How to survive an economic crisis? Lessons from the innovation profiles of EU regions

Andrea Filippetti
Petros Gkotsis
Antonio Vezzani
Antonio Zinilli

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Joint Research Centre

Contact information
Name: Alexander Tübke
Address: Edificio Expo - C/ Inca Garcilaso 3 - 41092 Seville (Spain)
Email: alexander.tuebke@ec.europa.eu
Tel.: + 34 954 488 326

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Abstract

Whereas the European project has long been described as a ‘convergence machine’, the recent economic crisis has halted convergence in certain dimensions, and triggered divergence in others.

By exploiting a dataset that includes patents, trademarks and design registrations at the regional level (NUTS2) in the period 2007-2016, this report aims to identify the different innovation profiles of European regions. Moreover, we also investigate to what extent the innovation profiles of regions have contributed to their resistance to the shock brought by the 2008 economic crisis, as well as their paths of economic recovery in the aftermath of the crisis.

Innovation did help to sustain employment both during the economic downturn as well as in the aftermath. The most resilient regions are those that have a strong performance in the three intellectual property rights (IPRs) analysed; patents, trademarks and design. This suggests the presence of comparative advantages for those regional innovation systems which couple technology-intensive innovation in manufacturing with a strong service-intensive sector.

Evidence also suggests that European regions should no longer be divided into the advanced regions in the West and the lagging-behind regions in the East. There is a group of regions in Eastern countries that is consistently improving its innovation performance, while growing disparities in innovation arise within the EU-15 countries.

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List of abbreviations

API	Application Program Interface
CEECs	Central and East European Countries
EPO	European Patent Office
EU	European Union
EU-15	EU-15 Member States in the European Union prior to the 1 May 2004.
EUIPO	European Union Intellectual Property Office
IPC	International Patent Classification
IPR	Intellectual Property Right
KIBS	Knowledge Intensive Business Sector
NUTS	Nomenclature of Territorial Units for Statistics
S3	Smart Specialization Strategy
WIPO	Worldwide International Patent Organization

Executive summary

Whereas the European project has long been described as a 'convergence machine', the recent economic crisis has halted convergence in certain dimensions, and triggered divergence in others. This concerns the areas of employment, income and social protection, but also broader outcomes such as working and living conditions.

By exploiting a dataset that includes patents, trademarks and design registrations at the regional level (NUTS2) in the period 2007-2016, this report aims to: 1) identify the different innovation profiles of European regions over the considered period; and 2) to investigate to what extent the innovation profiles of regions have contributed to the resilience of regions during the 2008 economic crisis, as well as their paths of recovery in the aftermath of the crisis. To this end, patents are considered as an indicator of technological innovation, trademarks as an indicator of innovation in the service sector (particularly in the knowledge-intensive sector), and design registrations as an indicator of innovation in medium and low-tech industries in the manufacturing sector.

There is a significant overlap in the use of patents, trademarks and design in several regions, thus suggesting complementarity among the three IPRs for several innovation activities. However, some regions score high in just one or two IPRs; this suggests the presence of some 'specialization' in their innovation activities.

An overall process of convergence arises in which regions from Easters Europe and (several) regions from Southern Europe display higher rates of growth. This process occurs when considering patents, trademarks and design registrations over the period 2007-2016.

An "innovation core" of Europe emerges going from the North of Italy, throughout the manufacturing regions of Germany, reaching Denmark and the south of Sweden and Finland in the north, and some regions of France and the south of the UK. This core features prominently in patents, trademarks and design, reflecting the presence of a high-tech specialization in the manufacturing sector coupled with a strong knowledge-intensive sector. The Eastern and Southern regions are lagging behind concerning technological innovation, but they tend to improve their relative performance in trademarks and design.

By comparing the concentration of innovation in 2007 and 2016, it can be observed that:

- technological innovation is more concentrated than service innovation and design innovation: more than 30 per cent of patents are concentrated in the ten most innovative regions;
- the concentration of patents grows over the period of analysis, while it diminishes for trademarks and design: technological innovation becomes more concentrated among the greater innovators, while service innovation and design innovation is less concentrated.

Innovation did help to sustain employment both during the economic downturn as well as in the aftermath. The most resilient regions are those that have a strong performance in the three IPRs, namely patents, trademarks and design. This suggests the presence of comparative advantages for those regional innovation systems which couple technology-intensive innovation in manufacturing with a strong service-intensive sector.

European regions can no longer be divided into the advanced regions in the West and the lagging-behind regions in the East. There is a group of regions in Eastern countries that is consistently improving its innovation performance. However, growing disparities in innovation arise within the EU-15 countries. Only the most advanced regions in the South of Europe join the "innovation core" of Europe, while the remaining regions are lagging behind.

1 Introduction

1.1 Development policy in the European Union: is the convergence machine broken?

Whereas the European project has long been described as a ‘convergence machine’, the recent economic crisis has halted convergence in certain dimensions, and triggered divergence in others. This concerns the areas of employment, income and social protection, but also broader outcomes such as working and living conditions.

The study of economic development has at its roots the interest for uneven economic growth of countries, regions and cities. Great disparities in the level of development exist at any point in time, as some remarkable migration flows underline. But great disparities also characterize regions and places over time as a result of cumulative processes – as explained long ago by Myrdal and Hirschman, and more recently by studies in economic geography (Rodriguez-Pose and Crescenzi, 2008). Today, this is witnessed by those regions in most advanced countries that have experienced the transition from a production paradigm based on manufacturing and on the Fordism organization of work, to the current post-industrial paradigm driven by agglomeration economies, knowledge-intensive services and flexible specialization (Piore and Sabel, 1984).

Economic development studies try to keep up with the relentless pace of changes of the economic systems, as the recent waves of technological change and the greater international integration. Their ultimate aim is to provide a better understanding of the mechanisms behind the patterns of economic development in order to provide a framework, tools and suggestions to policy makers.

Policy makers have always been concerned with uneven economic development. Disparities in the level of income across regions can cause forced migration, which in turn can bring about negative externalities, e.g. congestion costs, which can cause social tension that can ultimately undermine social cohesion itself.

The concern of the European Union (EU) for social cohesion goes back since its foundation. The founders of the EU clearly understood that economic (and eventually political) integration, in order to work, would have required avoiding excessive economic imbalances, not only among countries, but notably among regions. Hence the need for economic convergence across regions, as a tool to reach and reinforce social cohesion, echoed the words by Gunnar Myrdal, who back in the 1950s warned about the perils of economic integration in Europe for poor regions (Myrdal, 1957).

The 1970s and the 1980s have seen a proliferation of policies aimed at reducing regional disparities. This took place in the context of a Fordism-Keynesian policy framework, in which public capital, by means of investment and large public companies, was directed towards the less developed areas to boost local process of self-sustainable economic growth. Something similar occurred after the reunification of Germany, were a remarkable flow of resources flew in towards the less-developed regions of East Germany to catch up with the richest Westers part of the country, in order to make the reunification economically and socially sustainable.

Cohesion policy, by means of Structural Funds, has played the same role since the 1990s. One could travel to Greece, and later on to Spain and Portugal, to actually “see” the impact of Cohesion policy on infrastructures such as underground stations, public buildings, like museums, and other infrastructures. Something similar can be observed today by travelling to the New Member States, or Central and Eastern European countries (CEECs), that joined the EU since 2004. In these countries the share of investment provided by the EU has in some cases reached more than fifty per cent of the national aggregate. There are few doubts that Structural Funds directed towards investment in infrastructures have helped these regions to take off. In fact, a significant process of economic convergence has taken place across European regions over the past two decades.

Despite that, today we are facing possibly the most severe institutional crisis in Europe which is putting at risk the *raison d'etre* of the EU. Political phenomena such as the shocking vote for Brexit and the generalised rising of anti-Europeanism has been explained as the "*revenge of places that do not matter*" (Rodríguez-Pose, 2018). Two major phenomena can explain the crisis of that model of development and policy intervention, which is putting cohesion at risk today. The first is the underline process of structural change that has characterized the entire world economy over the past decade, driven by technological change and international integration. The second is the Great Depression started in 2008.

The economic systems in most developed countries have undergone a major transition from an economic paradigm centred upon the manufacturing sector coupled with the Fordism mode of production as a driver of productivity, innovation and job creation, towards a serviced-based economy organised around flexible specialization and fast-adapting innovation processes. The Schumpeterian world depicted in Capitalism, Socialism and Democracy (1942) were large companies were the engine of technological innovation developed in large R&D labs, has leaved the way to the rise of flexible and lean organizations, which learn and innovate by relying on a number of different sources, both internal and external to the firm (Chesbrough et al., 2008; Freeman, 1998; Lundvall, 1998). The generation of science as the engine of technological innovation has also undergone major changes, passing from the so-called linear model of innovation towards more complex and interacting modes of production (Archibugi and Filippetti, 2015; Gibbons et al., 1994; Leydesdorff and Etzkowitz, 1996; Rosenberg, 1994; Stokes, 1997).

This process of structural change has been at the same time affected and amplified by greater international integration. The Bretton Woods age was characterized by a classical international division of labour based on comparative advantages, with trade acting as a driver of specialization and technological change (Archibugi and Lundvall, 2001; Archibugi and Michie, 1995); conversely, in the new globalization paradigm most of the cross-border circulation of goods and knowledge take place within the global value chains of large transnational corporations, which search the space internationally seeking the most suitable location for their production of goods and knowledge (Baldwin, 2011; Iammarino and McCann, 2013; Ietto-Gillies, 2005).

As a result, the sources of economic development of regions, cities and peripheral territories have remarkably changed. Building infrastructures and pumping public money is no longer a viable policy. In fact, convergence in labour productivity across European countries and regions has been driven mostly by means of fixed capital accumulation; by contrast, lagging behind regions have not managed to close their technology gap with the more advanced regions (Filippetti and Peyrache, 2015, 2013).

The search for the competitiveness of places has emphasized the need for more tailored policies that could foster endogenous process of economic growth. This shift in emphasis is well visible in Cohesion Policy, which has devoted increasing attention, and resources, to policies oriented towards intangible forms of investment, such as innovation, human capital, cluster policies, industry-university linkages and, more recently, an emphasis on institutions (Farole et al., 2011).

The bottom line of this shift in policies is the generalised emphasis on the so called *place-based* policy (Barca et al., 2012). A recent report prepared for the European Commission (Iammarino et al., 2017) argues that, since *"regional economic divergence has become a threat to economic progress, social cohesion and political stability in Europe"* it is needed to develop different development policies depending on the type of region, an approach they have labelled *place-sensitive distributed development policy*.

