TECHNOLOGICAL ACTIVITY IN THE EUROPEAN REGIONS

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Abstract
This paper investigates technological activity in the European regions. The analysis is based on a statistical databank set up by CRENoS on regional patenting at the European Patent Office spanning from 1978 to 2001 and classified by ISIC sectors at the 2 digit level. We consider 175 regions of 17 countries in Europe, the 15 members of the European Union plus Switzerland and Norway.
An analysis of the spatial distribution of innovation activities in Europe is performed. Some global and local indicators for spatial association are presented, signaling the presence of a general dependence process in the distribution of the phenomena under examination. The analysis is implemented for different manufacturing sectors to assess for the presence of significant differences in the their spatial features. Moreover, the extent and strength of spatial externalities are evaluated for some subperiods spanning from the early eighties to the late nineties.

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1. Introduction

The European Union is one of the wealthiest economic zones in the world but economic disparities among countries and regions seriously undermine its dynamism. Moreover, such disparities have increased since Europe has opened to new accession countries to become a composite ensemble of 25 countries and 254 regions. Two thirds of its population live in regions with a GDP per head of less than half the European average. Innovative activity is not less dispersed: the quota R&D performed by enterprises on GDP, for example, goes from 0.6% in Cyprus to more than 3% in Sweden. The gap is even larger at the regional level, with some regions very close to zero innovation activity, where the most innovative region (Vatsverige) shows an index of more than 5%.

Since innovation is increasingly identified as the major catalyst for productivity and output growth, any policy aiming at reducing economic inequalities has to target this technological divide. Innovation is therefore not only a priority of the whole EU to become the most competitive and dynamic knowledge-based economy in the world (according to the Lisbon agenda) but also in its internal battle against national and regional disparities.

As a consequence, the European Commission is devoting particular attention to the territorial dimension of technological change and economists and policymakers are taking increasing account of the importance of region specific factors, in particular the role of agglomeration economies, in the innovation process. Modern analyses of innovation processes have placed agglomeration economies and other forms of local externalities at the center of the empirical research agenda.

One of the outstanding feature of the recent tendency in the economic growth processes, is the firms tendency to concentrate their activities in space. This is true for production, but it is even more remarkable for innovation. Consequently the economic literature has devoted a large effort to investigate into the spatial dimension of innovative activities; more specifically, into the determinants and the mechanisms which make profitable for firms to cluster spatially their innovative activities. The answers are not simple, since there are several forces which influence firms localization decision; however most of these factors refer to local increasing returns and to knowledge spillovers (Audtresch and Feldman, 2004).

Starting from the seminal contribution by Marshall (1890), there has been a long tradition of studies which relate externalities to geographical space. Such increasing returns are usually classified in two categories: pecuniary and pure technological externalities (Krugman, 1991). The former are due to market mediated mechanisms (availability of qualified workers and specific primary and intermediate inputs), whilst the latter are associated to knowledge spillovers.

In trying to explain the nature of knowledge spillovers, a wide empirical evidence suggests that location and proximity are mostly important. Jaffe (1989) shows the existence of localized externalities from university research to commercial innovation. In addition, Jaffe *et al.* (1993) emphasize that patent citations tend to occur more frequently within the state in which they were patented. According to this views, knowledge produced by universities is a sort of local public good embodied in individuals and it is virtually impossible to make it explicit and to communicate unless through personal contacts (Von Hipple, 1994). Indeed, despite the great progress in information technology, the "death of distance" is far to happen and knowledge is still costly and difficult to transmit across space. Consequently, local collective learning processes, mainly based on tacit knowledge, may constitute an important ground for the competitive advantage of regions (Lawson and Lorenz, 1999; Capello, 1999; Maskell and Malmberg, 1999). In this case firms decision to agglomerate innovation activities in a specific place is a rational response to facilitate knowledge sharing and learning processes. Local innovation clusters, therefore, arise since the innovation process is sensitive to geographical distance and technological spillovers are spatially bounded. This concept of localised technological spillovers has been refocused and strengthened by several empirical works such as the ones by Acs *et al.* (1994), Audrestsch and Feldman (1996), and Anselin *et al.* (1997), Paci and Usai (1999).

Another line of research has attempted to directly investigate the mechanism of spatial diffusion of innovative knowledge using a full set of spatial econometric techniques (Fisher and Varga, 2003; Autan-Bernard, 2001; Greunz, 2003; Varga *et al.*, 2005). In particular, Moreno *et al.* (2005a) find that the external knowledge spillovers decay over space, that they occur mainly across regions within a country rather than across nations and, finally, that technological together with geographical proximity may matter in defining the strength and extent of spillovers. However, the general approach of this research does not allow for discriminating between different sources of technological externalities (specialisation or diversity, for example) which would imply very different policy suggestions. (Moreno *et al.*, 2005b).

Our contribution aims at providing a descriptive analysis of the spatial distribution of innovation activities in Europe. Some global and local indicators for spatial association are presented, signaling the presence of a general dependence process in the distribution of the phenomena under examination. The analysis is implemented for different manufacturing sectors to assess for the presence of significant differences in the their spatial features. Moreover, the extent and strength of spatial externalities are evaluated for some sub-periods spanning from the early eighties to the late nineties.

We use an original databank on regional patenting at the European Patent Office spanning from 1978 to 2001 to analyse the spatial distribution of innovative activity across 175 regions of 17 countries in Europe (the 15 members of the pre-2004 European Union plus Switzerland and Norway) in 23 manufacturing sectors. The use of this rich panel dataset is an advantage with respect to previous studies on Europe for investigating how technological agglomerations are forming and evolving through space and time in main industrial sectors.

The paper is organised as follows. The next section provides a discussion of some measurement issues. In the third section we examine the spatial mapping of innovative activity throughout the European regions. Section four discusses the evidence on the phenomenon of clustering of innovative activity in certain sectors in Europe. Final remarks conclude the analysis.

2. Measurement issues

The issue of measuring innovative activity is a long standing one and a general statement remarked by all researchers is that no single measure is perfect (see, for instance, Pavitt, 1982 and Griliches, 1990). Two types of indicators have been usually suggested as suitable proxy: technology input measures (such as R&D expenditure and employees) and technology output measures (such as patents and new product announcements). The former indicators include, without distinction, firms' effort for invention, innovation and imitation activities. The latter represent the outcome of the inventive process that is expected to be economically valuable, although such a "value" is highly heterogeneous and the propensity to patent or to announce can vary across space, firms and sectors.

