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THE KNOWLEDGE REGIONS IN THE ENLARGED EUROPE

Alessandra Colombelli, Marta Foddi, Raffaele Paci

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CRENoS – CAGLIARI
VIA SAN GIORGIO 12, I-09100 CAGLIARI, ITALIA
TEL. +39-070-6756406; FAX +39-070- 6756402

CRENoS - SASSARI
VIA TORRE TONDA 34, I-07100 SASSARI, ITALIA
TEL. +39-079-2017301; FAX +39-079-2017312

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Via Is Mirrionis, 1
09123 Cagliari
Tel./Fax 070 291201
www.cuec.it

The knowledge regions in the enlarged Europe

Alessandra Colombelli, Marta Foddi, Raffaele Paci

University of Cagliari, CRENoS

Since the Lisbon agenda in 2000, Europe stated the goal to become the most advanced knowledge economy in the world relying specifically on the increase and strengthen of its human capital and technological endowments. However, given the presence of localized externalities in the knowledge accumulation process, this policy may produce distortive and unwanted consequences at the territorial level reinforcing the existing high inequalities among regions. Another crucial feature to be considered is the recent enlargement process of the European Union which has brought on stage new players characterized by a low average level of knowledge activity accompanied by a huge degree of internal territorial disparity.

The aim of this paper is to identify the "knowledge regions" in Europe and to examine their main territorial features. To this aim we first build, for 287 regions belonging to 31 European countries, a comprehensive picture of the two variables - human capital and technological activity - which constitute the main pillars of the knowledge economy. We compute two synthetic indicators for human capital and technology and, on the basis of these two dimensions, we identify 74 knowledge regions, mainly located in the centre and north of Europe. This results are confirmed by a cluster analysis.

Keywords: knowledge, human capital, technological activity, regions, Europe

JEL: R11, O30, J24, O52

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1. Introduction

Since the Lisbon agenda in 2000, Europe stated the goal to become the most advanced knowledge economy in the world relying specifically on the increase and strengthen of its human capital and technological endowments. This strategy is in line with the economic literature that has widely proved the positive impact of knowledge, embedded in both human and technological capital, on economic growth and productivity. However, the recent enlargement process of the European Union, which has brought on stage new players characterized by a low average level of knowledge activity accompanied by a huge degree of internal territorial disparity, raises the question of how to reduce high inequalities among regions. Economic geography has indeed shown that, as a result of knowledge cumulability and learning processes, unequal levels of economic growth across regions may emerge. Due to increasing returns to knowledge, if one region gets ahead by chance in the innovation process it tends to stay ahead and even increases its lead (Arthur, 1994). In this line of reasoning, a knowledge economy can have disequilibriating effects.

In order to cope with this problem, policies seeking to ease the process of integration and cohesion, on the one hand, and to expand the opportunities for innovation, on the other hand, are concerned about the process of knowledge generation, diffusion and absorption. This is in line with the economic literature showing that knowledge spillovers are localised and mainly occur between neighbouring regions as a result of spatial decay effects. Knowledge spillovers, in turn, have a positive impact on the growth and productivity of neighbouring regions. However, the magnitude of this effect depends on the receiver's capacity to absorb knowledge spilling over from other regions (Cohen and Levinthal, 1990). As recent empirical literature in the area of regional economics have proved, regions with a larger stock of knowledge are more able to absorb new knowledge with respect to regions that do not perform any knowledge generating activity (Maurseth and Verspagen, 2002).

Following these arguments it seem relevant to propose a classification based on the region's knowledge endowment able to identify the "knowledge regions" in Europe and to examine their main territorial features. More precisely, we aim at identifying different typologies of regions in enlarged Europe including knowledge regions, human capital intensive regions, research intensive regions and regions with no specialization in knowledge activities. Mapping the geographical distribution of knowledge in enlarged Europe is useful from a policy perspective. In this line of reasoning with strands of both the theoretical and empirical literature we propose a workable definition of knowledge regions which is based on the two main pillars of the knowledge economy: human capital and technological activities. The rationale behind this choice is clearly shown by the literature: these two elements, which represent a complex and multifaceted process composed by input and output elements, are able to capture either the creation of new knowledge within the region and also the capacity of the local firms to absorb knowledge spilling from the internal and external economies.

In this paper we will identify knowledge regions under the two main perspectives of technological activities and human capital. We thus aim at selecting regions above the EU average in terms of specialisation on both dimensions. This will allow us at developing a synthetic indicator that provide, first, a unique classification of European regions and, second, the rankings of regions according to their knowledge innovative performance. Moreover, as a robustness check of the previous taxonomy, we perform a cluster analysis based on several indicators of human capital and technology.

Our contribution is based on a broad dataset which includes 287 NUTS2 regions belonging to EU27 countries and the 4 Efta countries (Iceland, Liechtenstein, Norway and Switzerland). The different knowledge indicators for human capital and research activities used to identify knowledge regions are described in Appendix 1. The number of regions for each country is presented in Appendix 2.

The remainder of the paper is organized as follows. Starting with a brief overview of the literature, section 2 defines the conceptual framework of our empirical analysis. Human capital and technological indicators are presented, respectively, in section 3 and 4. Section 5 presents and discusses the identification of knowledge regions. Section 6 presents the cluster analysis. Section 7 concludes with some general remarks on the main findings and on their possible policy implications.

2. A brief survey of the literature

It is widely recognised that knowledge is crucial for economic growth. Since the endogenous growth theory development, economic geography and regional economics have focused on the spatial dimension of this phenomenon and have demonstrated that barriers to the diffusion and absorption of knowledge, in turn leading to differences in the stock of knowledge, can explain the differential growth rates among regions. The debate on the spatial dimension of knowledge diffusion has evolved through different steps based on the different characteristics assigned to knowledge through time (see Döring and Schnellenbach, 2006; Antonelli, 2008; Camagni and Capello, 2009). Based on the works by Arrow (1962) and Nelson (1959), knowledge has firstly been regarded as a public good. The basic idea behind this assumption is that knowledge may spill over instantaneously through the whole economy and it is freely available to individuals;

as such, it cannot be the source of differences in regional productivity. Subsequently, knowledge has been considered as a quasi-proprietary good (Nelson and Winter, 1982). In this view, a fraction of the knowledge created and accumulated by individuals within firms can be appropriated and protected. From this perspective knowledge can diffuse but only to a limited extent. In particular, it has a limited spatial range. This is particularly true in the case of tacit knowledge, while codified knowledge can diffuse also over great distances. Finally, the literature has shifted towards the concept of knowledge as a collective process. This approach focuses on external knowledge, generated by interactions among the diverse economic agents (Griliches, 1992; David, 1993; Cooke, 2002). Interrelation and local networks among economic agents are now considered vital for the generation, diffusion and absorption of new knowledge. Knowledge can indeed be transferred and disseminated among different actors in the economic system. The spillovers of knowledge generate positive externalities by stimulating innovation activities and productivity.

The existence of barriers to the diffusion of knowledge, which depend on knowledge accumulated in the past and on the absorptive capacity of regions, has emphasized the importance of investments in research activities and human capital formation. Thus, research activities and human capital - the two main pillars at the base of the knowledge regions definition – have become the object of flourishing strands of the literature at the regional level.

As far as the first pillar of our approach is concerned, the appreciation of the role of knowledge spillovers and knowledge externalities in the area of regional science has emphasized the importance of advanced functions like research efforts (R&D expenditure, patenting activities) for the regional economic development. Indeed, the innovation process requires exploring activities that denotes a deliberate and active effort to search for new technical and organizational solutions, new products and processes. The main economic agents involved in this process are R&D professional laboratories in private firms, and research institutes and universities in the public domain. In this line of thought, institutional approaches in regional economics have been developed and regions hosting large and well-known scientific institutions have become the object of this new field of enquiry. In this area, concepts like Regional Innovation Systems (RIS) (Cooke et al. 1997, Braczyk et al. 1998) and Triple Helix (TH) (Etzkowitz and Leydesdorff, 1997, 2000) emphasize the active role of territorial actors within regional development dynamics and give relevance to the institutional foundations of regions' competitive advantage in the areas of education and research and development. These institutional approaches argue that differences in economic behaviours and outcomes are primarily related to differences in institutions (Hodgson, 1988, 1998; Whitley, 1992, 2003; Saxenian, 1994; Gertler, 1997).

