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Geography of Innovation in European Area Through Patent Statistic

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Abstract

This paper aims to explore the spatial distribution of innovative activity at regional level for the whole European territory, through patent statistics. Innovation has become a very important factor to economic growth and to improvement of technology both at regional and national level. The important role of innovation is presented through the effects of the introduction and diffusion of major technological discoveries and inventions in industry and the world economy. This paper examines through theoretical and empirical analysis both agglomeration and disparities of innovation activities throughout time in Europe. The empirical analysis is based on patent data from OECD (1998-2011) for 31 countries and 890 sub-units (regions). Patent data seems to be the appropriate indicator giving us information about inventors' resident in order to geo-localize innovation activity, The paper is structured as follows: Section one discusses the theoretical and empirical framework of innovation and regional development in relation to patent. Section two describes the data that has been used and the methodology that has been followed in the study. The analysis is based on patent data from the OECD patent database from 1998-2011. Section three presents the empirical results of the study. European regions classification based on their patent stocks, growth, contribution to European innovation activity and concentration. There is a classification both on top twenty innovative countries and regions. Conclusions are briefly presented in section four.

Keywords

Patent Data, Innovation Activity, R & D in Europe

1. Introduction

According to Romer (1994), endogenous growth models depend on knowledge and technological progress and when spatial dimension is concerned, the analysis must be focused on localized knowledge and the local adsorptive capacity (Krugman, 1993).

Knowledge externalities explain the interaction between regions and the existence of knowledge flows that last decays are in the center of analysis. Localized knowledge spillovers have become the corner stone of the geography of innovation literature in order to examine knowledge flows through geographical units. Moreover spatial and technological proximity foster the transmission of ideas and as a consequence regions have a positive impact when they are located near to innovative regions and when there are technological similarities, knowledge externalities are stronger (Moreno, Paci, & Usai, 2003). Although the role of spatial proximity for the process of spatial concentration of inventorship, innovation activity and agglomeration were for many years ignored from economists. Geographical proximity is a necessity in order to share tacit knowledge and to enhance trust between innovators. However some authors go as far as to proclaim the death of distance (Cairncross, 2001) because of the advent of information and communication technologies.

This paper aims to examine through theoretical and empirical analysis both agglomeration and disparities of innovation activities throughout time in Europe. The theoretical framework of innovation and regional development is discussed in relation to patent and the data that has been used in the methodology will be presented. The analysis is based on patent data from the OECD patent database from 1998-2011.

There is a relationship between patents and geography that must be explored in order to understand the role of innovation

in the process of shaping economic geography, which has become the center of analysis the last decade and economists were focused on the importance attributed to knowledge externalities as agglomeration forces (Lissoni & Miguelez, 2014).

Regarding on spatial dimension of innovative activity we must focus our interest in knowledge flows or knowledge spillovers estimating the contribution of spatial proximity in the process of innovation. The phenomenon of spatial concentration of innovative activity in the Europe is an issue that this paper examines through patent data.

During 1970s-1980s most economists argued that knowledge externalities shouldn't be on the centre of analysis because of their un-measurability. As Krugman (1993) mentioned "knowledge flows are invisible; they leave no paper trail by which they may be measured and tracked". In the 30 years that followed many way were found to measure and track spillovers (large survey methods, sophisticated econometric methods, and patent citations as a proxy for knowledge spillovers). Jaffe, Trajtenberg and Henderson, (1993) challenged Krugman's statement on the invisibility of knowledge by arguing that "knowledge flows do sometimes leave a paper trail, in the form of citations in patents". To find geographic localization of spillovers, Jaffe (as stated in Jaffe, Trajtenberg, & Henderson, 1993) proposed a methodology, which has become the basis of the patent-based geography of innovation literature. He proposed to compare the geographical location of the inventors of the cited and the citing patents in order to localize knowledge flows (Lissoni, & Miguelez, 2014). Patents which provide information for inventors into address level, give the possibility to examine where these trails actually lead.

Concerning to distance Jaffe focused on whether patent citations occur mostly within states or within metropolitan areas. Murata (2013) studied cross-boundary, spatially close knowledge spillovers and found that continuous geographical distance and technological agglomeration plays important role. Singh and Marx (2013) showed that physical distance and administrative borders play independent roles as obstacles to knowledge diffusion and Belenzon and Schankerman (1993), who concentrate their attention on university-industry knowledge spillovers, shown that citations to patents decline sharply with distance from the universities and are strongly constrained by state borders (Lissoni & Miguelez, 2014).

