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Innovation and industrial districts: a first approach to the measurement and determinants of the I-district effect

Rafael Boix and Vittorio Galletto

Departament d'Economia Aplicada
Universitat Autònoma de Barcelona
Edifici B, 08193 Cerdanyola del Vallès, Barcelona (Spain)
Tel. +34 93 5811528 Fax. +34 93 5812292
E-mail: rafael.boix@uab.es / vittorio.galletto@uab.es

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Abstract. Why the rates of innovation per capita in the Spanish Marshallian Industrial Districts are higher than in the other Local Production Systems (including the Manufacturing Local Production Systems of Large Firms)? We analyse an exhaustive database of patents granted in Spain between 2001 and 2006 aggregated in a panel of 806 Local Labour Markets classified in seven typologies of Local Production Systems. Our analysis show that Marshallian Industrial Districts generates 30% of Spanish patents and an innovative output per capita 47% above the national average and 31% larger than the Manufacturing Local Production Systems of Large Firms. The econometric estimates of a fixed effects model confirm the existence of an Innovation-district effect (I-district) and its size. The I-district effect is mainly related to the presence of Marshallian district economies (specialization, specialized suppliers and social capital) and to a lesser extent to urbanization economies (density although not local market size). However, no solid evidence is found between patent intensity and other knowledge variables as university graduates, knowledge-intensive industries or ICT.

Keywords: industrial districts, innovation, external economies, district effect
JEL: O14; O31; R12

"*What is not good for the swarm is not good for the bee*"
Marcus Aurelius (The Meditations, 170-180 a.c)

1. Introduction

One of the less investigated aspects of the industrial district continues to be the generation and introduction of technological innovations. The Economic Theory continues to attribute greater dynamism to the technological change due to capital and R&D indivisibilities which are generated inside large firms. However, in many cases the stubborn reality suggests that other mechanisms lead the generation and use of innovation.

The initial stages of this research arise from an inductive approach. During the course of a research on the spatial impacts of universities in Spain, the authors accidentally observed the extraordinary intensity of patent generation of the Spanish industrial districts in relation to the large-firm manufacturing local production systems and the services systems. Since the microdata were very accurate[1] and the differentials too large, these results were an anomaly conflicting with a considerable part of the literature on innovation, that defends the superior performance of R&D and large firms in the production of innovations. The local development theories, and in particular the Marshall-Becattini's paradigm of the industrial district provided a normal framework to explore the existence of this differential by turning the research to a deductive approach. However, we notice that our intention is not to validate or to subject to falsification the theory of the industrial district (or a part of this theory) against other theories.

The main question is why the Spanish industrial districts show higher rates of innovation per capita than the other local productive systems in the country (including the large-firm manufacturing ones). Departing from the industrial district framework, we can focus on three hypotheses to answer the question, representing three complementary approaches to the industrial district. Following Bagnasco (1977) and Bagnasco and Trigilia (1984), we can centre on the interaction between market,

[1] Patents and utility models covered national, EPO, UPSTO and WIPO databases. Other datasets included protected designs and two types of public loans and grants to R&D&i (CDTI and PROFIT programs).

institutions and policy. Following Brusco (1975; 1991), we can focus on a network of small and medium enterprises characterized by heterogeneous production functions which results in higher levels of technical efficiency. Finally, following Marshall (1890) and Becattini (1975; 1979), the external economies are at the basis of the system of innovation in industrial districts. Although the three ways provide suggestive and complementary explanations, it is not possible to explore all of them in this research. We will centre on the mechanism we are more interested: the external economies. Thus, our hypothesis is that higher rates of innovation per capita in the Spanish industrial districts are explained by the external economies. The objective is to quantify the differential effect of the industrial district on innovation (the I-district effect) and to test if this effect is explained by the external economies.

2. Industrial districts, innovation and "district effect"

2.1 Industrial districts

Marshall (1980) documented the existence of a form of organization of production based on the concentration, in some districts of the industrial English cities, of population and small and medium sized firms specialized in the different parts of a productive process. In these "industrial districts", internal large scale economies were substituted by external economies related to the existence of qualified workers, specialized suppliers and an informal system of knowledge diffusion. The figure of the Marshallian Industrial District (MID) was recovered by Becattini (1975) to explain the success of the specialized Local Production Systems (LPS) of Small and Medium Enterprises (SME) in the Italian Tuscany at the same time as the large-firm productive model of Turin and Milan experienced a serious crisis. Becattini (1979) transferred the unit of analysis from the "firm" or the "sector" to the "industrial district", a "social and territorial entity that is characterized by the active presence of both a community of people and a group of enterprises in a natural and historically determined area" (Becattini, 1991). In the district the community and the firms tend to mutually develop in a harmonious relationship". Departing from a Marxist approach, Brusco (1975; 1991) arrived to the same figure, where the industrial district is a network of SME with heterogeneous production functions. Bagnasco and Trigilia (1984) introduced an additional element based on the interaction between market, institutions and policy.

Bagnasco (1977) coined the term "Terza Italia" (Third Italy) to define those environments where industrial districts tend to flourish. Since the end of the 1970s, Italian scholars have provided the key elements of the Marshallian Industrial District theory (Becattini, 1991; Bellandi, 2002; Dei Ottati, 2002; Lazzeretti and Storai, 2003; Sforzi, 1989).

The most special feature of the industrial district is the "community" of people who lives and works in the same locality. Embedded in the community there are institutions that can be formal (social agents, local government, training centres, etc.) and informal (values, attitudes and above all implicit norms of behaviour) (Dei Ottati, 2006). A second characteristic is the concentration of many small firms and workers specialized in the different phases of a same productive process (*filiere*). Although small firms does not benefit from the large scale economies as big firms, the social organisation of the production in specialized localities produces external localization economies, which depends on conditions that are external to the firm and internal to the place. These advantages are translated to reductions in costs and higher productive efficiency (static and dynamic) producing the so-called "district-effect". This allows the local firms to transform some of the apparent limitations of the LPS in advantages[2].