The Smart Specialization Strategy (S3) implemented in the current period of programming of Cohesion policy is the quintessential of the paradigmatic shift from top-down capital-driven policies, towards place-based innovation-driven development policies. The Smart Specialisation framework has introduced new ways of thinking about local development and structural change, contributing to the redefinition of the EU regional policy. In particular "the concept of Smart Specialisation was defined to address the issue of specialisation in R&D and innovation and provides a basis to design effective strategies for the medium-long term development of territories. Smart Specialisation is therefore an innovation policy framework designed to support regions (and countries) in the identification of the most promising and desirable areas of specialisation, and to encourage investment in programs which may complement the local productive and knowledge assets to create future comparative advantages" (Vezzani et al., 2017, p. 5).[1] The key message of S3 is that regions have to discover themselves their way to be innovative (McCann and Ortega-Argilés, 2013). This means not only to find the sources of economic growth at present, but also envisaging their "own" dynamic process to foster a long-term path of economic growth driven by innovation. As such, the S3 has inherently the concepts of change, adaptation, and innovation at its roots.

1.2 Innovation profiles, resilience and economic recovery: does creative response help in times of destruction?

By exploiting a novel dataset that includes patents, trademarks and design registration at the region (NUTS2) level in the period 2007-2016, this report aims to: 1) identify the different profiles of innovation of European regions over the considered period; and 2) to investigate to what extent the innovation profiles of regions have contributed to their performance during the economic crisis, as well as their paths of recovery in the aftermath of the crisis. Following Martin (2012) and Faggian et al. (2018) we will focus on two dimensions of resilience: 1) The *resistance* of a region *to a shock*, proxied by the sensitivity index; and 2) Its capacity to *recover from a shock*, proxied by the reaction index.

The study of resilience has received increasingly attention by regional scientists and economic geographers. Policy makers have also joined the debate and two recent JRC reports provide a conceptual framework and indicators to measure resilience beyond

[1] See also the European Commission Communication COM(2017) 479 final titled "Investing in a smart, innovative and sustainable Industry A renewed EU Industrial Policy Strategy", available here.

the standard economic dimension (Alessi et al., 2018; Manca et al., 2017). In a world characterised by rapid and continuous change, the capacity of the regional economic system to manage exogenous shocks is increasingly a concern for scholars and policy makers, given the amount of social distress brought about during and after these events. Thus, the current pressing question is: *what makes region more (or less) resilient?* Scholars who have explored the *sources* of regional and local resilience have mostly looked into their industrial specialization. This follows a long tradition of studies that looks at the industrial and technological specialization as a source of economic growth. More recently, the *related variety* concept has been added building on intuition as that by Jane Jacob about the importance of diversity as a source of adaptation and innovation (Jacobs, 1969). The crux of the matter here is whether it is better to face an economic crisis being strongly specialized, or by having some degree of variety in the industrial structure. The argument being that in the latter case regional economic systems are better positioned to adapt and move away from industries and sector hit by the crisis towards more profitable ones (Frenken et al., 2007).

This report introduces in this debate the *role of innovation as a source of regional resilience*. We base our hypotheses upon an argument made by Schumpeter long ago in an article which has been relatively neglected compared to the other works of the Austrian economist. In his article "*The creative response in history*", Schumpeter makes an important distinction about the way in which economies respond to what today we could define as exogenous change, and that Schumpeter, as formal as he used to be, defined as a "*change in the data*". He distinguished between *adaptive response* and *creative response.* The former is a reaction to a change "*in the way that traditional theory describes*"; this is some form of change that can be predicted *ex-ante* on the base of current economic theories. By contrast, a creative response is when "*the economy or an industry or some firms in an industry do something else, something that is outside of the range of existing practice*". According to Schumpeter, the creative response has three characteristics. Firstly, it can be understood only *ex-post.* Secondly, it shapes the long-run economic path. Thirdly, it has something to do with the level of human capital and its behaviour, mostly the behaviour of the entrepreneurs.

This is the rationale behind exploring whether innovation helped resilience in European regions during and after the recent economic crisis. In principle, one is expected to observe more innovative regions to be better equipped to react to major economic downturn such as the 2008 recession. There is already evidence that most innovative countries and the most established innovative firms have performed better during the 2008 financial crisis (Archibugi et al., 2013; Archibugi and Filippetti, 2011; Bakhtiari, 2012; Paunov, 2012). This report looks at the region level by investigating whether being innovative has brought some comparative advantage in the reaction of the crisis. To put it differently, this report explores whether creative response is helpful in times of creative destruction.

In the first part (Sections 2 and 3) we study the innovation profiles of the regions, identified by means of three indicators of innovation, namely patents, trademarks and design registration. As explained below in detail, each of these indicators is a proxy of some forms of innovation that differ from each other, although there are also complementarities among them. In the second part (Section 4), we investigate econometrically the relationship between innovation profiles and regional resilience, measured in terms of employment. Final considerations are discussed in the final section.

2 Measuring innovation with patents, trademarks and design registrations: advantages and limits

Innovation is a phenomenon complex and multidimensional in nature. It involves the co-ordination over time of a number of different factors on different fields. Such a complex phenomenon is hard to identify, and consequently even harder to measure. Developing innovation measurement methodologies has always been a major effort of scholars of the economics of innovation. There are at least three main reasons which justify the need to measure innovation. Firstly, innovation measures can be used to increase and broaden our knowledge on how innovative processes are carried out. Secondly, theories can be tested and refined according to empirical findings. Thirdly, given that the processes of creation and diffusion of innovation are considered the main determinants of economic growth, productivity and competitiveness, innovation measures have become extremely relevant for policy makers at regional, national and local level.

The rationale of the development of indicators is to establish a stable proportion between the phenomena and the related instruments. As Mendonca et al. argue *"Indicators capture, but only partially, some aspect of the object in question…[they] are not a direct, object and complete measurement"* (Mendonca, Pereira et al. 2004). Over the last fifty years, patents and R&D expenses have been the two major indicators used to measure the intensity of technological innovation. The development of these technology-based measurement methodologies has been based on the assumption that innovation is *technological in nature*.

Currently, technological innovation no longer represents the only driver of performances in terms of innovation. Advanced countries are shaping their national innovation systems towards a specialization structure which is no longer based only on technology, but also on non-technological sources of innovation, as for instance in the case of the service sector, namely the knowledge-intensive service sector (Gallouj and Savona, 2009).

This report uses measures of the innovation performance at the regional level (NUTS2) in the EU on intellectual property rights (IPRs): patents, trademarks and design registrations.

Patent data at the regional level were retrieved from the OECD REGPAT 2017B edition database.[2] Patent data are fractionally counted by applicant and aggregated at the NUTS-2 regional level. Applicants have a legal title to granted patents (OECD, 2009) and thus aggregating data by applicants provide a regional mapping of ownership of technological inventions; where do go the returns of innovation. Regional profiles based on patent information of the location of inventors can be different and

[2] The OECD REGPAT database links patent data from PATSTAT to regions according to the addresses of the applicants and inventors. The dataset provides patents at a rather detailed geographical level. In this work we have aggregated patents at the NUTS2 level, which correspond to 281 different EU-28 regions plus other European countries (e.g. Switzerland or Norway)

meant to localise where technological activities are carried out and knowledge accumulated (De Rassenfosse et al., 2013; Evangelista et al., 2018).

Due to the lack of systematic information on the location of *creators* for design and trademark in European data, we decided to use patent data by applicant to keep consistency among the three datasets and guarantee an adequate level of coverage. Indeed, registered designs and trademarks are retrieved from the European Union Intellectual Property Office (EUIPO), which makes available applications for the period 2003 and 2017. Information has been regionalised by Idener, a research SME located in the Aerópolis Science and Technology Park of Seville. The way geographical information is stored by EUIPO makes the localization of their data easier compared to PATSTAT. Indeed, about 88% of applicants were localised directly using the postal code as reported in the data via a specific field available in the data, for the remaining 12% of observations postal codes have been retrieved from the address field using the Google maps geolocation API or other external services.[3] As for patents, registered designs and trademark applications were fractionally counted and aggregated at the NUTS2 regional level.[4]

2.1 Patents as a measure of technological innovation

Patents have been by and large one of the most exploited measure of innovation, both at the national, regional and firm level. Several advantages have been discussed along with their limitations (Archibugi, 1992). To summarize, patents are a reliable measure of technological innovation, are largely available and comparable across countries and over time. Several caveats associated to patents as a measure of the innovative performance of countries have been widely recognized. Not all innovations are associated with patents, and not all patents lead to new products or processes in the first place. Moreover, the usefulness of patents as a measure of innovation varies greatly across industries (Fontana et al., 2013). Nonetheless, patents have been widely used in accounting for technological innovation developed for commercial purpose (Griliches, 1990), and the literature treats it as a "tolerable assumption" that they measure commercially useful innovation. Even with these cautions, patents represent "the only observable manifestation of inventive activity with a well-grounded claim for universality" (Trajtenberg, 1990).

A further limitation of patents as a measure of innovation in our setting, is that they account for by *technological* innovations. As such, they tend to be concentrated in those regions close to the technological frontier, which are specialized in the most technologically advanced industries. If one needs to explore other (softer) forms of innovation, such as innovation in low-tech and medium-tech industries, or innovation in the service sector, their use becomes more problematic.

[3] The localisation of data for UK, which have a very detailed post code system, has made extensive use of PostCodes.IO, an open source API for geolocation in the UK.

[4] The decision of creating an integrated regional IP database was driven by the fact that this information is not updated regularly on Eurostat.

2.2 Trademarks as a measure of innovation in knowledge-intensive services

The World Intellectual Property Organization (WIPO) defines trademark as a *"distinctive sign, which identifies certain goods or services as those provided by a specific person or enterprise"* (WIPO 2007). According to the European Union Intellectual Property Office (EUIPO), a trademark *"is any sign which serves in business to distinguish the goods and services of one undertaking from those of other undertaking"*.[5]

While trademarks have been less employed as a measure of innovation compared to patents, their use has been growing over time.[6] The reason is that developed countries are more and more characterized by a *servitization* process. The manufacturing industry, both depending on its considerable pace of productivity growth and recent phenomena of offshoring, has been declining ever since in all advanced countries. True, manufacture is still responsible for a sizeable share of innovation, R&D and productivity growth. However, the service sector is increasingly seen not only as a low-tech industry sick with the Baumol disease, but as a sector which plays a fundamental role for innovation. An important part of this innovation activity goes hand in hand with that of the manufacturing sector, as in the so-called KIBS (knowledge intensive business sector) – i.e. service companies that provide knowledge inputs mainly to the business processes of other organizations.