Many empirical works have analysed regional differences in the distribution of research and innovative activities and have investigated the process of knowledge creation and diffusion within and across regions. These empirical studies are based on innovation input and output indicators like R&D expenditure, patents statistics and innovation counts. A first strand of the literature has focused on pure knowledge spillovers and proved that they are geographically bounded (Audretsch and Feldman, 1996; Baptista and Swann, 1998; Acs et al., 2002). In this line of research, a number of empirical contributions have investigated the role of universities in the process of knowledge spillovers (Jaffe, 1989; Anselin, 1997; Audretsch and Feldman, 1996) and found strong evidence in favour of a significant positive correlation between firms' concentration and university location (Varga, 2000; Audretsch and Lehmann, 2005). A second strand of the literature have attempted to investigate the main general mechanisms of the process of creation and diffusion of inventive knowledge rather than just looking for localized knowledge spillovers. Such studies have been applied to the US case (Varga et al., 2005; Carlino et al., 2007) as well as those of Europe (Bottazzi and Peri, 2003; Greunz, 2003; Moreno et al., 2005; Rodriguez-Pose and Crescenzi, 2008; Tappeiner et al., 2008; Acosta et al., 2009; Marrocu et al, 2011) and OECD countries (1, 2010). All in all, these contributions find that technological spillovers, both pure and pecuniary, may exist within and across regions and have shed light on the role of geographical distance in the economics of knowledge transmission. Moreover, this strand of the literature has suggested that knowledge spillovers may be also affected by cognitive, social, organizational, and institutional distance, as suggested by Torre and Rallett (2005) and Boschma (2005). A further set of empirical literature has addressed the issue of distinguish between Marshallian externalities and Jacobian externalities and has focused on the regional differences in the patterns of specialisation and diversification of innovation. While Feldman and Audretsch (1999) find that there is no evidence of specialization externalities, whilst diversity externalities are at work in the case of US metropolitan areas, these results have been somewhat disputed by several analyses based on European data (for example, Paci and Usai, 1999, 2000; Massard and Riou, 2002; Greunz, 2003; and Moreno et al., 2006), suggesting a notable difference in the functioning of the local innovation systems in the United States and Europe.

As far as the second pillar is concerned, since Solow's (1957) contribution the literature has emphasized the positive role of human capital on productivity level and growth. Two main approaches have been applied. The first approach was developed by Mankiw et al. (1992) that extended the Solow growth model by explicitly introducing human capital as an ordinary input in the production function. An alternative approach was introduced by the endogenous growth models (Lucas, 1988; Romer, 1989) that directly related human capital to the adoption of technology and underlined the positive interaction between knowledge, capabilities and innovative ability. On a parallel ground, the seminal paper by Cohen and Levinthal (1990) on the firm's absorptive capacity gave rise to a strand of the literature aimed at understanding key characteristics of firms, regions and countries that make it easier to understand and absorb external knowledge in an economically efficient manner. In this line of reasoning, human capital is not just a precondition for enhancing the growth capabilities of regions or countries, but rather provides the stock of accumulated knowledge that allow a region to identify and utilize proper knowledge from outside.

A recent and wide body of empirical literature have been developed in order to verify these theoretical predictions at the regional level of analysis. For example, Rauch (1993) find that at the regional level a higher availability of well educated labour forces represents an advantage for the localization of innovative firms thus promoting local productivity. Bronzini and Piselli (2009) assess the role of the technological knowledge, as measured by the stock of R&D capital, the human capital, and the stock of public infrastructure, in enhancing the levels of Total Factor Productivity (TFP) of Italian regions over the period 1980-2001. They shows that there exists a long-run equilibrium between productivity level and the three kinds of capital; among them, human capital turns out to have the strongest impact on productivity. Dettori et al. (2011) investigate for a sample of 199 European regions over the period 1985-2006 provide robust evidence on the role played by intangible factors like human capital, social capital and technological capital on the TFP levels thus enhancing economic efficiency and social cohesion. Abreu et al. (2008), using UK firm-level data, investigate the impact of absorptive capacity at the firm-level on the regional variations in innovation performance showing that innovation to be effective requires an appropriate endowments of human capital.

3. Human capital indicators

As previously said in the Introduction, we describe human capital in a region by means of both input and output indicators. As input indicator we use the percentage of population employed in the education sector assumed as a proxy of the regional effort to create and promote new knowledge and human capital activities. As output indicator, we use the share of population that has attained at least a university degree. Furthermore, we include funding per capita in the activities of the 5th Framework Programmes as a proxy for the quality of the human capital and technological activities conducted in the region and the diffusion of knowledge through cooperation. For each indicator we present average values, coefficient of variation, Moran index values and a map showing the spatial distribution of values. In the statistical description of indicators, we use two different regions' classifications: the first one is "political", classifying a region with respect to the country of membership, and the second classification is based on the eligible areas under the Convergence Objective and the European Competitiveness and Employment Objective (Cohesion Policy 2007–2013) .

Table 1 presents average values for the human capital indicators. If we consider the whole sample of regions, we observe that on average the 3.24% of population is employed in the education sector while the highest average value is presented by regions belonging to Efta countries (4.27%) and competitive regions (3.37%). Lower values are shown by transition regions (3.10%), convergence regions (2.84%) and regions belonging to New Entrants countries (2.87%). For what concerns the percentage of population that has attained a university degree, the average value for the whole sample is equal to 12.37% and as for the previous variable, the highest average value is presented by regions that belong to the Efta countries (16.41%), followed by the competitive regions (13.61%) and regions that belong to the EU 15 countries (12.88%). In the case of variable that proxies the quality of the human capital and research activities conducted in the region and the diffusion of knowledge through cooperation, measured by 5th FP funding per 1000 population, on average regions receive 22.27 thousands euro for 1000 population and Competitive regions, regions belonging to Efta countries and EU 15 countries show the highest average values (respectively 29, 47.9 and 24.31 thousands euro per 1000 population) while lowest average values are shown by convergence regions and regions belonging to New Entrants countries (respectively 6.94 and 7.13 thousands euro per 1000 population).

In table 2 we can observe the coefficient of variation values, a measure of the dispersion of data around the mean. In the case of the percentage of employees in the education sector, the range of variation is small in absolute terms and it can be seen by the coefficient of variation value equal to 0.26. In the case of tertiary education, it is equal to 0.36, slightly higher than for the previous variable. Higher than for the previous variables and equal to 1.19 for 5th FP funding, stressing greater distance between low and high values.

The Moran Index presented in table 3 shows strong evidence of geographical pattern of the values distribution and the presence of spatial association for the whole sample of indicators.

The spatial distribution of values for employees in the education sector can be observed in figure 1. As the figure clearly shows, regions characterized by the highest values are concentrated in the northern countries: Iceland, United Kingdom, Sweden, Norway and Denmark. The first highest class includes also 2 Belgian regions (Prov. Brabant Wallon and Prov. Namur) and a Dutch region (Utrecht) where important universities are located and this is true also for the two British regions like Oxfordshire and Essex. Moreover, most of the Swiss regions are also included in the top class together with few regions belonging to New Entrants countries: Estonia, Lithuania, Zahodna Slovenija (Slovenia) and Bratislavský kraj (Slovakia). The sample of regions included in the second and third class are less geographically concentrated. Finally, the lowest values class includes regions belonging mainly to central and southern countries. Countries more represented are Austria, Germany, Spain, France, Greece, Italy and Romania.

Looking at the map for tertiary education (figure 2), it appears a well defined geographical pattern of the values distribution and the presence of spatial association of the values is confirmed by the Moran Index value (0.144) that is highly statistically significant. As for the previous map, regions that show highest values are mainly concentrated on the northern countries but there are some exceptions, for instance Spanish northern regions, Swiss regions, Bulgarian regions, Cyprus. It is interesting to notice that in the top class there are several capital cities like the regions where Brussels, Sofia, Madrid, Paris, London, Stockholm, Helsinki, Amsterdam, Praha are located. In the second and third highest classes, ranging between 16% and 11%, there are again regions belonging to northern countries like Belgium, Switzerland, Germany, almost all Danish regions, Spain, France, Iceland, Netherlands, Norway, Sweden and UK. But also some important administrative regions belonging to New Entrants countries are included, for instance Közép Magyarország where Budapest is located, Lithuania, Latvia and regions there Warsaw and Bucharest are located. In the lowest 2 classes, where the percentage of graduates is lower than 10.66%, it is important to stress that 71 out 113 regions belong to EU 15 countries. Examples are Portuguese regions, the whole sample of Italian regions, almost all Greek regions but also most of French regions, Austrian regions and finally some German regions. Furthermore, most part of regions included in the lowest two classes are convergence regions and in fact the subsample showing the lowest average value is this group with a percentage of graduates equal to 9.21%.

Figure 3 shows the spatial distribution of values for the variable which proxies the quality of the human capital and research activities conducted in the region and the diffusion of knowledge through cooperation: the involvement of each region in the activities of the 5th Framework Programmes, measured by funding per 1000 population. Again, regions characterized by the highest values are mainly localized on the northern and central territories. In the highest 2 classes, ranging between 207 and 18 thousands of euro per 1000 population, are included regions that belong to Austria, Belgium, Switzerland, Germany, Denmark, Finland, France, Iceland, Liechtenstein, Luxemburg, Netherland, Norway, Sweden, and United Kingdom. Furthermore within these samples are also included southern, eastern and western regions where the most important administrative cities are located and most of them are characterized by a high population density. For instance Praha in Czech Republic, Estonia, Spanish regions including the Madrid region, the Hungarian region of Közép Magyarország where Budapest is located, the most important Italian regions. Among dark red coloured regions there are also almost all Greek regions. Regions included in the third and fourth class, ranging between 13.67 and 7.94 thousands of euro, are not so spatially concentrated as regions in the first two classes. However, we can see that they mainly belong to EU 15 countries and most part of them are competitive regions. A difference between the previous subsample is that most part of them are rural regions, where the population density is lower. Among regions included in the lowest class, most part of them belong to New Entrants countries and are convergence regions: Czech Republic, Bulgaria, Ceska republic, Poland, Romania and Slovakia but also an Austrian region, regions from Germany, from Spain, from France, from Greece, from Italy, from Netherlands, from Norway and a UK region. Summing up, again the map reveals a spatial concentration of high and low values that is confirmed by the Moran index (0.065), highly statistically significant.