2.2. Industrial districts and innovation

The literature on industrial districts highlights that the district model fosters the innovative ability of firms and helps the adoption of innovations. Bellandi (1989; 1996) points out that the agglomeration of small and medium sized enterprises producing the same good fosters a quick diffusion of innovations. He also remarks that in the industrial districts there is a "diffuse innovation capacity", an ability to learn from the experience (*learning by doing*) and to innovate from it, which conceptually substitutes the Research and Development department of the *fordist* large firm (*learning by R&D*). Garofoli (1989, p.81) highlights that innovation (technological and organizational) in industrial districts takes "the connotations of a continuous process, with accumulation and interdependence of the effects from a large number of technological changes, small each in its individual basis; therefore, the connotations of an incremental innovative

[2] Or remembering the delicious metaphor by Becattini (2001), the caterpillar was actually a butterfly.

process (*à la Rosenberg*), rather than through big steps (*à la Schumpeter*)", although with the special feature that they are not bound to a single firm but they tend to diffuse inside the local productive system at great speed by means of informal mechanisms. Trullén (2006) differentiates four mechanisms that are related to the generation of innovations in the LPS: (1) Radical innovations (Schumpeter); (2) incremental innovations (Baumol - Rosenberg); (3) backward linkages on innovation from large firms (Perroux - Nadal); (4) and innovation by spillover mechanisms (Marshall - Becattini) which is characteristic in industrial districts.

To understand how the innovation process takes places in an industrial district (and in many other environments) is necessary to emphasize the dual nature of knowledge regarding its transmission (Polanyi, 1958): contextual and codified. Contextual knowledge is closely related to the activity of a location, and growths at the same time that its spatial, temporal and social context. An important share of this knowledge is "tacit knowledge" which is difficult to transmit and reproduce away its cultural original context (Becattini, 2001). Codified knowledge mostly refers to that scientific and technical knowledge compiled in codes that can be transmitted and learned by means of the usual mechanisms of communication and formal education mechanisms, and doesn't need from the experience of other people or a precise context.

Regarding this distinction, Becattini (2001) divides the learning process in four phases: socialization of contextual knowledge; decontextualization and codification of the experience acquired in the place; re-elaboration of knowledge; and re-absorption of codified knowledge by the specific processes of production of goods. This sequence produces a "cognitive spiral" that enhances in a continuous feedback the local knowledge, the tradable produced goods, the local agents and the local environment as a whole. From this conceptualization of the learning process, Becattini (2001) drew three important conclusions: (1) The "empirical knowledge" becomes for the production as important as scientific knowledge; (2) Contextual knowledge should be codified in some way to influence local processes; (3) Codified knowledge needs to be contextualized and combined with the contextual knowledge to affect the processes of production and innovation.

The empirical research on the linkages between industrial district and innovation is one of the less raised themes in the literature on industrial districts. Despite this fact, some scholars contributed with important researches on this issue. Brusco (1975) finds that engineering small metal-mechanical firms around Bergamo have similar rates of technology than similar large firms by contradicting the theory that technological innovation originates exclusively from internal investment. Russo (1996) performs a detailed qualitative research on the mechanisms of technical change in the ceramic district of Sassuolo. The results remarks that the high rates of technical progress in Sassuolo's district can not be explained by R&D activities performed in individual firms but rather by the linkages between users and producers of machinery for the ceramic industry[3]. In Spain, Molina (2002) and Budí (2005) find that R&D and knowledge spillovers are important for the innovative dynamic in the Spanish ceramic district of Castellón. Cainelli and De Liso (2003) find a link between the innovative activity and the gross value added of the firms inside the industrial districts. As a collateral result from the research, they observe that traditional sectors in Italy performed more than was expected innovative activities (product innovation). Muscio (2006) analyses the factors that determine the probability of introduction of an innovation in a firm in the industrial districts. He finds that the innovation in industrial districts is related to the cooperation between firms and the local division of labour while innovation in non-district firms is more related to R&D activities.

However, few efforts have been done to know if the industrial districts are more or less innovative than other LPS, even if some evidence could be indirectly deduced from some researches[4]. Not too much has been done to measure the differential performance of the industrial districts regarding innovation or to model the determinants of this differential, which we think is a key issue in a context where innovation (and not cost) is more and more fundamental for the competitiveness of localities and firms. That is to say, if there is an I-district effect and what are their causes.

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[3] We refer to the anecdote told by Russo (2002) on the unfortunate prediction of a young Romano Prodi on the industrial district of Sassuolo, currently one of the first world producers and exporters of ceramic tiles.

[4] The maps on the spatial distribution of patents by Breschi (1998) and Paci and Usai (1999) showed a clear concentration not only around Milan but also in some provinces of Emilia Romagna, Tuscany and Veneto.

2.3. Theoretical determinants of the district effect

The term "district effect" was coined by Signorini (1994) to explain the higher productive efficiency of the firms located inside the industrial districts. Dei Ottati (2006, p.74) defines the "district effect" as the "collection of competitive advantages derived from a strongly related collection of economies external to the individual firms although internal to the district".

What are the determinants of the district effect? Following Marshall (1890), the performance of the firms in industrial districts is related to the external economies, which comes from:

1. A trained, specialized and flexible labour market: workers have higher levels of specialization and skills in the local industry and in the different stages of the productive process.

2. Specialized suppliers in all the phases of the productive chain of a good: the spatial concentration allows the existence of specialized (and differentiated) firms in all the stages of the productive process, each forced to innovate in order to survive, reinforcing at the same time the integration and the links between them.

