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Technological spillovers and industrial location in Spain

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Abstract

While different studies have supported the existence of knowledge spillovers and shown their importance for economic growth, very few have focused on analysing their relation with the propensity for industrial activity to cluster spatially.

The main purpose of this paper is to examine the geographic concentration of industrial activity in Spain, specially of innovative activity, and to link it with the existence of knowledge externalities. This analysis will be based in the Marshallian concept of external economies. As Marshall argues, there may be geographic limitations to information flows or knowledge spillovers among the firms in an industry.

Firstly, this paper will present the spatial distribution of innovative activities, using input and output indicators, for the United States and Europe. Secondly, the same analysis is done in the case of in Spain. The use of Gini's index shows that innovative activities cluster spatially more than economic activity in general. Also, the R+D intensive industries show a higher degree of concentration which could be a first indication of the important role of knowlededge spillovers.

Keywords: technological spillovers, regional innovation, R+D

TECHNOLOGICAL SPILLOVERS AND INDUSTRIAL LOCATION IN SPAIN

The purpose of this paper is to provide information about an ongoing research study that is attempting to examine the geographical concentration of innovative activity in Spain, and to link this with the existence of knowledge spillovers.

In this case, the prime objective is to examine the degree of concentration of industrial activities, and particularly innovative activities, in Spain. Through this, an attempt will be made to analyse their relation with the existence of external economies of a technological nature and, consequently, with growth. This analysis of industrial location is based upon a Marshallian concept of external economies. Marshall's contribution allows growth and location factors in geographical areas to be identified. Specifically, the main factors considered that generate external economies are the existence of entire markets for skilled workers, the supply of factors necessary for production and the diffusion in the local milieu of innovations (technological spillovers).

The present theoretical literature, together with a series of applied studies, has shown the importance of technological spillovers. Departing from this evidence the question is, therefore, to examine their relation with the spatial distribution and geographical concentration of innovative activities.

This paper is divided into the following parts. Firstly, the existing literature on the nature and consequences of the presence of external economies of a technological character on the location of industrial activities is examined briefly. This question enters into the importance of geographical proximity in the use made of technological spillovers. Secondly, existing evidence is presented on the spatial distribution of innovative activities in the United States and Europe. Finally, the spatial distribution and degree of concentration of innovative activities in Spain are presented.

1. External economies of a technological nature and location of industrial activities.

The new theories of growth have given prominence to the existence of external economies, and more precisely technological spillovers, as a fundamental condition for economic growth. Specifically, the contributions of Romer (1990) and Grossman and Helpman (1991), where knowledge is explicitly recognized as an input in the research process, emphasize this matter. Research allows, on the one hand, innovations and designs for new goods to be obtained, and on the other hand generates external economies, based upon the information derived from the research process. This is so given that it is not possible to appropriate the value of the information totally and as a consequence the externality generated allows the cost of future innovations to be reduced, with positive effects on growth.

Nevertheless, as Griliches (1991) indicates, whether technological spillovers allow decreasing returns to be avoided depends on their magnitude. Numerous applied studies on technological spillovers have been carried out in this direction from which can be drawn a series of general conclusions. These are (Griliches, 1991; Mohnen, 1996):

- Empirical evidence exists of the presence of technological externalities and that their magnitude is relevant. Estimates show that the rates of social returns are significantly above the private rates.
- The impossibility of appropriating the benefits of R+D activities totally, and the presence of technological externalities, should not lead to the conclusion that there are no transmission costs. Firms must have the capacity to absorb external technology. In this matter the level of skill of the workforce and the presence of external services are basic to having this capacity available.
- Although there is evidence of the existence and the importance of international externalities, applied studies show that geographical proximity has significant positive effects.
- Current knowledge about technological externalities is, in spite of the advances made, limited. For example, as Mohnen (1966) points out, we know little about how they are transmitted, where they originate and where they go, how long they take to spread or how they are picked up and used.

