40th Congress of the European Regional Science Association

Barcelona (Spain) 29th August – 1st September, 2000

Technology and regional development: the case of patents and firm location in the Spanish medical instruments industry

Manuela P. Pérez and Angel M. Sánchez

University of Zaragoza (Spain)

Departamento de Economía y Dirección de Empresas
Centro Politécnico Superior
María de Luna No. 3, 50015–Zaragoza, Spain
E–mail: manuela.perez@posta.unizar.es <Manuela P. Pérez>
anmarzan@posta.unizar.es <Angel M. Sánchez>

Abstract. This paper analyzes the spatial distribution of the results of the technological process (patents granted) in the Spanish medical equipment industry. The paper shows a polarization towards the two large urban agglomerations of Barcelona and Madrid. The regression analysis accomplished with the explanatory variables has shown that the innovative activity is positively correlated with networking and the proximity to medical agglomeration centers. The explanatory model has not found a significant contribution of agglomeration to patenting intensity which allows for the possibility that small 'hi–tech' medical equipment firms may develop and locate in peripheral regions.

1. Introduction

Over the past twenty years a considerable amount of empirical evidence of one sort or another has been amassed which demonstrates that the processes of innovation and technological change are spatially differentiated, both regionally within states and internationally between nations (Harris 1988). Similarly, empirical evidence around the world have demonstrated the interrelation between economic growth and technological change on a national scale and even at regional level. In that sense it can be admitted that activities related to technological innovation are a key factor in regional development (Stohr 1988). Economic growth and prosperity are materialized through the creation of new activities originated in firms by innovative managers. If the firm creates its own technology, or incorporates it exogeneously, this will result in an increase in its competitiveness. When this happen simultaneously in a group of firms located in a particular area the combined effects may contribute to a spatial dynamism and development of the area.

High technology industries are one of a region´s assets in achieving desired economic growh. During the 1970s and 1980s several agglomerations of 'hi-tech' companies - software, telecommunications, biotechnology, etc- developed in many 'Silicon Valleys' around the world. At the same time, regional governments from industrialized countries supported the exogenous and endogenous regional development of these companies within Technology Parks and Innovation Centers (Castells and Hall 1994). Some of these 'hi-tech' companies have exhibited spectacular rates of growth in employment, sales, exports and assets. At the same time, the geographical areas in which 'hi-tech' firms are important have also exhibited in some countries major indirect employment creation in the business and consumer service sectors. For example, the experience of the Japanese Tecnopolis indicates that the development of 'hi-tech' companies in peripheral regions has reduced the regional differences in production and employment (Stohr and Ponighaus 1992). There is also the role of 'hi-tech' firms in industrial networks, in which they are thought to contribute to the transfer of technologies and to strength the technology level of other companies (Autio 1997).

'Hi-tech' industries are usually defined as those which simultaneously invest more resources in research and development (R&D), employ higher percentages of qualified

personnel, and produce goods or services which are more innovative and with a shorter life cycle than the average industry. One of the industries that apply to these criteria in the US and Europe is the medical equipment industry. This industry develops and manufactures the instruments and equipments used by physicians and nurses in hospitals, clinics and primary care centers. Besides being a key technological element in the Health Care system, the medical equipment industry also exhibits high growth rates because the population of industrialized countries is rapidly ageing and demanding better health care. Medical equipment companies are also attracted towards medical complexes than can function as a growth pole for some urban economies (Van den Berg and Van Klink 1996).

The largest medical equipment industry is in the United States. In the European Union there are about some 5,000 manufacturers, employing some 240,000 persons; Germany is the largest european market and concentrates 40% of the production and 54% of the value added. Other important European manufacturers are located in France, United Kingdom and Sweden. The medical equipment industry shows a high degree of spatial concentration. For example, agglomerations of medical equipment companies are found in the southeast of England, the surroundings of Paris, or near the scientific universities of Lund in Sweden.

In spite of the importance of the medical equipment industry, there are almost no studies that analyze the factors determining the spatial concentration of innovative activities within this industry. This paper wants to contribute to the research area of regional development and technological change, and studies the degree of spatial concentration of economic and innovative activities in the Spanish medical equipment industry. The paper is structured in the following way. The second section shows the spatial distribution of economic and innovative activities using patents granted in the 1979–1995 period as an indicator. The third section offers an approach to the factors determining the spatial distribution of medical equipment's innovative activities, and discusses the results from an empirical study. Finally, some conclusions are included.