3. Knowledge spillover effects: the diffuse industrial culture, made up of a set of intangible elements pertaining to the LPS as a whole (entrepreneurship, cooperative spirit, technical know-how, knowledge socialisation) which Marshall referred as an "industrial atmosphere". It permits knowledge to flow through the district and allows district firms to benefit from higher rates of innovation and productivity.

Dei Ottati (2006) differentiates two families of economies of district: semiautomatic and planned. Semiautomatic economies arise from: the scale and scope effects from specialization; the existence of specialized suppliers along the different phases of an integrated chain; external flexibility in the division of work between firms; learning by doing and knowledge spillovers; creativity and continuous innovation; and entrepreneurship. The necessity of planned economies comes as a reactive or proactive response to the existence of discontinuities originated away of the district. In this case, the local agents (public and private) can lead a collective action designed to provide the quantity and type of public goods necessary to generate new external economies.

Although these factors have been exposed as the main determinants of the success of the industrial districts, Marshall (1890; 1919) exposes other sources of local advantages related to the characteristics of the city, as the size and income of the local market or the existence of other local specializations which can absorb the effects on the community of external shocks on the district specialization. Regional and urban economics theories collect these factors under the term "agglomeration economies" (Capello, 2007), where the "localization economies" basically are the Marshallian district economies and the "urbanization economies" describes the effects due to the size of the local market and the effects of cultural and productive diversity (not only as a shock-absorbing but also as an element that fosters the production of new knowledge).

The empirical researches on the "district effect" have followed two approaches: parametric and non-parametric. The parametric approach is based on the econometric estimations of an economic function (such as a production function) so that the parameters can give information about the existence of the district effect. Signorini (1994) uses this approach on a production function, obtaining evidence on the existence of a district effect on productivity, profitability, vertical integration and finance. Fabiani et al. (2000) find evidence that productive inefficiency is reduced for firms located in industrial districts. Gola and Mori (2000) and Bronzini (2000) find evidence on the existence of a district effect in terms of export performance. Costa and Viladecans (1999) also find evidence regarding industrial districts' characteristics and its positive influence on the international competitiveness of the Spanish LPS[5].

The non-parametric approach used by Hernández and Soler (2003) departs from the concept of Efficient Production Frontier and Data Envelopment Analysis (DEA) to obtain the inefficiency of each firm as the difference between its actual output and the maximum feasible output that can be obtained from the inputs used by the firm. Their

[5] However, this research does not differentiate the industrial districts from other local production systems.

findings for Valencia confirm the existence of a district effect for the firms located in industrial districts.

3. First evidence on the I-district effect

3.1. Measurement of innovation

The measurement of innovation is a widely discussed topic in the literature and there is no agreement about which should be the most appropriate indicator (Grilches, 1990; Acs et al., 1992). Usually, innovation indicators are divided in “input indicators” (R&D expenditure or jobs) and “output indicators” (patents, new products announcements). The main inconvenient with the first ones is that they fail to take into account activities related with contextual knowledge, which are more important in smaller firms, underestimating its innovative capacity. On the other hand, patents and new products announcements represent the outcome of the innovation process. As long as granted patents implies novelty and utility, and also an economic expenditure for the applicant, it is supposed that patented innovation has an economic value (although very variable) (Griliches, 1990). Furthermore, patent documents contain very useful data as applicant’s address, name, date and technological classification (so that we can geo-reference the data by LPS). For these reasons patent indicators are the most wide employed indicators of innovation (Khan and Dernis, 2006). Therefore, we will employ patents as our innovation indicator, which has the additional advantage that we can discuss our results regarding the most extended empirical line and to use other indicators for the same period that allow comparing the strength of the results.

In order to avoid yearly fluctuations and taking into account the lags in the outcome of innovation processes, it is usual to consider data about innovation in periods of 4-5 years (Griliches, 1992; Moreno et al., 2003). We will focus on the data for the period 2001-2006 (both included)[6]. Another feature of this research is that the data does not

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[6] Our complete patent database covers the period 1991-2006 including 70,000 documents although we decided to focus on this latter period. Patent counts include the “utility models”, a figure granted by the OEPM which is similar to the patent although legal requirements are less strict and protection covers only ten years. Similar figures exist in Austria, Denmark, Finland, Germany, Greece, Italy, Japan, Poland and

restrict to a unique register as is usual but rather covers several sources to produce the most precise counts. Patent data were obtained from the Spanish Patent and Trademark Office (OEPM), European Patent Office (EPO), USPTO (United States Patent and Trademark Office) and WIPO (World Intellectual Property Organization) and covers applications with at least one applicant with address in Spain by year of application[7]. The data are treated to avoid double-counting (patents first applied at the Spanish office and then extended by means of the European or World treaty, or vice-versa) and the final database covers 22,500 documents for the whole period 2001-2006.

3.2. Typology of local production systems in Spain

Data on innovation were compiled by address so that any level of territorial aggregation is possible. The territorial units are the 806 Local Labour Markets (LLM) in Spain (Boix and Galletto, 2007) identified using the Italian Sforzi - ISTAT (2006) methodology, which is also very close to the English Travel-To-Work Areas (TTWA). We differentiate seven types of LLM or LPS divided in (Figure 1):

Three types of manufacturing systems:

1. 205 Marshallian industrial districts, identified by Boix and Galletto (2007) using the new Italian Sforzi - ISTAT (2006) methodology. The industrial districts are LPS specialized in a manufacturing (*filiere*) and basically composed by SME. Nine specializations were identified: Food and beverages; Transport equipment; Machinery, electrical and optical equipment; Metal products; Chemistry and plastics; Paper; publishing and printing; Leather and footwear; Products for the house; Textile and textile products.

Portugal (Portillo, 2007). Employment data comes from 2001 Census of the Spanish Institute of Statistics (INE).

