EU regions as well as the long-terms changes in their technological profiles.

5.1 The technological specialization of EU regions

Figures 2 and 3 provide a first broad picture of the patterns of technological specialization of EU regions (at a NUTS2 level) respectively at the beginning and at the end of the time span considered in this study and taking into account 5 main macro-technological areas (ICT & Electrical Engineering, Chemistry, Mechanical Engineering, Instruments, Others technological fields). The figures show the technological areas where regions exhibit their highest revealed technological advantages (RTAs). The revealed technological advantage of a region i in a technology j is computed as:

$$RTA_{ij} = \frac{P_{ij} / \sum_j P_{ij}}{\sum_i P_{ij} / \sum_{i,j} P_{ij}}$$

that is, its share of patents (P) in a given technology, divided by the world share of patent in the same technology (a value above 1 indicates that the region is specialized in the specific technology). Table 8 shows the RTAs values in the 5 technological areas for each of the 4 EU macro-regional zones (NORTH, MITTLE_EU, SOUTH and EAST) and at a country level.

Despite both Table 8 and Figures 2 and 3 provide (as expected) a rather complex and variegated picture of the technological profiles of main regional areas and countries a few emerging features seem to emerge: regions in the Northern EU countries (with the exception of Denmark) show a relatively strong specialization in the ICT and Electrical Engineering technological areas while being de-specialized in most of the other technological areas. The Mittle-EU area is composed by a rather heterogeneous mix of regional technological profiles. German and Austrian regions have a rather similar technological profile presenting an area of relative specialization in the Mechanical Engineering technological fields while being de-specialized in all the other technological areas (with the exception of Austrian regions specialized also in the less technologically dynamic area of Other technological fields). Also UK and Ireland share a similar technological profile. French regions show an above-one RTA in the ICT & Electrical Engineering fields but all in all present a rather balanced distribution of patent activities across the 5 technological classes with most RTAs being close to 1. All southern countries (as expected) show a relatively high specialization in the residual (and technologically less dynamic) “Other technological fields” area with Italy presenting a relative strength also in the Mechanical Engineering area (as German and Austrian regions). Finally all EU new member state regions present a strong specialization in the Chemical technological area, probably a legacy of their industrial and technological position within the pre ’89 Comecon area.

Figure 2: Dominant technological specialization of EU-NUTS2 regions (1996-99)

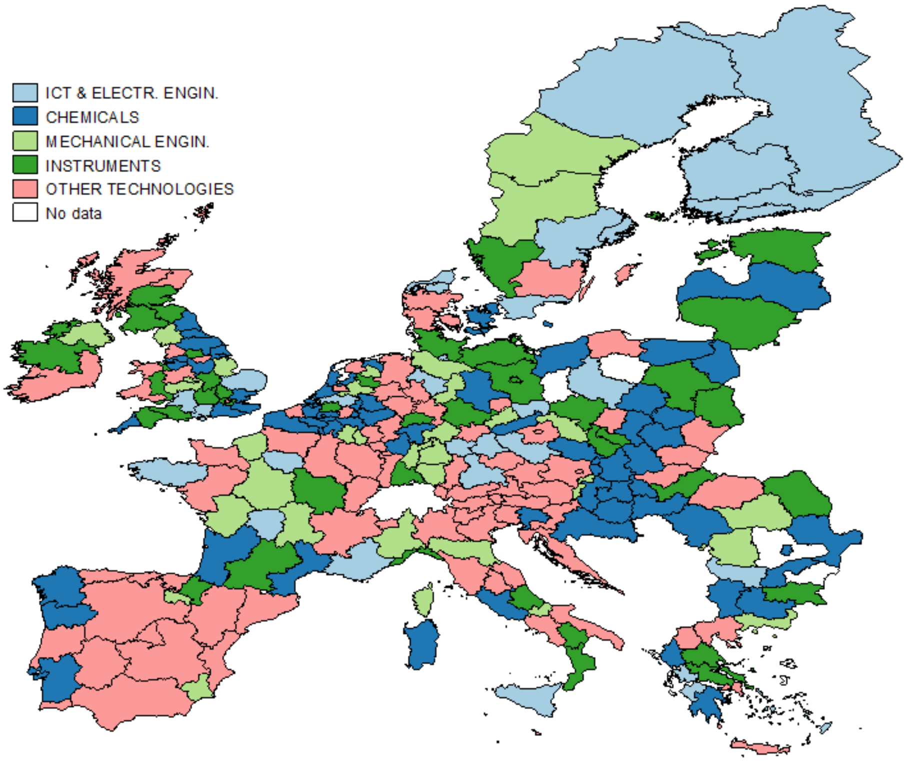


Figure 3: Dominant technological specialization of EU-NUTS2 regions (2008-11)

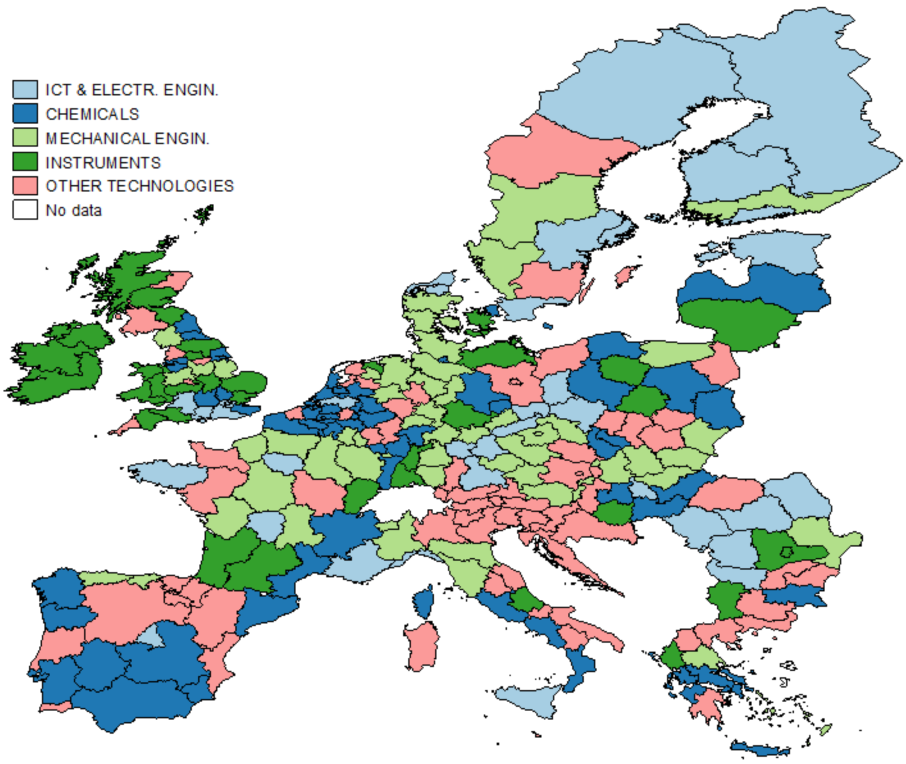


Table 8: Technological specialization of the main EU geo-zones and countries 1996/99 and 2008/11