2. Distribution and degree of spatial concentration of economic and innovative activities in the spanish medical equipment industry

The Spanish economy has traditionally been characterized by a concentration of economic activity in the two large metropolitan areas (Madrid and Barcelona), which in 1995 accounted for 35% of the total Gross Domestic Product. The rest of the Mediterranean area is of secondary importance with a few exceptions, mainly Valencia and Alicante, as is the Basque Country. One might add a few other provinces which have also maintained a high level of growth (Zaragoza, Navarra and Seville) but the rest of the country, with a few rare exceptions, does not possess a sufficiently high level of economic activity to be worth mentioning.

'Hi-tech' activities are concentrated in a few Spanish regions. In 1998, three out of seventeen regions accounted for 63.6% of total Spanish R&D expenditures (Madrid (30.9%), Catalonia (22.8%) and Andalucia (9.9%)). The industrial innovative activities are also spatially concentrated because three regions accounted for 58% of innovative expenditures in the Spanish industry in 1997: Catalonia (25.3%), Madrid (22.4%) and the Basque Country (10.3%). Regarding to the Spanish 'hi-tech' industries, all studies evidence that the medical equipment industry has been one of them for the last fifteen years (i.e. Giraldez 1988; Crespo and Velazquez 1999).

The European market share of the Spanish medical equipment industry in 1997 was 10,9% of consumption but only 5% of production or 3% of value added. The Spanish market relies heavily on imports from Europe and the US because only half of the Spanish market is supplied by firms located in Spain. An study of the Spanish foreign trade revealed that Spanish imports of medical equipment overcomed exports in each singular product in the period 1985-1995 (Martínez and Urbina 1998). Table 1 shows some descriptive statistics of the Spanish medical equipment industry in the 1993-1998 period and its comparison to the whole Spanish industry.

This section of the paper deals with the degree of spatial concentration of economic and innovative activities in the Spanish medical equipment industry. One straightforward measure of economic concentration is the regional or local distribution of firms and employment. Therefore, Table 2 indicates the provincial location of Spanish medical equipment manufacturers in 1998, and as it can be observed, two provinces (Barcelona and Madrid) concentrated 76.7% of manufacturing firms and 79.5% of manufacturing

employment in the medical equipment industry. The rest of Spanish manufacturing companies are evenly distributed among other provinces.

Table 1. The Spanish medical equipment industry in figures

	1993		1995		1998	
	MED	IND	MED	IND	MED	IND
Sales by employee	8,059	15,680	8,972	19,829	10,830	22,825
Investment by employee	317	759	353	870	473	1,089
Number of employees by company	7.0	14.9	7.5	15.6	7.7	15.7
% of firms with less than 20 employees	n.d.	n.d.	93.1	87.4	94.8	86.6
Hourly employee cost	1,409	1,897	1,477	1,983	1,564	2,116
Cost by employee	2,492	3,312	2,611	3,467	2,790	3,721
% employees in total industry	0.38	100	0.36	100	0.42	100
% sales in total industry	0.19	100	0.16	100	0.20	100

Notes: MED = Medical equipment industry; IND = Total Spanish Industry. Economic figures in national currency (thousand). n.a. = not available
Source: Spanish Industrial Survey. National Institute of Statistics.

Table 2. Province distribution of companies and employment in the Spanish medical equipment industry

Spanish province	No. manufacturers	%	Employees	%
Barcelona	231	48.7	6,804	53.8
Madrid	133	28.0	3,258	25.7
Valencia	26	5.5	542	4.3
Asturias	8	1.6	120	0.9
Alicante	7	1.5	227	1.8
Navarra	7	1.5	174	1.3
Guipuzcoa	6	1.2	268	2.1
Sevilla	6	1.2	152	1.2
Gerona	5	1.1	273	2.2
Vizcaya	5	1.1	100	0.8
Other provinces	40	8.6	730	7.1
Total	474	100.0	12,648	100.0

Source: Own elaboration

However the degree of spatial concentration of medical equipment manufacturers is even greater when only the 'hi□tech' products are considered (Table 3) because all were located in Madrid or Barcelona. Even when the analysis includes the main and most used medical equipment such as monitoring or diagnosis, the degree of spatial concentration of manufacturers in Madrid is over 50% in most equipments and more than 30% in Barcelona. With the exception of the Community of Valencia, the other provinces must rely on distributors and sales representatives to buy medical equipments.