A trademark is a sign that allows consumers to identify and distinguish between different goods or service, and thus it allows companies to pursue diversification strategies. From a legal point of view, a trademark "is an exclusive right, that is to say a legal monopoly, which pursues the aim of creating new information. It is an intellectual property right attributed to the owner […] to provide an incentive to produce information that is not itself the good being exchanged (as in the case of patents) but rather an accessory element to the exchange of other products" (Ramello, 2006, p. 551).

As such, trademarks have a twofold aim: to provide information and to protect the innovation. However, differently from patents, trademarks do not provide full protection against imitation, because they do not protect the innovation itself.[7] Nevertheless, similarly to patents, trademarks can increase barriers to entry (Gotsch and Hipp, 2012).

Intangibility is one of the attributes that makes service innovation easier to imitate. The limit of the materiality of innovation, which is present for patent, does not apply instead to trademarks. They can be used also for immaterial innovation. This is particularly important in several KIBS. For instance, in a study on Canada, Amara et al. (2008) find that 15.7% of KIBS rely on patents and 34.5% on trademarks. However, the same companies rely on 77% on confidentiality agreement, 53.3% on secrecy, and 60% on lead-time advantages over competition. In the report on services

[5] Council Regulation No 40/94 (CTMR). Signs that can be registered as a trademark include: words, figurative marks, colours or combination of colours, three-dimensional marks, sound marks and jingles.

[6] Papers that employ trademarks as a measure of innovation include: (Barnes, 2006; Baroncelli et al., 2004; Claes, 2005; Gotsch and Hipp, 2012, 2012; Livesey and Moultrie, 2008; Mendonca et al., 2004; OECD, 2008; Ramello, 2006).

[7] In fact, also patents do not provide full protection even though they protect the new technology itself.

"Patents in the service industries" Blind et al. (2003) found that patents are the least important IPR for the interviewed service companies – 65 service companies located in more than 10 member states - and result also extremely concentrated in few sectors like telecommunications and information technology. Trademarks resulted the most important protection instrument. They also show that in contrast to patents, trademarks are more relevant for a broader number of sectors and also for SMEs. Mendonca et al. (2004) investigated the use of trademarks as an indicator of innovation and industrial change. They argue that trademarks are particularly important in industries where the propensity to patent is low like in services and in low-tech manufacturing industries. Additionally, they claim that trademarks are better in capturing innovation in small firms.

Similarly to patents, trademarks tend to be registered just before the launch of a new product or service, hence in a later phase of the innovation process (Hipp and Grupp, 2005).

Trademarks have also some limits. Services that have no innovative content can be also protected: companies can register trademarks in order to increase visibility, differentiate their service, discourage potential new entrants (Hipp and Grupp, 2005). This is something that is diffused also in the case of patents, whereas strategic patenting is a quite popular strategy in some sectors. However, in the case of patents, novelty vis-à-vis the state of the art of the technology is a requirement to get a patent granted by any patent office.

Finally, it is interesting noticing that in many cases trademarks are registered by manufacturing companies. This comes as no surprise, in that the distinction between products and services has become less clear cut in the past decade or so.

2.3 Design registrations as a measure of innovation in low-tech and medium-tech industries

The story of the protection of industrial design is strictly related to the development of the manufacturing industry. Back on 1787, the "Designing and Printing of Lines, Calicoes and Cotton and Muslin Act" was the first law giving protection to industrial design in the United Kingdom. The protection of design to every manufacture industry was recognized in the Design Act of 1842 in which protection was extended to "any new and original design whether such design be applicable to the ornamenting of any article of manufacture…" (WIPO 2007).

The WIPO defines industrial design as "the creative activity of achieving a formal or ornamental appearance for mass-produced items that, within the available cost constraints, satisfies both the need for the item to appeal visually to potential consumers, and the need for the item to perform its intended function efficiently" (WIPO 2007). While according to the definition from the EUIPO "design means the appearance of the whole or a part of a product resulting from the features of, in particular, the lines, colours, materials, contours, shape, texture, ornamentation". The EUIPO regulation excludes from the protection of design registration "non-visible parts in normal use" and "features of appearance of a product which are solely dictated by the technical function of the design".[8] Design must be applied to an item

[8] Council Regulation (EC) No 6/2002 of 12 December 2001 on Community designs (available here).

having some utilitarian feature. Thus, the latter requirement distinguishes design from copyright protection inasmuch the latter is purely concerned with aesthetic creations, and makes design registrations more similar to patents. The content of the protection provided by the design registration is both aesthetic and functional in nature. Design can in fact affect a product in different ways according to the firm strategy (Filippetti and D'Ippolito, 2017). It can emphasize the aesthetic feature, quality and style according to a differentiation strategy of the firm. Or it can focus on usability, ergonomics, tailoring and modularization of the product, or additionally to save costs in the production process, transport, assembling etc. In order to be accepted, a design has to be new and original. The latter means that it can be distinguished from other designs thanks to relevant features.

The protection related to design registration accords to the owner the exclusive right to prevent the unauthorized commercial exploitation – production, selling, import or export - of the design in industrial articles. Obviously, novelty in design is not related to the object, inasmuch industrial design on chairs and wheels are continuously registered, and to our knowledge their invention goes back to some thousands of years ago. Novelty is rather linked to the way the object is designed. That is, the appearance and the form of the object (aesthetic element), the way a person can use it (functional element) and also the way objects are interconnected or produced. While novelty is a general requirement in every law dealing with design protection, it can be absolute or relative. In the former case, the design for which registration is applied must be new with respect all other designs produces in all the world and disclosed by any tangible or oral mean. In the latter case, a relative qualified standard of novelty is required. It can be related to time, territory (depending on the jurisdiction), or means of expression (i.e. limited to tangible or written forms of expression) (WIPO 2007). The duration of an industrial design right varies from country to country. Usually it goes from 10 to 25 years, often divided in to terms requiring the owner to renew the registration in order to obtain an extension of the term.

Compared to patents and trademarks, design registrations are relatively less employed as a measure of innovation. However, they have been increasingly used by the European Union to carry out cross-national comparative analysis; this is the case for instance of the European Innovation Scoreboard which includes design applications among the innovation intellectual assets activities pursued at the firm level along with patents and trademarks.[9]

There are some caveats in using design registrations as indicators of innovation.[10] Firstly, contrary to the case of patents, design registrations are assumed to be valid unless successfully challenged by some counterclaims. The lack of an ex-ante examination opens up room for strategic actions, in that firms might have an interest in resister design that should not qualify as innovations. Secondly, design registrations are cheap, compared to patents and trademarks. In addition, applicants can submit up to 99 individual designs in the same filing (thus this would count for one). Finally, a design that obtained a registration does not have to be "better" to some prior art, but it is required only to be "different". For these reasons some authors suggest some caution about the use of design registrations of design innovation (Filitz et al., 2015).

[9] See here: https://ec.europa.eu/growth/industry/intellectual-property/industrial-design/protection_en.

[10] What follows draws from: (Filitz et al., 2015).

However, design registrations can be a good proxy for innovation in some sectors, particularly those sectors in which patents do not play an important role, as characterized by low R&D intensity and mature markets. Descriptive statistics show that industries such as furnishing, clothing and packaging are those with higher design registration intensity; at the same time, there is also some degree of complementarity with patents in some hi-tech sectors, such as those of electronic equipment and transportation (Filitz et al., 2015).

Table 1 summarizes the advantages and weaknesses of using patents, trademarks and design registration as indicators of innovation.

Table 1: Patents, trademarks and design registrations: what do they measure, advantages and drawbacks

Instrument	What do they measure	Advantages	Drawbacks	Sources
Patents	❖ technological novelties or improvements (over the last years patents have been extended also to some non-technological fields) ❖ technological specialization of countries	❖ reliable measure of technological innovation ❖ very detailed technological classification (IPC) ❖ identification of knowledge domain ❖ one-to-one relation with technological novelties or improvements	❖ not able to properly capture innovative activities in the service sector and in manufacturing industries in which innovations are not technological in nature ❖ not all patents became innovations ❖ different propensity to patent across sectors and firms' size ❖ strategic patenting can bias innovation measures	WIPO EPO Patent National Offices
Trademarks	❖ marketing innovation linked to brand management and differentiation ❖ consumer-oriented specialization of countries' industrial structures	❖ good indicator of marketing innovation ❖ used in low-tech manufacturing industries ❖ more important IPR in the service industry ❖ largely used in SMEs ❖ possible measure of innovation in creative industry	❖ highly aggregated industry classification (not comparable with IPC) ❖ one-to-one relationship with new product or service not guaranteed ❖ the same trademark can be applied for different sectors	EUIPO WIPO National Offices
Design Registrations	❖ design innovation ❖ industry specialization	❖ reflects a process which involves knowledge and capabilities and can spur learning by doing ❖ one-to-one relationship with development of new and original designs ❖ less dependent on size and sector than R&D ❖ possible indicator of industrial structural specialization of countries ❖ can capture an important portion of non-technological innovation not captured by patents and R&D in low-tech industries	❖ highly aggregated industry classification (not comparable with IPC) ❖ multiple applications can be counted as one application ❖ possibility of strategic behaviour not reflecting innovation	EUIPO WIPO National Offices

Source: *authors' elaboration.*

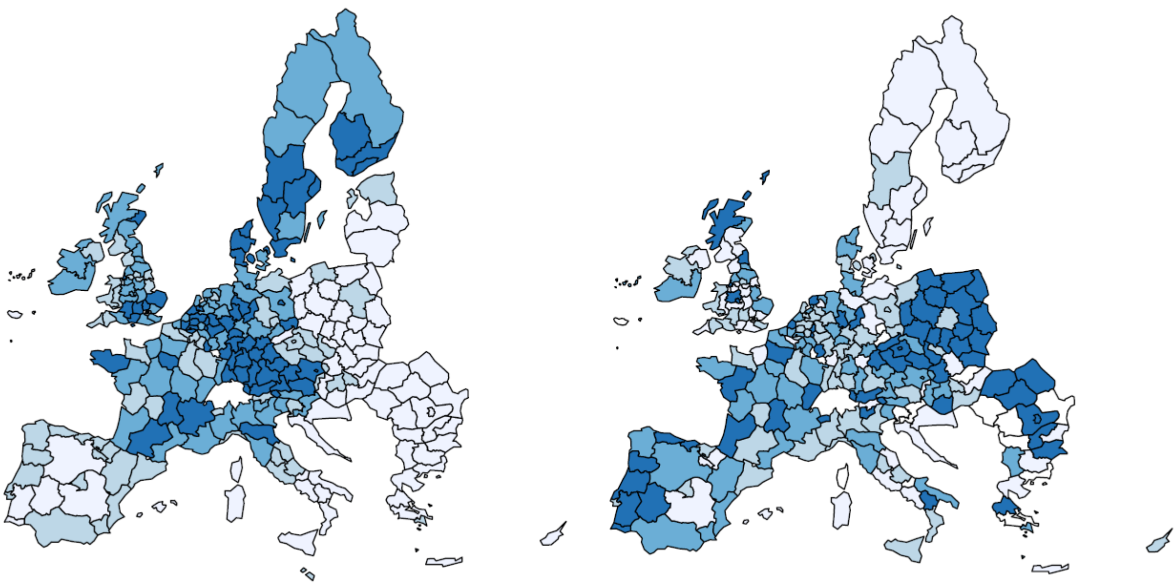
3 The innovation profiles of the European regions over the period 2007-2016

3.1 Trends in patents, trademarks and design in 2007-2016

In this Section we report some figures regarding the three measures of intellectual property rights considered: patents, trademarks and design. In line with the discussion above, we interpret patents as an indicator of technological innovation, trademarks as an indicator of innovation in the service sector (particularly in the knowledge-intensive sector), and design registrations as an indicator of innovation in medium and low-tech industries in the manufacturing sector.