4. Technological indicators

In this section we present the level of technological activities measured by means of both input and output indicators. As an input variable, we employ R&D expenditures (Millions of Euro) per 1000 population and the percentage of employees in R&D over total employment. To measure the inventive activities we rely upon patent counts including two complementary measures: the total number of patents released in a region in all economic sectors and the number of patents for the subsample of high-tech sectors. These output indicators are expected to measure the value resulting from technological knowledge generated by firms and can be used as a proxy for research and development effectiveness.

Similarly to what we did for the human capital indicators, the first table for the technological indicators (table 4) presents average values for different samples of regions. The whole sample average for R&D expenditure is equal to 0.44 millions of euro (per 1000 population). The average value for competitive regions and regions that belong to Efta countries is again higher than the same value for convergence and transition regions and regions that belong to New Entrants countries (respectively 0.60, 1.09 and 0.09, 0.18 and 0.07 millions of euro per 1000 population). In the case of the second research activity input variable, that is the percentage of employees in the R&D sectors over total employment, by considering the whole sample of European regions, on average the 0.65% of employees works in the R&D sectors. As for the previous variables the highest average value is shown by regions belonging to Efta countries and competitive regions (respectively 2.35% and 1.76%). Lowest average value is presented by regions belonging to New Entrants countries (0.86%). For what concerns the technological output variables, we consider the number of patents for all sectors and for the high-tech sectors per million population. For the first variable, the whole sample average value is equal to 103.2 patents. Higher values are shown by regions belonging to Efta countries (210.6), EU 15 countries (120.2) and competitive regions (153.1). The lowest average value is observed for regions belonging to New Entrants countries (7.2). In the case of patents for high-tech sectors, the ranking for the sample of regions is not the same: the highest average value is shown by competitive regions (20.4) patents per million population), followed by regions belonging to Efta countries (18.61). Average values lower than the whole sample average, equal to 13.12, are observed for regions belonging to New Entrants countries (0.85), convergence and transition regions (respectively 1.52 and 3.46).

Table 5 presents the coefficient of variation values. If we consider the whole sample values, we can observe that the highest value is shown by the measure for high-tech patents, stressing large differences within the distribution that emerge also in the previous table. Furthermore if we look at each single indicator, for all the different samples of regions, high-tech patents show the highest coefficient of variation and that's indicates great heterogeneity of distribution values.

The Moran index shown in Table 6 confirms the strong geographical pattern also for technological indicators that can be better observed in the maps (from figure 4 to figure 7).

In the case of R&D expenditure (Millions of euro) per thousand population (figure 4), the geographical pattern of values distribution clearly emerges: dark red colored regions are concentrated on the Scandinavian regions, southern UK regions and territories located on the centre of Europe. More specifically, regions belonging to the highest 2 classes, ranging between 2.63 and 0.39 millions of euro per 1000 population, mainly belong to EU15 countries and Efta countries. Furthermore, most of them are competitive regions. Also regions included in the third and fourth classes mainly belong to countries located in the north and centre but there are some exceptions like Czech Republic regions, Estonia, Spanish regions, Greek regions, an Hungarian region, Italian regions, Lithuania, Malta, Poland and a Romanian regions, Portuguese regions, Slovenian and a Slovak regions. Most part of regions included in the lowest class, ranging between 0.06 and 0.002 millions of euro per 1000 population, are strongly concentrated on the eastern territories. Mainly they are convergence regions and belong to New Entrants countries. Examples are Bulgarian regions, a region of the Czech Republic, Hungarian regions, Latvia, Polish regions, Romanian regions, Slovak regions. Among them, there are also overseas territories (i.e. Spanish Ciudad Autónoma de Ceuta and Ciudad Autónoma de Melilla), islands and peripheral territories characterized by other specialization than research activity (i.e. the French Corse, Greek regions, the Portuguese Algarve and the UK Cornwall and Isles of Scilly). Most part of them are also defined as rural territories.

Figure 5 shows the spatial distribution of values for the percentage of R&D personnel over total employment. The map shows a less marked spatial pattern than for the previous indicators. Although regions belonging to the lowest classes are mainly localized on the eastern part of the continent, there are some light yellow territory also on the north, for example UK regions, Dutch regions and German regions. The highest 2 classes include mainly competitive regions and regions that belong to the EU 15 countries. A large number are also regions with high population density. In this subsample there are regions belonging to Austria, Belgium, Switzerland, Czech Republic, Germany, Denmark, Spain, Finland, France, Greece, Hungary, Ireland, Iceland, Italy, Luxemburg, Netherlands, Norway, Poland, Portugal and Romania, Sweden, Slovenia, Slovakia, United Kingdom.

In figures 6 and 7 we can observe variables maps' used to measure the inventive activities. As described previously, we rely upon patent counts including two complementary measures: the total number of per capita patents released in the region in all economic sectors (figure 6) and the number of per capita patents for the subsample of high-tech sectors (figure 7). Figure 6 represents the spatial distribution of the number of patents per 1000 population (average 2005-2006). This high spatial concentration, with respect to the previous maps, is confirmed also by the visual inspection of the map which reveals a well defined territorial pattern. Regions in the highest classes are highly concentrated in the central territories. By moving towards peripheral areas, colours are lighter. If we look at the composition of the highest two classes (ranging between 0.728 and 0.089), we can observe territories belonging to Austria, Belgium, Switzerland, Denmark, Spain, Finland, France, Italy, Luxemburg, Netherlands, Norway, Sweden, United Kingdom and above all Germany with most part of its regions. Notice that among them there are only 2 transition regions and 2 convergence regions. There are no regions belonging to New Entrants countries. If we distinguish among rural, urban, agglomerated regions and regions where huge cities are located, a large number of territories included in the first two classes are urban regions. If we focus on regions included in the third e fourth class, ranging between 0.089 and 0.005, they belong to Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Germany, Estonia, Spain, Finland, France, Greece, Hungary, Ireland, Italy, Latvia, Malta, Netherlands, Norway, Poland, Portugal, Romania, Sweden, Slovenia, Slovakia and UK. The lowest class includes mainly convergence and rural regions. These territories are located above all on the eastern part of Europe and belong to Bulgaria, Spain, France (3 out of 26 that are the overseas territories), Greece, Hungary, Lichtenstein and Lithuania, Poland, Portugal, Romania and Slovakia.

In figure 7 we can observe the map of the variable related to the number of high-technology fields patents per million population. As the map shows, the spatial distribution of values is very similar to that observed for the previous variable. Highest values are concentrated on the North and Centre of the continent. Regions included in the two highest classes, ranging between 181.51 and 6.74, are mainly competitive regions, that belong to EU 15 and Efta countries. Furthermore, they are urban regions and belong to Austria, Belgium, Switzerland, Germany, Denmark, Spain, Finland, France, Ireland, Italy, Luxemburg, Netherland, Norway, Sweden and United Kingdom. Regions included in the third and fourth class, ranging between 6.74 and 0.45, are mainly rural areas that are not geographically concentrated. Conversely, regions included in lowest class, ranging between 2.71 and 0, are mainly concentrated in the eastern countries like Bulgaria, Czech Republic, Greece, Hungary, Lithuania, Poland, Romania and Slovakia. There are also some exceptions as Spain regions including overseas territories, the French Guyane, Iceland, the Italian Calabria, Liechtenstein, Nord Norge that belongs to Norway and Portuguese regions.

5. The knowledge regions in Europe

The aim of this section is to identify the subsample of knowledge regions under the two main perspectives of research activities and human capital. We thus aim at selecting those regions which exhibit a value above the European average in terms of specialisation on both dimensions. This will allow us at developing a synthetic indicator that provide, first, a unique classification of European regions and, second, the rankings of the regions according to their scientific innovative performance.

As described in the previous sections, we measure the level of human capital stock in a region by means of the following indicators:

1. the percentage of population employed in the education sector
2. the share of population that has attained at least a university degree
3. funding per capita in the activities of the 5th Framework Programme

Similarly, the level of research activities is measured by:

1. the R&D expenditures per capita
2. the percentage of employees in R&D
3. the number of patent per capita for all economic sectors
4. the number of patent per capita for the subsample of high-tech sectors.