Table 3. Province distribution of manufacturers and commercial firms of 'high tech' medical equipment

	Manufacturers	Distributors	Importers	Services
Madrid	6	8	10	1

Barcelona	3	8	11	2
Valencia	□	1	□	□
Other provinces	□	6	□	□
Total	9	23	21	3

Notes: Other provinces are Las Palmas with two companies, and La Coruña, Navarra, Toledo and San Sebastian with one company each.
Source: Own elaboration

The second spatial dimension analyzed in this paper is the distribution of technological activities. However, although the question of how to measure technological change has concerned economists for a long time, no widely accepted procedure has been developed so far. Much of the technological change is the product of R&D activities and one of the few direct reflections of the output of R&D activities is the number and kind of patents applicated or granted to different firms (Griliches 1990). The number of inventions which have been patented is probably the most widely used proxy measure of innovative activity though patents are a flawed measure of innovative activity. The major problems with patents are that not all inventions are patented and that not all patented inventions will become innovations. In addition, patents differ in their economic impact. The quantity and quality of patenting may depend on chance, how readily a technology leads itself to patent protection and business decision□makers´ varying perceptions of how much advantage they will derive from patent rights. Surveys of firms in the US and in Europe give evidence that the percentage of innovations that are patented vary by sector (Arundel and Kabla 1998).

In spite of the previous considerations, many authors have used patent data as a basic indicator of the technological activities that are converted after in products and process innovations (i.e. Ernst 1997). Similarly we have used the CIBEPAT database of the Spanish Patent Office to value the degree of spatial concentration of the innovative activities in the Spanish medical equipment industry. The study includes all patents and utility models granted to Spanish residents in the 1979□1995 period. Both patents and utility models have been included in the analysis because both are results of technological activities carried out at a firm or R&D center . The difference between a patent and a utility model consists in the period granted to the applicant which is 20 years to a patent and 10 years to an utility model, and in the innovativeness degree which it is smaller in an utility model that in a patent. The period of study begins in 1979 because the CIBEPAT database did not include information on the province residence of the applicants before that year. The study ends in 1995 because there is a

time lag of some years between a patent or an utility model is applicated and when is later granted, and we wanted to make sure that at least all patents granted in 1995 were included in the study.

Table 4 shows that 38.8% of patents and utility models of medical equipment inventions have been granted to residents from Catalonia, a 24.3% to residents from Madrid and a 11.5% to residents from the Community of Valencia. These three regions concentrated 75% of the protected innovations developed during the 1979–1995 period, a higher degree of concentration than all the industrial patents in Spain (Coronado and Acosta 1997). But if we take into account only the patents granted to firms –and we exclude patents granted to individuals or institutions– the degree of spatial concentration is even higher because Madrid, Catalonia and the Community of Valencia account for 84.3% of patents and 86.6% of utility models granted to firms in the 1979–1995 period.

Table 4. Regional distribution of patents and utility models granted to Spanish residents in the 1979–1995 period for medical equipment inventions

Spanish region	No. Patents	%	No. Utility models	%	Firm patents	Firm utility models
Andalucia	36	5.0	68	3.7	6	12
Aragón	24	3.3	67	3.7	10	17
Asturias	7	1.0	38	2.1	0	9
Baleares	8	1.1	17	0.9	2	4
Canarias	14	1.9	23	1.3	1	0
Cantabria	1	0.1	6	0.3	0	0
Castilla–La Mancha	7	1.0	5	0.3	0	1
Castilla–León	2	0.3	37	2.0	1	3
Catalonia	280	40.0	697	38.7	107	267
Extremadura	5	0.7	14	0.8	0	2
Galicia	17	2.3	25	1.4	1	1
Madrid	152	21.1	461	25.6	35	168
Murcia	9	1.2	25	1.4	0	4
Navarra	24	3.3	16	0.9	6	6
Basque Country	25	3.4	109	6.1	5	17
La Rioja	3	0.4	5	0.3	0	0
Community of Valencia	104	14.4	185	10.2	30	57
Total	718	100.0	1,798	100.0	204	568

Notes: The codes of the International Classification of Patents included in the study are: A61B, A61C, A61D, A61F, A61G, A61H, A61J, A61K, A61L, A61M, A61N, H04R25/00, H01J35/00, H05G2/00, and G02C.
Source: Own production

This high degree of spatial concentration in the number of patents and utility models is similar to the concentration of the R&D expenditures in medical and health related activities in Spain. Table 5 shows that these three regions –Catalonia (basically the

province of Barcelona), Madrid and the Community of Valencia (mainly the province of Valencia) concentrated 86.4% of firms and 85.7% of employment in the medical equipment industry, and 69.1% of the R&D expenditures in medical and health activities.

