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SCIENCE-TECHNOLOGY FLOWS IN SPANISH REGIONS: AN ANALYSIS OF SCIENTIFIC CITATIONS IN PATENTS

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Abstract:

Many regions of the European Union with a high degree of self-government have elected very clearly to stimulate scientific research and technological development (R&D) as a specific means of promoting economic growth and the welfare of their citizens. In Spain, several Autonomous Regions have organised their efforts in science and technology by means of the adoption of regional R&D plans. In some cases, particular concern is taken to link the scope of scientific research with that of technology, but even in these few cases, it is acknowledged that little is known of the mechanisms by which the results of scientific research are translated into technological development, and how this latter in turn influences the objectives of scientific research. Our aim in this article is to study in greater depth the relationship between science and technological development in the various Regions of Spain. The methodology that we apply to investigate the links between science and technology is based on analysing the scientific citations in patent documents (non patent citation NPC). The results obtained from this study provide some relevant data on the interconnection between the scientific and technological systems from a regional perspective.

Key words: science-technology flows, scientific citations, patents, regional R&D planning.

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1. Introduction

In Spain, as in other developed countries, it is a customary practice to produce regional planning documents for research and technological development (R&D) that generally complement, by providing additional resources, the activities covered by corresponding national and supranational plans. The relevant instruments in our country include not only the National R&D Plan and the European Framework Program, but also a diverse set of regional plans; however, the processes for formulating these regional plans do not always take account of the need for equilibrium between the scientific and technological aspects of the local system of innovation. In some cases, it is clear that particular concern has been taken to link the scientific and technological fields, but little is known of the ways in which the scientific output is translated into technological development, and how this, in turn, influences scientific research activity.

In this article we make a deeper study of the science-technology relationships in the Autonomous Regions of Spain. We compare three types of region: those less developed regions (with per capita GDP less than 75% of the European Union average, designated “Objective Nº1 Regions"); those regions that are around 90% of the European average on the same measure; and lastly, the Autonomous Community of Madrid, which is the only one of the 17 Spanish Regions that is in full convergence with the European level.

Our central purpose is to provide elements of objective judgment to open a debate on the design and planning of regional policies for science and technology that would enable us to clarify whether the stimulation of scientific research is the best path to take, or whether the balance should be tilted more towards technological aspects favouring innovations for the productive systems of the region; a third and possibly most beneficial approach may be to seek some kind of equilibrium between basic science and applied technology. As the specific objective, our intention is, firstly, to answer the following questions: On which type of knowledge, scientific or technological, is industrial innovation most fundamentally based? Which sectors of industry and commerce are the most dynamic in their employment of scientific knowledge? Which scientific fields are most in demand by industry? Are there significant differences between sectors in the use of science? Secondly, we set out to explore whether these differences exist between the three types of region previously defined.

There are two novel features to this study: in the first place, it is one of the first attempts to identify by means of indicators and quantitative techniques the interrelationships between science and technology in the Regions of Spain; the second novel aspect is the application on a regional scale of NPC methodology, which to date has normally been used only in national analyses, generally for industrialised countries.

The paper is organised as follows: in the next section, we present a theoretical framework to establish the relationship between science and technology, and its measurement; secondly, an analysis is made of the spatial scope of the subject under study, in which we discuss the situation of the main economic indicators, of scientific research and technological development at the regional level. Next we formulate the initial working hypotheses, and describe the methodology employed and the results obtained. The article finishes with certain conclusions that may serve as a useful basis, in conjunction with other instruments of diagnosis, for future thinking on the design of policies for research and technological development at the regional level.

2. Theoretical framework

One of the principal reasons why economists have devoted such notable effort to the study of science and scientific policy is its effect on economic growth, and more specifically, on technological development as the intermediate step between science and economic growth. Various lines of research have been opened, utilising different methodologies, to examine the relationships between scientific knowledge and the development of innovations (Mansfield, 1995, 1998; Nelson and Wolf, 1997). Other authors have identified the scientific antecedents of technological innovation with the object of explaining science-technology flows (Narin et. al., 1997; Meyer, 2000; Tijssen, 2001), or have examined the contribution of universities to the processes of innovation in companies (Meyer-Krahmer and Schmoch, 1998; Mansfield and Lee, 1996; Beise and Stahl, 1999; Schartinger et al., 2002).

In regional contexts, the application of a descriptive methodology based on the analysis of particular geographic spaces, such as high technology complexes (Markusen et al. 1986; Saxenian, 1994; Sternberg and Tamásy, 1999; Weber and Stam, 1999), regional systems of innovation (Cooke et. al. 1998; Brazyck et al., 1998). Others who propose an econometric methodology to identify the externalities or real effects of scientific research (Varga, 1998; Anselin et al., 1997, 2000) have demonstrated that the generation of scientific knowledge is also important on scales smaller than the national. The proliferation of such literature consistently stressing the importance of physical proximity (and geographical community relationships) for the two-way flow of knowledge and for the development and fostering of innovation, underpinned by the high degree of self-government enjoyed by many European regions that has enabled regional plans to be adopted specifically dealing with R&D, serves to demonstrate that the study of scientific activity is not only relevant on national or supranational scales, but also in the regional context.

The idea that basic scientific research drives technological development and consequently has direct repercussions on economic growth originally corresponded to a hypothesis of linearity in the process of innovation that arose from the visible success of the application of science in the industrial and commercial development of certain high technology activities in the USA after World War II (Malecki, 1997, page 52). However, the technological impulse that this linear model suggests or assumes is insufficient to explain the mutual transfer of knowledge between science and technology. The appearance – sometimes voluntary, sometimes imposed – of numerous institutions (associations of companies, universities, research institutes and others providing an interface allowing the integration of science and technology), organised systematically, has replaced the old linear model.

Modern theories of innovation, based on an evolutionary approach put forward in the pioneer work of Nelson and Winter (1982), adopt a more sociological perspective of the process of innovation, in the sense that knowledge as a resource and interactive learning are regarded as fundamental aspects of the process (Lundvall and Borras, 1997; Lundvall and Johnson, 1994). New organisational forms have appeared among the institutional spheres – higher education, industry and government – that demonstrate the importance attached to knowledge and its exchange in learning processes for economic growth and for social transformation: these include the national/regional system for promoting innovation (Nelson, 1993; Lundvall, 1992; Braczyk et al, 1998), the system of research in transition (Cozzens et. al.; Ziman, 1994), the triple helix model (Etzkowitz and Leydesdorff, 1997; 2000; Leydesdorff, 2000), etc.