	ICT & Elect. Engin.		Chemicals		Mechanical Engin.		Instruments		Other tech. Fields	
	1996-9	2008-11	1996-9	008-11	1996-9	2008-11	1996-9	008-11	1996-9	008-11
NORTH_EU	1.43	1.59	0.83	0.80	0.88	0.81	1.09	0.96	0.76	0.74
SE	1.32	1.75	0.68	0.67	1.00	0.80	1.27	1.00	0.77	0.67
FI	2.18	1.99	0.60	0.74	0.77	0.71	0.73	0.74	0.51	0.60
DK	0.66	0.85	1.58	1.14	0.72	0.93	1.11	1.08	0.97	1.10
MITTLE_EU	0.99	0.98	1.03	1.02	0.99	1.01	1.01	1.04	0.94	0.96
DE	0.89	0.85	0.97	0.95	1.14	1.17	0.97	0.97	0.94	0.95
AT	0.67	0.81	0.89	0.93	1.19	1.06	0.77	0.97	1.75	1.45
FR	1.10	1.15	1.03	1.05	0.90	0.93	0.96	0.95	1.06	0.83
GB	1.03	1.14	1.21	1.07	0.73	0.71	1.26	1.30	0.87	0.97
IE	1.14	1.30	1.04	0.95	0.68	0.46	1.32	1.89	1.17	0.81
NL	1.58	1.26	0.93	1.04	0.70	0.65	1.00	1.39	0.84	0.84
BE	0.71	0.86	1.55	1.68	0.77	0.73	1.10	0.78	0.78	0.92
LU	0.38	0.53	1.28	1.10	1.50	1.41	0.40	0.75	0.86	0.95
SOUTH_EU	0.70	0.65	0.88	1.01	1.19	1.14	0.84	0.80	1.63	1.59
IT	0.71	0.59	0.85	0.90	1.22	1.22	0.85	0.81	1.76	1.55
ES	0.66	0.81	1.01	1.31	1.07	0.94	0.76	0.75	1.29	1.86
PT	0.34	0.68	1.69	1.47	0.78	0.79	0.67	1.00	1.80	1.30
GR	0.60	0.70	1.10	1.54	1.04	0.80	1.12	0.90	1.34	1.19
EAST_EU	0.60	1.05	1.67	1.26	0.75	0.76	0.98	0.83	1.27	0.96
PL	0.47	1.05	1.40	1.14	0.84	0.76	1.24	0.83	1.30	1.53
CZ	0.53	0.73	1.38	1.14	0.96	1.09	0.99	0.99	1.21	1.04
SK	0.24	1.08	1.83	0.86	1.18	1.20	0.40	0.60	0.74	1.10
HU	0.74	1.53	1.91	1.19	0.62	0.70	0.81	0.70	0.62	0.69
BG	0.82	0.88	1.99	0.99	0.55	0.73	1.15	1.35	0.00	1.63
RO	1.01	1.99	1.42	0.58	0.63	0.60	1.15	1.26	0.83	0.56
SI	0.74	0.60	1.34	1.87	0.73	0.42	0.80	0.60	1.83	2.28
HR	0.29	0.88	2.33	1.33	0.54	0.77	0.72	0.58	0.88	1.83
EE	0.23	1.57	0.90	1.16	0.77	0.45	3.69	1.12	0.05	0.88
LT	1.24	0.50	1.42	1.72	0.30	0.50	1.45	2.09	0.97	0.45
LV	0.32	0.62	2.60	2.82	0.35	0.30	1.23	0.44	0.00	0.66

Some interesting indications and distinct patterns of change emerge if we look (Table 8) at the long-term dynamics of RTA indexes especially focussing on the technologically dynamic area of ICT & Electrical Engineering and on the more mature and less dynamic area of Other technologies. Northern EU regions increase their specialization in the former technological area and the same pattern is followed by UK and Ireland. Within the Southern EU area Italy increases its weaknesses in the ICT & Electrical Engineering fields maintaining a strong specialization in the Other technological fields. Spanish regions seem to follow a somewhat different pattern characterized by the strengthening of competencies in both areas of Chemicals and Other technologies.

Perhaps the most relevant and striking pattern of change in the model of technological specialization is the one experienced by Eastern European regions. The majority of these regions significantly increase their relative strength in the ICT & Electrical Engineering area, and at the same time diminish their traditional strength in the area of Chemicals and (in most countries) also in the area of Other technologies. This technological trajectory is confirmed by Table 9 showing for the 35 technological fields the top three EU regions - in terms of RTA values - in periods 1996-99 and 2008-11. While in the first period we do not find among the most specialized regions in the ICT and Electrical engineering fields any Eastern EU region in the in the last period four Easter EU regions are found. In the chemistry areas the opposite pattern occurs.

Table 9: Regions with the highest technological specialization in the 35 main technological fields (1996/99 and 2008/11)