Of this group of conclusions, this paper concentrates upon the importance of geographical proximity. In this sense, and in parallel with the importance given to knowledge spillovers as a factor in growth, there is a whole group of relatively recent studies concerned with the geographical dimension of knowledge spillovers, and as a consequence on their influence on the location of productive activities. (Jaffe et. al., 1993; Audrestch and Feldman, 1966; Glaeser et. al., 1992; Feldman, 1994; Henderson et. al., 1995).

These analyses take up the contribution of Marshall, departing from the argument that there must be certain barriers or geographical limits to flows of knowledge. That is to say that presumably the cost of diffusion and transmission of knowledge must increase with distance. The capacity to receive technological spillovers must be influenced by distance in the same way.

As Ottaviano and Martin (1996) state, a close relation must exist between the theories of endogenous growth and the analyses of the 'new economic geography'. The object of analysis of the latter is to determine the motives for the location of firms and the concentration of firms in a few regions. For its own part, a fundamental objective in the theory of endogenous growth is to determine the motives for creating new firms and new products through technological change. In addition, the absence of the geographical dimension in growth models contradicts the statement of Lucas (1988) who considers that the external effects that are at the base of the mechanisms that determine growth require interaction between agents and are, by nature, basically local.

Lucas made this statement when attempting to find evidence to confirm estimates of the external effects of human capital on production. The work of Jacobs (1986) is, in the opinion of Lucas, a very stimulating approach towards examining the external effects of human capital in more detail, although it does not allow the quantitative effects to be determined. Jacobs emphasizes the importance of the interaction between agents and the role of cities in economic growth. Lucas suggests that the 'forces' that explain the central role of cities in economic growth are of the same type as those considered in the case of the external effects of human capital.

This group of contributions shows, as Lucas (1988) points out, that to use the nation as a unit seems totally arbitrary from the point of view of technology. As a consequence there is a group of arguments (Antonelli, 1995) that explain the concentration of innovative activities and show that the greatest use is made of technological spillovers in local or regional situations. These arguments are:

- Spatial proximity facilitates the circulation of information and opportunities for external learning, that is to say learning from specific knowledge generated by other firms.
- The technological effects of specific knowledge and skills embodied in the workforce and derived from mobility among firms take place by preference in a local milieu.
- Firms located in the same region benefit from the externalities of research carried out by the universities situated in the region.
- The local or regional level is favourable for interaction among firms based on relations to do with subcontracting and cooperation.

Studies carried out on industrial districts support these ideas. These depart from the contribution of Becattini (1979) that recovers and expands upon the Marshall's concept of an industrial district with an increase in the advantages derived from location in an industrial district. Among these, the diffusion of knowledge framed within the 'local industrial atmosphere' continues to occupy first place. In the same direction it is possible to include such well-known cases as Silicon Valley.

Confronting the concept of new knowledge as a public good, easily accessible and with very low transmission costs, the empirical evidence shows the shortcomings of this idea. As Audrestch and Feldman (1996) point out, although the cost of transmitting information may not vary with distance, presumably the cost of transmitting knowledge increases with distance. In addition, a great part of innovations take place in cities (Jacobs, 1986), which is a reflection of the importance of the interaction among individuals and firms in the generation and the adoption of innovations. For their part, Glaeser et. al. (1992) state that 'after all, intellectual breakthroughs must cross hallways and streets more easily than oceans and continents'.

It therefore seems relevant to analyse the importance of geographical proximity in the transmission of spillovers and in the capacity to make use of them. The fundamental problem, as Jaffe (1993) points out, is that knowledge about where the spillovers go is very limited.

The few existing studies show that technological spillovers are geographically concentrated (Jaffe et. al., 1993). As such, if distance influences the capacity to receive technological spillovers, there must be a certain concentration, particularly in those industrial activities in which they play an important role (Audrestch and Feldman, 1996). The existing evidence shows that industrial activity, and especially innovative activities, do not distribute themselves uniformly over an area but show a high degree of geographical concentration. As Jaffe (1993) and Audrestch and Feldman (1996) indicate, one of the main difficulties in this type of study is to separate the effects of the spillovers from the correlation due to the existence of a determined pattern of location, that is the obvious explanation of why innovative activity, in certain industries, tends to be concentrated geographically is that the location of the production shows a spatial concentration. The hypothesis that should be verified is that innovative activity will tend to concentrate itself in those industrial activities in which new technological knowledge plays a greater role.