The main drawback of single indicators is that they embrace firms' efforts for invention and innovation together with imitation activities. Moreover, they do not take into account for informal technological activity and, as a consequence, tend to underestimate the amount of innovative activity of medium and small firms. On the contrary, technology output measures represent the outcome of the inventive and innovative process. The fact that there are inventions that are never patented and many patents are never developed into innovations marks the shortcomings of this measure. However, patenting procedures require that innovations have novelty and usability features and imply relevant costs for the proponent. Therefore innovations which are patented, especially those extended in foreign countries, are expected to have economic value, although highly heterogeneous and the propensity to patent or to announce can vary across countries and sectors.

With respect to the object of our research, i.e. to study local patterns of specialisation, patents have, therefore, advantages and disadvantages. On the one hand, they are considered a more reliable indicator than R&D for innovative activity of small and medium firms because most such firms do not formally register R&D expenditure. On the other hand, patents underestimate the innovative activity of small firms given that direct and indirect costs of patenting, especially at EPO, may prove very high for them. Despite these problems, we choose patents because they represent the only available indicator with some useful characteristics. In particular, patents give information on the residence of the inventor and proponent and can thus be grouped regionally, while R&D statistics are available just for some regions or at the national level. Second, they record the technological content of the invention and can, thus, be classified according to the industrial sectors. Finally, they are available for a long time span permitting some dynamic analysis. This allows us to take advantage of a three-dimensions database.

Our proxy for innovative activity refers to patents applications at the European Patent Office over the period 1981-2001 classified by the inventor's region in Europe. During the period from 1981 until 2001 EPO received nearly 611.500 applications for patents. We consider applications instead of granted patents because granting process requires time whose length can be long and require several years. Moreover it could vary across sectors, introducing a bias in information. Applications at EPO should provide a measure of sufficiently homogenous quality, due to the fact that applying to EPO is difficult, time consuming and expensive. This indicator, in other words, should prove particularly effective in order to take into account potentially highly remunerative innovations which for this reason are patented abroad. As a matter of fact EU regional patents at EPO are significantly correlated to other measures of innovative activity such as business R&D over GDP (coefficient of correlation is equal to 0.77) or the employment in medium-high and high-tech manufacturing (0.60).

As for the localization of the patent, we prefer choosing the inventor's residence, rather than the proponent's residence (Paci and Usai, 2000, Breschi 2000). Indeed, the latter generally corresponds to firms' headquarters and it might lead to an underestimation of peripheral regions' innovative activity whenever the invention has been developed in a firm's subsidiary located in another area. Moreover we assign patents not just to the first investor, given that this may bias our result as inventors are usually listed in alphabetical order. For the case of patents with more than one inventor, therefore, a proportional fraction of each patent is assigned to the different inventors' regions of residence.

As for the territorial break up we have only partially followed the classification provided by EUROSTAT through NUTS (*Nomenclature des Unités Territoriales Statistiques*). For some countries, this classification turns out to be artificial, based mainly on statistical concerns while failing to identify uniform regional areas in terms of economic, administrative and social elements. In fact we have tried to select, for each country, a geographical unit with a certain degree of administrative and economic control. The result is a division of Europe (15 countries of the European Union plus Switzerland and Norway) in 175 sub-national units (which, from now on, we will simply call, *regions*) which are a combination of NUTS 0, 1 and 2 levels.

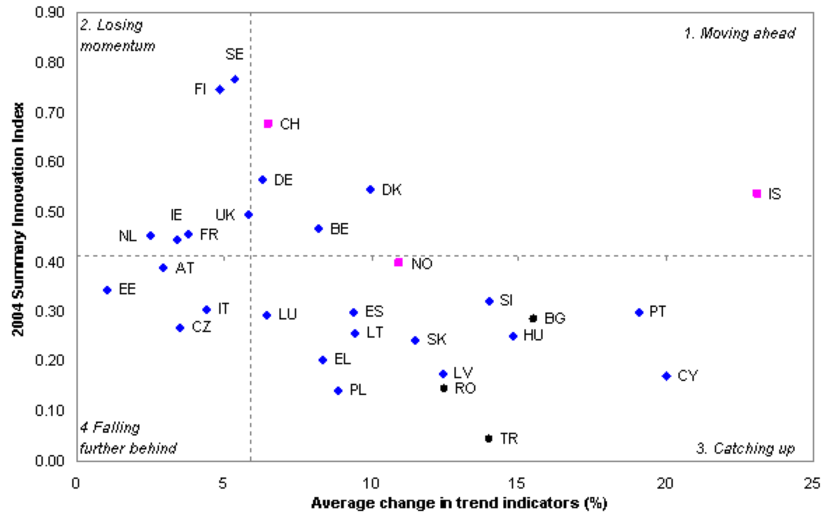
As far as the sectoral classification is concerned, it should be noted that patent data are still of minimal use for economic analysis due to their mode of classification. Patents are recorded for administrative purposes using the International Patent Classification (IPC) system, which categorizes inventions by product or process. Instead, most economic data and analyses are interested in the particular sectors of the economy responsible for the invention or its subsequent use. For this reason patent data, originally classified by means of the IPC, have been converted to the industry of manufacture thanks to the Yale Technology Concordance (Evenson, 1993). Such a concordance uses the probability distribution of each IPC or product code across industries of manufacture in order to attribute each patent proportionally to the different sectors where the innovation may have originated. As for result we can take advantage of a 23 sectors database, following the ISIC rev. 3 classification. This allows us to catch evidences on industrial characteristics and differences, even thanks to largeness of data: during the period 1981-01 EPO received nearly 611500 applications for patents.