[7] Data treatment follows international standards: patents are located according to the first applicant with address in Spain (inventor's address is not available for national patents); reference date is the first between application data in any register because is the closest to the invention date and does not introduce biases due to legal or procedure delays.

2. 66 Manufacturing LPS of Large Firms, obtained from the procedure for the identification of industrial districts as those manufacturing systems which are specialized in large firms and where the main specialization contains at least one large firm (above 250 employees).

3. Rest of manufacturing LPS. They are 61 LPS obtained as a residual since they are not classified as industrial districts or Manufacturing LPS of Large Firms. They include those LPS with characteristics of industrial district that Boix and Galletto (2007) excluded because the number of employees in the main specialization was lower than 250 employees (were considered too small), and also some LPS where manufacturing as a whole has an average size of large firm but without any large firm into the main specialization.

We classify as Services' LPS those which in the first stage of the Sfozi - ISTAT algorithm are specialized in services (Consumer services; Business services; Traditional services; and Social services). Two types of Services' LPS are differentiated regarding innovation:

4. LPS specialized in services that belong to Large Metropolitan Areas. Boix (2006a; 2006b) identified five metropolitan areas in Spain above 1,000,000 million people (Madrid, Barcelona, Valencia, Seville and Bilbao) and found that their behaviour regarding innovation was quite different from the other metropolitan areas. However, most of the LPS belonging to these metropolitan areas are in fact industrial districts and in the case of Valencia, the core LPS is classified as industrial district. This reduces our category to only four central LPS: Madrid, Barcelona, Seville and Bilbao.

5. Other LPS specialized in services add up to 102 LLM and their innovative performance is much lower than the largest metropolitan areas.

And finally, other two categories come from the first stage of the Sforzi - ISTAT algorithm:

6. 333 LPS specialized in Primary (Agriculture, fishing, etc.) and Extractive activities.

7. 35 LPS specialized in Construction.

3.3. First evidence on the I-district effect

The territorial distribution of innovations and innovative intensity in Spain shows five stylized and categorical results:

1. The couple formed by Marshallian industrial districts and the core of the largest metropolitan areas are determinant for the innovative capacity of the country regarding both absolute and relative figures (Table 1). The four cores specialized in services of the largest metropolitan areas (28% of the employment) generate 35% of the Spanish innovations and a ratio of 288 innovations per employee, which is 25% above the national mean (230 innovations per employee)[8]. Marshallian industrial districts (21% of the national employment) generate 30.6% of the Spanish innovations and a ratio of 337 innovations per employee, 47% above the national average, being the most innovative LPS in Spain. Furthermore, 57.1% of industrial districts have an innovative intensity above the national mean and only 20 districts have not innovative activity in this period.

2. Manufacturing LPS of Large Firms (10.9% of the employment) account for 12.1% of innovations. The innovative intensity is 256 patents per million employees a year, which is 11% above the national average but 32% below the industrial districts (Table 1). The sum of metropolitan areas, industrial districts and Manufacturing LPS of Large Firms adds up to 78% of total innovations in Spain and tends to be spatially concentrated, as points out the Figure 1.

3. The rest of LPS account for 22% of new innovations generated in Spain and their innovative intensity is below the national average. The rest of manufacturing industrial districts (basically micro-SLP) account for only 0.6% of national innovations and their innovative intensity is 24% below the national average. Services SLP which do not pertain to a metropolitan area have 16% of innovations and the innovative intensity is 36% below the national average. LPS specialized in Construction (2.2% of employment) generate 1.1% of total innovations with an innovative intensity 53%

[8] Only Seville is below the national mean.

below the national average. Despite accounting for 41% of total LLM, those LPS specialized in Primary and Extractive activities are the less innovative units with only 4.7% of total innovations and an innovative intensity 62% below the national average. We also notice that they account for 64% of the LPS that does not have any innovation in the period analyzed (Table 2).

4. In the previous periods 1991-1995 and 1996-2001, the innovative intensity of industrial districts was also 33% and 35% above the national average.

5. Regarding the sensitivity of the indicator of innovation (patents) we test if the results maintain with other two variables that are available at microdata level and were already treated in our database covering the same period: (1) industrial designs and models from the databases of the Spanish Patent and Trademark Office (OEPM), which is another indicator for output innovation; (2) and grants and loans provided by the Centre for the Development of Industrial Technology (CDTI), belonging to the Ministry of Industry, that can be interpreted as an input indicator (demand of public loans to innovate). The Figure 3 shows the innovations per million employees a year in differences on the mean of each indicator. Industrial districts show in the three cases the most important differential effect on the total Spanish average, clearly above the Large Metropolitan Areas and Manufacturing LPS of Large Firms. Furthermore, the choice of patent indicators seems to be the most conservative option since the differentials are much larger regarding designs and CDTI loans.

4. Modelling the determinants of the I-district effect

4.1. Empirical model

To test the existence of a district effect on innovation (I-district effect) and model its determinants, we need to relate this effect with some model of innovation. The most common specification in the literature is the knowledge production function introduced by Griliches (1979) and implemented by Pakes and Griliches (1984)[9]. This function relates innovation to research and development (R&D) inputs. We modify the production function to also take into account other factors influencing innovative activity, such as in our case, external economies. Thus, the knowledge production function can be specified as:

$$I_j = \gamma R_j^{\beta} Z_j^{\delta} \varepsilon \qquad (1)$$

where I stands for a measure of knowledge creation (innovation) in a LPS j, R is a measure of R&D activities, Z is a vector that collects other variables affecting innovation (e.g. industrial district's external economies), ε is a nuisance, and γ, β and δ are parameters[10].