In these approaches, the relationship between science and technology is not presented as a unidirectional linearity: to the contrary, the flows are at least two-way (often multi-way in networks) and the interaction is continuous. In this new context, basic scientific research contributes to technological progress through both direct factors (generation of useful knowledge) and indirect factors (problem-solving capacity, building of networks,...). More specifically, the following mechanisms for science-technology transmission and interconnection have been suggested (Martin et al., 1996; Lundvall and Borras, 1997; Salter and Martin, 2001): 1. Increases in the stock of valuable knowledge; 2. The development of new methodologies and techniques; 3. The creation of scientific instrumentation; 4. The training of scientists and engineers; 5. The formation of networks and stimulation of social interaction; and 6. The direct transfer of technology to appropriate companies, based on the knowledge accumulated in the universities. Nevertheless, it is a generally-accepted notion that the principal contribution of scientific research as a whole is through the provision of key personnel to the stock of human resources: scientists capable of generating scientific output, exchanging knowledge by means of international networks and resolving technological problems. But even under this new perspective, the classic justification and legitimisation for scientific research remains valid: it makes inestimable contributions to human society and culture, as well as to fields such as military defence, public and individual health, protection of the natural environment, etc. However, it increasingly appears that the future legitimisation of scientific research will rest more fundamentally on it being an inexhaustible source of new knowledge on which economic development can be based (Etzkowitz and Leydersdorff, 2000).

When it comes to analysing and quantifying these flows and the benefits of basic scientific research for technological development and economic growth, various methodologies can be employed, although none are without their disadvantages and difficulties: a) Econometric studies (the reviews given in the articles of Griliches (1995) and Salter and Martin (2001) reflect the proliferation of this type of study). b) Descriptive studies (the regional studies contained in Brazyck et. al. (1998) and the descriptions of certain high technology zones and parks (Markusen et al. 1986, Saxenian, 1994) are good examples of this type of analysis). c) Surveys (the work of Beise and Stahl (1999) is a good example of this methodology). Surveys are usually an initial method for gathering information to which various types of statistical treatment are subsequently applied. d) Case studies: these are oriented towards the direct examination of a particular innovation and the historical roots of a particular technology. The methodology based on scientific citations in patent documents (NPC) applied in the recent studies of Meyer (2000) and Tijssen (2001, 2002) constitute good examples of this type of study.

But how does a regional focus fit into this debate? The modern theories of innovation based on evolutionary propositions have added new and solid reasons to the need for a deeper investigation of the spatial aspects of innovation. It has been argued that the social determinants of innovation (political, economic and industrial institutions, etc.) show profound differences between regions, an approach that illustrates the essential role of regional economies as the building blocks of an increasingly globalised world (Storper, 1995, 1997). Moreover, various authors have stated that the economy based on knowledge, on the capabilities of the labour force and on the presence of highly-competitive firms operates more effectively on the local or regional scale than on the national (Krugman, 1992, 1995; Porter, 1990; Cooke, 1997). This type of reasoning has led many regional economists and geographers to bring the theory of innovation without a specific spatial dimension into convergence with regional studies.

Various lines of study have been opened, the most notable exponents of which are the authors with close links to the "Groupement de Recherche Européen sur Les Milieux Innovateur-GREMI" (European Grouping for Research on the Innovative Local Environment) (Aydalot and Keeble, 1988; Camgani, 1991; Maillat, 1991, 1998; Ratti et. al., 1997), the analysts of the High Technology Industrial Districts (Markusen et. al. 1986; Saxenian, 1994) and the Californian School of Economic Geography (Storper, 1992, 1993, 1995, 1997). The output of these tendencies is the development of concepts such as: the learning region (Asheim, 1996; Simmie, 1997; Morgan, 1997); structural competitivity (Cooke and Schienstock, 2000); regional innovative capacity (Lawson, 1999; Lawson and Lorenz, 1999); the regional system of innovation (Cooke et. al., 1998; Braczyk et al., 1998); technological enclaves and districts (Castells and Hall, 1994; Storper 1995, 1997; Paci and Usai, 2000); and others. All this literature has a point of convergence: the importance of the environmental and institutional factors that come together in a particular territorial framework to foster certain kinds of *collective learning* that constitute a favourable climate for increased activity aimed at innovation and the stimulation of competitivity. In general, the factors of geographical proximity, accessibility, physical concentration and the presence of favourable externalities together exert a powerful influence on the flow of knowledge (i.e. learning) that is the fundamental basis of technological change and the process of innovation. This interaction is very often found to happen within a regional context. All these theoretical arguments just expounded would, however, be sterile if there did not exist the climate necessary for the organs of government with decision-making power in regional policies to set in motion the appropriate measures of consultation and planning to permit scientific research, technological development and innovation to be mutually strengthened; and fortunately, these are conditions that do exist in many European regions, including some in Spain.

3. The spatial context

To be logically consistent with the objectives of this study and with the hypotheses that we wish to test, we have classified the 17 autonomous regions of our national territory into groups according to their respective levels of economic development. On this basis, we have grouped together for the purposes of this study those regions with per capita GDP below 75% of the European Union average, the so-called "Objective Nº 1" regions (Andalucía, Asturias, Canary Islands, Cantabria, Castilla and León, Castilla-La Mancha, Community of Valencia, Extremadura, Galicia and Murcia); then we consider separately Catalonia and the Basque Country, which are Autonomous Communities well-established industrially and with similar levels of economic development (per capita GDP of around 90% of the European Union average); and finally, the Autonomous Community of Madrid is considered, as the only Spanish region that is in convergence economically with Europe.

The following tables identify the basic regional profile of R&D activity. It is observed from Table 1 that the "Objective Nº 1" regions show weakness in all the principal indicators: their combined contribution to the total R&D activity undertaken in Spain only represents 32.2% (ten Autonomous Communities provide practically the same R&D resources as the Autonomous Community of Madrid); the level of combined technological effort (R&D expenditure as % of national GDP) of these regions is lower than the Spanish average and much lower than the other more developed regions; it can also be appreciated that the companies of these regions only participate to a very limited extent in the combined R&D-related activities that are undertaken. A very different panorama from the deficiencies presented by the private sector is reflected by the resources destined to higher education (universities), where the principal indicators present the "Objective Nº 1" regions in a more favourable light. This situation is the consequence of a relatively uniform government policy towards the less developed Spanish regions aimed at balancing the total expenditure by allocating proportionately more public resources to the universities.

-TABLE 1-

INDICATORS OF R&D ACTIVITY IN 1998: REGIONAL DIFFERENCES IN SPAIN

R&D: Basic data	"Objective 1"	Catalonia	Madrid	Basque Country	Rest	Spain
R&D Expenditure as % of National GDP	0.64	1.19	1.77	1.37	0.65	0.99
R&D Expenditure (Spain=100)	32.20	22.81	30.89	8.79	5.32	100
R&D Personnel (Spain=100)	37.05	20.62	29.13	7.51	5.69	100
Nº of Researchers (Spain=100)	41.81	19.03	26.18	6.90	6.08	100
R&D in the private sector						
R&D Expenditure as % of National GDP	0.22	0.76	0.94	1.10	0.35	0.52
R&D Expenditure (Spain=100)	21.50	27.98	31.59	13.52	5.40	100
Company R&D Expenditure as % of Total R&D Cost	34.79	63.94	53.30	80.21	52.96	52.11
Nº of Researchers (Spain=100)	21.50	27.98	31.59	13.52	5.40	100
R&D in universities						
R&D Expenditure as % of National GDP	0.32	0.31	0.32	0.24	0.22	0.30
R&D Expenditure (Spain=100)	51.68	19.44	18.03	5.00	5.85	100
University R&D Expenditure as % of Total R&D Cost	48.97	26.00	17.81	17.38	33.58	30.51
Nº of Researchers (Spain=100)	54.03	17.37	15.39	6.18	7.03	100

Source: I.N.E. and authors' own data.