Table 5. Spatial concentration of production and technology in the Spanish medical equipment

Spanish region	% manufacturers	% employment	% R&D in medical sciences	% Patents	% Utility models
Catalonia	51.2	53.8	27.1	39.0	38.8
Madrid	28.0	25.7	34.3	21.1	25.6
Com. of Valencia	7.2	6.2	7.7	14.5	10.3
Total 3 regions	86.4	85.7	69.1	74.6	74.7

Notes and sources: The percentages are on the national total for each variable. The R&D data in medical sciences are from the period 1983-1995 and come from the Annual Reports of the National Health and Pharmacy Plans. The data on patents and utility models are from the period 1979-1995.

Table 6 shows the Patenting Index (PI) and the Relative Technological Advantage (RTA) of each Spanish region in the medical equipment products. The Patenting Index is defined as the number of patents granted by million of inhabitants. Two Patenting ratios have been calculated: the first ratio (PI1) only includes patent data while the second ratio (PI2) also includes utility model data. For the first index Navarra has the largest value (46.1 patent by million of inhabitants), followed by Catalonia (45.9) and Madrid (30.2), and the lowest values are for Cantabria (1.9) and Castilla-León (0.8). The second Index gives the largest value to Catalonia (160.4 patent and models by million of inhabitants), followed by Madrid (122) and Navarra (76.9), while the lowest values are for Cantabria (13.2) and Castilla-La Mancha (7.2).

Table 6 also shows the percentage of medical equipment patents on the total patents granted to residents in each region. The national average is 3%, which means that 3% of the patents granted to Spanish residents between 1979 and 1995 were for inventions related to medical equipments. Ten out of seventeen Spanish regions have higher percentages than national average, which indicates that those regions have some degree of patenting specialization in medical equipment in comparison to patenting in other activities.

Table 6. Patenting Index (PI) and the Relative Technological Advantage (RTA)

Spanish region	% total patents	PI1	PI2	RTA1	RTA2
Andalucia	3.3	4.9	14.4	1.08	1.24
Aragón	3.4	20.2	76.6	1.11	1.05
Asturias	2.6	6.4	41.3	0.86	0.42

Baleares	4.5	10.5	32.9	1.49	1.46
Canarias	8.1	8.7	23.0	2.66	1.67
Cantabria	0.7	1.9	13.2	0.22	0
Castilla La Mancha	2.5	4.1	7.0	0.82	0
Castilla León	0.5	0.8	15.5	0.17	0.39
Catalonia	3.1	45.9	160.4	0.98	1.21
Extremadura	6.4	4.6	17.7	2.10	0
Galicia	5.0	6.2	15.3	1.64	2.96
Madrid	2.6	30.2	122.0	0.85	0.63
Murcia	3.5	8.2	31.0	1.16	3.71
Navarra	4.2	46.1	76.9	1.37	1.04
Basque Country	1.5	11.9	63.8	0.48	0.23
La Rioja	2.7	11.3	30.3	0.89	0
Com. of Valencia	4.9	25.9	72.0	1.61	1.74

Notes: The percentage of patents means the ratio of medical equipment patents on the total patents granted to residents in that region. They have been considered two Patenting ratios. PI1 has been calculated as the number of patents granted in the 1979 1995 period to Spanish residents in the medical equipment sector for million of inhabitants. PI2 also includes the utility models. The Relative Technological Advantage RTA is the ratio between the national and regional percentage of the patents granted to medical equipment and the total number of patents in each region. There are two RTA ratios: RTA1 includes all patents while RTA2 only includes patents granted to companies and institutions.
Source: Own production

This result is also given by the Relative Technological Advantage (RTA). The ratio RTA_{ij} of a region i in an industry j is defined as:

$$RTA_{ij} = \frac{PAT_{ij} / \sum_{j=1}^{m} PAT_{ij}}{\sum_{i=1}^{n} PAT_{ij} / \sum_{i=1}^{n}\sum_{j=1}^{m} PAT_{ij}}$$

where PAT_{ij} is the number of patents granted to residents of the region i in the industry j, n is the number of regions and m is the number of industries. We have calculated two ratios: RTA1 includes all patents granted, and RTA2 includes only patents granted to industrial firms and institutions, because those patents are the result of R&D activities in companies and universities. Those regions with a RTA (Table 6) higher than 1 have a greater patenting specialization in medical equipment than in other activities.

3. An approach to the factors determining the spatial distribution of medical equipment innovative activities

Any explanation of the patenting activities of industrial firms has to be based on an understanding of the determinants influencing this behaviour (Fischer *et al* 1994). In this section elements from different theoretical contributions and empirical studies will be drawn into a conceptual framework for analysing determinants that may explain the

spatial patenting in the medical equipment industry. Four factors have been analyzed: firm size, proximity to medical activities, agglomeration, and networking.