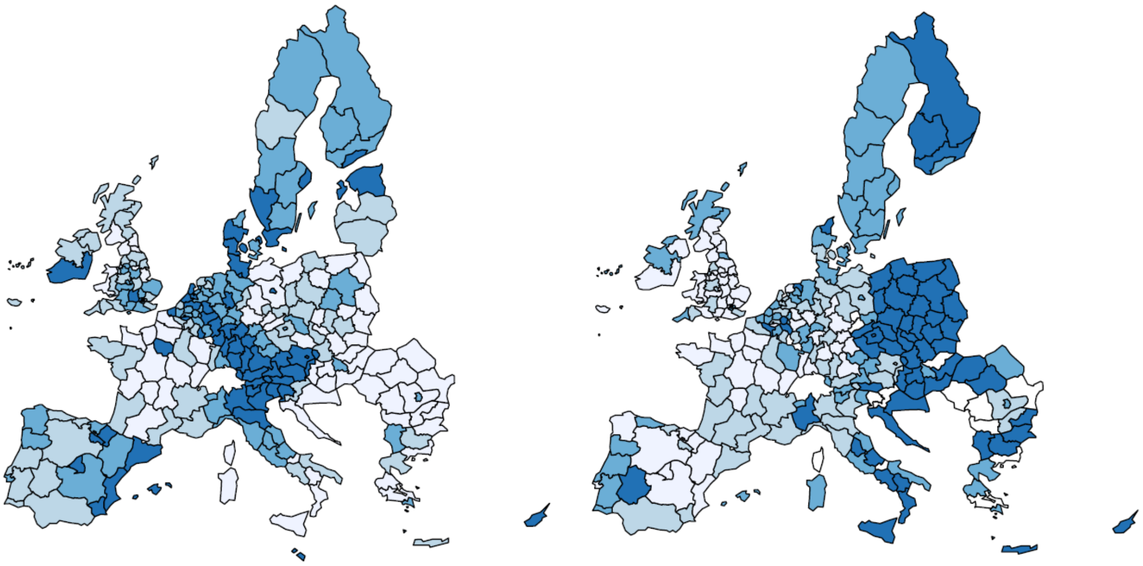
The maps reported in Figures 1a, 1b and 1c show regional per capita statistics for 2016 (left) and changes over the years 2007-2016 (right) for patents, trademarks and design, respectively. By comparing the static snapshots in 2006 two facts emerge. Firstly, there is some significant degree of overlapping among the three IPRs. Several regions in the belt going from Northern Italy, to the core of the German manufacturing industry, along with Denmark and the capital regions of the UK, Sweden and France, are consistently in the higher quartile of patents, trademarks and design. The second fact is about the presence of several regions that are instead characterised by having a high performance in only one or two of the indicators. So, for instance the south-east of Spain scores higher in trademarks and design, while several regions of Poland, which are low in patents, tend to score prominently in design registrations. There are also some regions that score high only in patents, as it is the case for some regions of France.

Figure 1a: Patents per capita (left) and change over time (right)



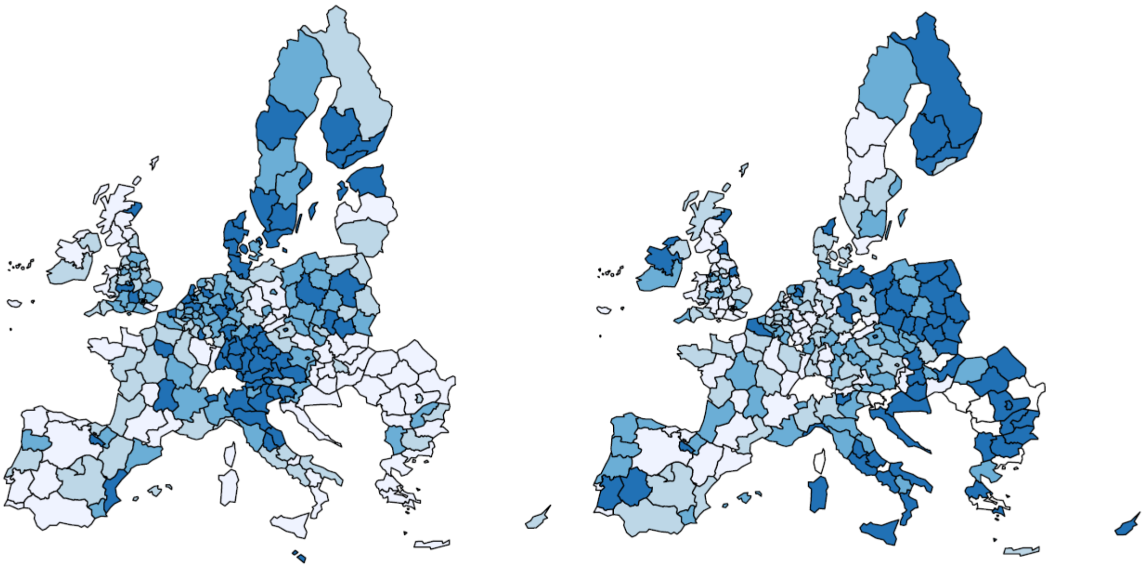
Source: *authors' elaboration on Regpat 2017b data.*
Note: *rate of change is calculated as compound average growth rate (CAGR). Regions are split in five equally populated groups (quintiles, 20%); a darker blue indicates a higher quintile.*

Figure 1b: Trademarks per capita (left) and change over time (right)



Source: *authors' elaboration on EUIPO data regionalised by the JRC.*
Note: *rate of change is calculated as compound average growth rate (CAGR). Regions are split in five equally populated groups (quintiles, 20%); a darker blue indicates a higher quintile.*

Figure 1c: Design registration per capita (left) and change over time (right)



Source: *authors' elaboration on EUIPO data regionalised by the JRC.*
Note: *rate of change is calculated as compound average growth rate (CAGR). Regions are split in five equally populated groups (quintiles, 20%); a darker blue indicates a higher quintile.*

Changes in patents, trademarks and design in 2007-2016 show a different pattern. In the first place, a pattern of overall convergence does emerge at a cursory look. Regions from Eastern Europe countries and Portugal show a systematic better performance for the three IPRs considered. Regions from the Southern Italy and from

Finland instead perform better that the median EU region when considering design and trademarks, but not patents.

Summing up, this first series of charts suggests the following:

- there is a significant overlap in the use of patents, trademarks and design in several regions, thus suggesting the complementary among the three IPRs for several innovation activities (as further explained below);
- there is also the presence of regions that score high in just one or two indicators; this suggests the presence of some 'specialization' in the innovation activities, as for instance in only hi-tech, or service innovation, or design-based innovation. (This supports the use of trademarks and design, along with patents, to capture the regional specialization in some form of non-technological innovation);
- it arises an overall process of convergence in which regions from Easters Europe display higher rates of growth in patents, trademarks and design registrations; the same holds true for Southern Europe when considering trademarks and design registrations.

3.2 The concentration of innovation among the greater innovators in Europe

In this section we analyse the top innovators in Europe, by taking the *absolute* figures in the three indicators of innovation. Table 2 shows the cumulative percentage of patents, trademarks and design for the top ten innovators among European regions in 2016.

In all the three cases regions belong to the EU-15 block of countries, with the only exception of the region PL12 (this is the region of the Poland capital city, i.e. Warsaw) that scores in the seventh place for design. This is also the case for most of the other regions, whereas the capital cities tend to score quite prominently in all the three indicators.

Table 2 - The cumulative percentage of patents, trademarks and design for the European regions in 2016

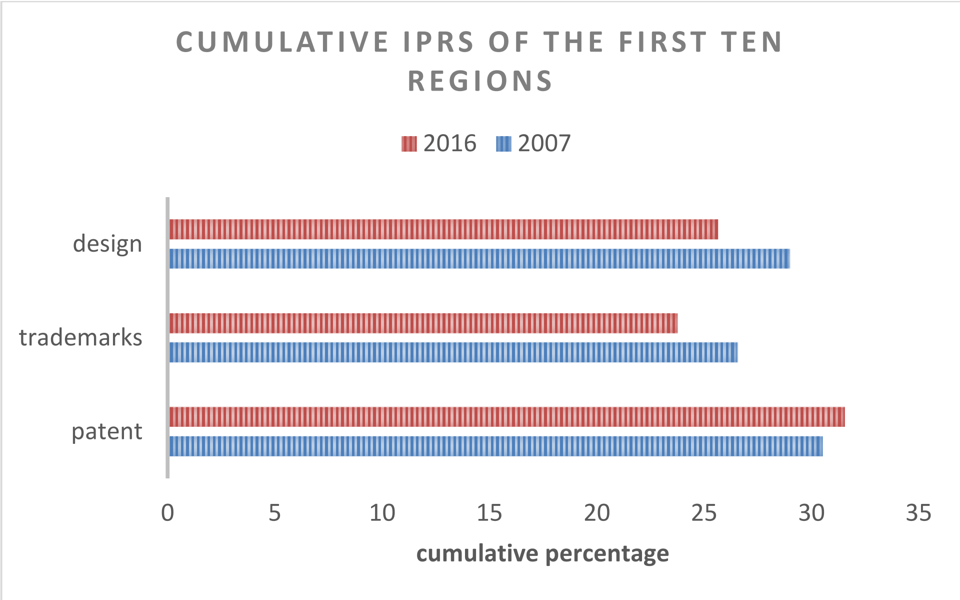
Rank	Region	Patents	Region	Trademarks	Region	Design
1	FR10	6.1	FR10	3.9	ITC4	3.9
2	DE21	10.6	ITC4	7.6	FR10	7.7
3	DE11	14.8	ES51	10.8	ITH3	10.4
4	NL41	18.8	UKI3	13.8	DE21	12.8
5	FR71	21.7	DE21	16.3	DE11	15.0
6	DE71	23.9	ES30	18.7	ITH5	16.9
7	DE12	25.9	ITH3	20.5	PL12	18.8
8	DEA1	27.8	SE11	22.4	ES52	20.5
9	ITC4	29.7	DEA1	24.1	ES51	22.2
10	DEA2	31.6	ITH5	25.6	SE11	23.8

Source: *authors' elaboration on Regpat 2017b and EUIPO data regionalised by the JRC.*

By looking at the Figure 2 below, we can comment on the relative concentration of innovation for the three indicators over time. Two comments are in order:

- technological innovation tend to be relatively more concentrated than service and design innovation, in that more than 30 per cent of patents are concentrated in the ten most innovative regions;
- concentration of patents grows over the considered period, while it diminishes for trademarks and design, thus: technological innovation becomes more concentrated among the top innovators, while service innovation and design innovation is less concentrated.