We make also use of a more complex indicator for innovative activity, the "European Innovation Scoreboard" (EIS), published by the European Commission as requested by the Lisbon Council in 2000 in order to monitor EU process of narrowing the technological divide across nations and regions. The EIS is regarded as the main reference for innovation analysis since its first issue in 2001. The latest report (2005) makes use of a set of several indicators of input and output innovation measures which are used to build a Summary Innovation Index. More specifically the the Summary Innovation Index is build on the following indicators: (1) population with tertiary education, (2) lifelong learning, (3) employment in medium/high-tech manufacturing, (4) employment in high-tech services, (5) public R&D expenditures, (6) business R&D expenditures, (7) EPO high-tech patent applications, (8) all EPO patent applications, and five indicators using unpublished CIS-2 data: (9) and (10) the share of innovative enterprises in both manufacturing and services, (11) and (12) innovation expenditures as a percentage of turnover in both manufacturing and services, and (13) the share of sales of new-to-the-firm products in manufacturing.

3. Spatial distribution of technological activities

Innovative activity in Europe is dispersed both at the national and the regional level. The EIS proposes a large set of indicators which can be used to measure technological activity, however for our purposes it may prove interesting to have a simple visual idea of the innovation gap across EU countries and its dynamics. Therefore in Figure 1 we report the level of innovative activity in 2004 (given by the Summary Innovative Index) plotted against the average change in some technology indicators in the year before. The picture shows that the innovation gap is slightly closing up since most countries with a low innovation index are experiencing a good performance. and are therefore included in the *catching-up* quadrant. This is the case of the new EU member states which indeed start from relatively low levels. Sweden, Finland and Switzerland are the most innovative countries but the former two are losing momentum; whilst Germany, Denmark and Iceland are performing well above the EU average. Other leading countries, such as the Netherlands, Ireland and France, are slowing down.. Italy is one of the countries, together with CZ, falling further behind.

Figure 1. Average country trend by Summary Innovation Index



Dotted lines show EU25 mean performance
Source: European Innovation Scoreboard (2004).

EIS data tables refers not only to countries but also to regions given that it is widely acknowledged that regional analysis are of value for two reasons. First, innovation policies are often developed and implemented at the regional level, even though within the framework of national and EU strategies. Second, and more importantly from our point of view, many innovative activities are strongly localized into clusters of innovative actors, mainly firms, but also public institutions such as research institutes and universities. The Revealed Regional Summary Innovation Index (RRSII) is a composite indicator, which tries to identify local leaders by taking into account both the region's relative performance within the EU and the region's relative performance within the country.

Table 1 shows to the three leading European regions (EU15) for each countries, whilst Table 2 refers to the three least innovative regions. Table 1 shows that, in most countries, less than one third of the regions performs above the country mean confirming that national innovative capabilities tend to be concentrated in few regions (especially those where the capital city is located). The leading innovative regions in the EU are Stockholm and Västsverige (SE), Uusimaa (FI), Oberbayern and Stuttgart (DE), South East (UK) and Noord-Brabant (NL) mostly located in the Northern rich countries. On the contrary, the least innovative regions are usually peripheral and located in Southern lagging countries. The least innovative regions are as a matter of fact Ionia Nisia (EL), Algarve and Madeira (PT), Extremadura (ES) and Calabria (IT).

Tab 1. Local leading regions based on Revealed Regional Summary Innovation Index

	no of regions	% regions > country average	Leading regions (RRSI)					
			first		second		third	
Austria	**9**	*11*	Wien	0.79	Vorarlberg	0.43	Steiermark	0.41
Belgium	**3**	*67*	Brussels	0.71	Vlaams Gewest	0.52	Région Wallonne	0.17
Germany	**40**	*33*	Oberbayern	0.95	Stuttgart	0.80	Karlsruhe	0.75
Greece	**13**	*15*	Attiki	0.61	Kentriki Makedonia	0.38	Dytiki Ellada	0.32
Spain	**18**	*28*	Madrid	0.72	País Vasco	0.58	Navarra	0.57
France	**23**	*13*	Île de France	0.82	Midi-Pyrénées	0.58	Rhône-Alpes	0.55
Finland	**6**	*17*	Uusimaa	0.97	Etelä-Suomi	0.61	Pohjois-Suomi	0.55
Ireland	**2**	-	Southern and Eastern	0.74	Border, Midland, Eastern	0.15		
Italy	**20**	*25*	Lombardia	0.67	Piemonte	0.66	Lazio	0.63
Netherlands	**12**	*33*	Noord-Brabant	0.90	Flevoland	0.67	Limburg	0.55
Portugal	**7**	*14*	Lisboa e Vale do Tejo	0.60	Centro	0.33	Norte	0.23
Sweden	**8**	*50*	Stockholm	1.00	Västsverige	0.71	Sydsverige	0.69
United Kingdom	**12**	*33*	South East	0.87	Eastern	0.76	South-West	0.59

Source: European Regional Innovation Scoreboard (2003)

Tab 2. Local lagging regions based on Revealed Regional Summary Innovation Index

	average RRSI	Coefficient of variation	Lagging regions (RRSI)					
			last		second last		third last	
Austria	*0.38*	*0.49*	Burgenland	0.18	Salzburg	0.19	Niederösterreich	0.25
Belgium	*0.47*	*0.59*						
Germany	*0.44*	*0.44*	Weser-Ems	0.12	Dessau	0.13	Trier	0.19
Greece	*0.21*	*0.75*	Ionia Nisia	0.00	Dytiki Makedonia	0.10	Sterea Ellada	0.10
Spain	*0.30*	*0.63*	Extremadura	0.06	Illes Balears	0.07	Castilla-la Mancha	0.10
France	*0.31*	*0.55*	Champagne-Ardenne	0.12	Corse	0.12	Limousin	0.19
Finland	*0.51*	*0.55*	Åland	0.17	Itä-Suomi	0.33	Väli-Suomi	0.40
Ireland	-	-						
Italy	*0.35*	*0.60*	Calabria	0.06	Puglia	0.10	Sicilia	0.15
Netherlands	*0.45*	*0.48*	Friesland	0.14	Zeeland	0.15	Drenthe	0.24
Portugal	*0.23*	*0.87*	Algarve	0.03	Açores	0.03	Madeira	0.14
Sweden	*0.52*	*0.56*	Småland med öarna	0.21	Norra Mellansverige	0.26	Mellersta Norrland	0.26
United Kingdom	*0.47*	*0.42*	Northern Ireland	0.19	Yorkshire & The Humber	0.33	Wales	0.34

Source: European Regional Innovation Scoreboard (2003)

The data provided by EIS are extremely interesting and useful but they fail in providing information on technological performance at the sectoral level and on the evolution of innovative activity over time. For such aims we have to rely on other data such as EPO patents from the CRENoS database as described in the previous section.