-TABLE 2-

REGIONAL DISTRIBUTION OF EXPENDITURE ON INNOVATION, BY SECTOR (SPAIN=100)

TECHNOLOGY SECTOR	Objective Nº1	Catalonia	Madrid	Basque C'ntry	Rest
I. ELECTRICAL ENGINEERING					
1. Electrical machinery and apparatus, electrical energy	20.17	36.65	22.73	13.67	6.78
2. Audio-visual technology. 3. Telecommunications. 5. Semiconductors	8.93	12.56	71.90	3.50	3.10
4. Information Technology	6.65	81.13	10.89	0.89	0.45
II. INSTRUMENTS					
6. Optics 7. Analysis, measurement, control technology 8. Medical technology	38.50	16.64	31.59	12.69	0.58
III. Chemistry, pharmaceuticals					
9. Organic fine chemistry 10. Macromolecular chemistry, polymers 16. Chemical Engineering	36.76	39.38	11.58	6.00	6.27
11. Pharmaceuticals, cosmetics	9.21	62.13	25.25	2.29	1.12
13. Materials, metallurgy	60.53	7.83	5.50	15.81	10.32
14. Agriculture, food chemistry	58.08	28.82	4.16	4.00	4.95
15. Chemical and petrol industry, basic materials chemistry	18.22	40.76	38.51	2.50	0.00
IV. PROCESS ENGINEERING, MACHINERY					
17. Surface technology, coating	17.88	22.21	9.26	47.84	2.81
18. Materials processing, textiles, paper	23.64	35.06	30.28	4.38	6.64
V. MECHANICAL ENGINEERING, MACHINERY					
21. Machine tools	15.62	26.52	17.92	19.24	20.70
24. Handling, printing	28.04	28.70	33.79	3.15	6.32
26. Transport	27.11	29.59	5.32	11.84	26.14
28. Space technology, weapons	8.26	0.02	64.75	26.29	0.68
29. Consumer goods and equipment	59.14	16.53	16.07	4.17	4.08
30. Civil engineering, building, mining	62.42	7.73	17.20	8.61	4.04
TOTAL	30.46	27.77	20.93	11.19	9.65

Source: National Statistics Institute and authors' own data.

If we look in more detail at the differences between sectors for the regions selected, the technological specialisation data (Table 2) show that companies' expenditure of innovation follows a similar pattern to that of total R&D resources. Analysed by technology sector, it is evident that the "Objective Nº 1" regions concentrate their expenditure on industrial activities of "low technological intensity", apart from a few exceptions. These regions concentrate more than 50% of innovation expenditure in sectors like metallurgy, agriculture and food chemistry, consumer goods and equipment, and civil engineering, whereas other sectors in which technological competition is stronger (pharmaceuticals, audio-visual technology, telecommunications, etc.), barely account for 10% of the total.

In Table 3, the relative importance and the coefficients of specialisation have been calculated and shown alongside the “results” of the process of innovation, in terms of the number of patents issued. These data confirm that, in the “Objective Nº 1” regions, the sectors of certain relative relevance (those accounting for more than 5% of the total patents issued in the whole of Spain) can be classified as of medium-low technological intensity (handling and printing, agricultural and food processing, consumer goods and civil engineering); it is precisely in those sectors that these less-developed regions are more specialised (with coefficients greater than unity).

-TABLE 3-

Nº OF PATENTS BY TECHNOLOGY SECTOR and AUTONOMOUS COMMUNITY (1998-2001)

	Regional distribution of total nº of patents					Coefficients of specialisation			
TECHNOLOGY SECTOR	Obj.nº1	Madrid	Catalonia	Basque	Total	Obj.nº1	Madrid	Catalonia	Basque
I. ELECTRICAL ENGINEERING									
1. Electrical machinery and apparatus, electrical energy	3.16	5.65	15.11	9.78	9.31	0.34	0.61	1.62	1.05
2. Audio-visual technology	1.58	5.65	3.36	0.00	3.17	0.50	1.78	1.06	0.00
3. Telecommunications	0.40	15.32	1.20	6.52	4.95	0.08	3.10	0.24	1.32
4. Information technology	0.40	1.61	0.00	1.09	0.59	0.67	2.72	0.00	1.83
5. Semiconductors	0.79	0.00	0.24	0.00	0.30	2.66	0.00	0.81	0.00
II. INSTRUMENTS									
6. Optics	0.00	0.40	0.72	0.00	0.40	0.00	1.02	1.82	0.00
7. Analysis, measurement, control technology	5.93	10.48	3.36	4.35	5.84	1.01	1.79	0.57	0.74
8. Medical technology	4.35	4.44	3.36	1.09	3.66	1.19	1.21	0.92	0.30
III. CHEMISTRY, PHARMACEUTICALS									
9. Organic fine chemistry	0.79	5.24	9.59	5.43	5.94	0.13	0.88	1.61	0.91
10. Macromolecular chemistry, polymers	0.79	2.02	0.24	0.00	0.79	1.00	2.55	0.30	0.00
11. Pharmaceuticals, cosmetics	3.16	3.23	5.52	0.00	3.86	0.82	0.84	1.43	0.00
12. Biotechnology	1.19	3.63	1.20	2.17	1.88	0.63	1.93	0.64	1.16
13. Materials, metallurgy	2.37	2.42	1.68	6.52	2.48	0.96	0.98	0.68	2.63
14. Agriculture, food chemistry	5.93	2.42	3.60	0.00	3.56	1.66	0.68	1.01	0.00
15. Chemical and petrol industry, basic materials chemistry	1.58	2.02	1.44	1.09	1.58	1.00	1.27	0.91	0.69
IV. PROCESS ENGINEERING, SPECIAL EQUIPT.									
16. Chemical engineering	4.35	1.61	2.40	2.17	2.67	1.63	0.60	0.90	0.81
17. Surface technology, coating	1.98	0.81	1.92	1.09	1.58	1.25	0.51	1.21	0.69
18. Materials processing, textiles, paper.	4.35	2.82	6.00	2.17	4.46	0.98	0.63	1.35	0.49
19. Thermal processes and apparatus	3.16	0.81	0.72	4.35	1.68	1.88	0.48	0.43	2.58
20. Environmental technology	1.19	1.61	2.16	0.00	1.58	0.75	1.02	1.36	0.00
V. MECHANICAL ENGINEERING, MACHINERY									
21. Machine tools	2.77	1.61	2.64	9.78	3.07	0.90	0.53	0.86	3.19
22. Engines, pumpes and turbines	1.98	0.40	1.68	2.17	1.49	1.33	0.27	1.13	1.46
23. Mechanical elements	1.98	0.40	2.88	3.26	2.08	0.95	0.19	1.38	1.57
24. Handling, printing	8.70	3.63	10.55	9.78	8.32	1.05	0.44	1.27	1.18
25. Agriculture and food processing, machinery and apparatus	8.30	2.82	2.64	5.43	4.36	1.91	0.65	0.61	1.25
26. Transport	3.56	5.24	4.08	4.35	4.26	0.84	1.23	0.96	1.02
27. Nuclear engineering	0.00	0.40	0.00	0.00	0.10	0.00	4.07	0.00	0.00
28. Space technology, weapons	0.40	1.21	0.00	0.00	0.40	1.00	3.05	0.00	0.00
29. Consumer goods and equipment	11.46	5.24	6.24	9.78	7.62	1.50	0.69	0.82	1.28
30. Civil engineering, building, mining	13.44	6.85	5.52	7.61	8.02	1.68	0.85	0.69	0.95
TOTAL	100	100	100	100	100	1.00	1.00	1.00	1.00
TOTAL Nº of Patents	253	248	417	92	1010	-	-	-	-