Firm size

The relationship between firm size and invention/innovation has been a matter of long-standing debate (Rothwell and Dodgson 1994; Dijk *et al* 1997). Some scholars argue that large size favours invention because larger firms have a greater capacity to raise capital, manage information, maintain large R&D facilities and attract the best technical specialists. However, other scholars (i.e. Rothwell and Zegveld 1982) stress the importance of smaller roles, especially of 'hi-tech' firms, in the process of technological change due to their greater flexibility to adapt to changes in external environments (Noteboom 1994; Rothwell 1991). Besides, small firms explore more technological areas by innovation in less 'crowded' areas, and are tied into regional knowledge networks to a greater extent than large firms (Almeida and Kogut 1997).

The development of medical equipments requires different technical capabilities. While it is possible to develop and manufacture surgery instruments in a very small 'hi-tech' firm, other medical equipments such as a magnetic resonance equipment demands large technical resources which they are only available at large firms. Nevertheless an analysis of the Spanish foreign trade of medical equipments revealed that the deficit is greater in the 'hi-tech' small instruments than in the larger and more traditional equipments (Martínez and Urbina 1998). Therefore we would establish the following hypothesis:

H1 - Patent intensity at regional level is positively correlated with average firm size in the medical equipment industry.

Proximity to medical activities

The second determinant of regional patenting activities included in this analysis is the local proximity to medical equipment users. The development of medical equipment requires a close user-manufacturer interaction between scientists and engineers in the medical equipment companies and physicians and nurses in the hospitals and clinics (Mitchell 1991). For example, Lotz (1991) found that, in the Danish medical equipment

industry, science appears predominantly in the user-environment and as a result, invention is fuelled by specific requirements from physicians and by new medical knowledge. Shaw (1998) also found in an study of new product development in the UK medical equipment industry that there was continuous interaction at all the 10 stages in the innovation cycle identified, resulting in 65% of these innovations being commercially successful. This interaction occurred in part because one major element in the innovation process for medical equipment which tends to make this process unique is the requirement that any equipment that is to be potentially introduced into clinical use first needs extensive clinical assessment and trial because human life may be at risk.

The scientists and engineers then work together with the user in an attempt to test out the conceptual basis of their solution to the need normally in the form of a hand-built prototype. Dependent upon the perceived degree of output-embodied benefit arising from being involved in the further process of the innovation, the user could then be involved in the development, testing and evaluation of the prototypes and final products, making marketing assessments, joint specifications, involvement in the market launch, marketing, and the diffusion of the innovation. Therefore we expect that:

H2 – Local proximity to medical activities is positively correlated with patenting intensity at regional level.

Agglomeration

The third determinant of patenting is the agglomeration of economic and technical activities. The advantages of agglomeration for 'hi-tech' companies have traditionally been claimed by supporters of the location theory on the basis of external economies of scale, i.e. access to R&D facilities, skilled labour force, research universities, and high levels of information (Kleinknecht and Poot 1992; Mustar 1997). The experience indicates that agglomeration is an important factor in the early phases of a 'hi-tech' complex. For example. in the Tecnopolis of Cambridge (United Kingdom) Segal *et al* (1985) estimated that 12% of the early 'hi-tech' companies were spin-offs from the University of Cambridge and that most of the other companies were spin-offs from the university spin-offs.

However, once this early phase of agglomeration is over, the closeness to the university or to the initial agglomeration of 'hi-tech' companies becomes less important. For example, in Cambridge currently only 10% of the 'hi-tech' companies are located in the Technology Park that it was the nucleus of the early agglomeration. This and other evidences suggest that we must think at least in regional terms if we want to analyze technological complexes (Vedovello 1997; Westhead 1997). Besides, since urban agglomeration is an indicator of economic and technological concentration we would expect to find a positive relationship at regional level between patenting and urban agglomeration.

H3 – Patenting in the medical equipment industry is positively correlated to urban agglomeration.

Networking

Scientific research increasingly depends on network linkages and information diffusion. The emergence of institutional or informal networks, formed by clusters, groups or vertical filières of firms, appears to be one major feature of the contemporary industrial economy indicated by the application of new telecommunications and information technologies. These resources are needed for investing cooperatively in the creation of new knowledge (R&D, design, engineering), and for the external introduction of new knowledge through innovation adquisition, adaptation, and implementation (Belussi and Arcangeli 1998). The major bottlenecks for small firms in peripheral regions, which are poor in terms of the environmental complexity needed for innovation projects, are found in the areas of human capital, information provision and risk capital. However, 'hi-tech' regions sustain their competitive advantage in their capacity for continuous learning and innovation (Lawson and Lorenz 1999). Larger firms and particularly multi-site establishments may overcome such limitations more easily but small firms in peripheral regions may be in great disadvantage to innovate due to the infradevelopment of information resources. Therefore we would expect to find a positive correlation between the use of information technologies and medical equipment patenting at regional level.