We develop two synthetic measures by standardizing all simple indicators around the European average imposed equal to zero and by constraining the distribution within the range -1 and 1. Following the methodology used in the Community Innovation Scoreboard, re-scaled values are calculated by first subtracting the minimum sample value and then dividing by the difference between the maximum and minimum value. The maximum re-scaled value is thus equal to 1 and the minimum re-scaled score is equal to -1. For positive and negative outliers and small countries where the value of the relative value is above the maximum score or below the minimum score, the re-scaled value is thus set equal to 1 (respectively -1).[1] In this way we have no longer the problem of different unit of measurement (and this allows us to add the various indicators) and we solve the problem of outliers. We construct the two synthetic measures by imposing the same weight to each simple indicator: 1/3 for each human capital indicator and 1/4 for each research activity indicator[2].

We detect Knowledge regions as a subsample of the total number of European regions showing for both indicators values greater than zero. Regions showing values greater than zero for human capital indicator but less than zero for research activity are labelled Human capital intensive regions. On the contrary, regions characterized by values greater than zero for research activity and less than zero for the human capital indicator are indicated as Research intensive regions. Finally, regions showing values less than zero for both indicators are defined as Regions with no specialisations in knowledge activities.

In figure 8 we present the scatter of regions with respect the two dimensions of human capital and research activity. We can observe 74 Knowledge regions, 30 Research Intensive regions and 52 Human capital Intensive regions. But most of regions, 126, are concentrated on the third quadrant where we identify regions with no specialisation in knowledge activities.

In order to classify territories with respect to a single dimension, we build a synthetic indicator as the sum of the human capital and research activity composite indicators. In table 8 we can observe the ranking for the 74 Knowledge Regions related the value of this synthetic indicator, that is shown in the third and sixth column. On the top ten positions there are respectively Hovedstaden (Denmark), Stockholm (Sweden), Oslo og Akershus (Normay), Zurich (Switzerland), Noord Brabant (Netherlands), Trøndelag (Norway), Etelä Suomi (Finland), Sydsverige (Sweden) and finally Brabant Wallon (Belgium). As we can observe, Scandinavian countries are largely represented in the highest part of the ranking and if we look at the whole sample of Knowledge

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[1] Re-scaled value = $[(xi)- \min(x_{1-n})]/(\max(x_{1-n})-\min(x_{1-n}))$. For more info see "European Innovation Scoreboard 2009"
[2] Since the choice of the weights is arbitrary, we have done extensive simulations with different weights structures, but the classification of the knowledge regions remains quite stable. Therefore we have preferred to adopt a distribution with equal weights.

Regions we can observe that most of regions that make up these countries are indicated: for Denmark 3 out of 5, for Finland 4 out of 5, for Norway 4 out of 7 and for Sweden 5 out of 8. Furthermore notice that all the Swiss regions and most part of Belgian regions are listed. Among Knowledge regions there are also 12 (out of 39) German regions, 6 regions belonging to Netherlands and 14 (out of 37) British regions. Moreover there are regions where important administrative towns are located: the Wien region for Austria, Praha for Czech republic, Madrid and Paris regions. Italian regions are not represented in this group. We can also observe that Knowledge regions are above all regions belonging to EU15 countries and Efta countries, as we could expect. But we also notice the absence of Italian regions and some territory belonging to New Entrants countries: Praha (Czech republic), Zahodna Slovenija (Slovenia) and Bratislavský kraj (Slovakia) .

Figure 9 shows the spatial distributions of the four categories of regions and we can observe that Knowledge regions are concentrated on the centre and on the north of Europe. Regions with no specialization in knowledge activities are mainly located on the peripheral territories of Europe and Research Intensive regions are concentrated on territories characterized by a manufacturing productive specialization (i.e. Northern Italy, German regions). Finally, as expected Human capital Intensive regions are mainly on the north. The spatial pattern is confirmed by Moran estimation (table 8), positive and highly significant for both specifications.

6. A robustness check

As a robustness test, we use a cluster analysis estimate to determine the natural groupings (or clusters) of our observations based on the set of seven simple indicators used in the previous sections. This kind of analysis has been widely used in the knowledge and economic innovation literature (among others: Evangelista et al. 2001; Roelandt and den Hertog, 1998; Padmore and Gibson, 1998).

There are several general types of cluster-analysis methods, each having specific methods. Moreover, most cluster-analysis methods allow a variety of distance measures for determining the similarity or dissimilarity among observations. In this case we use the *partition method* which breaks the observations into a distinct number of groups by creating an iterative process during which each observation is assigned to the group whose mean is closest. The iterative process ends when no observation changes group.

To make possible comparisons with the previous taxonomy, we impose 4 groups and use the same standardized variables for the Knowledge regions taxonomy. In Fig. 10 we can see that the distribution of regions among the four classes is quite similar to that obtained previously for

Knowledge regions. Indeed the correlation index between the two taxonomies is equal to 0.81. More specifically, all class 1 regions' are Knowledge regions and they are located on the middle of Europe, on the Scandinavian countries and UK. In the second class there are Knowledge and Research Intensive regions and in the third class are included Knowledge, Research Intensive and Human capital region. Finally, the forth class includes mostly the regions with no specialisation in knowledge activities (125 regions over 142) but also 2 Human capital regions and 8 Research Intensive regions. It is important to note that no Knowledge regions fall in this fourth-class.

7. Conclusions

Intangible assets, such as human capital and research activity, are recognised as the key factors in determining the competitiveness of firms and territories, especially among the industrialised countries. Therefore a lot of efforts must be devoted to define and measure these elements and to assess how they influence the regional economic performance.

In this paper we developed a classification based on the region's knowledge endowment able to identify the "knowledge regions" in Europe and we examined their main territorial features. The analysis has been applied to 287 NUTS2regions in 31 European countries (EU27 plus 4 Efta countries).

We propose a feasible definition of knowledge regions based on the two main pillars of the knowledge economy: human capital and technological activities. These two factors are able to capture either the creation of new knowledge within the region and also the capacity of the local firms to absorb knowledge spilling from the internal and external economies.

The human capital endowment in a region has been expressed by means of both input and output indicators. Among the former, the share of population employed in the education sector which measure the regional effort to create a new flow of human capital. Among the latter, we have used the share of population with a university degree and participation in the EU 5th Framework Program which measure the human capital quality and the knowledge diffusion through international research cooperation.

The regional level of technological activities has been described by input indicators (R&D expenditures and employees) and output measures (total number of patents granted and patents in the high-tech sectors). The first indicators show the amount of resources invested in the technological activities while the second can be used as a measure of their effectiveness.

All variables confirm the presence of huge differences among the European regions with a clear spatial divide between western vs eastern regions and northern vs eastern regions. It is interesting to note that all indicators show the presence of spatial dependence signalling that a knowledge spillovers process with spatial features is taking place in Europe.

On the basis of these seven indicators we develop two synthetic measures for human capital and technological activity by standardizing the simple indicators around the European average. The intersection of the two indicators allow to identify four areas and to define the following taxonomy for the European regions.

- *Knowledge regions*: both indicators above the European average (74 regions).
- *Human capital intensive regions*: human capital above and research activity below the average (52 regions).
- *Research intensive regions*: technological activity above and human capital below the average (30 regions).
- *Regions with no specialisations in knowledge activities*: both indicators below the European average (126 regions).

We have remarked that among the Knowledge region there are most regions in the Scandinavian countries, in Belgium and the Netherlands, all regions in Switzerland some German regions in Germany and UK; the capital city in France, Spain, Austria and Czech republic.

Finally, as a robustness check of the previous taxonomy, we have performed a cluster analysis based on several indicators of human capital and technology.

The analysis of the performance of the European regions in term of knowledge activities is becoming particularly important since the recent enlargement process has included new countries characterized by a low average level of knowledge activity and by a high degree of regional territorial disparity. To favor the process of integration and cohesion of these territories there is a need of specific policies aimed at developing the generation, diffusion and absorption of knowledge.

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Appendix 1. Data sources and definitions

Knowledge variables		Weights	Measurement unit	Description	Sources	Years
Human capital	Employees in education	1/3	Percentage	Percentage of population employed in the NACE education sector	CRENoS elaborations on Eurostat data	2005-2007
	Tertiary education	1/3	Percentage	Percentage of population aged 15 and over by highest level of education attained		2005-2007
	5th FP Funding	1/3	Thousands of Euro per 1000 POP	Funding over population divided by 1000	CRENoS elaboration on CORDIS data	1998-2002
Research activities	R&D Expenditure	1/4	Millions of Euro per 1000 POP	Millions of Euro spent per RD activities over population divided by 1000	CRENoS elaboration on Eurostat, ISTAT and Institut National de la Statistique et des Études Économiques data	2006-2007
	R&D Personnel	1/4	Percentage	Head Count Employment in R&D over employment		2006-2007
	Number of patents	1/4	Patents per 1000 POP	Number of Patents released at NUTS2 over population divided by 1000	CRENoS elaboration on OECD REGPAT database	2005-2006
	Number of high-tech patents	1/4	Patents high-tech per capita	Number of patents per million population in high- tech IPC sectors		2005-2006
Other variables:						
Population		POP	Thousands	Total population at 1st January	Eurostat	2005-2007
Employment		EMP	Thousands	Head count employment aged 15 and over	Eurostat	2006-2007