	1996-1999									2008-11								
	RTA	NUTS1/0	-Region	RTA	NUTS1/0	-Region	RTA	NUTS1/0	-Region	RTA	NUTS1/0	-Region	RTA	NUTS1/0	-Region	RTA	NUTS1/0	-Region
ICT/electrical eng.																		
Audiovisual	5.8	NL4	S. Netherlands	2.8	DE6	Hamburg	1.8	UKJ	S. E. England	3.7	UKJ	South E. Engl.	2.7	IE0	Ireland	2.6	FR7	Centre East
Basic commun.	8.4	ITG	Islands	4.6	NL4	S. Netherlands	2.6	DE6	Hamburg	2.9	UKI	Greater London	2.8	FR8	Mediterranean	2.4	NL4	S. Netherlands
Computer	3.1	FR8	Mediterranean	2.9	NL4	S. Netherlands	2.7	UKK	S. W. England	5.6	HU1	Central Hungar	5.2	SE1	East Sweden	4.4	FI1	M.land Finland
Digital comm.	6.7	FI1	M.land Finland	3.8	SE1	East Sweden	2.9	UKK	S. W. England	2.1	PL5	S.W. Region	1.9	NL4	S. Netherlands	1.9	PL2	South Region
Electrical Mach.	2.2	DE3	Berlin	1.9	NL4	S. Netherlands	1.7	FR6	S. W. England	9.1	SK0	Slovakia	5.1	FR8	Mediterranean	4.8	UKI	Greater Londor
IT meth. Manag.	9.1	UKM	Scotland	7.7	IE0	Ireland	5.1	BE1	Brussels Capita	3.7	FR7	Centre East	3.5	AT2	South Austria	3.1	ITG	Islands
Semiconductors	15.1	ITG	Islands	3.4	DED	Saxony	2.8	DE2	Bavaria	3.7	FR7	Centre East	3.5	AT2	South Austria	3.1	ITG	Islands
Telecommunic.	4.5	FI1	M.land Finland	2.7	SE1	East Sweden	2.3	UKH	E. England	3.0	FR5	West	2.9	SE1	East Sweden	2.8	SE2	South Sweden
Chemistry																		
Organic chem.	5.0	HR0	Croatia	4.3	PL1	Central Region	4.1	HU1	Central Hungar	6.4	LV0	Latvia	4.6	DE6	Hamburg	4.3	EL1	Voreia Ellada
Macromole chem.	6.0	BE3	Walloon	4.8	DEB	Rhineland-Pal.	4.2	DEE	Saxony-Anhalt	3.8	BE3	Walloon	3.7	LU0	Luxembourg	3.1	DEE	Saxony-Anhalt
Microstruct. Nano.	3.0	FR7	Centre East	2.1	DE2	Bavaria	2.0	ITC	North West	6.2	FR7	Centre East	2.8	UKJ	S. E. England	2.6	DED	Saxony
Pharmaceutical	9.2	LV0	Latvia	5.5	HU2	Transdanubia	5.3	HR0	Croatia	7.8	LV0	Latvia	5.7	SI0	Slovenia	3.9	EL3	Attica
Biotechnology	5.3	HU3	Great Plain & N.	4.2	DK0	Denmark	3.6	SK0	Slovakia	3.0	DEE	Saxony-Anhalt	2.7	AT1	E. Austria	2.6	NL3	W. Netherlands
Food chemistry	4.9	NL3	W. Netherlands	4.3	FR3	N.-Pas-de-Calai	4.2	ES6	SUR	##	EL4	Nisia Aigaiou, K	6.0	NL2	E. Netherlands	5.3	NL1	N. Netherlands
Biolog. Mater.	4.9	UKL	Wales	3.3	UKM	Scotland	2.6	UKH	E. England	5.5	UKN	North. Ireland	3.3	UKL	Wales	3.2	DE8	Mecklenburg-V.
Basic mat. Chem.	8.8	UKC	N.E. England	5.0	BE1	Brussels Capita	3.5	UKD	N. W. England	8.6	UKC	N.E. England	6.6	UKD	N.W. England	3.5	BE1	Brussels Capita
Surface techn.	2.7	DED	Saxony	2.1	DEC	Saarland	2.0	LU0	Luxembourg	2.9	EL3	Attica	2.5	DEC	Saarland	2.1	BE3	Walloon Region
Materials, met.	6.4	LU0	Luxembourg	4.0	FR3	N.-Pas-de-Calai	3.8	ES1	NOROESTE	5.2	LU0	Luxembourg	3.6	BE3	Walloon	2.8	DEE	Saxony-Anhalt
Chemical engin.	2.3	DEC	Saarland	2.1	ES6	SUR	1.9	DEE	Saxony-Anhalt	3.7	DEC	Saarland	1.9	UKC	N.E. England	1.8	DEE	Saxony-Anhalt
Environ. technology	2.9	CZ0	Czech Rep.	2.8	PT1	CONTINENTE	2.2	DEE	Saxony-Anhalt	6.1	PL3	East Region	3.0	NL1	N. Netherlands	2.0	UKC	N.E. England
Mechanical Engin.																		
Engines, turbines	3.9	SK0	Slovakia	2.4	DE1	Baden-Württ.	1.6	PT1	CONTINENTE	5.2	UKF	E. Midlands	2.6	DK0	Denmark	2.1	DE4	Brandenburg
Handling	3.1	ITH	North East	2.8	DE5	F.H. City Breme	2.5	ES2	NORESTE	2.7	ITH	North East	2.4	ES1	NOROESTE	2.3	FR2	Paris basin
Machine tools	3.8	SE3	North Sweden	2.5	ES1	NOROESTE	2.2	AT3	West Austria	3.1	SE3	N. Sweden	2.9	HU3	Great Plain & N.	2.4	EL3	Attica
Mech. elements	2.1	SK0	Slovakia	2.1	UKG	W. Midlands	1.8	FR2	Paris basin	3.2	DEC	Saarland	1.8	FR2	Paris basin	1.7	DE1	Baden-Württ.
Other sp. Mach.	2.7	DE8	Mecklenburg	2.7	NL1	N. Netherlands	2.2	NL2	E. Netherlands	2.3	NL2	E. Netherlands	2.2	DE9	Lower Saxony	2.0	LU0	Luxembourg
Textile/paper mac.	3.0	BE2	Flemish Reg.	3.0	SE3	N. Sweden	2.7	CZ0	Czech Republic	3.1	SE3	N. Sweden	2.2	CZ0	Czech Republic	2.2	BE2	Flemish Region
Thermal processes	3.8	NL1	N. Netherlands	3.4	ES2	NORESTE	2.8	DE8	Mecklenburg	4.5	PL6	North Region	4.6	ES1	NOROESTE	4.1	ES6	SUR
Transport	2.6	LU0	Luxembourg	2.4	DE9	Lower Saxony	2.1	UKG	West Midlands	2.4	DE9	Lower Saxony	2.4	DE5	F. H. Bremen	2.2	LU0	Luxembourg
Instruments																		
Control	4.7	ES2	NORESTE	4.0	UKM	Scotland	2.5	DE4	Brandenburg	2.3	CZ0	Czech Rep.	2.2	AT1	East Austria	1.9	PT1	CONTINENTE
Measurement	12.8	FI2	Åland	7.4	EE0	Estonia	2.8	DEG	Thuringia	3.8	RO3	Sud, Bucuresti	2.2	DE5	F.H. Bremen	1.6	DEG	Thuringia
Medical tech.	6.4	ITF	South	4.8	EL1	Voreia Ellada	3.2	HU3	Gr. Plain and N	3.5	IE0	Ireland	3.3	UKE	Yorkshire & H.	2.8	UKG	West Midlands
Optics	5.4	BE2	Flemish Reg.	3.9	DEG	Thuringia	2.7	UKI	Greater London	6.2	DEG	Thuringia	4.8	PL1	Central Region	3.4	NL4	S. Netherlands
Others tech. Fields																		
Civil engineering	4.1	ES4	CENTRO (ES)	3.3	DEC	Saarland	2.6	UKM	Scotland	4.0	UKM	Scotland	3.8	PL2	S. Region	2.2	UKN	N. Ireland
Furniture, games	2.7	ITH	North East	2.6	ES2	NORESTE	2.5	FR7	Centre East	4.3	SI0	Slovenia	2.3	AT3	West Austria	2.2	UKK	S. W. England
Other consumer g.		ES2	NORESTE	3.2	ITH	North East	2.5	ITI	Centre	3.9	PL1	Central Region	3.8	ES2	NORESTE	3.8	DE4	Brandenburg

*: Regions with a very low numeber of patents have been excluded from the analysis.

Note: southern regions are reported in red, while eastern regions are reported in purple.

Table 10 allows us to analyse the technological profile of regions characterized by different levels of innovativeness and operating in different (more and less advanced) science and technology contexts. The table shows the RTA indexes computed for the four groups identified by the stage of regional technological development (LEADERS, FOLLOWERS, MODERATE and MODEST), and taking into account a larger and more detailed set of technological fields.