An important issue is if the district effect should be measured regarding the total number of innovations in a LPS or its relative intensity per capita. Most specifications of the empirical innovation function focus on the absolute number of innovations and after Jaffe (1989) it is usual to include a variable of scale (e.g. population) to take into account that the number of innovations is directly related to the size of the LPS. However, for the measurement of the district effect the relevant question is if there are significant differentials in innovative intensity between the industrial districts and the other LPS[11]. Thus, the output and the input factor are divided by the total number of employees in the LPS:

$$i_j = \gamma r_j^{\beta} Z_j^{\delta} \varepsilon \qquad (2)$$

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[9] Since this has been one of the approaches most used in the literature, we think that basing our research on this framework allows comparing the results and facilitates the discussion. The choice of the dependent variable (patents) was also related to comparability.

[10] Notice that if $\beta = 1$ the returns of R&D are constant to scale.

[11] This follows the line of other researches that uses relative indicators to the measurement of the district effect, e.g. productivity (Signorini, 1994) or efficiency (Hernández and Soler, 2003).

where i is the average innovation per worker and r is average R&D per worker in the LPS. The variables included in Z can also be normalized by size if necessary. Taking logarithms, we transform the production function in a simple log-linear expression:

$$\log i_j = \gamma + \beta \log r_j + \delta \log Z_j + \varepsilon_j \qquad (3)$$

We can also consider that the sources of innovation are related to idiosyncratic effects associated to each typology of LPS so that $\delta^* = f(Z_i)$, and following Hsiao et al. (2003) the equation can be specified as a fixed effects model:

$$\log i_j = \gamma + \beta \log r_j + \delta^* + \varepsilon_j \quad (4)$$

4.1. Dependent variable

The dependent variable is the innovative intensity (innovation per employee) in the local labour systems. The dependent variable is expressed in annual average per employee, using 2001 as base year for employment.

4.3. Explanatory variables

Explanatory variables use data of 2001 to reinforce causality and avoid simultaneity, and following the theoretical model are expressed in logarithms so that can be interpreted as elasticities. They are divided in three groups:

1. Inputs: R&D by LPS was assigned from regional data departing from regional R&D intensity per employee in each institutional sector (business sector, universities and public administrations) and multiplied by the jobs by institutional sector in each LPS. Since university R&D and jobs are concentrated in few local systems producing problems with the logarithms, the data were grouped in two categories: private and public R&D by LPS[12].

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[12] R&D and employment data proceed from INE. It is also possible to use hierarchical multilevel models to avoid the assignation although the hypothesis introduced on the data generates other restrictions. We

2. Marshallian industrial district economies, grouped in four categories:

2.1. Rate of specialization or non diversity of the LPS, computed as a Hirschman-Herfindahl index of diversity on employment at 2 digits inside the LLS. Higher values indicate higher specialization (less diversity) of the economic structure:

$$DIV_j = \sum_j \left(E_{ij} / E_j \right)^2 \quad (5)$$

2.2. Specialized pool of manufacturing workers: represented by the share of manufacturing employment in the LPS. We associate a larger average of manufacturing workers with more specialized skills in the local manufacturing productions.

2.3. Specialized suppliers in the LPS. Following the approach of Dumais et al. (2002) and Viladencas (2003), P_{ij} the presence of suppliers of sector i in the LPS j is:

$$P_{ij} = \sum_{i \neq z} \upsilon_{is} E_{zj} \text{ , where } \upsilon_{is} = v_{is} \Big/ \sum v_{is} \quad (6)$$

where υ_{is} is the share that sector i demands from the rest of sectors, and E_{zj} is the local employment in the sector. These shares are obtained from the Spanish Input-Output Tables (INE)[13]. The sum of these weighted sector employments are used to obtain a global indicator of suppliers' presence in each LPS:

$$S_j = \sum_i E_{ij} \Big/ \sum_i P_{ij} \qquad (7)$$

If S_j is larger than one implies that employment in supplying sectors in LPS j (E_{ij}) is larger than the weighted sum of employment in supplying sectors (P_{ij}) so that the

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control the results by using additional data on R&D&i grants and loans provided by the Ministry of Industry. This data covers CDTI and PROFIT databases.

[13] We assume that the same productive structure applies for all local productive systems. Although this is a strong assumption, no better information is available.

presence of suppliers is above the local requirements and indicates the existence of a powerful chain of suppliers.

2.4. Social organization of production, using as a proxy the social capital index developed by IVIE (Pérez et al., 2006). This index is only available by province and informs if the province has a level of social capital above, equal or lower the national average. We assign to a LPS the value of the province.

2.5. Average of SME in the LPS, to control which model of organization of production is related to differentials in the innovative intensity. In the Marshall-Becattini framework, the district effect should be related to SME:

$$SME_j = \sum E_{SME,j} \Big/ \sum E_j \qquad (8)$$

, where E_{SME} is the employment in SME.

3. Urbanization economies:

3.1. Total population in the LPS (from 2001 Census).

3.2. Spillovers index. This index is a variation of the density index by Carlino et al. (2007) substituting land by population (N) in the denominator, and interprets that more density of employment is related to denser work-related networks, which generates higher spillovers. The index can not differentiate between intra and inter-industry spillovers.

$$D_j = \sum E_j \Big/ \sum N_j \quad (9)$$

4.4. Econometric evidence on the I-district effect

To test the existence of the I-district effect we estimate the equations 3 and 4 as a panel of 806 local labour markets divided in seven typologies of LPS. The estimates were done in two stages: first, we test the existence of the I-district effect and its size and later we model its determinants.