Appendix 2. Regions and NUTS level

Code	Country	Nuts	Number of Regions
AT	Austria	2	9
BE	Belgium	2	11
BG	Bulgaria	2	6
CH	Switzerland	2	7
CY	Cyprus	0	1
CZ	Czech Republic	2	8
DE	Germany	2	39
DK	Denmark	2	5
EE	Estonia	0	1
ES	Spain	2	19
FI	Finland	2	5
FR	France	2	26
GR	Greece	2	13
HU	Hungary	2	7
IE	Ireland	2	2
IS	Iceland	0	1
IT	Italy	2	21
LI	Liechtenstein	0	1
LT	Lithuania	0	1
LU	Luxembourg	0	1
LV	Latvia	0	1
MT	Malta	0	1
NL	Netherlands	2	12
NO	Norway	2	7
PL	Poland	2	16
PT	Portugal	2	7
RO	Romania	2	8
SE	Sweden	2	8
SI	Slovenia	2	2
SK	Slovakia	2	4
UK	United Kingdom	2	37
	TOTAL		287

Table 1. Human capital indicators, average values for selected samples

	Whole sample	Countries			EU Regions		
		EU 15	EU new entrants 12	EFTA 4	Convergence	Transition	Competitive
Employees in education (% pop)	3.24	3.24	2.87	4.27	2.84	3.10	3.37
Tertiary education (% pop)	12.37	12.88	9.34	16.41	9.21	12.66	13.61
Project Funding per 1000 pop (Thousand of Euro)	22.27	24.31	7.13	47.89	6.94	15.25	28.99

Table 2. Human capital indicators, coefficient of variation for selected samples

	Whole sample	Countries			EU Regions		
		EU 15	EU new entrants 12	EFTA 4	Convergence	Transition	Competitive
Employees in education (% pop)	0.26	0.26	0.21	0.13	0.19	0.26	0.26
Tertiary education (% pop)	0.36	0.35	0.41	0.19	0.39	0.44	0.30
Project Funding per 1000 pop (Thousands of Euro)	1.19	1.08	1.61	0.82	1.55	1.01	0.96

Table 3. Human capital indicators, Moran (standardized distance), whole sample

	I	z	pvalue*
Employees in education (% pop)	0.144	28.725	0
Tertiary education (% pop)	0.129	25.86	0
Project Funding per 1000 pop (Thousands of Euro)	0.065	13.47	0

Table 4. Technological indicators, average values for selected samples

	Whole sample	Countries			EU Regions		
		EU 15	EU new entrants 12	EFTA 4	Convergence	Transition	Competitive
RD expenditure per 1000 pop (Millions of Euro)	0.44	0.49	0.07	1.09	0.09	0.18	0.6
RD Personnel (% employment)	1.46	1.56	0.88	2.35	0.86	1.09	1.76
Number of patents per million pop (total sectors)	103.2	120.2	7.2	210.6	11.8	32.9	153.1
Number of patents per million pop (high-tech sectors)	13.12	15.9	0.85	18.61	1.52	3.46	20.4

Table 5. Technological indicators, coefficient of variation for selected samples

	Whole sample	Countries			EU Regions		
		EU 15	EU new entrants 12	EFTA 4	Convergence	Transition	Competitive
RD expenditure per 1000 pop (Millions of Euro)	1.07	0.92	1.52	0.49	1.39	0.67	0.78
RD Personnel (% employment)	0.65	0.59	0.9	0.4	0.62	0.56	0.56
Number of patents per million pop (total sectors)	1.25	1.05	1.61	0.89	1.99	1.1	0.85
Number of patents per million pop (high-tech sectors)	1.74	1.56	1.67	1.07	2.7	1.38	1.34

Table 6. Technological indicators, Moran (standardized distance), whole sample

	I	z	pvalue*
RD expenditure per 1000 pop (Millions of Euro)	0.091	18.391	0
RD Personnel (% employment)	0.026	5.791	0
Number of patents per 1000 pop (total sectors)	0.156	31.168	0
Number of patents per million pop (high-tech sectors)	0.056	11.882	0

Table 7. Typology of Knowledge regions, Moran index

Inverse distance matrix (row std)

VARIABLE	I	MEAN	ST.DEV.	Z-VALUE	PROB
KR	0.052	-0.004	0.005	10.208	0.000

Inverse of squared matrix (row std)

VARIABLE	I	MEAN	ST.DEV.	Z-VALUE	PROB
KR	0.160	-0.004	0.019	8.459	0.000

Table 8. Ranking of knowledge regions

Code	Region Name	Synt Ind	Code	Region Name	Synt Ind
DK01	Hovedstaden	0.89	UKD2	Cheshire	0.25
SE11	Stockholm	0.85	CZ01	Praha	0.25
NO01	Oslo og Akershus	0.67	CH05	Ostschweiz	0.25
CH04	Zürich	0.62	LU00	Luxembourg	0.22
NL41	Noord Brabant	0.59	CH06	Zentralschweiz	0.22
NO06	Trøndelag	0.59	DE13	Freiburg	0.21
FI18	Etelä Suomi	0.59	BE21	Prov. Antwerpen	0.20
SE22	Sydsverige	0.58	ES21	Pais Vasco	0.19
DE21	Oberbayern	0.58	DEA2	Köln	0.19
BE31	Brabant Wallon	0.55	FR62	Midi Pyrénées	0.19
UKJ1	Berkshire, Bucks, Oxfordshire	0.55	ES30	Comunidad de Madrid	0.18
BE10	Région de Bruxelles	0.55	CH07	Ticino	0.18
UKI1	Inner London	0.53	DK04	Midtjylland	0.18
CH03	Nordwestschweiz	0.51	DE50	Bremen	0.17
CH01	Région lémanique	0.51	SK01	Bratislavský kraj	0.17
UKM5	North Eastern Scotland	0.49	NL32	Noord Holland	0.17
DE11	Stuttgart	0.48	DED2	Dresden	0.17
SE23	Västsverige	0.47	DE60	Hamburg	0.16
SE12	Östra Mellansverige	0.47	FR71	Rhône Alpes	0.16
UKH1	East Anglia	0.47	BE23	Prov. Oost Vlaanderen	0.16
FR10	Île de France	0.47	NL11	Groningen	0.15
BE24	Prov. Vlaams Brabant	0.45	UKF2	Leicestershire, Rutland, Northants	0.15
FI1A	Pohjois Suomi	0.45	NL22	Gelderland	0.14
SE33	Övre Norrland	0.41	NL33	Zuid Holland	0.13
AT13	Wien	0.39	SI02	Zahodna Slovenija	0.13
DE12	Karlsruhe	0.36	UKH3	Essex	0.12
UKK1	Gloucestershire, Wiltshire, Bristol	0.35	UKG1	Herefordshire, Worcestershire, Warks	0.12
FI19	Länsi Suomi	0.34	DE72	Gießen	0.12
NL31	Utrecht	0.32	ES22	Comunidad Foral de Navarra	0.12
DE14	Tübingen	0.32	UKF1	Derbyshire and Nottinghamshire	0.09
UKJ3	Hampshire and Isle of Wight	0.32	UKM3	South Western Scotland	0.09
UKH2	Bedfordshire, Hertfordshire	0.31	NO03	SørØstlandet	0.07
DE30	Berlin	0.30	BE22	Prov. Limburg	0.06
CH02	Espace Mittelland	0.29	DK05	Nordjylland	0.05
IS00	Iceland	0.27	FI13	Itä Suomi	0.03
NO05	Vestlandet	0.26	FR42	Alsace	0.03
UKJ2	Surrey, East, West Sussex	0.25	DEG0	Thüringen	0.01