From the data reported in Table 10 it is hard to identify any clear pattern or relationship linking the innovativeness of regions and their technological specialization. However, by comparing and contrasting the technological specialization of the most innovative regional group (LEADER) and the most backward regional category (MODEST) few stylized facts seem to emerge. Leader regions show (as expected) an above 1 RTA index in most of the ICT and Electrical Engineering fields (the exception being the IT methods for management field) while regions belonging to the MODEST group tend to be relatively weak in these technological fields. It is however interesting to note that there is some evidence of catching-up in this crucial technological area as evident in the generalised and significant increase of the RTA indexes of the regions belonging to the MODEST group. In the case of Audio-visual and Digital communications technological fields MODEST regions seem to have significantly increased their technological capacities and strengths reaching in the period 2008-11 above 1 RTA values. FOLLOWERS and MODERATE innovative regions remain on the contrary de-specialized in these technological fields without showing significant changes over the last 15 years.

The area where MODEST regions show the highest level of technological specialization is Chemicals, and this result is influenced by the large presence in the MODEST group of East European regions characterized (as already shown) by a high level of specialization in chemical related products and technologies. Despite the fact that MODEST regions have (during the period 1996-2011) decreased their overall specialization in the area of Chemical technologies in two key technological fields such as Bio-materials and Bio-technologies, RTA values have been increasing over time and the same dynamics has occurred in the area of environmental technologies.

Mechanical engineering and Instruments are the technological areas where it is hard to find any interpretable pattern and systematic difference between the RTA of the most and the least innovative regions. As far as the “Other technologies” field is concerned, these do not show a clear pattern across different stages of regional technological development. One can observe a low level of specialization of LEADERS regions and a high specialization of MODEST regions; however, also regions belonging to the FOLLOWER group show a relatively high specialization in these technologies.

Table 10: Technological specialization of regional innovation groups

(average RTA indexes in 19996/99 vs 2008/11)

	LEADERS		FOLLOWERS		MODERATE		MODEST	
	1996-9	2008-11	1996-9	2008-11	1996-9	2008-11	1996-9	2008-11
ICT & Elect. Engin.	**1.12**	**1.10**	**0.81**	**0.89**	**0.79**	**0.80**	**0.44**	**0.95**
Audio-visual tech.	1.17	1.14	0.80	0.97	0.61	0.53	0.49	1.73
Basic communications	1.15	1.06	0.73	0.86	0.76	0.98	0.24	0.66
Computer	1.04	1.09	0.92	0.92	0.97	0.80	0.50	0.96
Digital communications	1.24	1.16	0.75	0.86	0.36	0.64	0.35	1.03
Electrical machinery	1.04	1.09	0.83	0.85	1.07	0.88	0.65	0.69
IT methods for manag.	0.93	0.92	1.56	1.08	0.54	1.14	0.16	1.26
Semiconductors	1.04	1.02	0.59	0.88	1.40	1.09	0.06	0.60
Telecommunications	1.21	1.09	0.80	0.93	0.42	0.78	0.27	1.11
Chemicals	**0.97**	**0.93**	**1.14**	**1.13**	**0.94**	**1.07**	**1.53**	**1.26**
Analysis of bio-materials	0.99	0.95	1.33	1.22	0.61	0.90	0.74	1.23
Basic materials chemistry	0.92	0.94	1.38	1.36	0.82	0.79	0.76	0.79
Biotechnology	0.91	0.88	1.47	1.34	0.73	0.99	1.12	1.37
Chemical engineering	1.00	1.00	1.03	1.04	0.96	0.96	0.90	0.89
Environmental technology	1.04	1.03	1.00	0.96	0.84	0.94	1.26	1.71
Food chemistry	0.75	0.72	1.56	1.64	1.25	1.18	2.28	1.21
Macromole chemistry	0.98	0.96	1.07	1.10	0.97	1.01	1.59	1.22
Materials, metallurgy	0.92	0.95	1.21	1.11	0.98	1.01	3.78	2.19
Microstructural & nano tech.	1.02	0.88	0.56	0.79	1.54	1.66	0.36	0.92
Organic fine chemistry	1.07	0.94	0.85	1.03	0.93	1.17	1.22	1.15
Pharmaceuticals	0.92	0.85	1.16	1.02	1.10	1.45	1.96	1.66
Surface technology, coating	1.01	1.05	1.02	0.97	0.91	0.89	1.60	0.41
Mechanical Engin.	**0.99**	**1.01**	**0.94**	**0.93**	**1.10**	**1.05**	**1.05**	**0.87**
Engines, pumps, turbines	1.15	1.08	0.70	0.96	0.81	0.79	0.83	0.89
Handling	0.86	0.91	1.07	0.96	1.49	1.38	0.80	0.42
Machine tools	1.00	1.10	0.89	0.79	1.15	0.93	1.00	1.04
Mechanical elements	1.04	1.10	0.87	0.80	1.01	0.90	0.72	0.55
Other special machines	0.88	0.90	1.24	1.14	1.17	1.17	1.40	1.05
Textile/paper machines	0.96	1.02	1.07	0.97	1.08	0.98	0.45	0.55
Thermal processes and app.	0.96	0.95	0.95	0.88	1.21	1.27	1.99	1.76
Transport	1.08	1.02	0.80	0.91	0.94	1.04	1.39	0.92
Instruments	**1.01**	**1.03**	**1.06**	**1.05**	**0.87**	**0.84**	**0.86**	**0.90**
Control	1.05	1.05	0.94	0.91	0.87	0.95	0.37	0.92
Measurement	1.07	1.07	0.96	1.02	0.76	0.76	0.92	0.97
Medical technology	0.94	0.99	1.09	1.13	1.10	0.90	1.32	0.78
Optics	0.98	1.12	1.25	0.95	0.75	0.68	0.33	0.86
Other tech. Fields	**0.83**	**0.85**	**1.15**	**1.11**	**1.49**	**1.38**	**0.89**	**1.05**
Civil engineering	0.90	0.86	1.30	1.23	1.03	1.17	0.69	1.22
Furniture, games	0.73	0.85	1.09	1.02	1.96	1.48	1.21	0.93
Other consumer goods	0.80	0.82	0.91	0.96	1.94	1.67	0.94	0.84

The existence of a link between the stage of technological development of the regions and their pattern of technological specialization has been explored – on a more robust statistical basis -carrying out an analysis of variance on the RTAs of EU (NUTS1) regions for the 5 main technological areas and the four groups of regions identified by the Regional innovation scoreboard. ANOVA has been used to disentangle the overall inter-regional variance in the

RTAs in two parts: a within (macro-regional) component and a between-one allowing to test for the existence of statistical differences in the models of technological specialization of regions characterized by different levels of technological development. Table 11 shows that (as expected) the technological specialization of regions is only weakly associated to their stage of technological development. The between-group component is only a very marginal part (less than 10%) of the total inter-regional variance of RTAs, and this holds for all 5 technological areas and in both periods taken into consideration in our analysis. Nonetheless, in the first period we find statistically significant differences in the average values of RTAs of the four regional innovation groups in two technological areas (Chemistry and Other technologies). However, in the second period these differences become less significant, while the opposite holds true for ICT/Electrical engineering. A more in depth analysis of the differences in the average values of RTAs across the four regional groups (Table 12) confirms that the specialization patterns of regions have progressively become less and less associated to their overall innovation performance. More in particular Table 12 clearly shows that being specialized in the ICT and Electrical Engineering area has progressively become less and less a prerogative of more innovative regions; similarly being specialized in Other (more traditional) technological fields has does not seem to be a prerogative of less innovative EU regions anymore.