(1) (Sij/Rj)/(Si/   Rj). Sij: patents in sector i of region j. Rj: patents in region j.
SOURCE: OEPM and authors’ own data.

Lastly, it is well known that the most intensive flows between science and technology take place in sectors where the use of technology is more intensive (activities characterised by strong competition and rapid changes). Table 4 presents the principal indicators of high technology activity by region. It is clear from these data that in high technology sectors, the ten “Objective Nº 1” regions account for 31.46% of total companies and only 17.27% of total value added, in respect of Spain as a whole. If we consider sectors classified as employing medium-high technology, these figures look slightly better, but it is still observed that the sectors of high and medium-high technology in the “Objective Nº 1” regions are characterised by a corporate dimension notably lower than the rest of Spanish regions and productivity (in terms of Value added per person occupied) lower than the regional average.

-TABLE 4-

HIGH TECHNOLOGY INDICATORS BY REGION 1999 (*)

Region	Companies (%)		Value Added (%)		Nº of Persons Occupied (%)		Nº of persons occup/ Nº of companies		VAB / Nº occupied
	HT	MHT	HT	MHT	HT	MHT	HT	MHT	HT+MHT
Objective 1	31.46	41.46	17.27	33.19	18.93	35.02	41.85	25.77	93.16
Catalonia	38.57	30.68	35.67	34.70	32.44	28.92	58.49	28.76	118.42
Madrid	21.76	11.03	39.96	13.32	40.98	13.57	130.97	37.52	102.03
Basque Country	4.33	8.44	4.12	12.81	4.89	10.70	78.57	38.71	114.64
Rest	3.89	8.39	2.98	5.98	2.76	11.80	49.21	42.89	-
Total Spain	100	100	100	100	100	100	69.53	30.51	100

(*) HT: High technology. MHT: Medium-high technology (according to the OECD classification).
Source: I.N.E. and authors’ own data.

4. Hypotheses

The situation of strong competition within the same sector is now in itself an incentive for the development of innovative activities: the high technology industries are necessarily more innovative (Malecki, 1997, page 23). These high technology industies are looking for the advantage offered by having access to up-to-date scientific knowledge, particularly for those sectors of rapid technological advance in which the support of scientific literature is necessary because the inventions that are continually being made are not immediately available (Schmoch, 1993). These statements lead us to think that, in terms of the science-technology flows generally, there must be significant differences between the less and the more advanced regions; such discrepancies will ultimately be conditioned by the degree of specialisation in sectors of high technology. As demonstrated in the preceding section of this paper, the “Objective Nº 1” regions present a very unfavourable profile in respect of high technology sectors: fewer companies, of smaller size and with a lower productivity than the other regions of intermediate or high economic development. These initial premises lead us to formulate the following hypotheses:

H1. Significant interregional differences exist in the use of science, between the less developed (Objective 1) regions and those of intermediate development (Catalonia, the Basque Country).

H2. Significant interregional differences exist in the use of science, between the less developed (Objective 1) regions and the most developed region (Madrid).

This type of comparison may be subject to certain kinds of potential bias. In general, there exist substantial inter-sector differences in the number and type of scientific citations in the patent documents that are directly related to the different patterns of innovation or propensities to seek patents presented by each sector (Bell and Pavitt, 1993). With the object of avoiding the distortions introduced by sector differences, these hypotheses will be tested taking account of the degree of technological complexity of the sector. Further, in diverse spatial contexts (countries) it has been shown that science-technology relationships are specific: chemical patents cite scientific articles in chemical journals; medical patents cite articles on biomedicine, etc. (Klevorick et. al. 1995; Goldin, 1996; Hicks and Katz, 1997; Narin et. al., 1997). In principle, it would be thought that the level of regional development might alter this relationship, to the extent that those regions more specialised in a particular sector would be more knowledgeable of the scientific advances affecting the technological development of their activities. To allow for this situation, the first and second hypotheses will also be tested taking into account not only the technological complexity of the sector, but also the scientific field of the citation.

In the "Objective Nº 1" regions there exists a technological specialisation by sector in activities of intermediate or low complexity (above all in materials and metallurgy, agriculture and food chemistry, and civil engineering, building and mining). Unlike in the sectors of high technological competition, in these activities, technological development arises more from knowledge of the technology itself (i.e. on previous inventions) than on the use of scientific literature. This idea leads us to formulate the following hypotheses:

H3: There exist significant differences in the knowledge of the technological antecedents of innovations (patent citations) between the less developed (Objective 1) regions and those of intermediate development (Catalonia, the Basque Country).

H4: There exist significant differences in the knowledge of the technological antecedents of innovations (patent citations) between the less developed (Objective 1) regions and the most developed region (Madrid).

As in the first case, these hypotheses will be tested taking into account the degree of technological complexity of the technology sectors.

5. Methodology

The methodology applied in this study to investigate the links between science and technology is based on the scientific citations in patent documents (NPC). This method originated with the pioneer papers of Carpenter et. al. (1980), Carpenter and Narin (1983), Narin and Noma (1985) and Van Vianen et. al. (1990); it has recently been applied in the studies of Meyer (2000), McMillan et al. (2000) and Tijssen (2001, 2002). Three questions must be dealt with in relation to this methodology: the basis on which it is founded, its limitations and the interpretation of the results. After making brief comments on these three aspects, we describe the procedure followed in our analysis.

In relation to the foundation or basis of the method, it is well known that patent applicants and examiners are obliged to cite *prior art*, or the previous technical status of the subject, that has contributed to the development of a specific invention of process or of product. However, the prior art not only includes previous patent citations but also a good part of the bibliographical information given in the patents contains references to scientific literature and technical publications (known as non-patent citations or NPCs). These citations of scientific and technical articles provide an guide to the extent scientific research has contributed to any particular technological development, on the basis that these ideas and knowledge must have been utilised for the development of the invention. The presence of NPCs consequently indicates that an invention is related to or has been stimulated by the research activities undertaken in a particular field. The methodology consists of processing this information to obtain relevant data that may demonstrate how scientific knowledge is utilised for the development of new technologies. The data on NPCs that are obtained by this procedure constitute an appropriate indicator to quantify the relationships of a technology sector with one or more scientific fields (Schmoch, 1997).