Figure 2 – The relative concentration of innovation in 2007 and 2016



Source: *authors' elaboration on Regpat 2017b and EUIPO data regionalised by the JRC.*

We also analyse the ***spatial concentration*** of employment by means of the Moran index.[11] Figure 3 reports the spatial autocorrelation for the three indicators over the considered period. It arises that patents and design tend to be more spatially correlated than trademarks. This seems to reflect a well-known characteristic of innovation in the manufacturing sector. The strong presence of knowledge spillover and other agglomeration economies makes spatial correlation a typical feature of innovation manufacturing industries, particularly hi-tech and knowledge intensive industries (Iammarino and McCann, 2006; Rodriguez-Pose and Crescenzi, 2008). By contrast, innovation in the service sector seems to be relatively less affected by agglomeration economies.

[11] Moran's I is a measure of spatial autocorrelation which is more complex than simple correlation in that it include the spatial dimension. It varies from -1 to 1. In a black and while chessboard, the spatial correlation of black and white would be equal to -1, reflecting perfect dispersion. By contrast, if the white squares were stacked to one half of the board and the black squares to the other, Moran's I would be close to +1. A random arrangement of square colours would give Moran's I a value that is close to 0.

The second interesting insight derives from the change in the autocorrelation over the considered period. By looking at figure 3 and figure 4, an inverse trend arises concerning patents and trademarks. As for patents, one can observe a growing trend in the period 2003-2011 that turns into a negative trend after 2011. By contrast, regarding trademarks one can observe a decreasing trend up to 2008 and a reversing slightly upward trend afterwards. These dynamics need to be interpreted with great caution. However, one can speculate that while the financial and economic crisis of 2008 has made technological innovation less dependent on agglomeration economies, the contrary has taken place for innovation in the knowledge-intensive sector. While this is outside the scope of the present report, exploring the extent to which the 2008 crisis has affected the spatial patterns of innovation in Europe deserves further study.

Figure 3 – Moran Index for patents, trademarks and design (2007-2016)

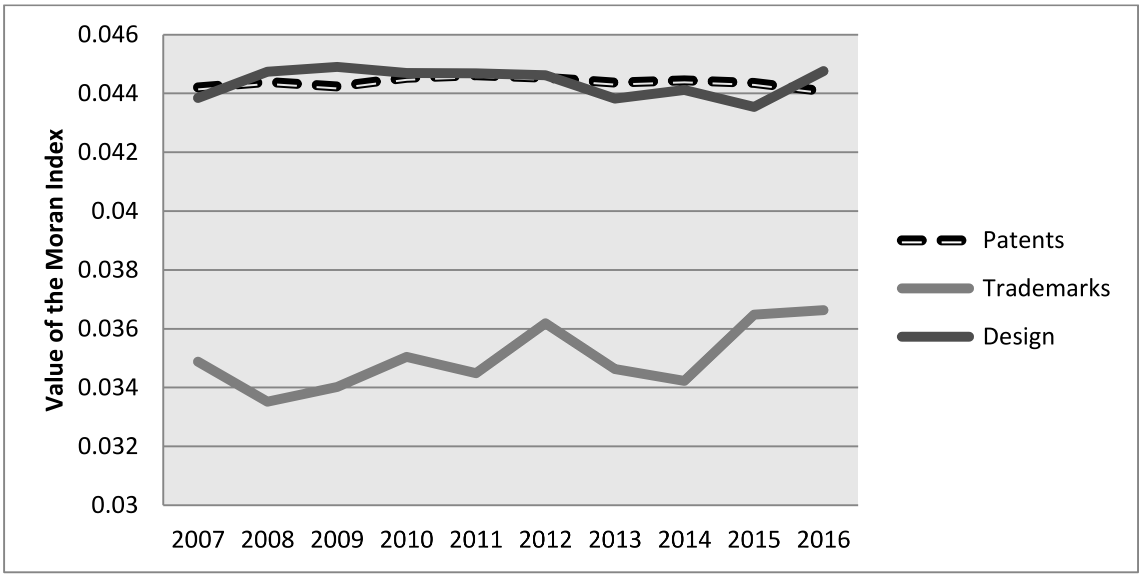
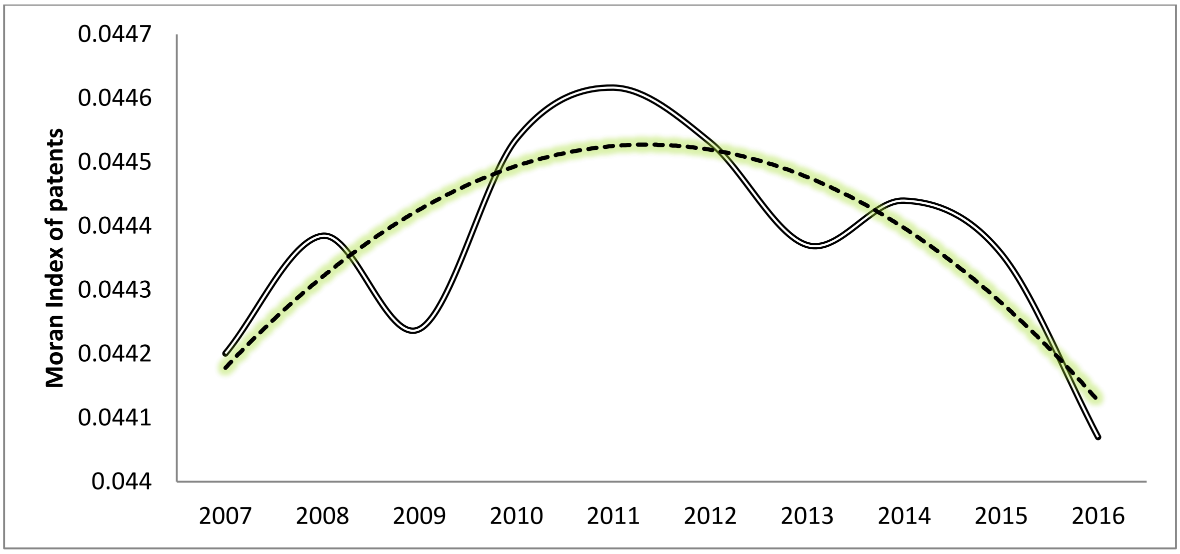


Figure 4 - Moran indicators for patents (2007-2016)
(In dash a polynomial trend line)



Source: *authors' elaboration on Regpat 2017b and EUIPO data regionalised by the JRC.*

Table 3 contrast patents, trademarks and design registrations per capita and as a share of the related absolute value, between capital regions and the other regions for 2016. The differences in the values per capita are significant, in that the capital regions perform better than the remaining regions in all the three IPRs. Capital regions have on average 11.5 patents per 100,000 inhabitants, compared to 8.5 for the remaining regions; the difference is higher for design (4.5 compared to 2.8) and remarkable for trademarks, where capital regions score 30 compared to 12.5. By looking at the shares in the absolute valued for the three IPRs, the capital regions show the higher share in trademarks: they account for 20% of the whole trademarks issued in 2016; they account for 15.4% of design registrations and 14.4% of patents.

Table 3 - patents, trademarks and design in capital regions versus other regions, 2016

		Per capita	Share (%)
Patents	*other region*	8.5	85.6%
	capital region	11.5	14.4%
Trademarks			
	other region	12.5	79.3%
	capital region	29.9	20.7%
Design			
	other region	2.8	84.6%
	capital region	4.5	15.4%

Source: *authors' elaboration on Regpat 2017b and EUIPO data regionalised by the JRC.*

These differences reflect the growing relevance of large cities for innovation driven by knowledge spillover and reinforcing mechanisms such as the circulation of skilled migrants, and the role of multinational corporations (Archibugi and Filippetti, 2015; chapters 6, 14, 15.). The difference that emerges regarding trademarks reflects in particular the concentration of knowledge-intensive sectors in large cities.