H4 – Patenting in the medical equipment industry is positively correlated at the regional level with the use of information technologies.

3. Empirical results and discussion

To explain the spatial distribution of innovative activities in the medical equipment industry we have carried out a regression analysis by OLS using regional patent and utility model granted to Spanish residents. The dependent variables used for the study have been two: the regional number of patents and utility models by employee granted to Spanish firms (PTMEH), and the regional number of patents and utility models by unhabitant granted to firms, institution and individuals in that region (PI2). Both variables are for the 1979–1995 period and are related to patenting in industrial companies (PTMEH) and patenting in all economic agents (PI2). The independent variables used have been:

- SIZE: average number of employees per firm in the regional medical equipment industry.
- BEDS: number of beds in regional hospitals and clinics. A large number of beds is an indicator of a greater demand for medical equipment but also of a greater specialization and qualification of physicians than at regions with smaller hospitals.
- AGGLOMERATION: percentage of region's population living in cities of over 500,000 unhabitants.
- NETWORKING: Logaritm of regional expenditure per inhabitant in computer and software.

Table 7 indicates the descriptive statistics and correlations of the independent variables. The values of the independent variables are for 1996. Then, Table 8 shows the results of the regression analysis for each dependent variable. Both are explained by the model in more than 70%, which indicates that the approach developed in this paper is valid to both firm's and total's patenting at regional level.

Table 7. Descriptive statistics and correlations

	Mean	SD	1	2	3
SIZE	27.4	32.1			
BEDS	4,476.3	678.0	−0.019		
AGGLOMERATION	9.8	18.2	0.239	0.171	
NETWORKING	4.2	0.4	−0.130	0.000	0.636***

Notes: Observations = 17 ***p<0.01
Source: Own production

Table 8. Explanatory model of regional patenting of medical equipment by manufacturing firms (PTMEH) and by firms, individuals and institutions (PI2)

	PTMEH	PI2
Constant	−126.5 (−3.17)	−318.8 (3.31)
NETWORKING	22.6** (2.94)	59.8*** (3.23)
BEDS	0.008* (2.12)	0.002** (2.33)
SIZE	0.08 (0.88)	0.24 (1.12)
AGGLOMERATION	0.15 (0.73)	0.29 (0.58)
	$R = 0.847$ $R^2 = 0.718$ $\Delta R^2 = 0.624$ $F = 7.636$ $p = 0.003$ $n = 17$	$R = 0.859$ $R^2 = 0.739$ $\Delta R^2 = 0.652$ $F = 8.482$ $p = 0.002$ $n = 17$

Notes: PTMEH – Number of regional patents and utility models granted to Spanish firms divided by million of inhabitants. PI2 – Number of regional patents and utility models granted to firms, individuals and institutions by million of inhabitants. NETWORKING – Expenditures in computer and software by unhabitant. BEDS – Number of beds in clinics and hospitals. SIZE – Average number of employees by medical equipment manufacturing firm. AGGLOMERATION – Percentage of region´s population living in cities of over 500,000 unhabitants. t–values between brackets *p<0.1 **p<0.05 ***p<0.01
Source: Own production

The variable NETWORKING is statistically significant at 99% and the variable BEDS at 95%. The variables SIZE and AGGLOMERATION behave as expected but they are not statistically significant. The bivariate correlations among the independent variables (Table 7) show that AGGLOMERATION and NETWORKING are strongly correlated at 99%. Therefore we have repeated the regression analysis but excluding the variable AGGLOMERATION using an stepwise method. The results of the new model are shown at Table 9.

The results of the model evidence that NETWORKING is the most explanatory variable and that AGGLOMERATION is almost not significant. This is really important because the main input of a 'hi–tech' activity is the market and technological information, which it should not be restricted to any specific region. Many 'hi–tech' companies have their own "informal networking" of contacts with companies and R&D centers in other regions around the world. A few studies have evidenced the feasibility that a 'hi–tech' company may locate in regions with no labour or raw materials agglomeration, but as long as the already existing infrastructure –universities, communications, etc– does not prevent that the new 'hi–tech' company survives after its initial location (Oakey and Cooper 1989; Martínez 1992). Some studies (i.e. Karlsson and Olsson 1998) even evidence that peripheral regions are able to provide an

innovative environment for small firms, whereas large firms need the richer environment offered by the core regions. Therefore small firms can be early users of new technologies even if they are located outside the large urban areas.