Knowledge tend to spills over creating knowledge externalities and regarding the geographical context, knowledge can't be bounded neither in geographical limits neither in political ones. However, knowledge spillovers decay with distance, because there is a spatial autoregressive process, when the distance between the regions increases the autocorrelation decrease. In addition, knowledge spillovers have some geographical limits in the range of 250 km (Moreno, Paci, & Usai, 2003). From a national and transnational scope, knowledge essentially spills over to regions that belong to the same country, because of some cultural and institutional limits so that the national innovation systems seem to dominate the European one. Moreover, knowledge spillovers to regions that share a common border and belong to different countries, but knowledge spillover seems to be more effective at national level than transnational (Moreno, Paci, & Usai, 2003). Glaeser, Kallal, Scheinkman, and Shleifer (1992) argued that knowledge spillovers are more luckily to be generated in cities due to spatial proximity.

Regarding knowledge spillovers in the industry level, Jane Jacobs opposed to the Marshallian point of view, that it is more important to focus our interest in intra-industry externalities, arguing that inter-industry externalities must be in the centre of analysis, because in diversified cities and metropolitan areas there is the appropriate environment for inter-personal interaction.

The concept of localized knowledge spillovers (LKS) has become a cornerstone of the geography and innovation literature. Jaffe and Griliches through the LKS research programme tried to produce reliable methodologies for the estimation of the relationship between R & D and economic growth (Breschi & Lissoni, 2003)

Knowledge spills over more effectively when there is spatial proximity. As Glaeser, Kallal, Scheinkman and Shleifer (1992, p. 1126) observe, "Intellectual break through must cross hallways and streets more easily than oceans and continents." It is important to study the spatial distance between actors because innovative activity and knowledge are concentrated in specific space. According to some evidence and results from econometric analysis, there is positive association between the innovative output of a region and the innovative activity of a neighboring region, in the distance of 250 km (Moreno, Paci, & Usai, 2003).

Spatial proximity and spatial concentration of innovative activity weren't on the centre of analysis until recently. Paul Krugman (1993) asked "What is the most striking feature of the geography of economic activity? The short answer is surely concentration...production is remarkably concentrated in space." Feldman (1994) supported this argument not only for the production area but also for innovation activity (Audretsch & Feldman, 2003).

The first reason that reveals the necessity of the role of spatial proximity is tacit knowledge. Tacit knowledge can be shared easier when actors of innovation process are in short distance. Is the information that is transmitted through interactive social net-works between inventors and trust between the actors is gained through a frequent interactions (Simmie, 2003). In the case of cited patents face to face communication contributes to a more effective interaction because details and many practical issues can be easily explained. On the other hand, codified knowledge such as books and documents don't need direct social interactions.

Krugman (1993), invoking Marshall (1920) focused their interest on agglomeration forces. These forces are labour market pooling, which means that specialized workers tend to agglomerate, market for intermediate inputs because of returns of scale economies and transport costs and technological externalities. The last one shows that universities, research centres tend to concentrate because information is transmitted faster when there is geographical

proximity and there is a reduce of the exchanging knowledge costs. Agglomeration is the second reason that geographical proximity has an important role because empowers the communication.

However many argues that due to the development of ICT which favors the codification of knowledge, in the near future , knowledge would be easily transferred with low costs in long distances replacing face to face interaction. That is the phenomenon of death of distance (Cairncross, 2001).

Innovation activity and technological process of a region depend on localized knowledge and the absorptive capacity, so it is very important to take under consideration the knowledge production function which is identified by two indicators: first, technology input measures such as R&D expenditures and employees, and second indicator is the technology output measures like patents. Generally, patent data seems to be a useful indicator in order to measure innovation activity of a region and to find Localized knowledge spillovers through patent citations and knowledge production function.

There are some differences between the two types of indicators, R&D and patents data. More specifically technology input measures (such as R&D expenditure and employees) have some drawbacks and as a consequence patent data are more suitable according to three main reasons. Firstly, the main reason is that provide us information about the inventors' and proponents residents, so we can geo-localize the innovation activity to geographical units, such as regions. Patents data give information down to the level address. On the contrary R&D statistics are available just for some regions or at the national level. Moreover, we prefer to use inventors as an indicator because proponents' residents corresponds to firm's headquarters and there is the case that the invention took place in a subsidiary which maybe is located in another region. Also in the case of more than one inventors it is used a proportional fraction of each patent in order to define their regions. The regional distribution of the patent applications is assigned according to the address of the inventor. On the other hand the regional R&D gives us regional information about the institution in which R&D is performed and where inventions are developed.