As limitations of the methodology, the following have been reported (Verbeek et al., 2001; Meyer, 2000): incomplete databases, different types of citation, differences in the quality of the various types of scientific citation, difficulty of processing all the information and, fundamentally, that citations are not made in all sectors; this latter situation does not imply that there is no relationship between science and technology in non-citing sectors, but rather that there is a different type of interaction (through the mobility of scientists and engineers, or cooperation between a university and a company, for example). It should be taken into account, therefore, that the analysis of patent citations offers only a partial picture of the flows between science and technology, since what is really being quantified is the use made of the scientific literature published.

In relation to the interpretation of scientific citations in the patent documents, from the analyses conducted to date, it is not possible to infer a unidirectional relationship between scientific citations and patents. Rather than there being a relationship of causality, the presence of scientific citations should be understood as an indicator of the degree of interaction between science and technology.

In our case, we have conducted an exhaustive review of all the patents applied for in the period 1998-2001 by companies resident in the "Objective Nº 1" regions, Catalonia, Madrid and the Basque Country. Firstly, the total number of patent applications in these years was classified by technology sector. In total, the fieldwork involved an exhaustive analysis of 1010 patent documents, from which a total of 1162 scientific citations were extracted. The basic statistical source used is the databases of the Spanish Office of Patents and Trade Marks (OEPM). Having classified the patents, the scientific citations (all references included in the complete text of the application document) were collected and categorised. For this we took seven scientific or scientific-technical fields, which are used as basic divisions in the regional planning documents in Spain (once the non-relevant fields of economics and other social sciences, law and the humanities had been excluded):

1. AGR: Agro-food (agriculture and forestry, food and drink technology, food and drink quality and safety,...). 2. CVI: Life Sciences (biology, biotechnology). 3. CTS: Health Science and Technology. 4. RNM: Natural Resources and the Environment (atmospheric phenomena, marine ecosystems, water resources,...). 5. FQM: Physics, Chemistry, Mathematics. 6. TEP: Technologies of Production (fabrication and other production processes, automation and robotics, quality control systems, engineering in general,...). 7. TIC: Information and Communications Technologies.

It is generally difficult to establish clear boundaries between scientific areas, however they are classified. To allocate a particular scientific citation to one or other scientific field, assistance has been provided by specialists of the University of Cádiz and of the Spanish Government's "Consejo Superior de Investigaciones Científicas" (CSIC). The criterion adopted when an article of a multidisciplinary character could equally be allocated to two different scientific fields has been to consider it to fall under both. From this process a series of tables have been prepared from which we have attempted to draw the answers to some of the questions initially posed. However, to test the hypotheses formulated, we have adopted more rigorous statistical methods (test of differences of means).

6. Data and results

6.1. Descriptive Analysis

Table 5 gives the total numbers of patents and scientific citations that have been examined. It can be observed that of the 1010 patents reviewed, 11.29% on average (for the whole of Spain) are founded to a greater or less degree on scientific knowledge (patents that cite scientific articles). In the breakdown by regions, differences can be appreciated both in the proportion of patents that cite scientific articles, and in the number of citations per patent. In both indicators, the "Objective Nº 1" regions appear unfavourably. Firstly, in line with the pronounced territorial polarization of technological activity, there is also a regional concentration in the scientific citations: two Autonomous Communities - Madrid and Catalonia- account for 73.5% of total citations in patent documents. In Table 6 these scientific references have been classified by level of complexity (high, medium or low). As these data demonstrate, and as has been shown in several previous studies, science-technology flow are more frequent in the high technology sectors. This characteristic is common to all the regions studied, independently of the level of economic development. However, certain differences can also be appreciated in respect of the intensity of those flows within the high technology sectors; in principle, these differences derive from the differences in regional industrial specialisation.

-TABLE 5-

NºS OF PATENTS and SCIENTIFIC CITATIONS, BY REGION (1998-2001)

Regions	Nº of Patents (PAT)	Patents with scientific citations		Scientific citations (NPC)			Patent citations (PC)		
		Nº	%	Nº	Total=100	NPC/ PAT	Nº	Total=100	PC/PAT
Objective Nº1	253	22	8.70	217	18.67	0.86	1149	26.38	4.6
Madrid	248	34	13.71	395	33.99	1.59	1019	23.40	4.2
Catalonia	417	52	12.47	459	39.50	1.10	1799	41.32	4.4
Basque Country	92	6	6.52	91	7.83	0.99	387	8.89	4.2
TOTAL	1010	114	11.29	1162	100	1.15	4354	100	4.3

SOURCE: Authors' own, based on OEPM data.

-TABLE 6-

Nº OF PATENTS, BY TECHNOLOGICAL COMPLEXITY (1998-2001)

	Objective Nº1 Regions							Madrid						
COMPLEXITY	a	b	c	d	e	f	g	a	b	c	d	e	f	g
High	45	119	9	128	2,8	200	4,4	111	198	29	227	5,0	448	4
Medium	160	67	16	83	0,5	761	4,8	111	185	14	199	1,2	477	4,3
Low	44	31	2	33	0,8	188	4,3	19	12	1	13	0,3	94	4,9
TOTAL	249	217	27	244	1,0	1149	4,6	241	395	44	439	1,8	1019	4,2
	Catalonia							Basque Country						
COMPLEXITY	a	b	c	d	e	f	g	a	b	c	d	e	f	g
High	79	135	10	145	1,8	324	4,1	14	59	5	64	0,8	56	4,0
Medium	288	302	28	330	1,1	1307	4,5	69	32	1	33	0,1	292	4,2
Low	41	22	4	26	0,6	168	4,1	9	0	0	0	0,0	39	4,3
TOTAL	408	459	42	501	1,2	1799	4,4	92	91	6	97	0,2	387	4,2

NOTE: a. Nº of patents; b. Citations in journals; c. Other citations (books, congress papers, theses); d. Total Citations; e. Citations/Nº of patents; f. Patents cited; g. Patents cited per patent. Sector 20 cannot be rated by technological complexity.

SOURCE: OEPM and authors' own data.

In Tables 7a and 7b, the numbers of citations classified by type and by technology sector are presented. This represents the primary information on which the following discussion of the previously raised questions is based:

The greatest demand for scientific knowledge occurs in a relatively few sectors directly involved with chemical processes. From the break-down of total patents into thirty technology sectors, a pronounced concentration is observed in the use of science: for Spain as a whole, 85% of the citations are accounted for by only three sectors (organic fine chemistry, pharmaceuticals and biotechnology). The ratio of *citations to nº of patents* confirms that the biggest science-technology flows in Spain take place in these three sectors.

The technological advances in the high and medium-high technology sectors associated with electrical engineering and instruments make relatively little use of the relevant scientific literature; rather, they are based fundamentally on the accumulated technological knowledge acquired as a result of the development of previous technologies. This conclusion is supported by the number of patent citations. Therefore there exists a clear difference –even in the context of high technology- between those sectors in which technological advances are made on the strength of codified knowledge (eg. chemical processes) and others in which tacit knowledge is the key factor (e.g. high technology sectors related to engineering).