2. Spatial distribution of innovative activities. Evidence in the United States and Europe.

The analysis of the spatial distribution of innovative activities is confronted with the obstacle presented by the inexistence of any measurement that gathers together all aspects of the processes of innovation and particularly the output generated by innovative activities. This obstacle, obviously, is not simply limited to the study of spatial location, and is present in the analysis of the technological innovation as a whole.

For this reason, departing from the function of knowledge proposed by Griliches (1979), it is convenient to examine various indicators, that are divided into input indicators and output indicators. Among the first, the most common are expenditures on R+D and the personnel in R+D, while among the second patents are the basic indicator. None of these is exempt from problems nor allows all aspects of innovative activity to be gathered together.

Together with these indicators, on certain occasions, it is possible to have recourse to more direct indicators of innovative activity from occasional surveys or from information appearing in specialised publications. This is the case with the number of innovations used by Feldman (1994). Also, and as a complement to the indicators mentioned, figures can be included on the added value or employment in sectors with a high technological content.

After these initial considerations, the evidence on the spatial distribution and concentration of innovative activities in Europe and the United States is presented. The analysis carried out is fundamentally descriptive and its main purpose is to provide a framework for and facilitate international comparisons of the analysis of the case of Spain.

The most detailed analyses of the spatial distribution of innovative activities have been carried out, largely facilitated by the availability of information, in the United States. After the pioneer studies of Malecky (1991) concerned with the location of R+D activities, Jaffe (1989) and particularly Feldman (1994) have examined the degree of concentration of innovations and have gone into the motives explaining this fact in depth.

The following table shows, from the work of Jaffe (1989) and Feldman (1994), some of the main indicators of innovation and allows some primary conclusions to be obtained. In three states, California, New Jersey and New York, 48.73% of industrial innovations (INNOVA) and 34.18% of industrial patents had their point of origin, and 44.71% of expenditure on R+D by industrial firms was made. These three percentages are well above the 26.05% corresponding to the share of industrial employment of these three states of the 29 states for which complete information is available for the group of variables. Consequently, innovative activity, both from the angle of inputs as well as results, shows a greater geographical concentration than industrial activity. The calculation of Gini's concentration indices confirms this conclusion. In fact, Gini's index for the innovations (Feldman, 1994) is 0.65, for the patents is 0.56 and for industrial expenditure on R+D is 0.63, all of these being above the 0.44 for industrial employment.

Table 1. Spatial distribution of innovative activity in the United States.

	INNOVA	Patents	Industrial R+D.	Industr. Employ.
Alabama	0,13%	0,27%	0,32%	2,05%
Arizona	1,08%	0,96%	1,19%	0,87%
Arkansas	0,13%	0,15%	0,05%	1,17%
California	25,59%	12,66%	22,97%	12,18%
Colorado	1,10%	1,30%	0,99%	1,10%
Connecticut	3,47%	4,27%	3,85%	2,72%
Florida	1,73%	1,66%	2,22%	2,65%
Georgia	1,39%	0,75%	0,46%	3,08%
Illinois	6,07%	9,61%	5,29%	7,47%
Indiana	1,29%	3,07%	2,35%	3,84%
Iowa	0,53%	0,95%	0,80%	1,44%
Kansas	0,39%	0,57%	0,39%	1,13%
Kentucky	0,24%	0,82%	0,43%	1,59%
Louisiana	0,13%	0,64%	0,38%	1,23%
Massachusets	9,46%	5,25%	5,64%	4,07%
Michigan	2,94%	6,76%	10,74%	5,97%
Minnesota	2,89%	2,46%	2,36%	2,25%
Missouri	0,95%	1,66%	2,48%	2,58%
Nebraska	0,24%	0,20%	0,05%	0,56%
New Jersey	11,19%	10,32%	8,05%	4,79%
New York	11,98%	11,20%	11,00%	9,08%
N Carolina	1,00%	1,28%	1,14%	4,82%
Ohio	4,94%	7,84%	5,48%	7,36%
Oklahoma	0,53%	1,78%	0,55%	1,16%
Pennsylvania	6,44%	9,13%	7,65%	7,87%
Rhode Island	0,63%	0,37%	0,19%	0,76%
Utah	0,29%	0,40%	0,43%	0,55%
Virginia	1,00%	1,16%	1,22%	2,45%
Wisconsin	2,26%	2,49%	1,33%	3,23%
TOTAL	100,00%	100,00%	100,00%	100,00%