Table 11: Analysis of variance – ANOVA on RTAs across regional geographical groups

	First period (1996-99)				Last period (2008-11)			
	Total Var.	% within groups	% between groups		Total Var.	% within groups	% between groups	
ICT & Electr. Engin.	26.44	0.96	0.04		33.32	0.88	0.12	***
Chemistry	21.24	0.80	0.20	***	16.24	0.94	0.06	
Mechanical Engin.	16.14	0.95	0.05		8.58	0.98	0.02	
Instruments	27.86	0.92	0.08	*	20.86	0.93	0.07	*
Others tech.	36.21	0.88	0.12	***	30.40	0.92	0.08	*

Statistical significance: *** p. < 0.01; ** p. < 0.05;* p < 0.10

Table 12: Differences in the technological specialization of EU regions across regional innovation groups

(t-student tests for difference between regional groups averages)

	Diff. in RTAs - 1996-99			*p.*	Diff. in RTAs - 2008-11			*p.*
ICT & Electrical Engin.	LEADER	>	FOLLOWER	*0.007*	LEADER	>	FOLLOWER	*0.094*
	LEADER	>	MODERATE	*0.006*				
	LEADER	>	MODEST	*0.008*				
Other tech. fields	FOLLOWER	>	LEADER	*0.044*	MODERATE	>	LEADER	*0.012*
	MODERATE	>	FOLLOWER	*0.019*				
	MODERATE	>	LEADER	*0.000*				
	MODERATE	>	MODEST	*0.004*				

5.2 The dynamics of technological specialization of EU regions

The aim of this section is to take a closer look at the degree of specialization of European regions and at its evolution over time. An important dimension in the Smart specialization framework is the extent to which regions tend to deepen their knowledge bases by increasing the specialization in the technologies already mastered or to diversify their competencies and innovation efforts in new (not previously mastered) technological areas.

The issues that will be empirically addressed in this section are the following:

- How specialized are EU regions?
- Have technological profiles and capabilities of EU regions been widening or become increasingly concentrated in specific areas?
- Along with size, what are the other factors affecting the level and dynamics of specialization (differences across regional groups)?

To shed light on the extent to which European Regions concentrate their inventive activities in a subset of technological areas (level of technological specialization) we compute the Herfindahl index on the number patents registered in different technological fields. The technological specialization of a region i around a set of technologies - in each one of the four period considered in this study - is therefore calculated as:

$$Herf\_tech_{it} = \sum_{j} s(_{ij,t})^2$$

where s_(j,t) is the share of patents related to a technology j at time t. The index is calculated on the 35 technological fields defined by the WIPO classification (see table A1 in the appendix).

Figure 4 shows the cross-NUTS1 regional distribution of the Herfindahl indexes while Table 13 provides the average values and the coefficients of variation for the same index broken down at the level of the four regional groups (LEADERS, FOLLOWERS, MODERATE and MODEST). Distributions and descriptive statistics refer to the four periods taken into account in this study (1996-99; 2000-03; 2004-07; 2008-11).

Both Figure 4 and Table 13 show that the degree of specialization of European regions has (on average) decreased in the 1996-2011 period. However, from a closer look at Table 13 it emerges that technological concentration tends to diminish almost exclusively in the two least innovative groups of regions (MODEST and MODERATE innovative regions). Moreover, in these two regional groups the coefficients of variation of the Herfindahl index are also decreasing over time signalling that regions belonging to these two groups are becoming more similar to each other in their levels of absolute technological specialization. These regional groups are also becoming more similar to the regions belonging to the other two more innovative groups (i.e. LEADERS and FOLLOWERS). In particular, in the last period, the MODERATE innovative regions present (average) levels of specialization very close to those of the Follower innovative regions. As already shown in table 7 (last column), MODERATE and MODEST innovative regions are also those that have experienced the highest patent growth rates during the 15 years period considered in this study. Once combined, the evidences presented in tables 7 and 13 seem to suggest that when regions increase their technological capabilities they are also able to increase their level of technological diversification, entering into other (possible related) technological fields.

Figure 4: Technological concentration for the four periods considered

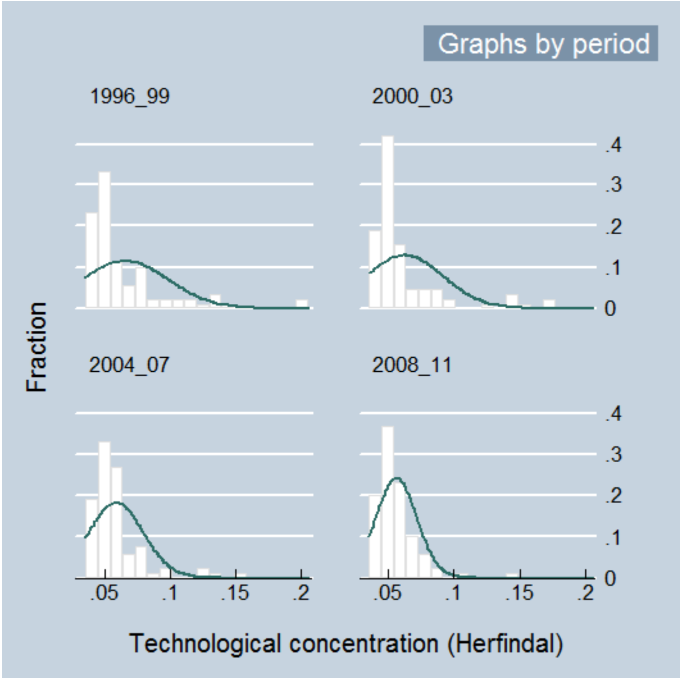


Table 13: Levels of technological specialization by regional group (Herfindahl indexes)

Reg. groups		1996_99	2000_03	2004_07	2008_11
Leaders	Average	0.052	0.053	0.052	0.051
	Coeff. Var.	0.211	0.269	0.212	0.219
Followers	Average	0.052	0.050	0.051	0.054
	Coeff. Var.	0.228	0.131	0.151	0.198
Moderate	Average	0.068	0.063	0.060	0.058
	Coeff. Var.	0.366	0.379	0.308	0.272
Modest	Average	0.117	0.103	0.085	0.068
	Coeff. Var.	0.431	0.428	0.328	0.370
All Regions	Average	0.066	0.062	0.059	0.057
	Coeff. Var.	0.494	0.452	0.327	0.276

In analysing the technological trajectories of regions an important issue to be explored is the extent to which regions modify – over time - their technological specialization profile. We call this process of (structural) change in the technological specialization of a region "technological shift". In presence of a strong "technological shift" technological competencies are moved from one specific set of technological fields to another set of technological areas. In presence of a low technological shift, specialization profiles tend to be stable over time reflecting high levels of cumulativeness.