As in the country taken as a whole, in the context of the more developed regions the demand for scientific research is heavily concentrated in a few sectors. In the Autonomous Community of Madrid, the sectors active in organic chemistry and biotechnology account for 85% of the citations (and in the Basque Country, this figure is 97%). In Catalonia, the sectors of organic chemistry and pharmaceuticals account for 80% of the citations. In contrast, in the "Objective Nº 1" regions the dispersion is wider: in the three sectors accounting for most of the demand for scientific research (biotechnology, pharmaceuticals and food chemistry), 65% of all the citations are concentrated; in these regions the citations of the six most active sectors must be taken together to present a similar percentage concentration as the top two sectors of the more developed regions.

Consequently, the high demand for scientific research in chemical sectors and the relative absence of interrelationship between engineering technology sectors and scientific citations, at least in Spain, is independent of the level of regional development and specialisation. However, the concentration of citations in only a few sectors, which characterises the more developed regions (Madrid, together with Catalonia and the Basque Country), is not observed in the “Objective Nº 1” regions.

-TABLE 7a-

PATENTS and TYPE OF CITATION. BY TECHNOLOGY SECTOR (1998-2001)

	Objective Nº1 Regions							Madrid						
TECHNOLOGY SECTOR	a	b	c	d	e	f	g	a	b	c	d	e	f	G
I. ELECTRICAL ENGINEERING														
1. Electrical machinery and apparatus, electrical energy	8	0	0	0	0	56	7,0	14	3	2	5	0,4	70	5,0
2. Audio-visual technology	4	0	0	0	0	16	4,0	14	0	0	0	0,0	51	3,6
3. Telecommunications	1	0	0	0	0	5	5,0	38	1	2	3	0,1	166	4,4
4. Information Technology	1	0	0	0	0	5	5,0	4	0	0	0	0,0	5	1,3
5. Semiconductors	2	0	0	0	0	14	7,0	0	0	0	0	0,0	0	0,0
II. INSTRUMENTS														
6. Optics	0	0	0	0	0	0	0,0	1	0	0	0	0,0	5	5,0
7. Analysis, measurement, control technology	15	0	0	0	0	69	4,6	26	2	1	3	0,1	108	4,2
8. Medical Technology	11	0	0	0	0	62	5,6	11	0	0	0	0,0	47	4,3
III. Chemistry, pharmaceuticals														
9. Organic fine chemistry	2	13	2	15	7,5	7	3,5	13	161	7	168	12,9	18	1,4
10. Macromolecular chemistry, polymers	2	16	2	18	9,0	6	3,0	5	1	1	2	0,4	18	3,6
11. Pharmaceuticals, cosmetics	8	61	0	61	7,6	21	2,6	8	12	3	15	1,9	46	5,8
12. Biotechnology	3	58	9	67	22,3	8	2,7	9	183	23	206	22,9	20	2,2
13. Materials, metallurgy	6	21	8	29	4,8	22	3,7	6	0	0	0	0,0	30	5,0
14. Agriculture, food chemistry	15	31	2	33	2,2	60	4,0	6	12	1	13	2,2	22	3,7
15. Chemical and petrol industry, basic materials chemistry	4	13	3	16	4,0	10	2,5	5	4	1	5	1,0	17	3,4
IV. PROCESS ENGINEERING, SPECIAL EQUIPT.														
16. Chemical engineering	11	4	0	4	0,4	48	4,4	4	2	3	5	1,3	20	5,0
17. Surface technology, coating	5	0	1	1	0,2	22	4,4	2	14	0	14	7,0	8	4,0
18. Materials processing, textiles, paper.	11	0	0	0	0	47	4,3	7	0	0	0	0,0	31	4,4
19. Thermal Processes and apparatus	8	0	0	0	0	43	5,4	2	0	0	0	0,0	10	5,0
20. Environmental technology	3	0	0	0	0	17	5,7	4	0	2	2	0,5	18	4,5
V. MECHANICAL ENGINEERING, MACHINERY														
21. Machine Tools	7	0	0	0	0	32	4,6	4	0	0	0	0,0	14	3,5
22. Engines, pumpes, turbines	5	0	0	0	0	25	5,0	1	0	0	0	0,0	6	6,0
23. Mechanical elements	5	0	0	0	0	24	4,8	1	0	0	0	0,0	6	6,0
24. Handling, printing	22	0	0	0	0	105	4,8	9	0	0	0	0,0	40	4,4
25. Agriculture and food processing, machinery and apparatus	21	0	0	0	0	105	5,0	7	0	0	0	0,0	40	5,7
26. Transport	9	0	0	0	0	56	6,2	13	0	0	0	0,0	65	5,0
27. Nuclear engineering	0	0	0	0	0	0	0,0	1	0	0	0	0,0	4	4,0
28. Space technology, weapons	1	0	0	0	0	2	2,0	3	0	0	0	0,0	13	4,3
29. Consumer goods and equipment	29	0	0	0	0	128	4,4	13	0	0	0	0,0	72	5,5
30. Civil engineering, building, mining	34	0	0	0	0	153	4,5	17	0	0	0	0,0	80	4,7
TOTAL	253	217	27	244	1,0	1168	4,6	248	395	46	441	1,8	1050	4,2

KEY: a= Nº OF PATENTS; b= CITATIONS IN JOURNALS; c= OTHER CITATIONS (IN BOOKS, CONGRESSES, THESES); d= TOTAL CITATIONS;
e= CITATIONS / Nº OF PATENTS; f= PATENTS CITED; g= PATENTS CITED PER PATENT .
SOURCE: OEPM and authors’ own data.

Table 8 presents the number of citations broken down by scientific fields. On average (i.e. for Spain as a whole), the scientific fields where research is most in demand by industry are Health Science and Technology (37.5% of total citations), Life Sciences (32.4% of citations) and Physics, Chemistry and Mathematics (19.8% of citations). It can be observed that the detailed analysis by regions produces a somewhat similar picture in the scientific fields to that found in the technology sectors: the more developed regions present a strong concentration of citations in two or three fields, whereas this degree of concentration is not seen in the “Objective Nº 1” regions. Again, the relative degrees of economic specialization seem to explain these results: in the more developed regions, specialised in sectors related to chemical processes and biotechnology, patents mainly cite articles on Life Sciences and Health Technology, whereas the less developed regions are basically specialised in sectors of medium-to-low technology, in which patents cite articles on the fields of Agrofood research and Technologies of Production.