We estimate the equation 4 introducing only R&D variables, which are the inputs in the model. After subtracting the effect of inputs, we can assume that the remaining differential is due to the characteristics associated to each type of productive system. Thus, we introduce a fixed effects estimation of the model. The seven fixed coefficients capture the different performance of each typology and informs if they are statistically different from the average of LPS. Since there are 206 LPS without innovations which logarithms can no be computed, there is some doubt about a possible selection bias in the sample. On one hand, it can be argued that LPS without innovations belongs to rural and very sparse populated areas and their inclusion could introduce more economic problems than statistical problems solve. This is reasonable since these 206 systems only have 3.5% of the Spanish employment and 67% of this employment belongs to Primary and Extractive LPS (41% of non-innovative LPS) (Table 2). On the other hand, if we suspect that any selection bias is introduced, we can treat the problem as a censured sample and introduce a Heckman estimate of the fixed-effects model[14]. Since both arguments are reasonable, we decided to provide the estimates for the LSP that innovate (600 LPS) and the estimates of the Heckman model (806 LPS)[15].

The results for input variables show that both private and public R&D are statistically significant. The coefficients range between 0.13 and 0.26 for private R&D and between 0.08 and 0.19 for public R&D (Table 3). The coefficients and statistical significance of the fixed effects provide robust evidence on the existence of an I-district effect that ranges between 0.44 and 0.48 in unitary deviations from the averaged group effect, and similar to the 47% deduced from Table 1. The Manufacturing LPS of Large Firms have a fixed effect between 0.05 and 0.10 although it is not statistically significant due that it is close to the average. The other manufacturing LPS also show a high fixed effect (0.43

[14] First, a Probit model is estimated trying to explain the existence of innovations in the LPS and obtaining the Mills ratio. In the second stage, the inverse of the Mills ratio is introduced in the regression. In most of regressions, the LR test did not reject the existence of sample selection.

[15] Additional controls on the functional form of the model and the relation between the dependent and explanatory variables were introduced. The log-linear specification without non-linearities proved to be the most suitable specification.

to 0.31). With the exception of the Large Metropolitan Areas (the coefficient is positive although not statistically different from the mean) all the other typologies show differential negative effects ranging from -0.18 for Other service LPS to -0.52 for Primary and Extractive activities. The F-test on fixed effects confirms that they are relevant in the estimates as a whole.

4.5. Modelling the determinants of the I-district effect

There are two possibilities to model the determinants of the fixed effects: we can directly model the fixed effects or we can introduce in the equation 4 the vector Z_i modelled as external economies so that:

$$\log i_j = \gamma + \beta \log r_j + \delta \log Z_j + \delta^* + \varepsilon_j \qquad (10)$$

Notice that if δ and δ^* are correlated, as in fact we assumed, the value of the coefficients and the statistical significance of δ^* will drop when we include Z_j.

We estimate the equation 9 introducing in a first step the determinants of the Marshallian economies and later the urbanization economies. The results introducing Marshallian economies (Table 4, estimates 2.1 to 2.3) show a reduction of the R&D coefficients (0.11 to 0.14 for private R&D and 0.12 to 0.17 for public R&D). The variables introduced are statistically significant, show large coefficients and the expected sign for the global rate of specialization (0.12 to 0.25), specialization in manufacturing (0.63 to 0.65), suppliers (0.29 to 0.33) and social capital (0.23 to 0.27). The percentage of employment in SME is negative and statistically significant although the coefficient is not very high (0.12 to 0.13). Given the very small average dimension of the Spanish firms, this can be interpreted as a correlation with a minimum dimension to innovate[16]. Regarding fixed effects, most of the coefficients reduce to get close to zero and become statistically non significant. The exception is Manufacturing LPS of Large Firms, where there is some evidence on the existence of any effect on their innovative performance that is not explained by Marshallian external economies.

[16] In fact, in industrial districts the average firm size is larger than in most of the other non manufacturing systems.

Next, we include urbanization variables (Table 4, estimates 2.4 to 2.6). Population's coefficient is small (-0.3 to 0.5), statistically non significant and negative except in the Heckman estimate, where the model detects that it is an important variable on the probability to have non-zero innovations[17]. Density of jobs on population has a large coefficient (0.43 to 0.77) and suggests the existence of general spillover processes related to the innovative performance. As was expected, this variable is correlated with social capital (which reduces its coefficient and losses statistical significance). Fixed effects do not suffer important variations although the persistence of the Manufacturing LPS of Large Firms coefficient informs that the unmodeled variable is not associated to urbanization economies.

4.6. Other related issues

We also test for the existence of other effects, mainly related to knowledge and creativity. However, no solid evidence is found between patent intensity and other knowledge variables as university graduates (Figure 4), knowledge-intensive manufacturing, knowledge-intensive services, ICT, creative class and percentage of employees in R&D sectors. In some cases, (e.g. tertiary graduates) the correlation is non significant or negative[18].

The existence of spatial autocorrelation between LPS was tested on the basis of a spatial contiguity matrix and simultaneous spatial lag and error effects. Although some

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[17] This is confirmed by the Probit estimates (annex 2).

[18] Significant positive correlation is detected only for districts specialized in Food and beverages and Textile and textile products. This result was already detected by Boix (2006b) who remarks the comparatively low levels of these variables in industrial districts and Manufacturing LPS of Large Firms, contrasting with their great performance regarding innovation indicators. This can be explained because in Spain more dynamic environments as industrial districts provide numerous job opportunities for young people so that the necessity of higher levels of education to get work is not perceived. This result should not be interpreted as a direct indicator of the impact of contextual knowledge on innovation although suggest the importance of contextual knowledge mechanisms (learning-by-doing, on-the-job training, etc.) to make up for the lower levels of standard-educated people. In Italy, Gola and Mori (2000) find a negative correlation between international trade and human capital intensity while Carlino et al. (2007) find a positive causality between human capital and patent intensity for the metropolitan areas of USA.

evidence on the existence of spatial simultaneous spillover processes is detected (the spatial lag is the dominant), its inclusion don't improve significantly the model[19].