Secondly, they provide the technological content of the invention and permit the classification to industrial sectors whilst R&D data is usually aggregated, especially at the regional level. Thirdly, one other advantage is that patents provide a dynamic analysis because the data are available year by year for a long time span and permit a dynamic analysis, on the contrary regional R&D data is available only for recent years and discontinuously.

According to Griliches (1990, p. 1661), "in this desert of data, patent statistics loom up as a mirage of wonderful plentitude and objectivity." Patents seems to be an appropriate indicator in order to measure knowledge spillovers and other spatial externalities (Griliches, 1979; Jaffe, Trajtenberg, & Henderson 1993). Also, through patent data experts can measure spatial inequality of inventorship and the distribution of innovative activity in both country and regional level (Audretsch and Feldman, 1996; Fornahl and Brenner, 2009).

The relationship between geography and innovation and the distribution of innovative activity in European territory were examined earlier by Moreno, Paci and Usai (2003). This research was based on a statistical databank on regional patenting from the European Patent Office (EPO) from 1978–2001. Had been selected 175 sub-national units (regions) from 17 countries (the 15 members of the pre-2004 European Union plus Switzerland and Norway), that had the appropriate administrative and economic control.

This research explored the geography of innovation focusing on the spatial distribution of innovative activity over two decades (1978-2001) in the European territory. The results were quite expected and show that innovative activity is rather concentrated. There is a strong central periphery distribution and more specifically in a country level Switzerland seemed to be the master over the two decades followed by Germany and Luxemburg who appeared to be less powerful at the 90s, and Finland took the third place. The intensity of innovation activity has increased within all the countries and the phenomenon of central-periphery distribution of innovation boom in the 80s because of the entrance of Southern and Northern countries. At country level, the results are almost the same, Germany at 90s became stronger (11 regions out to 20 are German) while Swiss lost some ground. Regions in Switzerland, in West Germany, the North and East of France, the North of Italy, the United Kingdom, Denmark, the Netherlands and Sweden present a strong patenting activity in the 80s, in the 90s Spain, North Italy and Scandinavian countries become more innovative.

Also through spatial econometric analysis estimated that there is spatial dimension of knowledge spillovers and spatial and technological proximity matters to knowledge interregional interdependence.

A more recent research follows about the spatial distribution of innovative activity in Europe. The classification of regions and countries according to their innovative activity including years that have been already examined in former researches shows. The results point a rearrangement of countries in the total classification but northern and western countries remain on the top of the list with some exceptions.

2. Methods

This section describes the methodology was used in order to explore the spatial distribution of innovative activity in European regions in 1998-2011, based on OECD patent databank. Research was based on patent data from 31 European countries, including Switzerland and Norway and 890 sub-national units (regions). As for the territorial break up, it is followed the classification of OECD for each country to NUTS 1,2,3. The results are based on the absolute value of patents without taking under consideration the population as indicator.

Our proxy for innovative activity refers to patent applications at the European Patent Office over the period 1998-2011, classified by the inventors' region in Europe. As it

is mentioned, it has been used of inventors' resident, rather than the proponents' one in order to attribute the spatial localization of each innovation (Breschi 2000; Paci and Usai, 2000). In cases that patents had more than one inventor, it has been used a proportional fraction of each patent in order to record the different inventors' regions.

3. Results

Table 1 presents a classification of the 20 most innovative European countries according the total number of patents that were reported in each region. The most innovative country is by far Germany with more than 313.388 patents and its total share to Europe is 42.49%, followed by France with 110.052 patents (14.92%) and United Kingdom with 72.485 (9.83%). In the third column of the table it is becoming apparent the predominance of Germany in Europe and the gap between the second France and the followed United Kingdom.