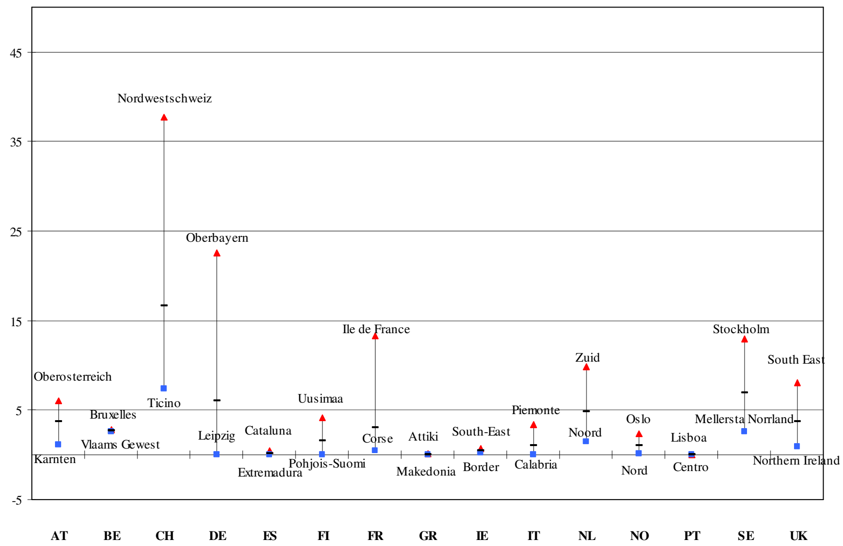
We therefore focus on the spatial distribution of innovative activity in Europe and its changes over two decades by using patents per 100,000 inhabitants as a measure of innovative intensity. We start referring to countries by examining Table 3 which reports the innovative activity for several periods starting from 1981-83 until 1999-2001. At the beginning of the period under consideration, the most innovative country is by far Switzerland, with 14.5 patents per 100,000 inhabitants, followed by Germany (8.3) and Luxembourg (7.2).

Tab 3. Innovative activity in European countries (patents per 100.000 inhabitants, annual average)

Nation	Num. of regions	patents per capita				variation (annual average)		
		1981-83	1988-90	1994-96	1999-01	82-90	90-96	96-00
1- Austria	9	3.3	6.8	6.8	10.5	10.0%	0.2%	8.5%
2- Belgium	3	2.2	4.5	6.6	10.1	10.3%	6.4%	8.6%
3- Switzerland	7	14.5	20.9	19.7	27.8	5.2%	-0.9%	6.9%
4- Germany	40	8.3	14.7	12.2	19.9	8.2%	-3.1%	9.8%
5- Denmark	1	2.5	4.8	7.6	12.9	9.5%	7.7%	10.6%
6- Spain	15	0.1	0.5	0.8	1.5	20.1%	9.5%	12.4%
7- Finland	6	1.4	4.7	9.6	18.3	17.1%	11.7%	13.0%
8- France	22	3.9	6.8	7.1	9.8	7.9%	0.8%	6.4%
9- Greece	13	0.1	0.1	0.2	0.4	12.0%	4.3%	14.3%
10- Ireland	2	0.5	1.3	1.9	4.2	13.2%	6.0%	16.0%
11- Italy	20	1.1	3.0	3.4	5.0	14.6%	2.0%	7.7%
12- Luxembourg	1	7.2	5.0	6.4	12.7	-5.0%	3.9%	13.8%
13- Netherlands	4	4.1	8.3	8.3	14.5	10.1%	-0.1%	11.1%
14- Norway	7	0.9	2.1	3.0	5.1	11.8%	5.5%	11.0%
15- Portugal	5	0.0	0.1	0.1	0.3	16.0%	9.8%	18.0%
16- Sweden	8	6.5	8.3	11.7	18.7	3.5%	5.7%	9.4%
17- United Kingdom	12	3.4	5.4	5.1	7.3	6.7%	-1.0%	7.4%
EU	**175**	**3.6**	**6.5**	**6.7**	**10.4**	**8.4%**	**0.4%**	**8.8%**
CV across nations		1.05	0.91	0.75	0.71	-2.0%	-3.1%	-1.3%
CV across regions		1.42	1.17	1.05	1.05	-2.8%	-1.8%	0.0%

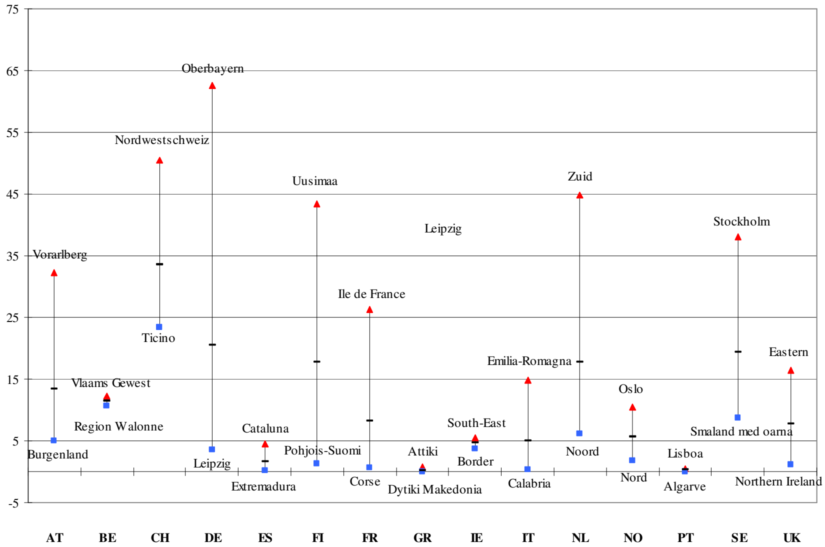
Regional performance can vary significantly within countries. In Figure 2, for each country for which regional data are available for at least three regions, the top and bottom innovative region and the spread per country is given. It is possible to observe mainly Swiss and German regions among the top performers. whilst little or no patenting activity is documented in the majority of regions in the south of Europe: Spain, Greece, Portugal (but also the South of Italy and France and the North of the United Kingdom). Looking at the evolution of the innovative activity from 1981-83 to 1999-01, one can see that innovation activity has increased considerably over the two decades in all countries: the average innovative output was 3.6 patents per 100,000 inhabitants in the early eighties and almost three times higher (10.4) at the end of the nineties. This is partly due to a shift of patent applications by firms from national patenting offices to EPO. Most importantly, innovations have been spreading to more regions in the south of Europe (especially in Spain and the South of Italy) and in the Scandinavian countries (see also Figure 3).