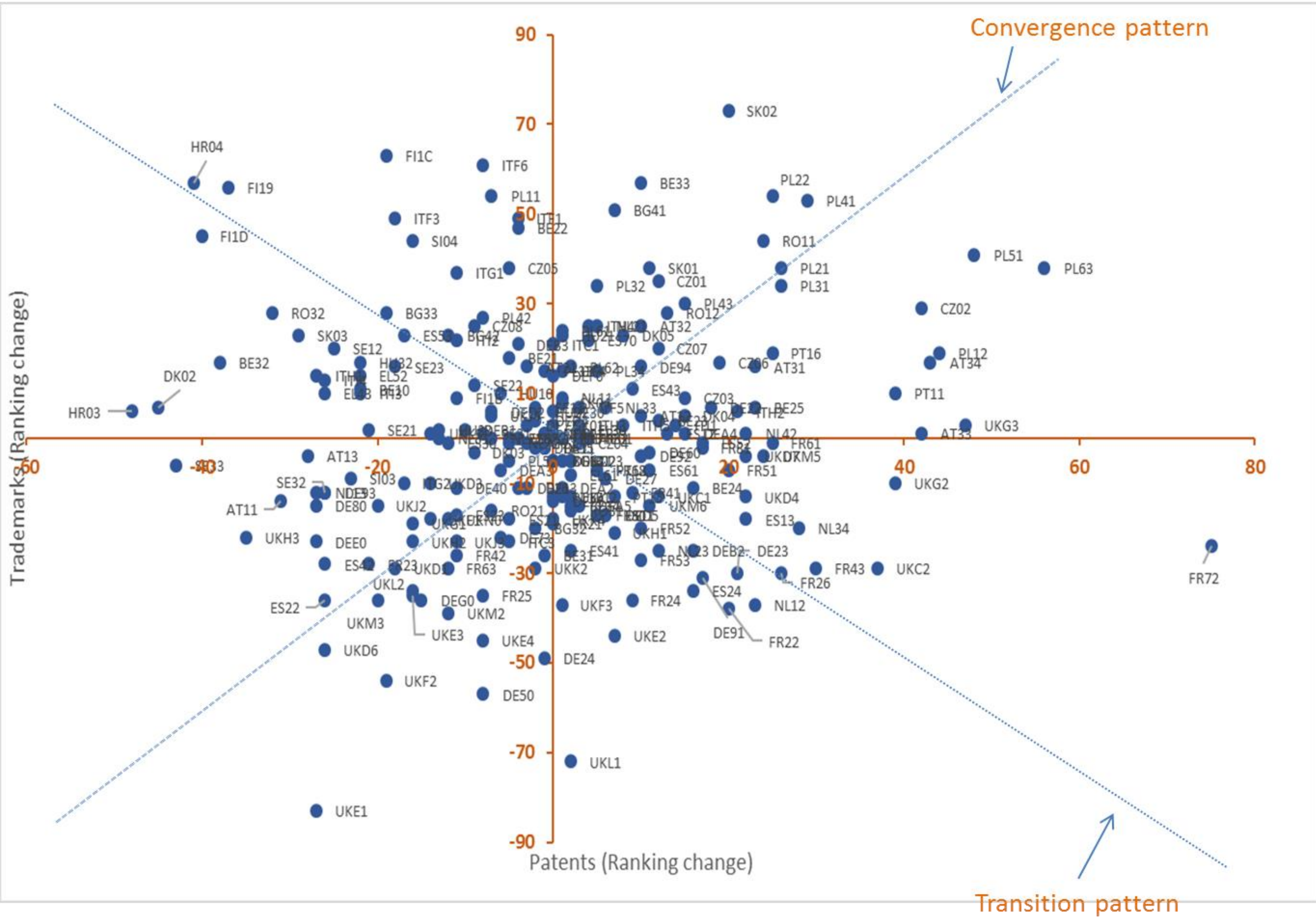
3.3 The changing innovation profiles of European regions

As mentioned above, patents can be interpreted as an indicator of technological innovation, trademarks as an indicator of innovation in KIBS and design registrations as an indicator of innovation in medium and low-tech industries in the manufacturing sector. A region with better patent performances compared to others is more oriented towards technological development and can be considered as high-tech; conversely, a region relatively stronger in trademark is more oriented towards the 'soft' kind of knowledge beyond the technological one. Therefore, analysing the relative performance of regions using these three indicators allow mapping the evolution of regional competences, innovation profiles, over the years.

This section examines the change in the innovation profiles of the regions over the period 2007-2016, by looking at the change in the three indicators in the considered period. We first rank regions in 2007 and 2016 by the number of patents, trademarks and design per capita. We then plot the change of the rankings between 2007 and 2016. Figure 5a shows the change in the ranking for patent (on the x-axis) versus the change in the ranking for trademarks (on the y-axis). The four quadrants can be divided as follows: ranking improvement in both patents and trademarks (north-east); ranking improvement in patents and decrease in trademarks (south-east); ranking decrease in patents and improvement in trademarks (north-west); ranking decrease in both patents and in trademarks (south-west).

The idea of this chart is to highlight the changing innovation profiles across European regions. A pattern of convergence emerges along the "convergence pattern" line going from south-west to north-east. Along this line one can observe that most of the regions losing ground both in patents and trademarks are from EU-15 countries e.g. form the UK, Austria, Denmark, Sweden etc. By contrast, those that have been gaining momentum in patents and trademarks, (north-east) are mostly from the CEECs, namely Poland, Check Republic, Bulgaria and Slovak Republic, along with a few regions from the UK, Austria and Belgium.

Figure 5a – Ranking change for patent and trademarks in 2007-2016

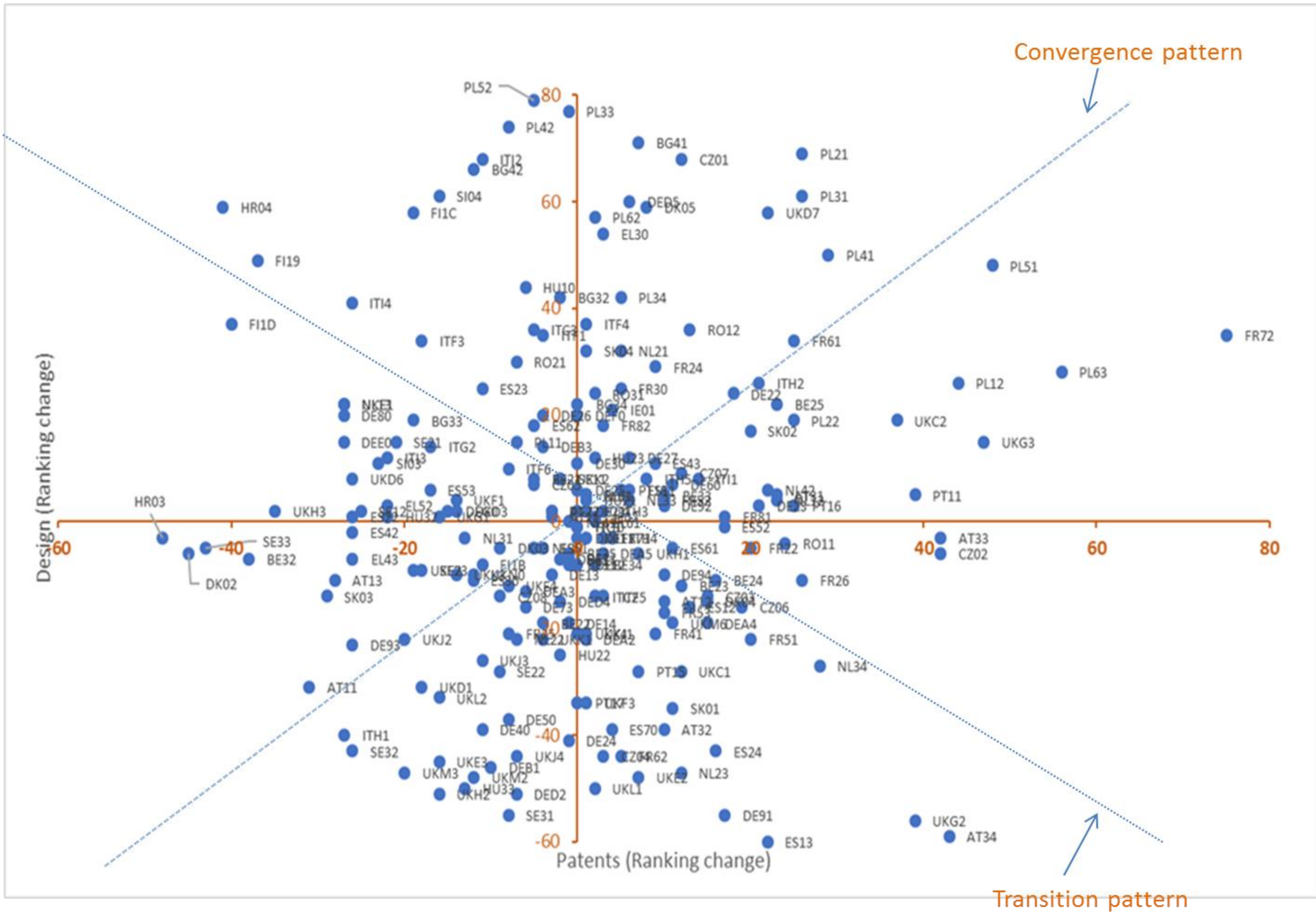


Source: *authors' elaboration on Regpat 2017b and EUIPO data regionalised by the JRC.*

Instead, the "transition pattern" reflects a transition from patents to trademarks or vice versa. Particularly, it reflects a transition from patents to trademarks (north-west) and a transition from trademarks to patents (south-east). Hence, regions in the north-west quadrant have been increasing their relative performance in trademarks while decreasing in patents. Here one can find both regions from EU-15 countries as well as regions from the CEECs. Regions in the south-east quadrant reflect instead an increase of their performance of patents coupled with a decrease in their performance in trademarks. In this quadrant one can find by and large regions belonging to the EU-15 countries.

Figure 5b reports the same chart as for figure 5a, but using design registrations instead of trademarks. As for the chart above, also in this case there are a convergence line and a transition line. The former shows in the north-east quadrant the strong presence of regions from the CEECs, with Poland featuring quite prominently, along some regions from EU-15 countries (mainly UK and France). Also in this case, the south-west quadrant is populated by EU-15 regions. The same holds true for the transition patterns from patents to design (north-west) and from design to patents (south-east), both populated by EU-15 regions

Figure 5b – Ranking change for patent and design in 2007-2016



Source: *authors' elaboration on Regpat 2017b and EUIPO data regionalised by the JRC.*

From the analysis above we can conclude the following. Over the period 2007-2016 there has been a qualitative reshaping in the innovation profiles of European regions. A general trend emerges confirming that many regions from the CEECs have gained in their relative performance across all the three indicators of innovation. This suggests a general trend of the CEECs to improve their innovation activity, both with respect to technological innovation, service innovation and design-driven innovation.

Along with this general convergence trend, another qualitative pattern also appears. There is a considerable number of regions that improved their ranking score in one indicator while decreasing in another. Figure 5a, quadrant north-west, suggests that a process of *servitization* of the economy is affecting also the underlying innovation activities of the regions, which as a result tend to show stronger innovation from knowledge-intensive sector. This process concerns by and large the more advance regions from the EU-15 countries. Figure 5b, south-east quadrant, suggests that several regions are undertaking a technological upgrade of their innovation activity reflected by the increased performance in patents vis-à-vis a relatively worse performance in design. By contrast, the north-west quadrant might suggest a somewhat technological downgrading, as regions in this quadrant are decreasing their technological content of innovation towards higher design-intensive innovation.