The extent to which the technological profile of a region *i* changes across time (technological shift) is measured through the following index:

$$Tec\_shift_{it} = \sum_{j} |(s_{ij,t} - s_{ij,t-1})|$$

where s_(j,t) is the share of patents related to technology j at time t, and s_(j,t-1) is the same share one period before. Also in this case the index is calculated on the 35 technological fields proposed by Schmoch. The range of variation of the index is between 0 (no change in the technological profile) and 2 (complete change in the technological specialization).

Figure 5 shows the distribution of our technological shift index over the four periods considered in this study. What the figure shows is that, overall, the level of stability of the technological profiles of regions tend to increase over time (or the level of technological shift to decrease).

Figure 5: Technological shift index for the four periods considered

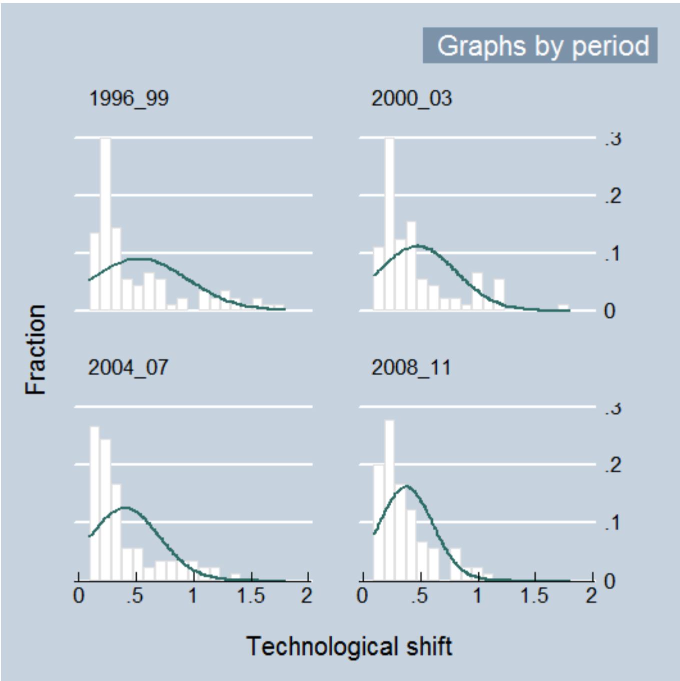


Table 14 allows us to carry out a deeper analysis of the long term dynamics of the absolute level of the technological specialization of regions providing average values and coefficients of variation of our technological shift index computed for the all sample of EU regions and for the four regional technological groups (LEADERS, FOLLOWERS, MODERATE and MODEST).

Table 14: Technological shift index
(Average values and intra-group coefficients of variation)

		1996_99	2000_03	2004_07	2008_11
LEADERS	Average	0.238	0.219	0.183	0.216
	Coeff. Var.	0.290	0.266	0.307	0.340
FOLLOWERS	Average	0.310	0.326	0.269	0.269
	Coeff. Var.	0.367	0.355	0.367	0.300
MODERATE	Average	0.648	0.561	0.460	0.432
	Coeff. Var.	0.612	0.582	0.580	0.525
MODEST	Average	1.245	1.019	0.937	0.735
	Coeff. Var.	0.307	0.344	0.326	0.324
All Regions	Average	0.527	0.472	0.402	0.372
	Coeff. Var.	0.805	0.725	0.761	0.623

Table 14 confirms a general tendency of EU regions to stabilize their technological specialization profile, a pattern which characterizes all groups of regions. However, the four groups of regions are characterized by very different levels of the technological shift index. The level of the index is clearly negatively correlated with the overall innovativeness of the region. In fact, the most innovative regions show a high level of stability/cumulativeness of their technological profile whereas less innovative regions tend to exhibit a greater dynamism (volatility) in their technological specialization patterns. Along with this cross-group regularity Table 14 also reveals the presence of a high level of intra-regional group variability in the level of our technological shift index, signalling the presence of very different region-specific technological trajectories and strategies, even among regions characterized by a similar stage of technological development. It is interesting to note that the inter-regional coefficient of variation in the level of stability of the pattern of technological specialization varies considerably across regional groups, being very high in the MODERATE group and much lower in the other regional groups. Furthermore while in some regional groups the internal variety in the technological shift index tends to decrease over time (MODEST and MODERATE groups), in other regional groups (FOLLOWER and MODEST groups) regions seem to adopt diverging specialization strategies.

6 The economic effects of technological specialization

The empirical evidence presented in the previous sections has highlighted the presence of a high level of heterogeneity in the technological trajectories of regions and namely in their long-term aggregate technological performances (patent growth) in the distribution of technological efforts among the different technological fields (level and type of technological specialization). More in particular, it has been shown that only to a limited extent the long term technological performances and trajectories of regions are connected to the broad geographical location of regions or to the their stage of technological development.

The objective of this section is to empirically test if these different technological profiles and trajectories are associated to different long term economic performances. The rate of change of the regional per capita GDP between 1999 and 2011 (GDP_ GR) will be regressed against the main technological indicators used in the previous section plus a set of additional potential explicative variables. The independent variables used in our econometric specification are the following:

- PAT_GROWTH: The long term patent growth rate of regions, i.e. the rate of change of the number of patents of each NUST1 region between the first period (t1: 1996-99) and the last period (t4: 2008-11);
- HUMAN_CAP2000: share of population with tertiary education in 2000 (first year for which data are available);
- GDP_POP2000: the level of per capita GDP in 2000 (in logs)(first year for which data are available.
- _RTA1: the regional RTA indexes at time t1 (1996-99) computed for the 5 main technological areas (Electrical engineering; Instruments; Chemistry; Mechanical engineering; Other technological fields);
- _RTA_CH1_4: changes in the RTAs values in the same five technological classes between t1 and t4;
- HERFINDAL med: the average value of the Herfindahl index over the period 1996-2011 (t1 to t4), measuring the level of technological concentration/diversification of innovative efforts of regions across the 35 technological fields;
- TECH_SHIFT1-4: The technological shift index (described in the previous section), measuring the extent to which regions change of the overall technological profile between the t1 and t4.

As anticipated in the introduction while the positive effects exerted by technology and human capital on the economic performance, as well as the negative effect of the starting level of GDP per capita on long term GDP growth, are widely acknowledged stylized facts, one can hardly find in the theoretical and empirical literature any clear indication regarding the effects that the level, type and change of technological specialization could have on the growth performances of regions. This implies that we carry out this econometric exercise without strong ex-ante hypotheses. However (as discussed in section 2.2.4), as far as the “type” of specialization is concerned, some studies at the national level, although not focussing directly on technological specialization, have nonetheless emphasized the pervasive nature of ICTs and their possible positive impact on total (aggregate) factor productivity and economic growth (for a survey see Evangelista et al. 2014). Furthermore, few studies (also at the national level) have related technological specialization in ICTs to economic growth finding positive results (Meliciani and Simonetti, 1998; Meliciani, 2001; Huang and Miozzo, 2004). To the best of our knowledge no analysis has been conducted at the regional level.