-TABLE 7b-

PATENTS and TYPE OF CITATION. BY TECHNOLOGY SECTOR (1998-2001)

	Catalonia							Basque Country						
TECHNOLOGY SECTOR	a	b	c	d	e	f	g	a	b	c	d	e	f	g
1. Electrical machinery and apparatus, electrical energy	63	0	0	0	0,0	302	4,8	9	0	0	0	0,0	51	5,7
2. Audio-visual technology	14	0	0	0	0,0	54	3,9	0	0	0	0	0,0	0	0,0
3. Telecommunications	5	0	0	0	0,0	22	4,4	6	0	0	0	0,0	29	4,8
4. Information technology	0	0	0	0	0,0	0	0,0	1	0	0	0	0,0	4	4,0
5. Semiconductors	1	0	0	0	0,0	2	2,0	0	0	0	0	0,0	0	0,0
6. Optics	3	0	0	0	0,0	11	3,7	0	0	0	0	0,0	0	0,0
7. Analysis, measurement, control technology	14	0	0	0	0,0	58	4,1	4	6	0	6	1,5	17	4,3
8. Medical technology	14	1	1	2	0,1	75	5,4	1	0	0	0	0,0	5	5,0
9. Organic fine chemistry	40	302	26	328	8,2	138	3,5	5	32	1	33	6,6	23	4,6
10. Macromolecular chemistry, polymers	1	0	0	0	0,0	3	3,0	0	0	0	0	0,0	0	0,0
11. Pharmaceuticals, cosmetics	23	68	5	73	3,2	84	3,7	0	0	0	0	0,0	0	0,0
12. Biotechnology	5	66	4	70	14,0	18	3,6	2	53	5	58	29,0	1	0,5
13. Materials, metallurgy	7	0	0	0	0,0	28	4,0	6	0	0	0	0,0	20	3,3
14. Agriculture, food chemistry	15	22	4	26	1,7	47	3,1	0	0	0	0	0,0	0	0,0
15. Chemical and petrol industry, basic materials chemistry	6	0	0	0	0,0	19	3,2	1	0	0	0	0,0	8	8,0
16. Chemical engineering	10	0	0	0	0,0	46	4,6	2	0	0	0	0,0	8	4,0
17. Surface technology, coating	8	0	1	1	0,1	37	4,6	1	0	0	0	0,0	6	6,0
18. Materials processing, textiles, paper.	25	0	0	0	0,0	118	4,7	2	0	0	0	0,0	6	3,0
19. Thermal Processes and apparatus	3	0	0	0	0,0	13	4,3	4	0	0	0	0,0	17	4,3
20. Environmental Technology	9	0	0	0	0,0	35	3,9	0	0	0	0	0,0	0	0,0
21. Machine Tools	11	0	0	0	0,0	46	4,2	9	0	0	0	0,0	36	4,0
22. Engines, pumpes and turbines	7	0	1	1	0,1	33	4,7	2	0	0	0	0,0	6	3,0
23. Mechanical elements	12	0	0	0	0,0	50	4,2	3	0	0	0	0,0	12	4,0
24. Handling, printing	44	0	0	0	0,0	219	5,0	9	0	0	0	0,0	32	3,6
25. Agriculture and food processing, machinery and apparatus	11	0	0	0	0,0	53	4,8	5	0	0	0	0,0	19	3,8
26. Transport	17	0	0	0	0,0	83	4,9	4	0	0	0	0,0	21	5,3
27. Nuclear engineering	0	0	0	0	0,0	0	0,0	0	0	0	0	0,0	0	0,0
28. Space technology, weapons	0	0	0	0	0,0	0	0,0	0	0	0	0	0,0	0	0,0
29. Consumer goods and equipment	26	0	0	0	0,0	121	4,7	9	0	0	0	0,0	39	4,3
30. Civil engineering, building, mining	23	0	0	0	0,0	119	5,2	7	0	0	0	0,0	27	3,9
TOTAL	417	459	42	501	1,2	1834	4,4	92	91	6	97	1,1	387	4,2

KEY: a= Nº OF PATENTS; b= CITATIONS IN JOURNALS; c= OTHER CITATIONS (IN BOOKS, CONGRESSES, THESES); d= TOTAL CITATIONS;
e= CITATIONS / Nº OF PATENTS; f= PATENTS CITED; g= PATENTS CITED PER PATENT
SOURCE: OEPM and authors' own data

-TABLE 8-

SCIENTIFIC CITATIONS BY SECTOR and FIELD OF KNOWLEDGE (1998-2001)

	Objective Nº1 Regions							Madrid						
TECHNOLOGY SECTOR	1	2	3	4	5	6	7	1	2	3	4	5	6	7
I. ELECTRICAL ENGINEERING	0	0	0	0	0	0	0	0	0	0	0	0	4	0
II. INSTRUMENTS	0	0	0	0	0	0	0	0	0	0	0	0	2	0
III. CHEMISTRY, PHARMACEUTICALS														
9. Organic fine chemistry	0	0	0	0	13	0	0	0	64	68	0	26	3	0
10. Macromolecular chemistry, polymers	7	9	0	0	0	0	0	0	1	0	0	0	0	0
11. Pharmaceuticals, cosmetics	1	10	40	0	10	0	0	0	2	8	0	2	0	0
12. Biotechnology	5	40	5	0	7	1	0	7	117	23	0	20	16	0
13. Materials, metallurgy	0	0	1	0	8	12	0	0	0	0	0	0	0	0
14. Agriculture, food chemistry	9	0	13	0	1	8	0	8	0	0	0	2	2	0
15. Chemical and petrol industry, basic materials chemistry	6	6	0	0	0	1	0	0	4	0	0	0	0	0
IV. PROCESS ENGINEERING, SPECIAL EQUIPT.	0	1	1	0	2	0	0	0	0	0	0	11	0	5
V. MECHANICAL ENGINEERING, MACHINERY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	28	66	60	0	41	22	0	15	188	99	0	61	21	5
TOTAL =100	12.90	30.41	27.65	0.00	18.89	10.14	0.00	3.86	48.33	25.45	0.00	15.68	5.40	1.29
	Catalonia							Basque Country						
TECHNOLOGY SECTOR	1	2	3	4	5	6	7	1	2	3	4	5	6	7
I. ELECTRICAL ENGINEERING	0	0	0	0	0	0	0	0	0	0	0	0	0	0
II. INSTRUMENTS	0	0	1	0	0	0	0	0	0	0	0	0	6	0
III. CHEMISTRY, PHARMACEUTICALS														
9. Organic fine chemistry	0	42	167	0	93	0	0	0	1	16	0	15	0	0
10. Macromolecular chemistry, polymers	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11. Pharmaceuticals, cosmetics	1	14	42	0	10	1	0	0	0	0	0	0	0	0
12. Biotechnology	1	31	19	0	8	7	0	0	29	24	0	0	0	0
13. Materials, metallurgy	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14. Agriculture, food chemistry	13	1	4	0	0	4	0	0	0	0	0	0	0	0
15. Chemical and petrol industry, basic materials chemistry	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IV. PROCESS ENGINEERING, SPECIAL EQUIPT.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V. MECHANICAL ENGINEERING, MACHINERY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	15	88	232	0	111	12	0	0	30	40	0	15	0	0
TOTAL =100	3.28	19.21	50.66	0.00	24.24	2.62	0.00	0.00	35.29	47.06	0.00	17.65	0.00	0.00

1. Agrofood (agriculture, forestry, food technology, food quality and safety,...). 2. Life Sciences (biology, biotechnology). 3. Health Science and Technology.
4. Natural Resources and the Environment (atmospheric phenomena, marine ecosystems, water resources,...). 5. Physics, Chemistry and Mathematics. 6. Technologies of Production (fabrication and production processes, automation and robotics, quality control systems, engineering in general,...). 7. Information and Communications Technologies.
SOURCE: OEPM and authors' own data.