Figure 2. Patents per 100.000 inhabitants in European regions (1981-83)



Source: CRENoS database on EPO patenting

Figure 3. Patents per 100.000 inhabitants in European regions (1999-2001)



Source: CRENoS database on EPO patenting

Accordingly, we observe a decrease in the degree of spatial concentration of innovative activity as it is shown by the coefficient of variation (CV) for countries and regions, reported in the last rows of Table 3. More specifically, the CV across nations decreases gradually from 1.05 at the beginning of the eighties to 0.71 twenty years later. Similarly, the coefficient of variation computed at the regional level shows a sharp decrease from 1.42 to 1.05 but this trend has stopped in the last period.

The process of spatial diffusion of technological activity characterizes some regions of central Europe (France and East Germany), where there is evidence of an expansion in spatial clustering. However, the most brilliant performance is shown by the Scandinavian countries, particularly by Finland, which in the nineties manages to reach the fourth position in the country rankings and place its capital region, Uusimaa, among the first producers of innovation in Europe. This region was 49th at the beginning of the eighties and sixth at the end of the nineties: undoubtedly one of the most remarkable catching up performances in Europe in the last twenty years. Interestingly, 15 regions which are in the top 20 in the last period were already there in the early eighties. Here, there are some interesting stories to highlight: Stutgart and Zuid Nederland, for example, were in the 13th and 18th position and are now second and fourth. The Austrian region of Voralberg (the most western Austrian region in between Switzerland and Germany) was 64th and it is now 14th. Conversely, among the most remarkable cases of decline are Luxembourg, which goes from 20th to 44th place, and Ilê de France, which moves from 9th to 23rd. Two Swiss regions (Region Lemanique and Espace Mittelland) and one German (Dusseldorf) have also lost their place among the top innovators in the two decades considered.

Figure 2 and 3 are of some interest also because they allow to examine intra-country and inter-countries regional dispersion. It is clear from the comparison of the two figures that dispersion among regions within countries has increased and that dispersion across regions and countries in Europe a has decreased. In other words one can conclude that there is a lot of inertia in the spatial distribution of innovative activity, that in each country some regions are performing well above the EU and the country average and that such regions are usually spatially clustered in some areas of Europe. In the following section these preliminary conclusions are tested thanks to appropriate spatial statistics.

However before turning to the cluster analysis we have to introduce the other dimension which is essential when spatial clusters are to be investigated, that of the industrial specialization, based on the CRENoS database. Table 4 shows that among the top innovating sectors we find Machinery and Chemicals with shares around twenty per cent, but both declining along time. As for the least innovative sectors we find traditional sectors such as Tobacco and Leather and footwear. The most dynamic sectors are those more involved in the information and telecommunication technologies, that is Office and computing and Radio, television and communication equipment, the share of the former goes from 1.7 to 2.4 whilst the latter goes from 6.7 to 10.0.

Tab 4. Innovative activity in European sectors (patents)

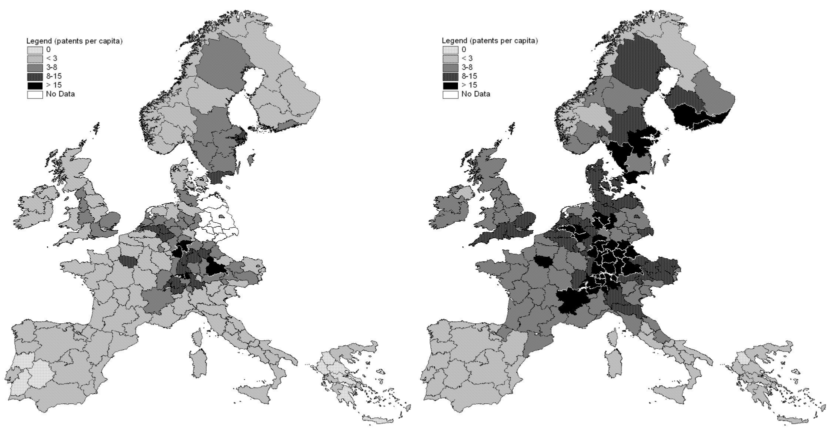
sector	absolute values (annual average)				% values				% variation (annual average)		
	81-83	88-90	94-96	99-01	81-83	88-90	94-96	99-01	82-90	90-96	96-00
Food and beverages	106	187	216	304	0.69	0.67	0.71	0.63	8.1%	2.1%	4.9%
Tobacco	11	16	21	20	0.07	0.06	0.07	0.04	5.2%	3.8%	-0.4%
Textiles	154	301	330	488	1.01	1.08	1.08	1.01	9.6%	1.3%	5.6%
Wearing apparel	37	70	81	123	0.24	0.25	0.26	0.25	9.2%	2.1%	6.0%
Leather and footwear	42	90	94	111	0.28	0.32	0.31	0.23	10.9%	0.6%	2.4%
Wood products, except furniture	135	235	246	340	0.89	0.84	0.81	0.70	7.9%	0.7%	4.6%
Paper	125	254	301	392	0.82	0.91	0.99	0.81	10.1%	2.4%	3.8%
Printing and publishing	45	86	89	136	0.30	0.31	0.29	0.28	9.2%	0.6%	6.0%
Coke and refined petroleum products	286	406	377	455	1.88	1.45	1.24	0.95	5.0%	-1.0%	2.7%
Chemicals and chemical products	3061	5482	5844	8400	20.16	19.56	19.18	17.43	8.3%	0.9%	5.2%
Rubber and plastic	333	673	743	1082	2.19	2.40	2.44	2.24	10.0%	1.4%	5.4%
Non metallic mineral products	352	610	667	956	2.32	2.18	2.19	1.98	7.9%	1.3%	5.1%
Basic metals	112	204	223	307	0.74	0.73	0.73	0.64	8.5%	1.3%	4.6%
Fabricated metal products	1086	1925	2085	3009	7.15	6.87	6.84	6.25	8.2%	1.1%	5.2%
Machinery	3504	6355	6683	9986	23.08	22.68	21.93	20.72	8.5%	0.7%	5.7%
Office, computing	244	491	562	1155	1.60	1.75	1.85	2.40	10.0%	1.9%	10.3%
Electrical machinery	1494	2822	3112	5339	9.84	10.07	10.21	11.08	9.1%	1.4%	7.7%
Radio, television, communication equip.	980	1894	2339	4824	6.45	6.76	7.68	10.01	9.4%	3.0%	10.3%
Precision and medical instruments	1262	2420	2671	4751	8.31	8.64	8.76	9.86	9.3%	1.4%	8.2%
Motor vehiclel, trailers and semitrailers	588	1183	1275	2050	3.87	4.22	4.19	4.25	10.0%	1.1%	6.8%
Other transport equipment	559	1035	1125	1905	3.68	3.69	3.69	3.95	8.8%	1.2%	7.5%
Furniture	617	1178	1268	1895	4.06	4.20	4.16	3.93	9.2%	1.1%	5.7%
Recycling and other	53	106	119	158	0.35	0.38	0.39	0.33	10.0%	1.6%	4.1%
Total manufacturing	**15184**	**28021**	**30472**	**48185**	**100.00**	**100.00**	**100.00**	**100.00**	**8.8%**	**1.2%**	**6.5%**