Table 1. *Top 20 innovative countries based on total number of patents (source: OECD .org, 2015).*

Country	Total Patents	Contribution to Europe %
Germany	313388,8599	42,49
France	110052,8465	14,92
United Kingdom	72485,7369	9,83
Netherlands	47410,0203	6,43
Switzerland	41405,8468	5,61
Sweden	33031,0121	4,48
Italy	22140,6758	3,00
Austria	19983,810	2,71
Belgium	19547,2724	2,65
Spain	15869,787	2,15
Denmark	15267,2265	2,07
Norway	5951,5662	0,81
Finland	4651,9238	0,63
Ireland	3776,5213	0,51
Poland	2137,1424	0,29
Hungary	1987,3019	0,27
Czech Republic	1787,0359	0,24
Slovenia	1306,4613	0,18
Luxemburg	1148,9818	0,16
Greece	1083,4265	0,15
Sum	737619,7	100%

According to previous research the classification was totally different, on the top of the list was Switzerland which now is in the 5th order of the classification and was followed by Germany which had presented an amazing progress. The leader countries, which represent the central Europe, continue to concentrate the innovative activities and Scandinavian countries still play a significant role on the list of the top innovative ones but in lower positions compared to former classifications, for instance Finland had lost some ground regarded to the 4th place of 1999. Table 1 illustrates an improvement of southern countries such as Italy with total number of patents 22.140, Spain, and Greece. Regarded the difficult economic circumstances remained among the most innovative countries in Europe the last decay. More specifically Italy is in the 7th place and Spain in the 10th and Portugal is still remaining in a good position (21) with lower values of contribution to total innovative performance of Europe.

The innovative divergence between northern and southern countries seems to be reduced over the decays, central and eastern countries such as Poland, Czech Republic , Hungary and Slovenia represent remarkably results in the last research and Southeastern countries continue to be out of competition.

A similar picture it is appeared at the regional level in Table 2, where among the top performers is Germany with 12 regions out of 20, followed by France, Switzerland, Sweden and Netherlands. Stuttgart is the pioneer of the list with 26.625 total number of patents. The absolute dominance of regions in Germany is clearly illustrated in this table. In the third column is represented the percentage of contribution of each region to European patenting activity; however the classification is based on the total number of patents. The first three most innovative regions, Stuttgart, Munchen and Noord-Brabant which the last one belongs to Netherlands , seems to have a great contribution to European patenting activity with a percentage of 3%.

Table 2. *Top 20 innovative regions 1998-2011 and the contribution to Europe (source: OECD. org, 2015).*

Region	Nation	Patents	Contribution to Europe %	Contribution To Country %
1. Stuttgart	DE	26625,49	3,60965	8,4959907
2. München	DE	24927,98	3,37952	7,9543278
3. Noord-Brabant	NL	23483,00	3,18362	49,53173
4. Düsseldorf	DE	14298,75	1,93850	4,5626233
5. Rhein-Main	DE	13466,05	1,82561	4,2969138
6. Paris	FR	10733,71	1,45518	9,7532308
7. Stockholms län	SE	10385,34	1,40795	31,441188
8. Industrieregion Mittelfranken	DE	10305,53	1,39713	3,288415
9. Berlin	DE	8835,98	1,19790	2,8194925
10. Hauts-de-Seine	FR	8753,09	1,18667	7,9535299
11. KölnDE	DE	8741,75	1,18513	2,7894262
12. Zürich	CH	8569,49	1,16178	20,696318
13. Unterer Neckar	DE	8202,97	1,11209	2,6175057
14. Isère	FR	7814,01	1,05935	7,1002313
15. Starkenburg	DE	6739,87	0,91373	2,1506405
16. Yvelines	FR	6640,60	0,90027	6,0340057
17. Mittlerer Oberrhein	DE	6603,97	0,89531	2,1072776
18. Zuid-Holland	NL	6565,76	0,89013	13,84888
19. Aachen	DE	6535,52	0,88603	2,0854334
20. Rheinpfalz	DE	6494,37	0,88045	2,0723056

It is important to mention that from the total amount of European countries that had been examined, the capital city of 22 of them is in the most innovative region of the country, for example, Paris, Prague, Oslo, Stockholm and Zürich. Innovation activity tend to concentrate in large cities, which in this case is capital cities, where population density (tacit knowledge) combined with other factors such as the spatial and technological proximity, favor knowledge externalities.