Source: Compiled by the author from Feldman (1994) and Jaffe (1989).

The analysis with the greatest degree of separation of data, by branches of industry, shows that geographical concentration is even greater in those sectors with a greater technological content such as the manufacture of computers, precision instruments, electronics and pharmaceutical products, among others.

This evidence presented by Feldman (1994) does not allow, as the author points out, to immediately conclude that geographical distance plays a relevant role in the distribution of innovative activities. In this sense it is necessary to put forward two hypotheses (Feldman, 1994). The first is to examine whether geography is really important, that is if it is an explaining variable, or whether the proportion of innovations attributed to each industry and each state is simply determined by the propensity to innovate of the various industries and states. The use of a chi-square test allows the rejection of the hypothesis of independence of innovations from industry and state, therefore it is possible to conclude that the number of innovations in each state and branch of industry is not strictly determined by the propensity to innovate of the various industries and states.

The second hypothesis is derived from the evidence of the geographical concentration of industrial activities and consequently the geographical distribution of innovative activity could be determined by the geographical distribution of industrial activity. The corresponding values of the correlation between both variables, innovations and industrial added value, globally as well as with a certain sectoral separation show that although the correlation is positive, the relation is not deterministic.

As far as the case of Europe is concerned, the limitations of the information have restricted the study of the spatial distribution of innovative activity for Europe as a whole. Currently, the existing information, with a certain degree of homogeneity for European countries, is made up of expenditure on R+D and personnel in R+D available from the REGIO data base, and of the statistics for patents from the figures of the European Patents Office.

From this data the existing evidence also shows a strong geographical concentration of innovative activity and as a consequence how certain regions enjoy comparative advantages in the production of technological innovations.

With regard to expenditure on R+D, homogenous information is available for NUTS 2 regions for France, Italy and Spain, and NUTS 1 for Germany. The calculation of Gini's indices for private expenditure on R+D in comparison with industrial employment clearly shows a greater concentration of innovative activity. For the four countries considered the Gini index for expenditure on R+D oscillates between 0.54 for Germany and 0.76 for Spain, values that are clearly higher than those for the degree of concentration of industrial employment. Obviously, for the group of countries considered as a whole there is also, to an even sharper degree, a greater concentration of innovative activities.

Table 2. Gini index. Private expenditure on R+D and industrial employment. 1990

	Expenditure on R+D	Indust. employment

European Union-4	0,77	0,50
Germany	0,54	0,46
France	0,69	0,39
Spain	0,76	0,45
Italy	0,73	0,45

Source: Compiled by the author from Eurostat.

Apart from this, the spatial distribution of patents in Europe has been examined by Caniels (1997). In this case the countries studied were France, Italy, the United Kingdom, Spain and Holland. The conclusions the author arrives at confirm the evidence already presented. Specifically, the comparison between the figures for gross added value and those for patents shows how, although there is a geographical concentration of both, it is greater for the innovative activity. Another conclusion of interest is that by sectors, with regard to patents, the degree of concentration all over Europe is similar while the manufacturing added value shows significant variations with regard to the degree of concentration.