In conclusion, the strong central-periphery distribution of innovation activity which characterized the eighties has weakened but this process is more recently slowing down. In each country certain regions have became innovative champions while other regions are falling behind. These champions are usually contiguous with other innovative regions suggesting that technological activity performed in one region may be associated to the one in neighbouring regions by some sort of spatial externality. This possibility can be precisely evaluated by means of the Moran's I statistic based on contiguity weight matrices as it is done in the following section which deals with the analysis of industrial clusters of innovation.

4. Industrial cluster of innovation

As explained in the previous sections innovative activity is relatively concentrated in few areas and countries. We will check in this section whether the spatial concentration of innovative activity we can observe from Map 1 generates a process of spatial dependence. In other words we will examine to what extent the technological activity performed in one region is associated to the one in neighbouring regions.

Map 1



Panel a **Panel b**

The degree of spatial association can be analysed by means of the Moran's I statistic, defined as:

$$I = \frac{N}{S_0} \frac{\sum_{i}^{N} \sum_{j}^{N} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{N} (x_i - \bar{x})^2}$$

where x_i and x_j are the observations for region i and j of the variable under analysis, patents per 100,000 inhabitants in our case; $\bar{x}$ is the average of the variable in the sample of regions; and w_{ij} is the i-j element of the row-standardised W matrix of spatial weights. $S_0 = \sum_i \sum_j w_{ij}$ is a standardisation factor which corresponds to the sum of the weights. The most general specification for the weight matrix is the physical contiguity one, given rise to a binary and symmetric matrix where its elements would be 1 in the case of two regions sharing a boundary and 0 otherwise. In the case of a row-standardised W matrix, in which each element in a row is divided by the total sum of the row, S_0 equals the number of observations, N, so that N/S_0 is equal to 1.

Table 5 presents the values for the Moran's index for innovative activity in total manufacturing sector and for 23 sub-sectors, as well as for different physical contiguity matrices (1st, 2nd and 3rd order neighbours) for late eighteens and nineties. Looking at the values we can observe a clear rejection of the null hypothesis for the total manufacturing (see first row for both periods) with a positive and significant value. There appears a strong positive spatial autocorrelation, confirming the visual impression of spatial clustering given by the maps and this rejection is observed till the third order of contiguity. Several sectors (18 over 23) turn out with the same outcome and a pattern of decreasing autocorrelation with increasing orders of contiguity, typical of many spatial autoregressive processes. There is no evidence of different performance for more traditional sectors, such as Wearing apparel and Leather and footwear sectors, and technological ones as Office and computing or Radio, television and communication equipment sectors. Moreover, Coke and refined petroleum products sector and Chemical sector show an increase in spatial concentration in time, being significantly correlated up to the second order of contiguity in the first three-year period, and becoming significant up to the third order in 1999-01. Autocorrelation only shows a fall in significance after the first order of neighbours for Manufacturing of tobacco.

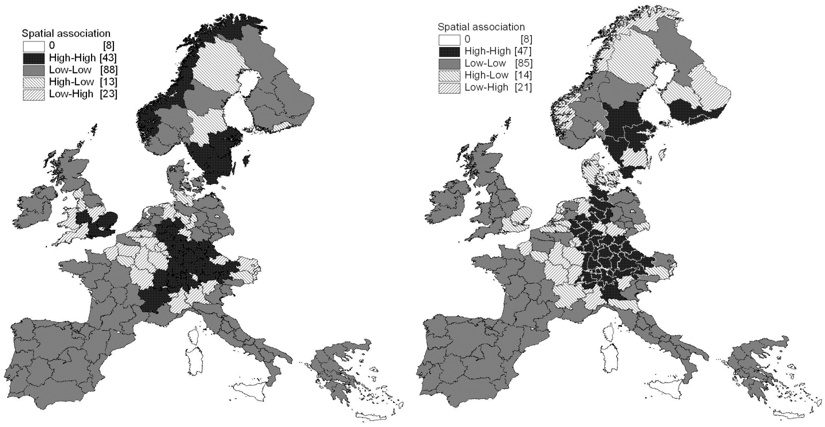
Another interesting issue is to analyse in which sectors the autocorrelation of innovation is considerably greater or lower than that for the Total manufacturing sector. If considering the late eighteens, the sectors of Furniture, Wood products and Fabricated metal products presented a higher value of the Moran's statistic than that for the sector of Total manufacturing; in other words, concentration in space in these sectors was more important than for the entire manufacturing industry. The opposite is obtained in the cases of Leather and footwear, Coke and refined petroleum products and Chemicals and chemical products, although the spatial autocorrelation encountered in those cases is also significant. At the end of the period we are analysing, the value of the Moran's index becomes more similar in the different sectors, even if it turns out to be quite low for Food and beverages and Leather and footwear sectors. All in all, this means that patenting activity in a certain sector tends to be correlated to patenting performed in the same sector in contiguous areas, determining the creation of specialised clustering of innovative regions in different sectors.