Fig. 1 Employment in education (% POP), average 2005-2007

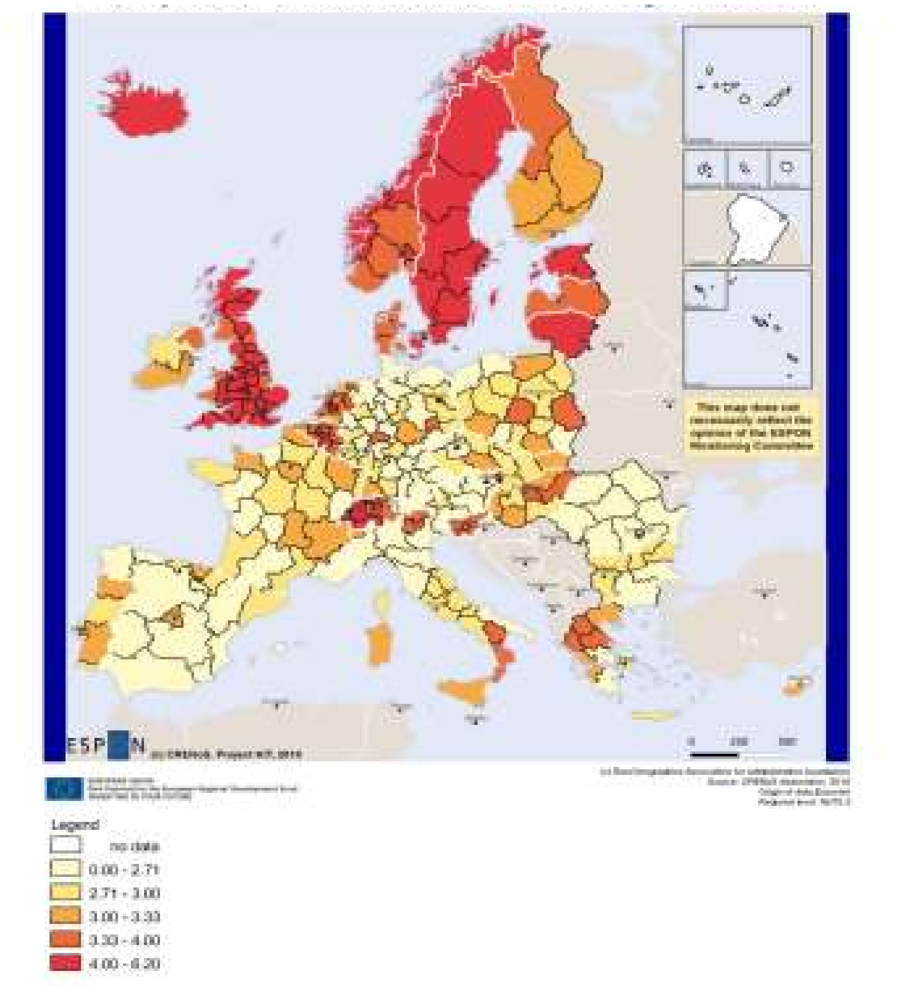

Fig. 2 Tertiary education (% over population), 2005-2007

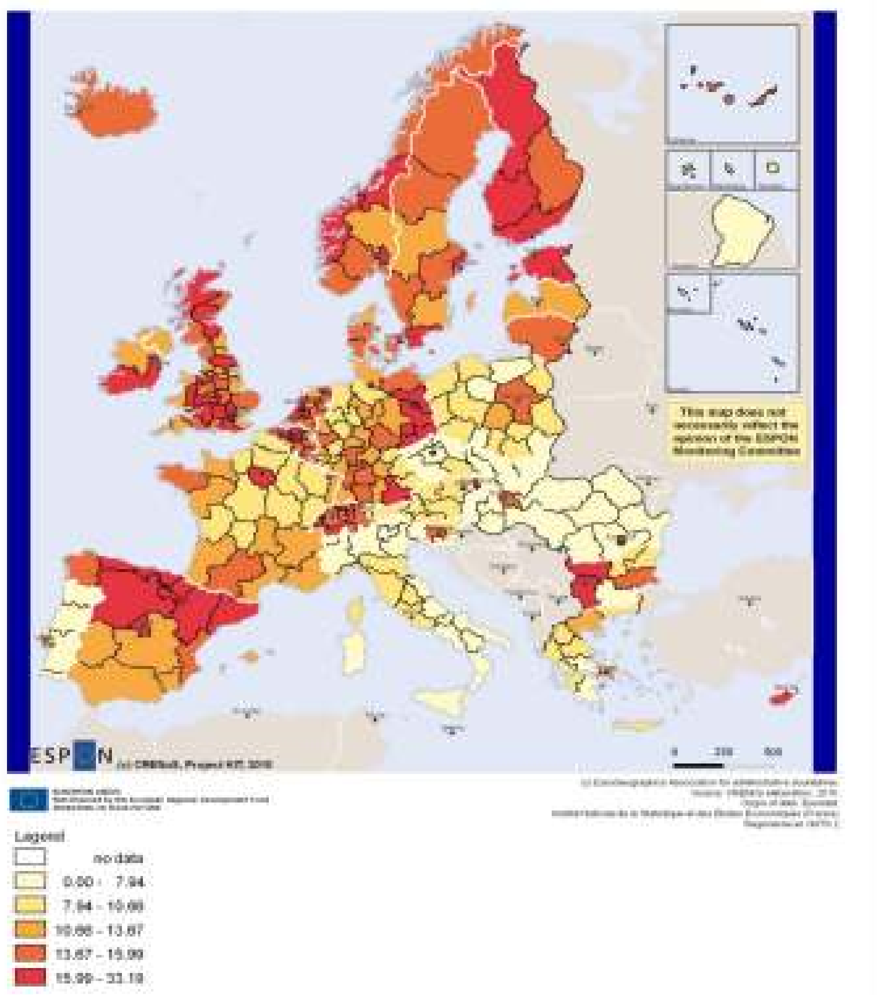

Fig. 3 Funding in the 5FP per 1000 POP, 1998-2002, Thousands of Euro

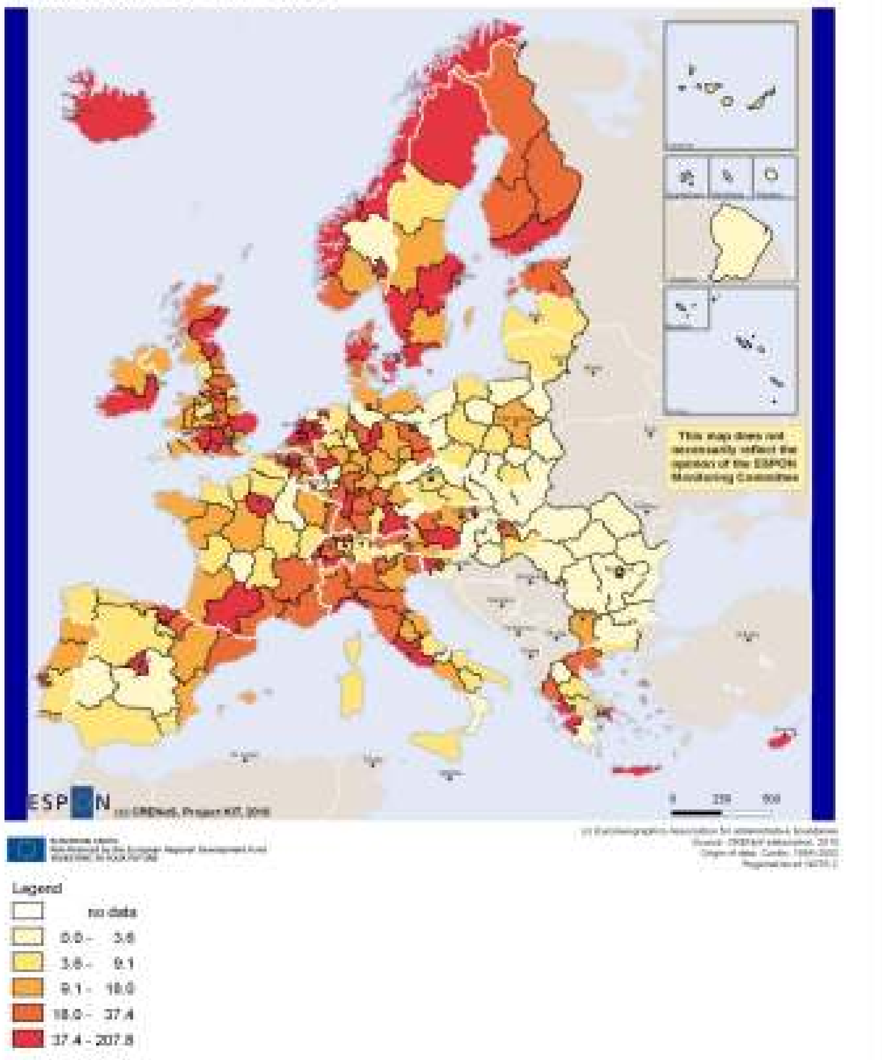

Fig. 4 RD Expenditure per 1000 POP, average 2006-2007, Millions of Euro