3. Spatial distribution of innovations in Spain

The Spanish economy presents, as is known, a strong concentration of productive activity, with the considerable weight of the Autonomous Communities of Madrid and Catalonia. From 1995 data it can be seen that these two Communities generate 35% of the total gross added value (VAB) in Spain. To examine the geographical distribution of innovation by Autonomous Communities, as a first approach, two input and one output indicator were used. The former were firstly total expenditures on R+D (GID) and secondly expenditures on innovation (GINNOV) made by innovative firms from a new survey carried out by the National Institute of Statistics (INE). In this case the expenditure on innovation, departing from the directives of the Oslo manual, includes together with expenditure on R+D, other types of expenditure that form a part of the process of innovation such as the acquisition of non-material technology, expenditure on industrial design or industrial engineering. As an output indicator patents (PAT) were used, assigned to the various Autonomous Communities depending on the place of residence of the first applicant (Coronado, Acosta; 1997), which is the only indicator of output available.

The regional distribution of these indicators shows a strong geographical concentration of innovative activity, greater than the global concentration of economic activity. Specifically, Catalonia and Madrid make up 55% of the expenditure on R+D, 50% of the expenditure on innovation and generate 51% of the patents. Following these two Autonomous Communities are the Basque Country, the Community of Valencia and Andalusia.

Table 3. Indicators of innovation. Geographical distribution.

	VAB. 1995	GID 1995	GINNOV94	PAT92
Andalucía	13,42%	9,71%	5,19%	7,21%
Aragón	3,47%	2,46%	9,66%	3,36%
Asturias	2,58%	1,63%	0,86%	1,85%
Baleares	2,41%	0,47%	0,10%	1,36%
Canarias	3,87%	2,02%	1,43%	1,02%
Cantabria	1,31%	0,85%	1,38%	0,68%
Castilla y León	5,88%	3,78%	5,26%	3,31%
Castilla-La Mancha	3,57%	1,88%	2,30%	1,70%
Cataluña	19,26%	21,04%	26,15%	28,69%
Comunid. Valenciana	9,78%	5,88%	6,45%	10,81%
Extremadura	1,93%	0,60%	2,32%	0,88%
Galicia	5,39%	3,33%	5,68%	2,44%
Madrid	15,96%	33,98%	21,61%	22,65%
Murcia	2,42%	1,43%	0,87%	1,75%
Navarra	1,64%	1,56%	1,95%	1,80%
País Vasco	6,35%	9,04%	8,10%	9,64%
Rioja (La)	0,77%	0,33%	0,67%	0,83%
TOTAL	100,00%	100,00%	100,00%	100,00%

Source: INE and Coronado and Acosta (1997).

To analyse the degree of concentration of innovative activity in more detail it is again convenient to use Gini’s index. Obviously values nearer to 1 indicate a greater degree of concentration and consequently the results obtained show how the concentration of innovative activity is, both for the input as well as for the output indicators, clearly above the value obtained for economic activity measured by Gross Added Value.

Table 4. Concentration of innovation. Gini index.

	Gini index
Gross Added Value	0,46
R+D expenditure	0,63
GINNOV	0,57
Patents	0,60

Source: Compiled by the author from data in the previous table.

In agreement with Arrow (1962) and Audrestch and Feldman (1966), technological spillovers play a more important role in sectors with a greater technological content. Consequently it can be expected that intensive R+D sectors show greater concentration. To examine this matter, in the case of Spain, the Gini indices for the branches of industry of a high technological content are presented below. In this case the variables used are industrial employment by Autonomous Communities and information is also offered on expenditure on innovation in these sectors. The entire group of selected sectors employs 8.5% of the total of industrial employment and makes 24.5% of the total expenditure on innovation made by innovative firms.

Table 5. Sectors with a high technological content. Gini index.