Tab 5. Spatial autocorrelation in the innovative activity, 1988-90 (Moran's I test, normal approximation)

sector	contiguity	Z-VALUE	PROB	sector	contiguity	Z-VALUE	PROB
Total manufacturing	first	10.70	0.000	Non metallic mineral products	first	11.39	0.000
	second	8.70	0.000		second	9.37	0.000
	third	5.73	0.000		third	6.39	0.000
Food and beverages	first	3.93	0.000	Basic metals	first	9.91	0.000
	second	3.65	0.000		second	8.79	0.000
	third	1.09	0.278		third	6.51	0.000
Tobacco	first	5.44	0.000	Fabricated metal products	first	11.76	0.000
	second	0.49	0.623		second	9.98	0.000
	third	-1.13	0.256		third	6.33	0.000
Textiles	first	11.13	0.000	Machinery	first	10.74	0.000
	second	7.93	0.000		second	8.49	0.000
	third	4.92	0.000		third	5.77	0.000
Wearing apparel	first	11.70	0.000	Office, computing	first	8.25	0.000
	second	9.90	0.000		second	5.78	0.000
	third	5.04	0.000		third	4.20	0.000
Leather and footwear	first	2.44	0.015	Electrical machinery	first	9.30	0.000
	second	5.54	0.000		second	6.01	0.000
	third	4.26	0.000		third	3.68	0.000
Wood products, except	first	12.19	0.000	Radio, television and communication equipment	first	6.27	0.000
	second	10.08	0.000		second	2.70	0.007
	third	6.58	0.000		third	1.77	0.077
Paper	first	10.31	0.000	Precision and medical instruments	first	9.59	0.000
	second	7.39	0.000		second	6.92	0.000
	third	4.67	0.000		third	4.23	0.000
Printing and publishing	first	10.50	0.000	Motor vehiclel, trailers and semitrailers	first	10.38	0.000
	second	8.35	0.000		second	8.17	0.000
	third	5.72	0.000		third	6.14	0.000
Coke and refined petroleum	first	3.91	0.000	Other transport equipment	first	10.12	0.000
	second	3.52	0.000		second	7.64	0.000
	third	1.79	0.074		third	5.07	0.000
Chemicals and chemical products	first	5.16	0.000	Furniture	first	12.41	0.000
	second	4.58	0.000		second	10.99	0.000
	third	2.45	0.014		third	6.96	0.000
Rubber and plastic	first	9.65	0.000	Recycling and other	first	11.95	0.000
	second	8.64	0.000		second	8.24	0.000
	third	7.13	0.000		third	6.05	0.000

Complementary to this analysis we have also constructed the scatter map in order to assess the sign of the spatial association in the different areas. Map 2 shows that there is a clear association of high-high values in the centre, and low-low values in the South. This positive association remains true over time, with just few exceptions: some regions in the North of Italy initially showed high value of patents surrounded by low values whilst in the nineties became a cluster of high values. Additionally, Finland has performed remarkably well along the period, presenting low values at the beginning surrounded by low values, but changing to high values.

Map 2



Panel a **Panel b**

The most innovative region for each sector is reported in Table 6. At the beginning of the period Swiss Zurich and Nordwestschweiz regions, with the German Oberbayern, were the undisputed leaders and show off the best performance in 9, 7 and 4 sectors, respectively. In the early nineties a different view comes, with a more diversified group of leading regions. Veneto, Aland, Auvergne, Uusimaa and Vorarlberg are new best-performers in more traditional sectors as well as in more technological ones.

Tab 6. Spatial autocorrelation in the innovative activity, 1999-01 (Moran's I test, normal approximation)

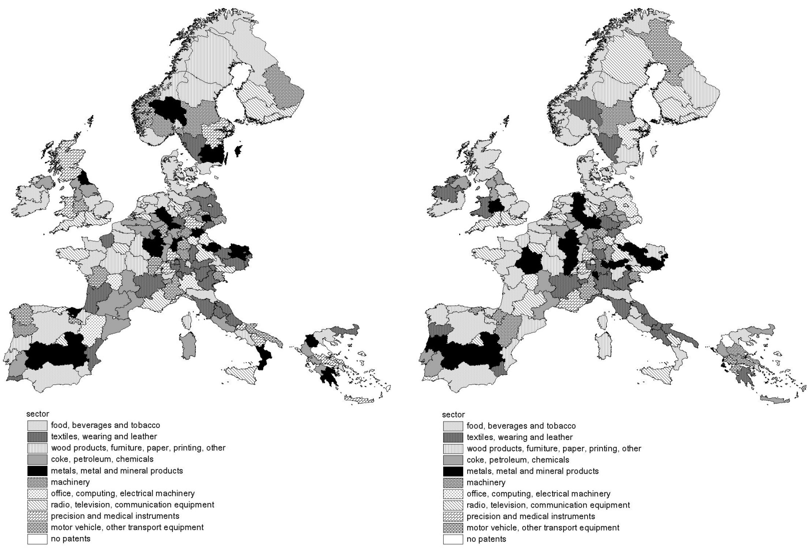
sector	contiguity	Z-VALUE	PROB	sector	contiguity	Z-VALUE	PROB
Total manufacturing	first	10.73	0.000	Non metallic mineral products	first	11.90	0.000
	second	9.47	0.000		second	12.07	0.000
	third	6.51	0.000		third	9.47	0.000
Food and beverages	first	2.90	0.004	Basic metals	first	11.23	0.000
	second	3.62	0.000		second	9.50	0.000
	third	1.70	0.088		third	6.45	0.000
Tobacco	first	8.50	0.000	Fabricated metal products	first	12.79	0.000
	second	-0.21	0.831		second	12.17	0.000
	third	-0.48	0.630		third	8.81	0.000
Textiles	first	11.86	0.000	Machinery	first	12.40	0.000
	second	11.01	0.000		second	10.84	0.000
	third	7.71	0.000		third	7.86	0.000
Wearing apparel	first	11.28	0.000	Office, computing	first	6.95	0.000
	second	10.98	0.000		second	4.22	0.000
	third	6.36	0.000		third	3.61	0.000
Leather and footwear	first	4.04	0.000	Electrical machinery	first	9.63	0.000
	second	5.11	0.000		second	7.23	0.000
	third	4.38	0.000		third	4.65	0.000
Wood products, except	first	9.91	0.000	Radio, television and communication equipment	first	5.61	0.000
	second	9.72	0.000		second	3.39	0.001
	third	6.91	0.000		third	1.37	0.172
Paper	first	10.72	0.000	Medical, precision and medical instruments	first	8.79	0.000
	second	8.50	0.000		second	6.62	0.000
	third	4.99	0.000		third	4.15	0.000
Printing and publishing	first	10.02	0.000	Motor vehiclel, trailers and semitrailers	first	9.71	0.000
	second	8.56	0.000		second	8.30	0.000
	third	6.64	0.000		third	6.17	0.000
Coke and refined petroleum	first	5.88	0.000	Other transport equipment	first	8.82	0.000
	second	5.03	0.000		second	7.18	0.000
	third	2.75	0.006		third	4.55	0.000
Chemicals and chemical products	first	7.19	0.000	Furniture	first	12.55	0.000
	second	6.25	0.000		second	12.40	0.000
	third	4.38	0.000		third	8.82	0.000
Rubber and plastic	first	8.38	0.000	Recycling and other	first	12.42	0.000
	second	7.91	0.000		second	10.80	0.000
	third	6.55	0.000		third	8.53	0.000