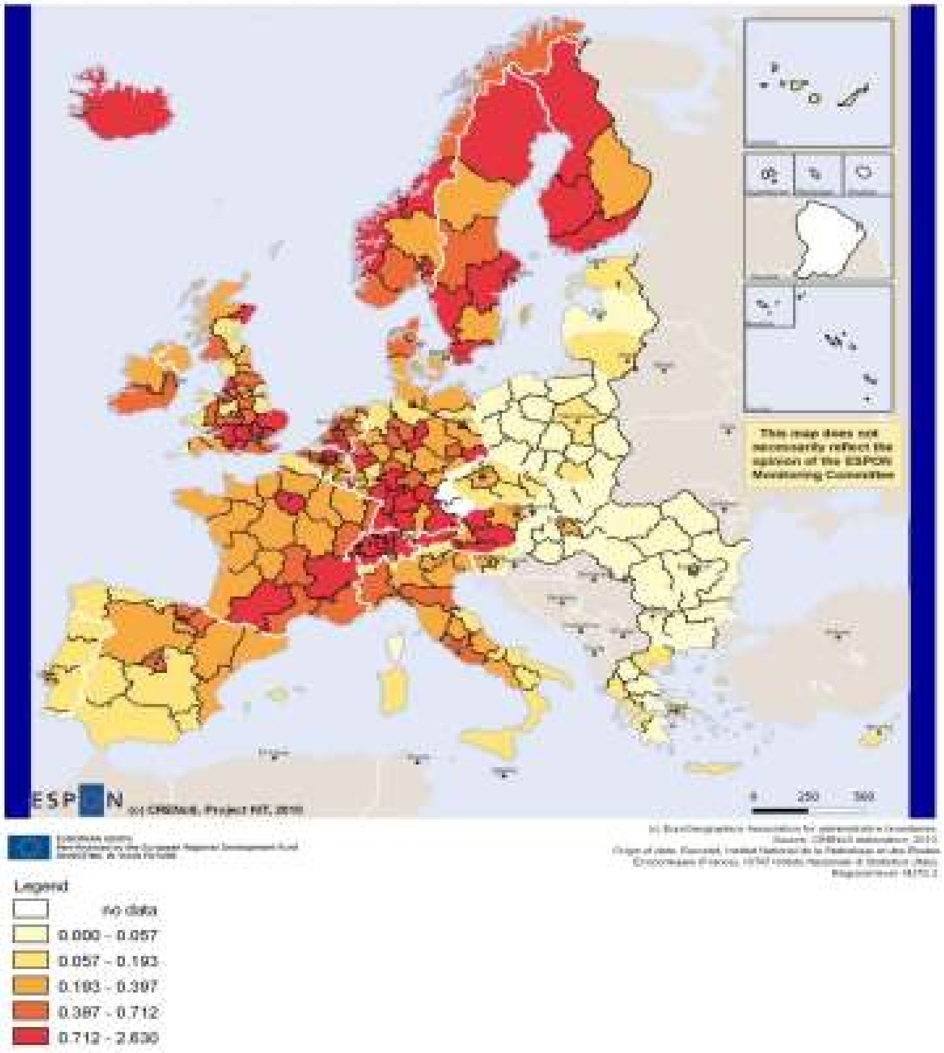

Fig. 5 RD Personnel % of total employment, Average 2006-2007

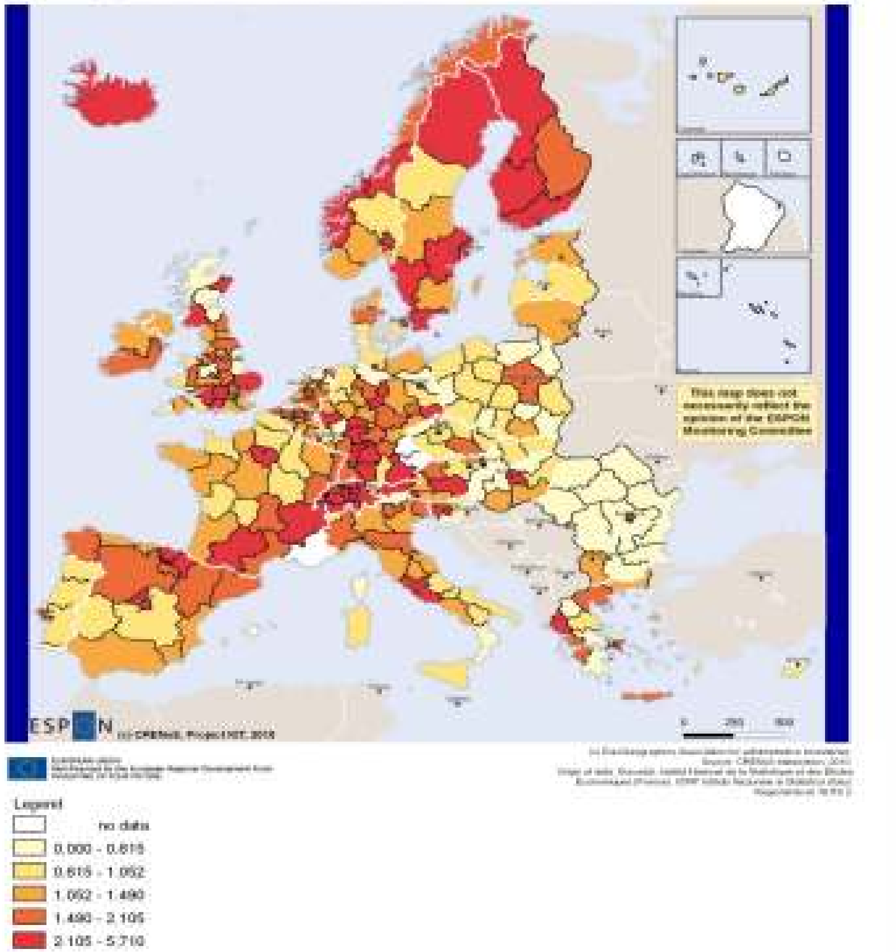

Fig. 6 Number of patents per 1000 POP, average 2005-2006

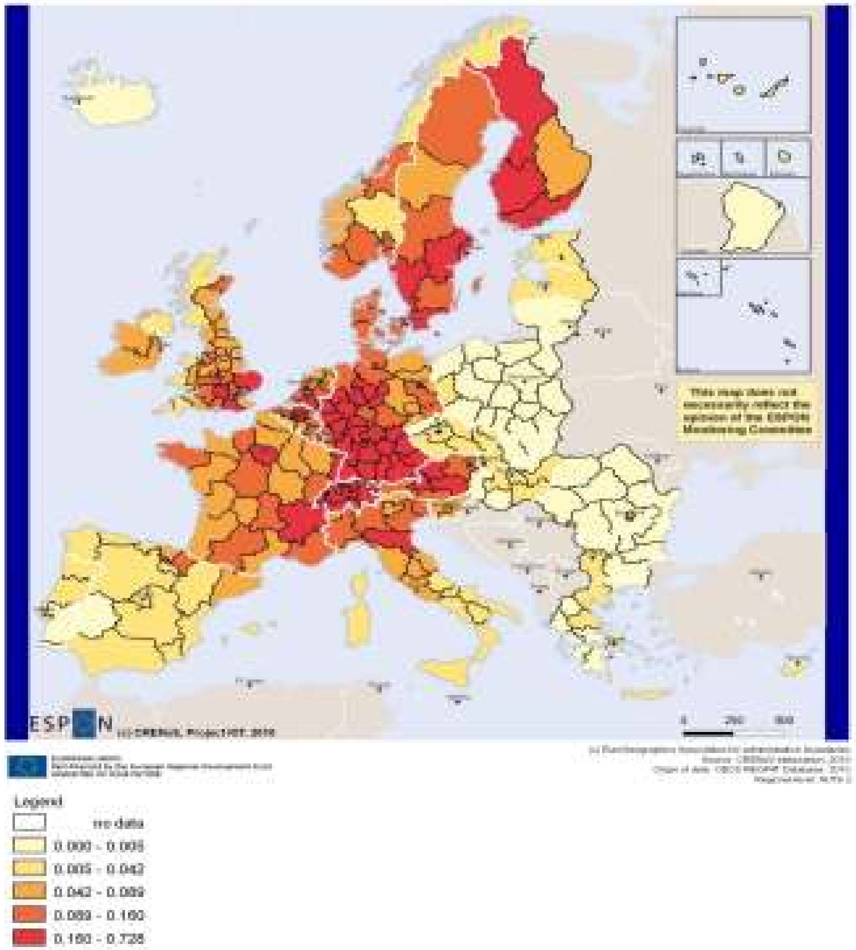

Fig. 7 Number of patents in high-technology fields per 1000 POP, average 2005-2006