	Empoyement (1991)	GINNOV
Pharmacy	0,88	0,84
Office machinery	0,89	0,91
Electrical machinery and material	0,68	0,66
Electronic material	0,83	0,87
Aircraft	0,89	0,89
Optical and precision instruments	0,79	0,80
Total	0,49	0,57

Source: Compiled by the author from data from the INE.

The results reflect the very high concentration of the sectors of high technological content in Spain, with Gini indices clearly higher than those for industry as a whole. In the same way expenditure on innovation in these sectors also shows greater concentration, with values very close to those for industrial employment. Certainly, these results do not permit the conclusion to be drawn that technological spillovers and the greater use made of them that geographical proximity could mean would be the determining factor of this greater concentration. Other reasons, among which the presence of economies of scale is the most obvious, could play a relevant role.

Finally, it seems relevant to examine the influence of policy on technology on the distribution of innovative activities in Spain. Various studies (Landabaso, 1995) have shown the persistence of regional disequalities in the level of innovation and the nil redistributive effect that public support of R+D has played. Also, already existing R+D activities constitute one of the main explaining variables of the regional distribution of public funds for the improvement of levels of technology (Vence and Guntín, 1998). To analyse this question the data corresponding to geographical distribution is presented for three of the main instruments for public support of research and innovation. These are the Industrial Technology Development Centre (CDTI), the National Research and Development Plan (PNID 1988-1992) and the III

Research and Development Framework Programme of the European Union (1990-1994). In the first case the total budget of the projects approved by the Industrial Technology Development Centre and its regional distribution is used as an indicator, and for the other two the distribution of support and funds by Autonomous Communities.

Table 6. Technological policy. Geographical distribution

	CDTI 1995	PNID8892	III PM
Andalucía	5,62%	7,21%	6,4%
Aragón	3,75%	3,59%	1,2%
Asturias	1,62%	2,01%	1,5%
Baleares	0,19%	0,51%	1,0%
Canarias	0,68%	1,79%	0,7%
Cantabria	0,98%	1,17%	1,2%
Castilla y León	4,53%	2,84%	1,4%
Castilla-La Mancha	3,21%	0,38%	0,3%
Cataluña	25,39%	21,16%	17,4%
Comunid. Valenciana	11,19%	6,05%	5,1%
Extremadura	0,41%	0,43%	0,1%
Galicia	2,20%	3,40%	1,5%
Madrid	15,81%	39,69%	47,5%
Murcia	2,08%	0,94%	0,7%
Navarra	4,84%	1,79%	0,7%
País Vasco	15,95%	6,90%	8,8%
Rioja (La)	1,57%	0,14%	0,0%
Not regionalized			4,6%
TOTAL	100,00%	100,00%	100,00%

Source: Landabaso (1995); Esteban and Velasco (1996); Vence and Guntín (1998).

Once again, the existing data shows the high concentration of public support for research and innovation, highlighting the importance of Catalonia and Madrid as the main destinations. Similarly, the calculation of Gini indices confirms this conclusion. These have values very similar to those obtained for the technological inputs and outputs, oscillating between the 0.57 corresponding to the Industrial Technology Development Centre and the 0.67 for the Research and Development Framework Programme.

To summarize, the examination, with a descriptive focus, of the distribution and degree of concentration of innovative activity in various countries clearly shows how innovative activities have a greater degree of concentration than economic activity as a whole. In spite of the fact that comparisons should be made with some caution, for the group of countries selected (the United States, Germany, France, Italy and Spain) the Gini indices for economic activity, measured by industrial employment, are between 0.39 and 0.46. On the other hand the values for the indicators of innovation are between 0.54 and 0.73. Similarly, industrial activities with a high technological content, studied in the Spanish case, present a degree of concentration much higher than that of economic activities as a whole. Obviously it cannot be immediately inferred from these results that the importance of geographical proximity in the use made of spillovers will be the main explaining reason for this greater degree of concentration. Nevertheless, the existing evidence (Jaffe, 1989; Audrestch and Feldman, 1996) seems to point towards it being a variable of importance in the United States, and it seems reasonable to suppose that it can also be so in other geographical areas.

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