Finally we are interested in analyzing the specialisation in European regions both for the beginning of the eighties and at the end of the nineties. For this matter we use as indicator the sector with the highest revealed technological advantage index (see Map 3). The technological specialisation index is measured as follows:

$$IST_{ij} = \frac{P_{ij} \Big/ \sum_{j=1}^{M} P_{ij}}{\sum_{i=1}^{N} P_{ij} \Big/ \sum_{j=1}^{M} \sum_{i=1}^{N} P_{ij}}$$

where i indexes the region (i=1,…, N), j indexes the industrial sector (j=1,…,M) and P stands for patents in the considered period. In order to allow an easier reading of maps, we proceeded with an aggregation in 10 macro sectors, shown in legends. The mapping, among other interesting evidences, shows that there seem to be some clusters of common technological specialisation patterns: Textiles and clothing in Italy, Fuels, chemicals and rubber in Germany, Food and beverages in Northern Europe.

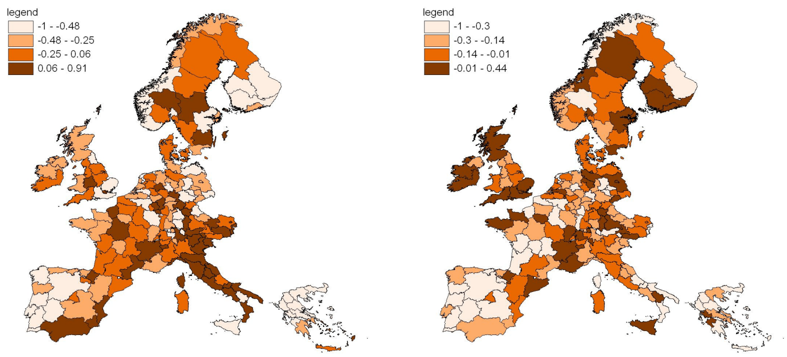
Map 3



Panel a **Panel b**

One way to investigate further on the geographical and sectoral specialisation of innovative activity is to visualize a map for each sector. We choose two different sectors: a traditional one (leather and shoes) and a high tech one (office and computing). Map 4 shows that there seem to be some clusters of common technological specialisation patterns in different parts of Europe. The same picture is found for all the other sectors. However, what these two maps suggest is that the geographical distribution, the intensity of the polarization process and the extent of the regions involved in the clusters are specific for each sector. In particular, Moreno *et al* (2005b) suggest that the innovation of a given industry in a certain region is influenced by the degree of innovation specialization in the same industry but it is not influenced by the degree of innovation diversity of the region's innovation system. Spatial autocorrelation is often present indicating that some externalities move across the regional borders even though further analyses show that they do not often go across national borders showing that institutional difference across nations are important phenomena in conditioning innovation activities.

Map 4



Panel a **Panel b**

5. Concluding remarks

The strong central-periphery distribution of innovation activity which characterized the eighties has weakened even though this process has more recently slowed down. The whole phenomenon proves to be related to spatial dependence, that is, to the fact that technological activity performed in one region may be associated to the one in neighbouring regions. In particular we found that patenting activity in a certain sector tends to be correlated to innovation performed in the same sector in contiguous areas.

This seems to determine the creation of specialised clustering of innovative regions in different sectors which seems to get stronger along time contrary to production cluster which are continuously eroded by the ongoing delocalisation process. In the former case it is clear that positive localization externalities are still at work whilst in the latter the balance of advantages and disadvantages of concentration has turned negative making the delocalisation process convenient

Our reading is that for firms' strategic activities, like innovation, the localization decisions are still greatly influenced by locally bounded interactions with firm with similar characteristics especially in terms of their specialisation. Consequently, it is clear that positive localization externalities are still at work. On the other hand, in the case of production activities the balance of advantages and disadvantages of specialized agglomeration (i.e. factors costs, pecuniary externalities, congestion effects) has turned negative, making the delocalisation process more convenient. National and regional governments in Europe should take these outcomes into account when deciding their strategies to implement the Lisbon agenda to transform the European Union in a big, if not the biggest, player in the knowledge society of the future.

The fact that innovative clusters appear in every sector should be read as a caveat against policies which are aimed myopically only at high tech sectors. Innovative policies, especially when aimed at lagging regions, both within Europe and at the world level, have to consider country specific characteristics and most importantly potential comparative advantages which are suggested by sectoral specialization.

Most importantly, spatial analysis have shown that cross borders spillovers may be important in sustaining innovative excellence. This implies that some policies should be targeted specifically at channeling such spillovers to facilitate the diffusion of knowledge and technological competences also towards developing countries.

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