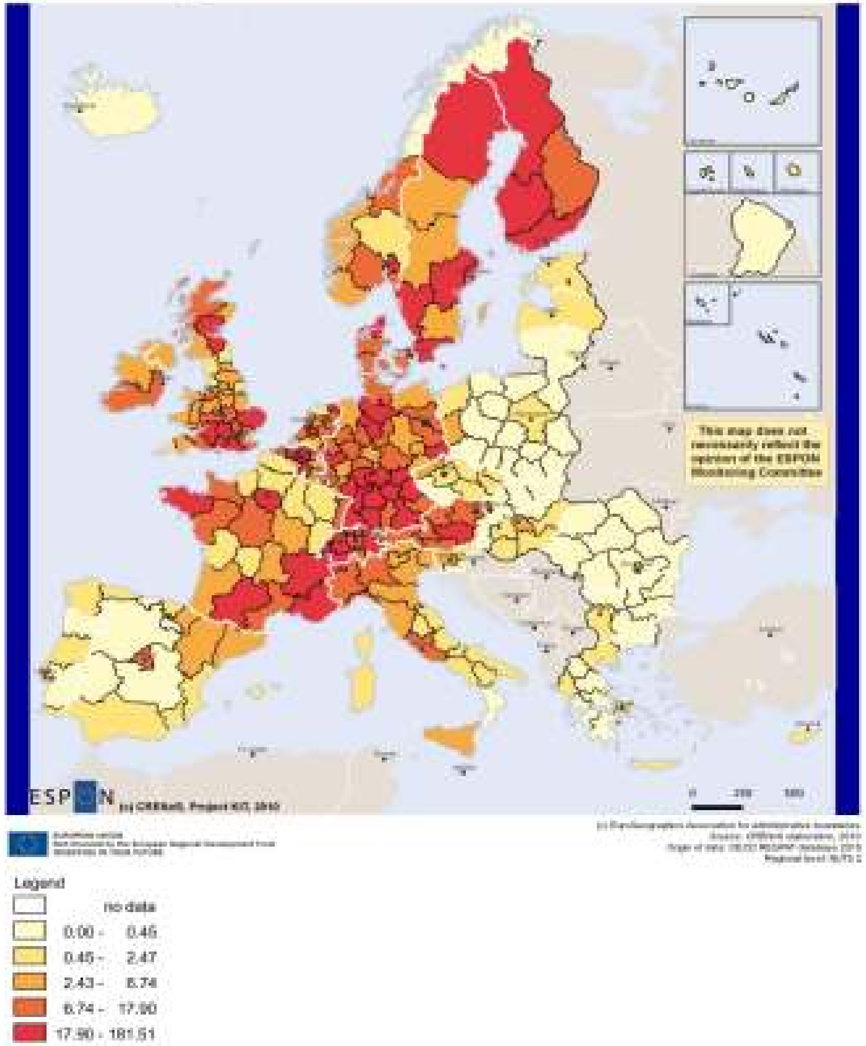

Fig. 8 The typology of Knowledge regions in Europe

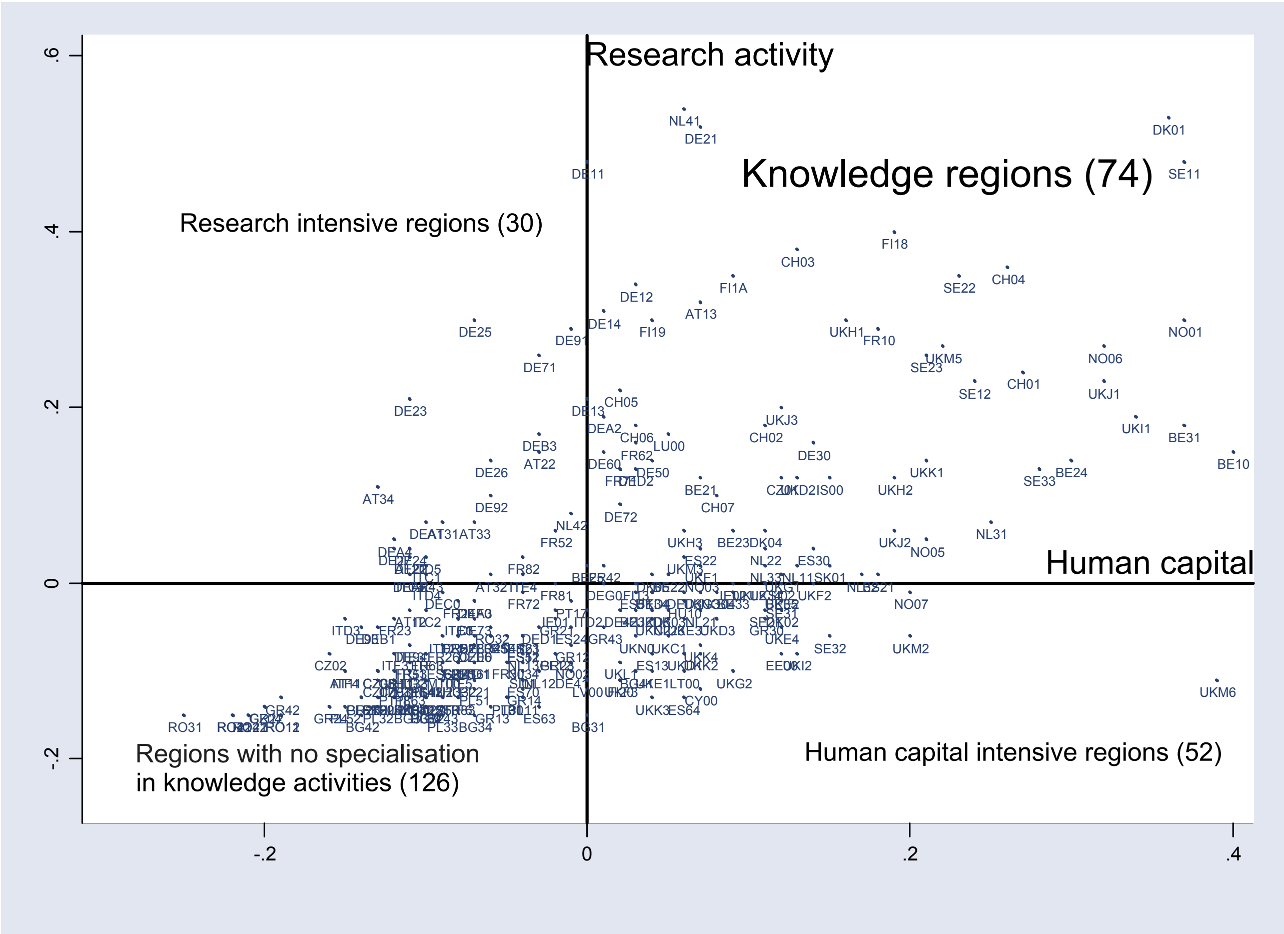

Fig. 9 Knowledge regions

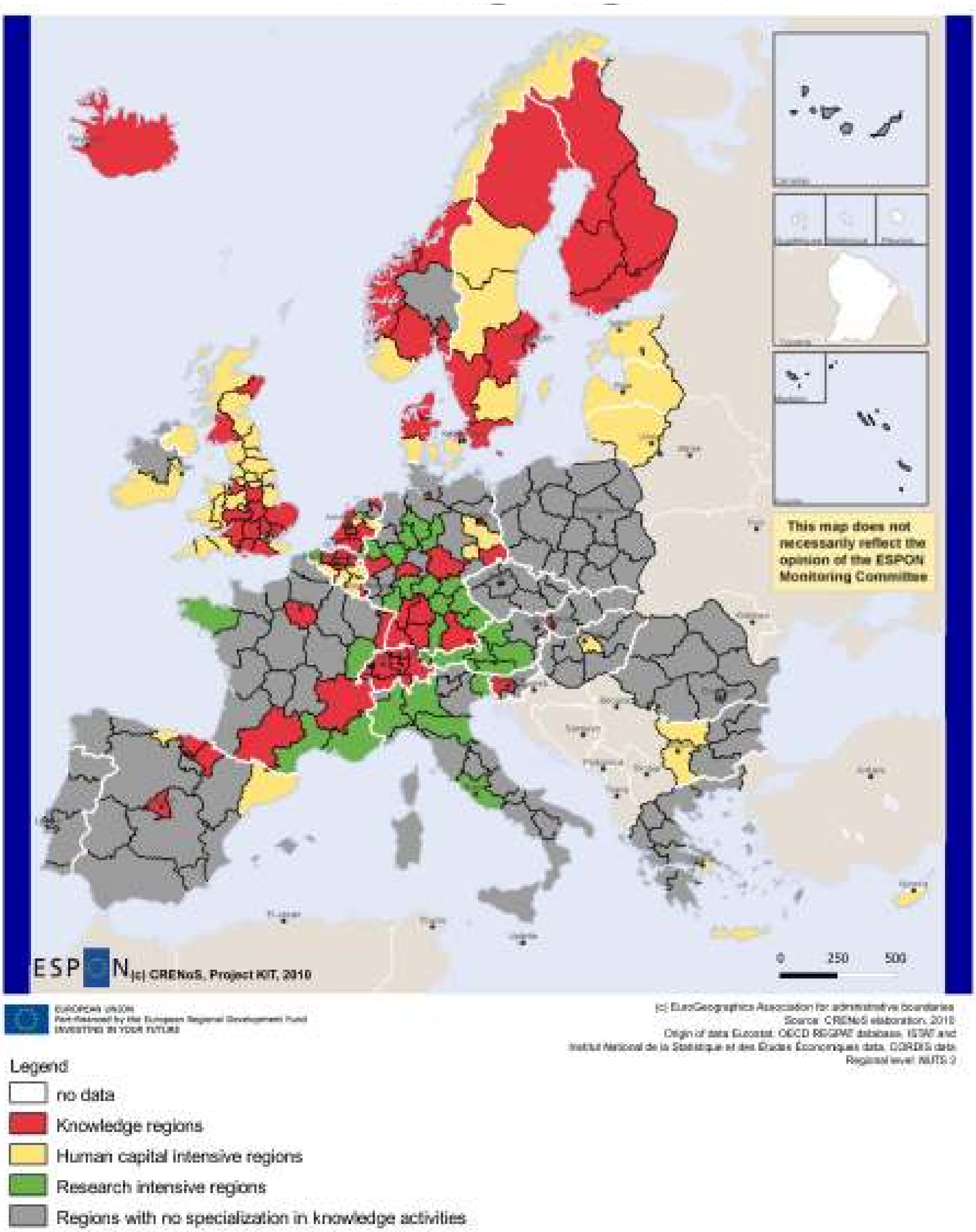

Fig. 10 Cluster analysis