Regarding the included variables and other non tested effects, the measurement of external economies in quantitative frameworks has proved to be hard difficult and depending on the availability of precise information. We try to focus on feasible proxies because the difficulty to find direct measures of variables as qualification (which in industrial districts partially comes from learning by doing processes and contextual knowledge), social capital or knowledge flows, particularly when the information for their elaboration needs to be territorially disaggregated. Regarding the variable used for the measurement of innovation, we refer to the discussion in the epigraph 3, although other two indicators also suggest the existence of the I-district effect (Figure 3). Additional indicators of innovation (e.g. trademarks) can be used although the treatment of databases and learning about the data requires considerable time.

5. Conclusions

The objective of the research is to explore the existence of higher rates of innovative intensity in the Spanish Marshallian industrial districts in the form of a "district effect" (I-district effect) as well as its causes. Given the importance of innovation for competitiveness and the arguments that presents industrial districts as a model of mature industries based on costs, the results we present, performed on the system of innovation of an entire country, can contribute to enlighten some points on this issue. The research introduces some peculiarities as the use of exhaustive databases and the division of the country in seven types of Local Production Systems so that the differential effects are compared not only with the national mean but also with Manufacturing LPS of Large Firms, Large Metropolitan Areas or Service's LPS. The most significant results are:

[19] When the data are pooled, the spatial lag (ρ=0.14) is statistically significant although does not improves the fit. When fixed effects and external economies are included, the lag reduces to ρ=0.08 and again the most parsimonious model is preferred. This weak evidence and the Figure 2 suggest that the impacts of inter-LPS spillovers could be locally important in the East and Nord-East of Spain where industrial districts and Large Firm LPS are concentrated.

1. There is robust evidence on the existence of an I-district effect. The Marshallian Industrial Districts generates 30% of Spanish patents and an innovative intensity (patents per employee) 47% above the national average and 31% larger than the Manufacturing LPS of Large Firms. The econometric estimates of a fixed effects model confirm the existence of a similar I-district effect set between 44% and 48% in deviations from the averaged group effect. The evidence on this effect maintains for previous periods and using other indicators as designs or loans for innovation.

2. The existence of the I-district effect is related to Marshallian economies as the specialization, the existence of a specialized pool of manufacturing workers, specialized suppliers and social capital. As a result of the very small firm dimension in the country, systems where the average firm dimension is less small tend to innovate slightly more. Urbanization economies have smaller impact on innovation and in the explanation of the I-district effect although an important impact of spillovers coming from dense work-related networks is detected. Regarding the variables related to the knowledge economy, only private and public R&D, introduced as an input in the model, results to be directly linked to innovation. No solid evidence is found with other knowledge variables as university graduates, knowledge-intensive industries or ICT.

3. The cores of the largest metropolitan areas specialized in services generate 35% of the Spanish innovations and a ratio of 288 innovations per employee, 25% above the national mean. The couple formed by Marshallian industrial districts and the core of the Large Metropolitan Areas are determinant for the innovative capacity of the country. These results suggest to strength the territorial scope of the innovation policies and to intensify the research on their determinants taking into account not only the characteristics of the firm but also the forms of innovation and the characteristics of the territory.

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Table 1. Distribution of innovation (patents) by Local Production System. 2001-2006

Type of LPS	Local production systems		Employment year 2001 (thousands)		Patents 2001-2006			LPS where patents per employee are above the national average		
	Nº	%	Total	%	Total	%	Per million employees /year	Total	% on typology	% on total LPS
Primary and extractive activities	333	41.3	1,994	12.2	1,048	4.7	88	41	12.3	5.1
Manufacturing	332	41.2	5,317	32.6	9,764	43.3	306	169	50.9	21.0
Industrial districts	205	25.4	3,419	20.9	6,908	30.6	337	117	57.1	14.5
LPS of Large Firms	66	8.2	1,776	10.9	2,728	12.1	256	30	45.5	3.7
Other manufacturing SPL	61	7.6	122	0.8	127	0.6	174	22	36.1	2.7
Construction	35	4.3	364	2.2	238	1.1	109	6	17.1	0.7
Services	106	13.2	8,654	53.0	11,502	51.0	222	28	26.4	3.5
Large metropolitan areas	4	0.5	4,567	28.0	7,901	35.0	288	3	75.0	0.4
Other services SPL	102	12.7	4,088	25.0	3,601	16.0	147	25	24.5	3.1
TOTAL	806	100	16,330	100	22,552	100.00	230	244	30.3	30.3

Source: Elaborated form Census 2001 (INE), OEPM, WIPO, USPTO and EPO.

Table 2. Local Production Systems without innovations (patents). 2001-2006

Type of LPS	Local production systems				Employment year 2001			
	Total	% on typology	% on non - innovative	% on total LPS	Total	% on typology	% on non - innovative	% on total LPS
Primary and extractive activities	132	39.6	64.1	16.3	379,657	19.0	67.2	2.3
Manufacturing	52	15.7	25.2	6.4	136,891	2.6	24.2	0.8
Industrial districts	20	9.8	9.7	2.5	72,982	2.1	12.9	0.4
LPS of Large Firms	8	12.1	3.9	1,0	21,627	1.2	3.8	0.1
Other manufacturing SPL	24	39.3	11.7	2.9	42,282	34.7	7.5	0.3
Construction	8	22.9	3.9	1,0	17,764	4.9	3.1	0.1
Services	14	13.2	6.8	1.7	31,009	0.4	5.5	0.2
Large metropolitan areas	0	0.0	0.0	0.0	0	0.0	0.0	0.0
Other services SPL	14	13.7	6.8	1.7	31,009	0.8	5.5	0.2
TOTAL	206	25.6	100.0	25.6	565,321	3.5	100.0	3.5

Source: Elaborated form Census 2001 (INE), OEPM, WIPO, USPTO and EPO.