Table 9. Explanatory model 2 of regional patenting of medical equipment by manufacturing firms (PTMEH) and by firms, individuals and institutions (PI2)

	PTMEH	PI2
Constant	−146.3 (−5.04)	−356.3 (−5.14)
NETWORKING	26.6*** (4.97)	67.3*** (5.27)
BEDS	0.009** (2.43)	0.002** (2.63)
SIZE	0.11 (1.37)	0.30 (1.56)
	R = 0.840 R^2 = 0.705 ΔR^2 = 0.637 F = 10.36 p = 0.001 n = 17	R = 0.855 R^2 = 0.731 ΔR^2 = 0.669 F = 11.79 p = 0.001 n = 17

Notes: PTMEH – Number of regional patents and utility models granted to Spanish firms divided by million of inhabitants. PI2 – Number of regional patents and utility models granted to firms, individuals and institutions by million of inhabitants. NETWORKING – Expenditures in computer and software by unhabitant. BEDS – Number of beds in clinics and hospitals. SIZE – Average number of employees by medical equipment manufacturing firm. t–values between brackets **p<0.05 ***p<0.01
Source: Own production

These peripheral regions may develop small 'hi–tech' sectors when the two following conditions are, at least, fulfilled: that the company´s entrepreneur has strong personal links within that region and assumes its lack of industrial services; and that the type of production of the company is economically feasible in that region. Even if there are few industrial services available, as long as the type of product or production are not in need of agglomeration economies with other 'hi–tech' companies, it is posible for a 'hi–tech' company to locate in a peripheral region when the distance to its markets is not an economic disadvantage. While such firms may encounter greater environmental constraints as they grow than their counterparts in core regions, these very constraints may in fact stimulate greater pro–active entrepreneurial behaviour which in turns renders the firm more competitive in wider markets. Although fewer small firms may be successful in peripheral environments, those that are may prove to be even more competitive than the average small firm in core regions which has not had to overcome environmental and resource constraints to the same degree (Vaessen and Keeble 1995).

This is what happens with many medical equipment products because they have high value added but low weight per unit. Therefore it would be feasible that a new medical

equipment company may locate out of the agglomeration zones indicated in this paper. Table 10 shows the regional distribution of the new medical equipment companies located in Technology Parks and Business Innovation Centers. These companies are developing medical equipments of high technological content and many of them are spin-offs. For example, the two companies located in the Business Innovation Center of Aragon are spin-offs from research projects, one from a university department and the other from a medical instruments company. The degree of spatial concentration indicated in Table 10 is very low in comparison with the distribution of medical equipment manufacturers (Table 2), which had 80% of firms and employment located in only two regions.

Table 10. Regional distribution of medical equipment companies located at Technology Parks and Business Innovation Centers

Andalucia	5
Aragón	2
Basque Country	2
Catalonia	3
Community of Valencia	1
Galicia	2
Navarra	1
Total firms	17

Source: Own production

Conclusion

In this paper we have carried out an analysis of the spatial distribution of innovative technology in the medical equipment industry using patent grants per region of residence of the first applicant as an indicator. The spatial distribution of the results of the technological process (patent grants per region of residence of the first applicant) shows a polarization towards the two large urban agglomerations of Barcelona and Madrid, while the rest is shared by the Community of Valencia and the Basque Country.

The spatial distribution of patenting has been found to be positively correlated with networking and local proximity to hospitals. The explanatory model has not found a significant contribution of agglomeration to patenting intensity which allows for the possibility that small 'hi-tech' medical equipment firms may develop and locate in peripheral regions. Due to low transportation costs of most of medical instruments to

their markets some industrial and university spin-offs have developed and located in Innovation Centers and Technology Parks around the country.