Also in relation to the economic effects of the “level” of technological specialization some tentative considerations can be put forward: on the one hand the tacit, cumulative and path-depend nature of technological change would suggest that accumulating competences in areas where a region has a consolidated technological advantage can lead to dynamic increasing returns. On the other hand, too much concentration and technological focussing could lead to processes of "lock in", while diversification, especially when occurring in related fields, could signal the presence of a process of technological upgrading (in a smart specialization fashion). That being said, the patent classification used in this study (also the more disaggregated one used in our econometric estimations, distinguishing between 35 technological fields) is likely to be too aggregated to capture processes of related diversification. Therefore, we might assume that in our econometric exercise a decrease in concentration and a high level of the technological shift indicator could signal "unrelated" changes in the technological profile of regions with the associated risk of a technological dispersion and the impossibility of reaching a critical mass of technological competencies. This might also reasonably assume that such a risk would be particularly severe in the case of laggard regions.

The estimated equations are the following:

$$GDP\_GR_i = \alpha_0 GDP\_POP_{2000i} + \alpha_1 PAT\_GR_i + \alpha_2 HUM\_CAP_{2000i} + \alpha_3 HERF_i + \alpha_4 TECH\_SHIFT_i + \epsilon_i \quad (1)$$

$$GDP\_GR_i = \beta_0 GDP\_POP_{2000i} + \beta_1 PAT\_GR_i + \beta_2 HUM\_CAP_{2000i} + \beta_3 RTA_{1i} + \beta_4 RTA\_CH_{1-4i} + \nu_i \quad (2)$$

The GDP_POP2000 and HUMAN_CAP2000 variables are computed in logs. As far as Equation 2 is concerned, in order to avoid multicollinearity problems among the five RTA indexes, 5 separate estimates will be carried out, each one estimating the effects of being specialized in one specific technological area. Due to the limited number of regions in each of the 8 geographical and technological regional groups taken into account in this study equations 1 and 2 will be estimated using data for all EU NUTS1 regions. The results of the estimations are presented in Table 15.

All estimations in Table 15 confirm the expected positive relationship between patent growth and human capital, and the long term economic performances of EU regions. Also the initial level of GDP per capita has (as expected) a negative effect on per capita GDP growth, signalling the presence of a process of economic convergence.

The Herfindahl index (the absolute level of technological specialization of the region) is found to be positively associated to the per capita GDP growth. The concentration of innovative efforts on a restricted number of technological fields seems therefore to be associated to above-the-average growth performances. An additional result emerging from the estimation of equation 1 is the one concerning the economic effect of changing the technological specialization profile. Our estimates seem to show - as expected and in line with the literature suggesting a better performance deriving from a related rather than unrelated diversification - that technological trajectories characterized by radical changes in the patterns of technological specialization penalize the long term economic performance of regions. The coefficient of the TECH_SHIFT variable is in fact negative and statistically significant. All in all the results of regression 1 seem to highlight the cumulative nature of regional technological trajectories, the importance of concentrating the innovative efforts - and accumulate competencies - in a selected number of technological fields (as indicated by the RIS3 literature) as well as the risk associated to strong changes in the technological specialization profile.

The results of the estimates of equation 2 indicate that technological specialization plays a role for explaining the long term economic performances of regions. The positive effect of technological specialization emerges even using (as we do, because of data constraints) a highly aggregated technological classification (one distinguishing between only five broad technological classes). Our results show that increasing the specialization in the ICT/Electrical engineering and Instruments areas is found to have positive effects on the per capita GDP growth while being specialized (and/or increasing the specialization) in the Chemistry area, as well as in the residual area of "Other technologies", is associated to poorer long term regional economic performances. These results can be interpreted and explained taking into account the dynamism and pervasive nature of the first two technological areas and the most traditional character of the other two technological areas. Somewhat more difficult is the interpretation of the negative sign associated to technological trajectories consisting of an increasing level of specialization in the Mechanical Engineering area. Unfortunately, the limited number of patents held by many NUTS1 regions in many technological fields of the 2 digit Schmoch classification - prevent us from carrying out a more in-depth analysis and econometric estimation of the economic effects of technological specialization at a regional level.

Table 15: The effect of specialization in the 5 technological areas on per capita GDP growth

	EQUATION 1		EQUATION 2									
	Coef.	P>t	Coef.	P>t	Coef.	P>t	Coef.	P>t	Coef.	P>t	Coef.	P>t
GDP_POP(2000)	-0.219	0.000	-0.195	0.000	-0.186	0.000	-0.210	0.000	-0.201	0.000	-0.205	0.000
PAT_GR	0.013	0.002	0.009	0.027	0.010	0.012	0.011	0.004	0.012	0.005	0.011	0.011
HUMAN_CAP(2000)	0.009	0.000	0.008	0.000	0.008	0.000	0.010	0.000	0.008	0.000	0.008	0.000
HERFINDAL med	1.306	0.084										
TECH_SHIFT1_4	-0.140	0.093										
ICT_rta1			0.017	0.550								
ICT_rta_ch1_4			0.085	0.000								
CHEM_rta1					-0.052	0.105						
CHEM_rta_ch1_4					-0.081	0.030						
MACH_ENG_rta1							0.025	0.600				
MACH_ENG_rta_ch1_4							-0.077	0.063				
INSTR_rta1									0.076	0.026		
INSTR_rta_ch1_4									0.046	0.043		
OTHERS_rta1											-0.066	0.011
OTHERS_rta_ch1_4											-0.044	0.021
Contast			-0.822	0.000	-0.694	0.000	-0.926	0.000	-0.899	0.000	-0.756	0.000
Number of obs			90		90		90		90		90	
F(5, 84) =			35.3	0.000	28.9	0.000	31.7	0.000	28.8	0.000	30.1	0.000
Adj R-squared =			0.659		0.611		0.633		0.610		0.620	

Statistical significance: *** p. < 0.01; ** p. < 0.05; * p < 0.10

7. Main findings and concluding remarks

The aim of this study has been to provide fresh and up-dated empirical evidence on the spatial distribution of technological activities in the EU area in order to support analyses and policy initiatives within the context of the EU Cohesion Policy 2014-2020. The study has dealt with the broad theme of technological and economic convergence in Europe adopting a regional perspective, highlighting main changes occurred in the pattern of technological specialization of EU regions, identifying the regional technological trajectories that have been more effective, able to sustain long-term economic growth and facilitate catching-up processes of EU laggard regions. The technological activities and performances of EU regions have been analysed using the OECD REGPAT database.

The first indication emerging from this study is the presence in the EU area of a very uneven distribution of technological capabilities, with all indicators of technological concentration being much higher than the ones referring to GDP. The level of technological concentration have a clear spatial dimension with the first four NUTS1 regions accounting for, in most technological fields, between one third and half of all EU patent activities.