4 Resilience and innovation in the Great Depression: econometric evidence

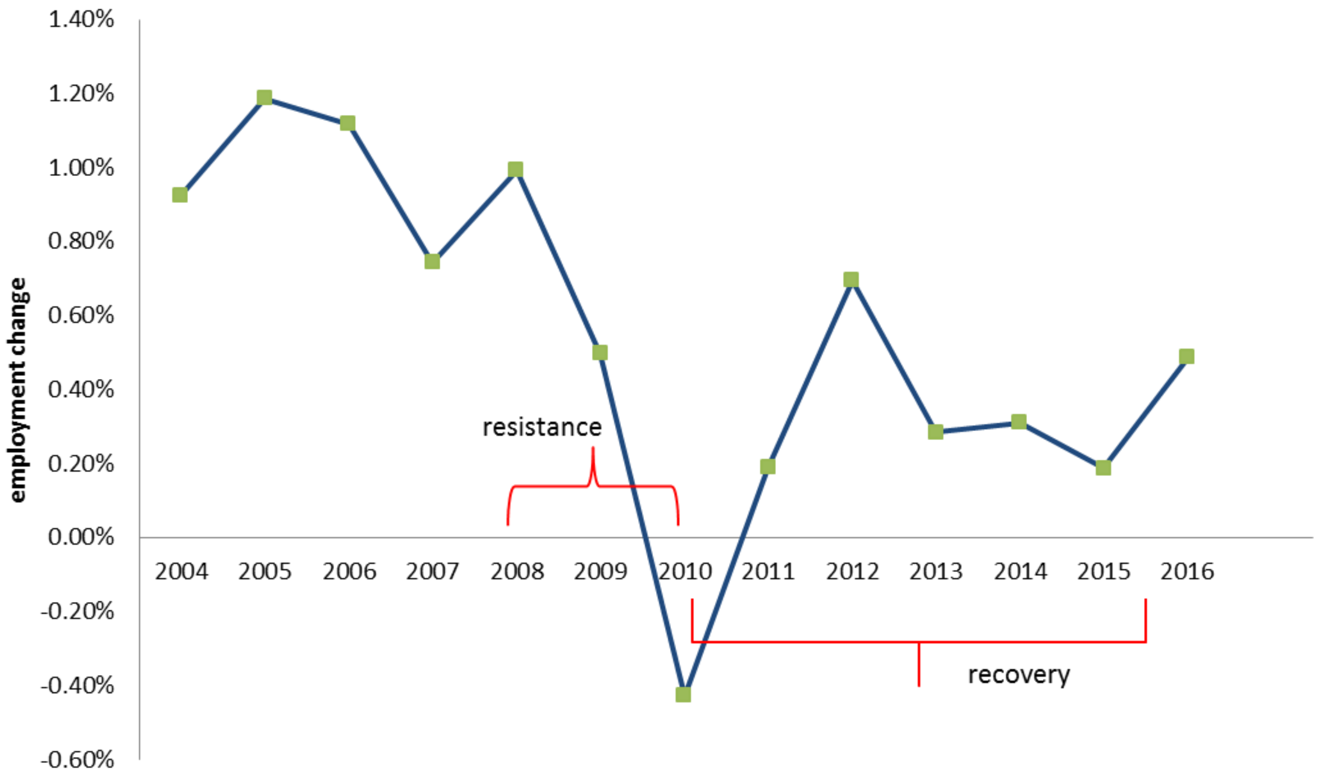
This section presents an econometric exercise to investigate the role of innovation for the economics resilience of regions during and after the 2008 Great Depression, where resilience is considered in terms of employment performance of EU regions. The aim is to answer to the following question:

- Does innovation make a region more resilient?

As said above, we follow Martin (2012) and Faggian et al. (2018) focusing on two dimensions of resilience: 1) The *resistance* of a region *to a shock*, proxied by the sensitivity index; and 2) Its capacity to *recover from a shock*, proxied by the reaction index. Figure 6 shows the impact of the 2008 crisis on the change in the level of employment in the EU (measured in terms of thousands of hours worked). It arises that the major drop in the average level of employment occurred in 2010. Thus the resistance of the region – i.e. its capacity to absorb a shock – is here defined as the relative performance of the regions during the years 2009-2010. Instead, the economic recovery of the region is defined as the relative performance of the region during the years 2010-2016. We are going to focus on the employment performance, rather than gross domestic product, given the greater relevance for policy makers for the former and the relative high unemployment rates in EU compared to other main economic areas (e.g. USA).[12]

[12] By employing the share of employment as a measure of performance in the labour market we are not capturing the increase in the involuntary part-time jobs resulting from the economic crisis. This could overestimate the relative performance of regions in those countries introducing specific legislation, e.g. Germany (Brenke et al., 2013). However, this issue arises at the nation level and in our analysis it should be mitigated by the introduction of country dummies.

Figure 6 - The impact of the 2008 crisis on the change in the level of employment in the EU, thousands of hours worked



Source: *authors' elaboration Eurostat data.*

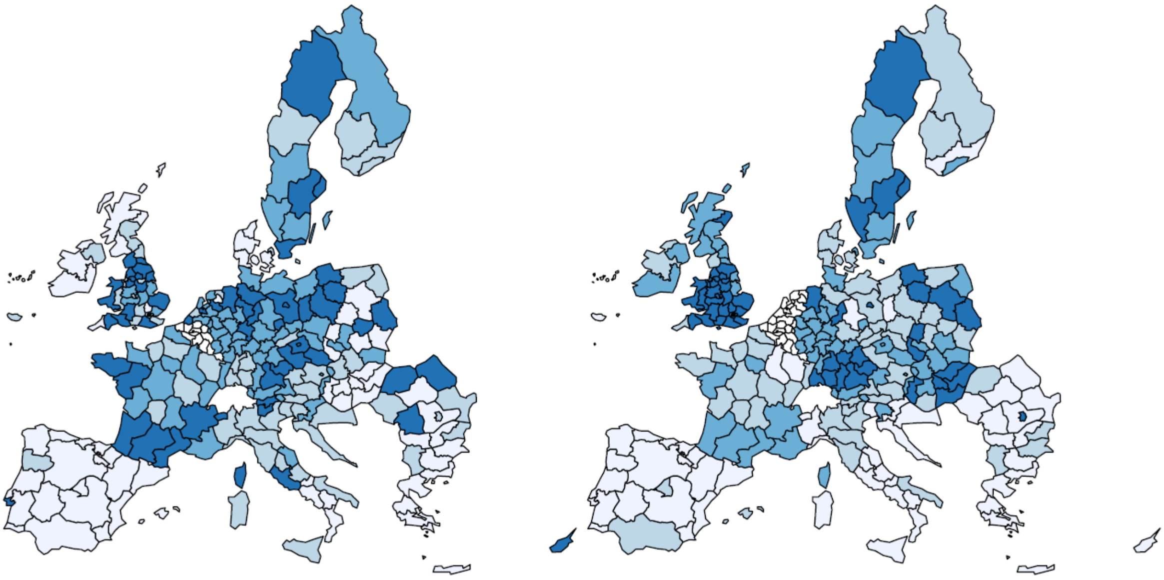
In order to measure resistance and recovery we built two indicators that are commonly employed in studies about resilience (Martin, 2012; Faggian et al., 2018). The first is the so-called *Sensitivity Index (SI)* and it is built as follows:

$$SI = \frac{E_{r,t}}{E_{r,t-1}} \Bigg/ \frac{E_{n,t}}{E_{n,t-1}}$$

Where *E* is the level of employment (measured in terms of hours of time worked) *r* is the region, *t* is 2010, *t-1* is 2008, and *n* is the EU average. The *SI* is thus measuring the relative performance of region *r* compared to the average performance of the EU. This is reflecting the capacity of the region to perform relatively better (or worse) compared to the average EU *during* the economic downturn. Likewise, the *Reaction Index (RI)* is built in the same fashion, but here *t* is 2016 while *t-1* is 2010. Hence, the *RI* measures the pace of economic recovery of region *r* compared to the pace of economic recovery of the EU. This is reflecting the capacity of the region to perform relatively better (or worse) compared to the average EU *after* the downturn.

Figure 7a and figure 7b report the *SI* and the *RI* for the European regions. By looking at resilience (*SI*) one can observe that the more resilient regions tend to concentrate in the continental Europe, plus the UK and Sweden, with some cases of strong resilience also in Eastern countries. Economic recovery (*RI*) provides a similar picture, but with a centre of gravity moved toward the north-est. Summing up, the regions performing relatively worse both during the economic downturn as well as after that are those in the periphery of Europe, especially Southern Europe. Regions in the Eastern countries show a higher capacity of resilience and a greater capacity of recovering in the aftermath of the economic crisis compared to the Southern countries regions.

Figure 7 - SI and the RI for the European regions



Source: *authors' elaboration on Regpat 2018a and EUIPO data regionalised by the JRC.*

In what follows we present some econometric evidence. The aim is to estimate the correlation between innovation, as measured through the three indicators of innovation, and the two indexes illustrated above. In other words, we want to explore whether innovation has helped regions employment performances during and after the recent economic crisis.

Our two dependent variables are the *SI* and the *RI,* while the main explanatory variables are patents per capita, trademarks per capita and design registration per capita. We estimate two cross-section OLS models: in the *SI* model the explanatory variables are referring to 2008, while in the *RI* model the explanatory variables are referring to 2010. We also add other several control variables: *1)* the share of workers in the manufacturing sector to control for the industrial structure (data source: Eurostat); *2)* a dummy variable equal to one is the region belongs to the Eurozone and equal to 0 otherwise; *3)* a dummy variable if the region is the capital region; *4)* the size of the region measured in terms of the population, in log; we finally include a set of country dummy variables to control for country fixed effect (characteristics) that may affect the regions' economic performance.

Table 4 reports the estimate for *SI* and innovation. It shows that innovation is positively associated with the resilience of the region, regarding patents and design, while it is still positive, but weakly statistically significant, the correlation between resilience and trademarks. This suggests that both technological innovation and design-based innovation have helped the region to keep their level of employment during the economic downturn, while this was less the case for KIBS.

Table 4 – SI and innovation, OLS estimates with robust standard errors

	(1) Sensitivity Index	(2) Sensitivity Index	(3) Sensitivity Index	(4) Sensitivity Index
Patents per capita	0.0064** (0.0028)			
Trademarks per capita		0.0060* (0.0036)		
Design per capita			0.0058** (0.0027)	
Innovation blend				0.0067** (0.0026)
Innovation tech				0.0038 (0.0057)
Euro Area	0.0257** (0.0105)	0.0202* (0.0107)	0.0225** (0.0103)	0.0324** (0.0130)
Share of workers in industry	-0.1601** (0.0721)	-0.1150* (0.0654)	-0.1493** (0.0718)	-0.1786** (0.0768)
Capital region	-0.0025 (0.0089)	-0.0018 (0.0094)	-0.0002 (0.0091)	-0.0046 (0.0093)
Population	-0.0031 (0.0028)	-0.0026 (0.0026)	-0.0021 (0.0028)	-0.0033 (0.0027)
Constant	1.0117*** (0.0370)	1.0004*** (0.0369)	1.0051*** (0.0375)	1.0233*** (0.0374)
Country dummies	*Included*	*Included*	*Included*	*Included*
Observations	220	221	221	220
Adjusted R^2	0.528	0.524	0.526	0.531

Note: *Standard errors in parentheses.* * *p < 0.10,* ** *p < 0.05,* *** *p < 0.01*

Table 5 reports the estimate for *RI* and innovation. Here the correlation between innovation and the performance of regions in the aftermath of the crisis is much stronger, and statistically significant for the three indicators of innovation. This suggests that both technological innovation, knowledge-intensive service innovation and design-driven innovation have helped the regional economic recovery after the crisis.