Table 3. *European countries and concentration (source: OECD.org, 2015).*

Country	No. Regions	NUTS	Concentration Ratio	Normalized Herfindahl index	Innovative Region	Capital City
Austria	36	3	0,07	0,05	Wien	yes
Belgium	12	2	0,12	0,04	Antwerpen	No
Bulgaria	29	3	0,40	0,37	Sofia	yes
Croatia	8	3	0,41	0,32	Primorje-Gorski Kotar	No
Cyprous	1	1	1,00	1,00	Kypros	yes
Czech Republic	15	3	0,11	0,05	Prague	yes
Denmark	12	3	0,13	0,05	Nordsjælland	No
Estonia	6	3	0,56	0,47	Pohja-Eesti	yes
Finland	7	2	0,51	0,43	Pirkanmaa	No
France	101	3	0,04	0,03	Paris	yes
Germany	97	3	0,03	0,02	Stuttgart	No
Greece	14	2	0,41	0,36	Attiki	yes
Hungary	21	3	0,30	0,27	Budapest	yes
Iceland	9	3	0,44	0,37	Capital Region	yes
Ireland	9	3	0,17	0,07	Dublin	yes
Italy	62	3	0,08	0,07	Torino	No
Latvia	7	3	0,59	0,52	Riga	yes
Lithouania	11	3	0,43	0,38	Vilnius	yes
Luxembourg	1	1	1,00	1,00	Luxembourg	yes
Malta	3	3	0,81	0,72	Malta	yes
Netherlands	13	3	0,29	0,23	Noord-Brabant	No
Norway	20	3	0,11	0,06	Oslo	yes
Poland	67	3	0,05	0,03	Miasto Warszawa	yes
Portugal	31	3	0,16	0,13	Lisbon	yes
Romania	43	3	0,26	0,24	Bucuresti	yes
Slovakia	9	3	0,21	0,11	Bratislava	yes
Slovenia	13	3	0,28	0,22	Osrednjeslovenska	yes
Spain	60	3	0,15	0,13	Barcelona	No
Sweden	22	3	0,18	0,14	Stockholms län	yes
Switzerland	27	3	0,09	0,06	Zürich	yes
United Kingdom	124	3	0,02	0,02	Cambridgeshire CC	No
Sum	890					

In the order to examine concentration of innovative activity in each country, it has been used Herfindahl index and the results are illustrated in the 4th column of table 3. In the 5th column there are the results which are related to Normalized Herfindahl index .Using the data from the 4th column of the same table, we can estimate the intensity of concentration.

$$H^* = [H - (1/N)] / [1- (1/N)]$$

Accordingly, H is Herfindahl index and N is the number of regions in each country. For example, Austria has thirty six regions and H= 0.07, as a consequence concentration ration is 0.04.

$$H^* = [0,07 - (1/36)] / [1- (1/36)] = 0,04$$

If H has value lower than 0.01 then in the country there is intensive competition in patenting activities. In the case that H is lower than 0.15 then there isn't concentration, when the value of H is between 0.15 and 0.25 there is medium concentration and when the value is upper than 0.25 there is high concentration.

Regarding the results United Kingdom followed by Germany and France present the lower values demonstrating the lack of concentration on patenting activity in regions within the country. In these cases the majority of regions within the country present similar values of innovative activity without extreme values and belong to the second category of no concentration tendency. These countries contribute equally to country's innovative outputs and total performance. Countries such as Sweden , Spain and Portugal presents inequalities between the distribution of innovative activity in each region, due to a greater contribution of a smaller amount of regions to total country value , presenting a more intensive innovative activity than the others. In these cases the centralization could be characterizes as medium. Countries such as Greece, Finland , Hungary and Netherlands present high concentration of innovative activity in specific regions, for example Noord-Brabant in Netherlands contribution to country is 49.53%. The fifty percent of the sample presents high concentration of innovative activity and region that presents the highest value are for the majority of countries the capital region.

4. Conclusions

This paper through the theoretical analysis attempts to explore the geography of innovation and the role spatial dimension to the creation of knowledge externalities. Patent data seems to be the appropriate indicator in order to study localization in space of knowledge flows and to explore the dimension of distance that affects knowledge diffusion.

Spatial proximity favors the transmission of knowledge and regions that are located near to innovative ones are advanced from knowledge externalities. The concentration of innovative activity in specific places and agglomeration play an important role on the geography of innovation that for many years had been ignored.

The empirical analysis demonstrated the differentiation of geographical distribution of innovative activity in European space from the primer researches. The strong central-periphery distribution of patenting activity is a phenomenon that belongs to the past; in the last decay regions from northern and southern Europe are participating in the process of technological development. However strong European economies, which are located in the central of European territory, present the most intensive innovative activity. There are disparities and inequalities of innovation outputs even in regions within the same country and the majority of the sample present strong innovative activity in one or two regions that seems to be the capital one.

The role of universities as localized knowledge spillovers and the role of income inequalities within European regions should be examined in order to explore further spatial disparities of innovation activity. Maps would be useful in order to explore the role of geographical proximity between regions even in a transnational level.

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