References

- Almeida, P. and Kogut, B. (1997) The exploration of technological diversity and the geographic localization of innovation, *Small Business Economics* **9**, 21-31.
- Arundel, A. and Kabla, I. (1998) What percentage of innovations are patented? epirical estimates for European firms, *Research Policy* **27**, 127-41.
- Autio, E. (1997) New, technology-based firms in innovation networks symplectic and generative impacts, *Research Policy* **26**, 263-81.
- Belussi, F. and Arcangeli, F. (1998) A typology of networks: flexible and evolutionary firms, *Research Policy* 27, 415-28.
- Castells, M. and Hall, P. (1994) *Technopoles of the world - The making of 21st century industrial complexes*. London, Routledge Publishers.
- Coronado, D. and Acosta, M. (1997) Spatial distribution of patents in Spain: determining factors and consequences on regional development, *Regional Studies* **31**, 381-90.
- Crespo, J. and Velazquez, F. (1999) Principales rasgos de los sectores innovadores en España, *Papeles de Economía Española* **81**, 104-13.
- Dijk, B. et al (1997) Some new evidence on the determinants of large and small firm innovation, *Small Business Economics* **9**, 335-43.
- Ernst (1997) The use of patent data for technological forecasting: the diffusion of CNC-technology in the machine tool industry, *Small Business Economics* **9**, 361-81.
- Fischer, M. *et al* (1994) An exploration into the determinants of patent activities: some empirical evidence for Austria, *Regional Studies* **28**, 1-12.
- Furio, E. (1996) Desarrollo territorial y procesos de innovación: los milieux innovateurs, *Estudios Territoriales* **28**, 639-49.
- Giraldez, E. (1988) Comportamiento inversor de los sectores de alta tecnología, 1975-1985, *Papeles de Economía Española* **34**, 431-53.
- Griliches (1990) Patent statistics as economic indicators: a survey, *Journal of Economic Literature* **28**, 1661-707.
- Harris, R. (1988) Technological change and regional development in the UK: evidence from the SPRU database on innovation, *Regional Studies* **22**, 361-74.

- Karlsson, Ch. and Olsson, O. (1998) Product innovation in small and large enterprises, *Small Business Economics* **10**, 31–46.
- Kleinknecht, A. and Poot, T. (1992) Do regions matter for R&D?, *Regional Studies* **26**, 221–32.
- Lawson, C. and Lorenz, E. (1999) Collective learning, tacit knowledge and regional innovative capacity, *Regional Studies* **33**, 305–17.
- Lotz, P. (1991) *Demand side effects on product innovation: The case of medical devices*. Copenhagen Business School, Institute of Industrial Research.
- Martínez, A. (1992) Regional innovation and small high technology firms in peripheral regions, *Small Business Economics* **4**, 153–68.
- Martínez, A. and Urbina, O. (1998) Estructura y competitividad exterior del sector de productos médico-quirúrgicos en España, *Boletin Económico de Información Comercial Española*. **2580**, 25–36.
- Mitchell, W (1991) Using academic technology: transfer methods and licensing incidence in the commercialization of American diagnostic imaging equipment research. 1954–1988, *Research Policy* **20**, 203–16.
- Mustar, P (1997) How french academics create hi-tech companies: the conditions for success or failure, *Science and Public Policy* **24**, 37–43.
- Noteboom, B. (1994) Innovation and diffusion in small firms: theory and evidence, *Small Business Economics* **6**, 327–47.
- Oakey, R. and Cooper, S. (1989) High technology industry, agglomeration and the potential for peripherally sited small firms, *Regional Studies* **23**, 347–60.
- Rothwell, R. (1991) External networking and innovation in small and medium sized manufacturing firms in Europe, *Technovation* **11**, 93–112.
- Rothwell, R. and Zegveld, W. (1982) *Innovation and the Small and Medium Sized Firms: Their Role in Employment and in Economic Change*. Frances Pinter, London.
- Rothwell, R. and Dodgson, M. (1994) Innovation and size of firm, in *The Handbook of Industrial Innovation*, Edward Eiger Publishing Limited, Aldershot, 310–24.
- Segal *et al* (1985). *The Cambridge phenomenon: the growth of a high-technology industry in a university town*. Cambridge, United Kingdom.
- Shaw, B. (1998) Innovation and new product development in the UK medical equipment industry, *International Journal of Technology Management* **15**, 433–45.
- Stohr, W. (1988) La dimensión espacial de la política tecnológica, Papeles de Economía Española **35**, 132–52.

• Stohr, W. and Ponighaus, R. (1992) Towards a data-based evaluation of the Japanese Technopolis policy, *Regional Studies* **26**, 605-18.
• Vaessen, P. and Keeble, D. (1995) Growth-oriented SMEs in unfavourable regional environments, *Regional Studies* **29**, 489-505.
• Van den Berg, L. and Van Klink, A. (1996) Health care and the urban economy: the medical complex of Rotterdam as a growth pole?, *Regional Studies* **30**, 741-47.
• Vedovello, C. (1997) Science parks and university-industry interaction: geographical proximity between the agents as a driving force, *Technovation* **17**, 491-502.
• Westhead, P. (1997) R&D inputs and outputs of technology-based firms located on and off Science Parks, *R&D Management* **27**, 45-62.