It is worth commenting briefly on the coefficients estimated for the variable "Share of workers in the industry", both in table 4 and table 5. In the former, the coefficient is negative and significant, while in the latter it is not statistically significant. This reveals a negative relation between the share of manufacturing and employment performances during the crisis, but not in its aftermath. The negative sign for the manufacturing sector can be explained by the fact that the most competitive part of it is already captured by the innovation measures included in the regression. Therefore, a tentative interpretation of this finding is that the crisis has hit stronger those regions characterised by more traditional and less competitive manufacturing firms. In a number of cases these firms did not survive the crisis, and thus in general this relationship does not seem to hold true anymore.

Table 5 - RI and innovation, OLS estimates with robust standard errors

	(1) Reaction Index	(2) Reaction Index	(3) Reaction Index	(4) Reaction Index
Patents per capita	0.0158*** (0.0048)			
Trademarks per capita		0.0243*** (0.0049)		
Design per capita			0.0180*** (0.0047)	
Innovation blend				0.0112** (0.0044)
Innovation tech				-0.0174 (0.0121)
Share of workers in industry	-0.1638 (0.1375)	-0.1911 (0.1234)	-0.2364* (0.1426)	-0.1164 (0.1348)
Euro Area	0.0656** (0.0259)	0.0696*** (0.0226)	0.0564*** (0.0183)	0.0619** (0.0280)
Capital region	0.0270* (0.0158)	0.0160 (0.0156)	0.0282* (0.0167)	0.0186 (0.0146)
Population	0.0012 (0.0044)	-0.0004 (0.0045)	0.0034 (0.0039)	0.0025 (0.0038)
Constant	0.9423*** (0.0605)	0.9299*** (0.0620)	0.9304*** (0.0542)	0.9427*** (0.0551)
Country dummies	*Included*	*Included*	*Included*	*Included*
Observations	217	227	227	208
Adjusted R^2	0.643	0.687	0.669	0.662

Note: *Standard errors in parentheses.* * *p < 0.10,* ** *p < 0.05,* *** *p < 0.01*

In order to explore the presence of complementarity between the different types of innovation behind the three indicators, we have performed a principal component analysis (PCA).[13,14] The PCA analysis, employing the three indicators as variables,

[13] Principal component analysis (PCA) is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables (entities each of

identified two principal components see (Table 5), which together account for 91.3 per cent of the total variance. The first component, labelled *innovation blend,* is correlated with all the three variables - patents, trademarks and design - and thus identifies those regions that are characterized by an innovation profile in which the three types of underlying innovation activities coexist (cf. Figure 1 and Table 6). The second component, labelled *innovation tech,* is positively (and highly) correlated only with patents, while it is negatively correlated with trademarks and design registrations. The advantage of relying on the PCA is that it allows considering the relationship between innovation and employment from a broader perspective. Indeed, it allows disentangling those cases in which innovation is focused on technological innovation from cases where regions show a more diversified innovation profile. In particular, the *innovation blend* component provides information on the performance of those regions endowed with both technical and 'softer' types on knowledge. In other words, it provides information of the relative advantages of having a more integrated knowledge base.

Table 6 – Results of the principal components analysis

Component	Proportion	Cumulative		patents	trademarks	design
innovation blend	0.79	0.79		0.56	0.59	0.58
innovation tech	0.12	0.91		0.81	-0.25	-0.54
component 3	0.09	1.00		0.01	0.15	0.10
Unexplained				0.01	0.15	0.10

The Columns 4 of tables 4 and 5 report the estimates in which the two principal components are employed as explanatory variables. In both cases, *innovation blend* is positively correlated with both *SI* and *RI;* conversely, *innovation tech* is positively and negatively correlated with *SI* and *RI* respectively, but the coefficient is not statistically significant.

Summing up, the first and foremost answer to the research question posed above is that innovation did help the regions during and after the recent major 2008 economic downturn, that is the ***most innovative regions have been more resilient***. In the case of the performances of the region *during* the crisis, both technological and design-driven innovation did a good job. As far as the performances of the regions *after* the crisis is concerned, all the three indicators of innovation show a strong positive association. It also arises that in both cases the positive association of innovation is driven by regions in which the three types of innovation coexist, while this is not the case for technology intensive only. This supports the idea of a positive role played by complementarity. Regional innovation systems that performed better are those in which technological specialization coexist with knowledge-intensive sector innovation and design-driven innovation.

which takes on various numerical values) into a set of values of linearly uncorrelated variables called principal components

[14] Note that we could not include the three indicators altogether in the same estimate due to collinearity problems.

5 Discussion and conclusions: is innovation changing across European regions?

This report explores the innovation profiles of the European regions in the period 2007-2016 employing a novel dataset collecting regionalised patents, trademark and design registrations. It has also investigated whether innovation performance improves the resilience of regions over the recent crisis 2008-2010 and in the subsequent period 2010-2016.

The rationale for collecting trademark and design registrations, along with patents, as a measure of innovation is that the former allow for the capture of different forms of innovation compared to the latter. Particularly, trademarks are a better indicator for innovation activity which takes place in the service sector, namely in the knowledge-intensive sector; whereas design registrations capture innovation taking place in less technology-intensive and R&D-based industries, such as furniture and apparel. Taken all together – and despite the limits discussed above – the three indicators offer a more comprehensive map of innovation in the EU. Importantly, they also provide a picture of the heterogeneity of the innovation activity across regions. In fact, patents are very likely to underestimate some forms of hidden or non-R&D-based innovation which are more likely to take place in the less-developed regions.

In addition, providing a comprehensive picture of the different regional innovation systems is informative for S3 strategies emphasizing the need for medium- and less-developed regions to find their own "innovative way". These should not necessarily mimic the more advanced hi-tech regions, but rather rely on their specific innovation profile (often based on low- or medium-tech manufacturing industries).

The analysis illustrated above offers both a static and a dynamic picture of the innovation map of the EU. There is evidence of a division of labour in innovation activities between the most advanced regions from the EU-15 countries on the one hand, and the regions from the Southern Europe and Eastern Europe on the other. An “innovation core” of Europe emerges going from the North of Italy, throughout the manufacturing regions of Germany, reaching Denmark and the south of Sweden and Finland in the north; this also includes some regions of France and the south of the UK. This core features prominently in patents, trademarks and design. This evidence suggests the presence of a high-tech specialization in the manufacturing sector coupled with the presence of a strong knowledge-intensive sector that may play a complementary role to the former.

By contrast, both eastern and southern European regions are weak concerning technological innovation, but they tend to score better when trademarks and design registrations are considered. This suggests a relative importance of innovation in the service sector, along with innovation activity in the low-tech and medium-tech manufacturing sector.

Overall, a convergence pattern seems to arise when looking at the *change in innovation measures* over the period 2007-2016. This is particularly true regarding trademarks and design, where regions from eastern countries systematically show high performance, along with regions from the south of Italy. As far as technological innovation is concerned, one can also observe faster rates of change in several eastern regions, although the picture is less systematic. The picture is also much scattered regarding regions from southern countries (i.e. Italy, Greece, Spain and

Portugal): no clear pattern of overall convergence emerges, apart from the case of Portugal.

Thus, when looking at the dynamic picture, a great dynamism for trademarks and design emerges for less-advanced regions, while a more scattered picture emerges for patents. This is also reflected by the fact that while patents have become more concentrated among the ten highest innovators in Europe from 2007 to 2016, both trademarks and design registrations are instead less concentrated. This may be due to the fact that less-advanced regions are *discovering* their proper innovation patterns based on less R&D-intensive industry specialization (e.g. furniture) or services (e.g. tourism).

The report also investigates to what extent innovation contributes in making European regions more resilient to shocks by looking at the role of innovation on the regional employment performance during the 2009-2010 economic downturn (resistance), and their capacity to recovery in the aftermath of the crisis during the 2010-2016 period (reaction). The results show the lack of clear-cut geographical patterns of both resistance and reaction, apart from a generalised lack in the capacity of reaction in the regions from the south of Europe.

Innovation did help to sustain employment both during the economic downturn as well as in the aftermath. In particular, the most resilient regions are those that have a strong performance in patents, trademarks and design. This suggests some degree of comparative advantages for those regional innovation systems which couple technology-intensive innovation in manufacturing with a strong service-intensive sector.

The building of a European System of Innovation is a fundamental priority to reach the Lisbon targets, as restated later on in Barcelona. The existence of major technological gaps within Europe has traditionally been recognized as constraining the building of a European System of Innovation. Enlargement has led to a more heterogeneous EU in terms of innovation capabilities and technological development. International economic integration, through international trade and global value chains, may have opposite effects on the distribution of innovative activities. One the one hand, economic, social and political integration helps to disseminate best-practice technologies and the diffusion of expertise. On the other hand, the strongest regions will attract the most knowledge-intensive economic activities, providing job opportunities to the best talents. Eventually, backward areas will find themselves confined in an economic specialization in the low-technology industries and with decreasing returns, while the most developed areas will further reinforce their leadership.

It is possibly too soon to fully understand the impact of the crisis on the innovation landscape of Europe. However, from the evidence reported above one can conclude that as far as innovation is concerned, **European regions can no longer be divided into two major groups, namely the advanced regions in the West and the lagging-behind regions in the East.**

One the one hand, there is a group of regions in Eastern countries that is consistently improving its innovation performance. This is possibly the result of three non-mutually excluding factors: 1) the presence of agglomeration economies in the capital cities; 2) the concentration of local capabilities; and 3) the role played by foreign affiliates, as in the case of the German and American large corporations in several Eastern regions (Hernández et al., 2018). On the other hand, growing disparities arise *within EU-15 countries*. Only the most advanced regions in the South of Europe are able to join the “innovation core” of Europe, namely the Northern regions of Italy, the regions of Madrid and Barcelona in Spain, and a few regions in France. By contrast, the remaining regions are lagging behind, a finding that is consistent with recent analysis (Evangelista et al., 2016; Iammarino et al., 2017).

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