6.2. Mean equality test

In addition to the information extracted from the preceding tables, the results of the statistical tests of means conducted are given in Tables 9 and 10. This analysis enables us to determine whether the difference in behaviour of the variables observed in the descriptive analysis of the data in the tables is significant or not. The test of means between groups becomes more relevant when the number of observations is limited; in these cases, a difference can be found but this may not be significant. The results are as follows:

In respect of hypothesis H1, the data given in Table 8 show that, although there are differences between each type of region, these differences are not statistically significant between “Objective Nº 1” regions and Catalonia.

H2: The test of means shows that there does exist a significant difference in respect of Field 2 between “Objective Nº 1” regions and Madrid.

Breaking the data down by scientific fields, it can be observed that the differences are found in field 2; in other words, that in the more developed regions, scientific articles are cited more, on average, in field 2 – related to the high technology sectors- than in the “Objective Nº 1” regions. These differences are sharper when the high technology sectors are considered. The explanation for these results lies, once again, in the degree of specialisation. In those regions where there is a high degree of specialisation in high technology sectors with a strong demand for scientific knowledge (Madrid), a high degree of concentration in respect of the citation of scientific literature is found, as previously demonstrated. However, such concentration is not found with the “Objective Nº 1” regions, where the scientific fields that are cited in patents are much more widely dispersed.

-TABLE 9-

MEAN EQUALITY TEST between REGIONS

	Nº of patents with citations	Means				
		Total citations	Citations in C2		Citations in C3	Citations in C7
OBJECTIVE Nº1 REGIONS vs MADRID						
Total Sectors						
Madrid	41	10,76	9,40		4,50	2,93
Objective Nº 1 regions	24	10,17	5,08	*	4,62	2,77
High technology sectors						
Madrid	18	12,61	11,90		2,82	2,20
Objective 1 regions	11	11,64	5,00	**	4,50	2,13
OBJECTIVE Nº1 REGIONS vs CATALONIA						
Total Sectors						
Catalonia	61	8,21	4,63		5,83	2,78
Objective 1 regions	24	10,17	5,08		4,62	2,93
High technology sectors						
Catalonia	19	7,63	5,00		5,64	1,80
Objective 1 regions	11	11,64	5,00		4,50	2,13

* 10% Significance; ** 5% Significance
NOTE: The scientific fields correspond to the following: C2= Life Sciences (biology, biotechnology).
C3= Health Science and Technology. C7= Physics, Chemistry and Mathematics.
NOTE: The results of the test of means coincide with the results of the test of medians.
SOURCE: Authors’ own data.

In respect of hypotheses H3 and H4, the analysis of means shows that the differences occur in sectors of intermediate technology, and always in favour of the “Objective Nº 1” regions, which are more specialised in this category of technology.

-TABLE 10-

MEAN EQUALITY TEST FOR THE PATENTS REFERENCED

	Nº of patents	Patents cited	
OBJECTIVE Nº1 REGIONS vs MADRID			
High technology sectors			
Madrid	114	4,04	
Objective 1 regions	46	4,39	
Sectors of intermediate complexity			
Madrid	115	4,3	
Objective 1 regions	163	4,77	*
Sectors of low complexity			
Madrid	19	4,95	
Objective 1 regions	44	4,27	
OBJECTIVE Nº1 REGIONS vs CATALONIA			
High technology sectors			
Catalonia	79	4,1	
Objective 1 regions	46	4,39	
Sectors of intermediate complexity			
Catalonia	297	4,52	
Objective 1 regions	163	4,77	
Sectors of low complexity			
Catalonia	41	4,1	
Objective 1 regions	44	4,27	
OBJECTIVE Nº1 REGIONS vs BASQUE COUNTRY			
High technology sectors			
Basque Country	14	4	
Objective 1 regions	46	4,39	
Sectors of intermediate complexity			
Basque Country	69	4,23	
Objective 1 regions	163	4,77	*
Sectors of low complexity			
Basque Country	9	4,33	
Objective 1 regions	44	4,27	

* 10% Significance; ** 5% Significance.
SOURCE: Authors’ own data.

6. Conclusions

As confirmed in the preceding sections, the “Objective Nº 1” regions of Spain, are characterised by specific circumstances that may condition science-technology flows: technological specialisation is in sectors of medium and low complexity; a relatively small number of companies undertake high technology activities; and those few high technology companies that do operate are of a smaller average size and present a lower productivity than similar companies in the more developed regions. Based on these initial premises as the main conditioners of science-technology flows, from the application of an established methodology of analysis to the regional level using the scientific citations in new patent documents (NPC), we have been able to identify certain regional characteristics of the science-technology flows and to test our working hypotheses. The following are the main results obtained:

- Significant differences exist in the science-technology flows in sectors where the application of technology is intensive, between the “Objective Nº1” regions and Madrid. In the “Objective Nº 1” regions, relevant scientific literature is cited less frequently in patents, on average; however, such differences are not observed between “Objective Nº 1” regions and others of intermediate economic development (Catalonia and the Basque Country).

- Significant differences exist in the knowledge of the antecedents of innovations (patent citations) between the “Objective Nº 1” regions and Madrid, in sectors of intermediate technological complexity. No such differences are observed between “Objective Nº 1” regions and Catalonia (which is classified as a region of intermediate economic development).

The reason for these differences lies in the degrees of specialisation of the regions. Madrid is weighted relatively heavily in importance among all the regions of Spain, and presents coefficients of specialisation higher than unity in sectors where the use of technology is intensive. Therefore in this region there is a greater diffusion of codified knowledge that is utilised for the development of innovations in such sectors. In contrast, the "Objective Nº 1” regions (and those of intermediate development such as Catalonia) are more specialised in sectors using technology of medium or low complexity that generally makes little use of scientific research to support new developments, relying instead more on knowledge accumulated from previous technological development. The data obtained reveal that these regions are more knowledgeable in technology of medium to low complexity and hence in these sectors, tacit knowledge of the technological antecedents of specific previous innovations is more prevalent.

It is appropriate, lastly, to include some reflections on the implications of the results obtained for regional policies in respect of the planning of R&D. In the “Objective Nº 1” regions, substantial efforts are being made to strengthen the resources in higher education and, in some cases, to encourage research groups working in fields related to the technology employed in sectors where there exists a certain degree of regional economic specialisation. Thought should be given to the relevance of such efforts when the sectors concerned are of lower technology and make a relatively little use of the results of scientific research for innovation and an extensive one of technological knowledge included in patents.

Finally, our intentions in respect of future investigations are directed towards extending the period of study, to respond to other questions such as how locally generated scientific knowledge is applied by local industry and by “out of region” industry. Another proposal is to put forward a micro-economic model to identify the causes of the regional differences in particular sectors and scientific fields; to explain these differences, one must take into account not only the external factors and the regional context but also certain micro-economic characteristics of the companies.

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