The second indication emerging from this study is that over the last 15 years some degree of technological convergence of the most peripheral and less innovative regions of Europe with respect to more advanced core EU regions has occurred. The evidence presented has shown that this process of spatial re-distribution of the innovation potential of EU regions has a clear sectoral characterization being more substantial in the area of ICT and Electrical engineering technologies. However, our analysis has also clearly shown that at the end of the period taken into account in this study (2008-11) technological gaps in the EU area have remained substantial suggesting that the overall process of convergence has been rather slow, and below the expectations and the EU cohesion policy targets. Furthermore, the process of economic convergence (GDP per capita) has been much weaker than technological convergence raising a series of issues and policy concerns regarding possible causes and remedies of these asymmetric dynamics. Also somewhat worrying is the fact that in the last decade the convergence path of Southern regions has progressively slowed-down and come to a complete stop in the last few years.

This study has also shown the presence of a high level of heterogeneity - within the main EU countries and stages of technological development - in the long-term technological performance of regions. The growth rates of patent activities have been found to significantly differ across regions signalling the co-existence of catching-up and falling-behind processes also within the same macro-geographical areas and among regions sharing the same level of technological development. It has also been shown that the level of heterogeneity in the technological performances of regions has progressively increased over time and it is higher among less innovative and more peripheral regions, two stylized facts with relevant policy implications and that would deserve a deeper investigation.

In section 4 we have explored the variety of the patterns of technological specialization of EU regions and their long term changes, taking into account the absolute level of technological specialization and the specific areas where regions concentrate their innovative efforts. One of the main empirical objectives of this section was to verify if the "geographical location" and the "stage of technological development" are associated to the "level" and the "type" of technological specialization.

The analysis of the Revealed Technological Advantage indicators has shown a rather complex picture of the regional distribution of technological strengths and weaknesses in the EU area. Some broad regional and country specific technological profiles have nonetheless been identified. The dynamic analysis of RTAs has shown a process of technological upgrading of the East-European area with most of the new member state regions increasing their relative strength in the ICT & Electrical Engineering technologies, while showing a parallel de-specializing trend in the areas of Chemistry and also in the more technological mature fields related to consumer goods, furniture and games, civil engineering (Other technologies area).

By comparing and contrasting the technological specialization of the most innovative and the most backward regional areas few stylized facts have also emerged. LEADER innovative regions have been found to be specialized in most of the ICT and Electrical Engineering technological fields while regions belonging to the MODEST innovative group have been found to be specialized in more mature technological fields. This was a largely expected research outcome. Also in this case a dynamic analysis of RTAs reveals some interesting (and less expected) patterns and some evidence of catching-up processes especially of the groups of least innovative regions in key technological fields such as those related to ICT and Electrical engineering. FOLLOWERS and MODERATE innovative regions appear on the contrary de-specialized in these technological fields without showing significant changes over the last 15 years.

An important dimension investigated in this study is the extent to which regions have deepened (or diversified) their knowledge bases by increasing (or decreasing) the level of concentration of their innovative efforts in specific technological areas. On this specific point the evidence presented show that the absolute level of technological specialization of European regions has decreased in the last fifteen years, that is regions have moved towards a more even distribution of innovative efforts across different technological fields. Our analysis suggests that this pattern is mostly typical of the least innovative EU regions that have become, in this respect, more similar to the most innovative ones. This indicates on the one hand that when regions increase their technological capabilities they are also able to explore and enter into other (possible related) technological fields; on the other hand it indicates that in order to diversify into new technological areas and broaden the areas of competences, regions have to overcome a certain technological threshold level in terms of resources devoted to science and technological activities.

We have also examined the extent to which EU regions have changed - over time – the overall structure of their technological competitive advantages changing their traditional areas of strengths and weaknesses. In other words we have analysed the level of cumulativeness and path-dependency in the technological specialization of regions. Our analysis has shown the presence of a high degree of cumulativeness in the technological trajectories of EU regions, in particular among the most innovative regional groups.

The empirical evidence presented in sections 4 and 5 has highlighted the presence of a high level of heterogeneity in the technological trajectories of regions and namely in their long-term aggregate technological performances (patent growth) in the distribution of technological efforts among the different technological fields (level and type of technological specialization). More in particular, it has been shown that only to a limited extent the long term technological performances and trajectories (changes in the pattern of specialization) of regions is connected to the broad geographical location of regions or to the their stage of technological development. A final empirical objective of this study has been to test if the different technological profiles and trajectories examined in section 5 have produced different effects on the long term economic performances of regions.

Our estimations clearly show that patent growth and the quality of human capital exert a positive impact on the long term economic performances of EU regions. This finding is consistent with the results of a large amount of theoretical and empirical literature emphasising the role that technology and innovation play as key drivers of the economic performance at a firm, industry and country level. Our estimates also confirm the presence of a process of spatial economic convergence even though the descriptive evidence presented in section 4 has revealed that this process has been rather slow and limited in size.

Are there technological trajectories that have been more rewarding than others in terms of GDP growth? Our results seem to suggest that the absolute level of specialization (level of technological concentration of innovative efforts) plays a role as well as the extent to which regions (discontinuously or smoothly) change their specialization profile. Focussing the innovative efforts on a restricted number of technological fields seems to be associated to better (above average) growth performance while radically changing the pattern of technological specialization risks penalizing the growth performance of regions.

Last but not least our results also indicate that technological specialization matters for regional development. Increasing competencies and strengthening the specialization in dynamic technological areas such as those related to ICT, Electrical engineering and Instruments seem to have paid back in terms of long term productivity growth and growth performances. The opposite seems to have occurred to regions that have increased their specialization in more mature technological areas such as Chemistry and in the residual area of Other technologies.

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Appendix

Table A1: Technological sectors and fields according to the WIPO classification

Electrical engineering	**Chemistry**
Electrical machinery, apparatus, energy	Organic fine chemistry
Audio-visual technology	Biotechnology
Telecommunications	Pharmaceuticals
Digital communication	Macromolecular chemistry, polymers
Basic communication processes	Food chemistry
Computer technology	Basic materials chemistry
IT methods for management	Materials, metallurgy
Semiconductors	Surface technology, coating
Mechanical engineering	Micro-structural and nano-technology
Handling	Chemical engineering
Machine tools	Environmental technology
Engines, pumps, turbines	**Other fields**
Textile and paper machines	Furniture, games
Other special machines	Other consumer goods
Thermal processes and apparatus	Civil engineering
Mechanical elements	
Transport	
Instruments	
Optics	
Measurement	
Analysis of biological materials	
Control	
Medical technology	

List of abbreviations and definitions

CIS – Community Innovation Survey

Comecon - Council for Mutual Economic Assistance

EPO – European Patent Office

FGTs - Fast Growing Technologies

GDP – Gross Domestic Product

GPTs - General Purpose Technologies

ICTs – Information and Communications Technologies

IPC - International Patent Classification

KETs – Key Enabling Technologies

RIS3 - Research and Innovation Strategies for Smart Specialisation

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