Table 3. Basic model and I-district effect

	(1.1) OLS	(1.2) Fixed effects	(1.3) Heckman fixed effects
Constant	0.3461 ***	5.4645 *	5.1464 ***
	(0.000)	(0.095)	(0.000)
R&D firms	0.1304 ***	0.2362	0.2635 ***
	(0.000)	(0.040) **	(0.000)
R&D public	0.0881 **	0.1418	0.1902 ***
	(0.016)	(0.057) *	(0.001)
Fixed Effects			
Industrial districts		0.4441 ***	0.4840 ***
		(0.000)	(0.000)
Manufacturing LPS of Large Firms		0.0514	0.1039
		(0.640)	(0.344)
Other manufacturing LPS		0.4379 ***	0.3167 **
		(0.001)	(0.016)
Large metropolitan areas		0.0716	0.0994
		(0.833)	(0.768)
Other service sectors		-0.2404 **	-0.1829 *
		(0.016)	(0.068)
Construction		-0.3387 **	-0.2989 **
		(0.018)	(0.036)
Primary activities		-0.4259 ***	-0.5222 ***
		(0.000)	(0.000)
Fixed effects F-test		0.000 ***	0.000 ***
LR selection (lambda=0)	0.924	0.000 ***	0.000 ***
Condition number	6.08	6.08	7.45
R2-ajd / Pseudo R2	0.126	0.282	0.297
Log-L	-755.85	-692.70	-681.46
Akaike	1517.70	1403.39	1370.91
BIC	1530.89	1442.97	1388.50
Number of obs	600	600	806

Notes: (a) Dependent variable = Patents on employment in the period 2001-2006); (b) All variables are natural logarithms; (c) P-values are in parentheses and asterisks represent statistical significance at 1% (***), 5% (**) and 10% (*); (d) Within group effect model estimates; (e) Fixed effects provided under the restriction that $\sum \alpha_i = 0$, so that he dummy coefficients mean deviations from the averaged group effect (intercept); (f) Heckman adjusted coefficients; (g) Robust Huber-White estimators when slight problems of heteroskedasticiy, collinearity or outliers are detected.

Table 4. Modelling the determinants of the innovative intensity

	District economies			Urbanization economies		
	(2.1) OLS	(2.2) Fixed effects	(2.3) Heckman Fixed effects	(2.4) OLS	(2.5) Fixed effects	(2.6) Heckman Fixed effects
Constant	3.8702 ***	4.0174 ***	3.2688 ***	4.5534 ***	4.5179 ***	3.5021 ***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R&D firms	0.1166 ***	0.1415 ***	0.1484 ***	0.1033 **	0.1264 ***	0.1269 ***
	(0.003)	(0.000)	(0.000)	(0.008)	(0.002)	(0.005)
R&D public	0.1431 ***	0.1251 **	0.1777 ***	0.1479 **	0.1284 **	0.1197 **
	(0.003)	(0.015)	(0.001)	(0.010)	(0.027)	(0.056)
Specialization	0.2517 ***	0.2536 ***	0.1264	0.1798 *	0.1889 *	0.1181
	(0.006)	(0.007)	(0.195)	(0.080)	(0.071)	(0.248)
Specialization in manufacturing	0.6509 ***	0.6346 ***	0.6590 ***	0.6465 ***	0.6408 ***	0.6951 ***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Suppliers	0.3360 **	0.2941 **	0.2927 **	0.3174 **	0.2878 *	0.3459 **
	(0.016)	(0.045)	(0.045)	(0.024)	(0.055)	(0.014)
Social capital	0.2742 ***	0.2307 **	0.2481 ***	0.1633 *	0.1430	0.1402
	(0.000)	(0.003)	(0.001)	(0.083)	(0.130)	(0.128)
SMEs	-0.1213 **	-0.1394 ***	-0.1229 **	-0.1094 *	-0.1298 **	-0.1064 *
	(0.034)	(0.009)	(0.022)	(0.058)	(0.016)	(0.052)
Population				-0.0311	-0.0263	0.0563
				(0.314)	(0.452)	(0.147)
Density of jobs				0.5029 *	0.4320	0.7729 *
				(0.069)	(0.136)	(0.005)
Fixed Effects						
Industrial districts		0.0184	0.0557		-0.0007	0.0874
		(0.844)	(0.543)		(0.994)	(0.335)
Manufacturing LPS of Large Firms		-0.2540 **	-0.2085 *		-0.2650 **	-0.1975 *
		(0.023)	(0.056)		(0.018)	(0.063)
Other manufacturing LPS		0.1547	-0.0238		0.1244	0.1054
		(0.218)	(0.850)		(0.363)	(0.418)
Large metropolitan areas		0.2027	0.1671		0.2783	-0.2749
		(0.524)	(0.590)		(0.405)	(0.398)
Other service sectors		0.0660	0.1680		0.0486	0.1696 *
		(0.530)	(0.107)		(0.647)	(0.096)
Construction		-0.0867	0.0037		-0.0953	0.1296
		(0.539)	(0.979)		(0.502)	(0.347)
Primary activities		-0.1011	-0.1620 *		-0.0902	-0.0195
		(0.259)	(0.066)		(0.339)	(0.828)
Fixed effects F-test		0.0730 *	0.0195 **		0.112	0.074 *
LR selection (lambda=0)	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***
Condition number	26.40	26.40	30.72	50.90	50.90	60.00
R2-ajd / Pseudo R2	0..3774	0.3760	0.4219	0.381	0.376	0.437
Log-L	-654.03	-648.14	-631.76	-652.02	-646.74	-615.62
Akaike	1324.06	1312.28	1281.53	1324.04	1313.48	1265.24
BIC	1359.23	1347.46	1321.10	1368.01	1357.45	1339.99
Number of obs	600	600	806	600	600	806

Notes: (a) Dependent variable = Patents on employment in the period 2001-2006); (b) All variables are natural logarithms ; (c) P-values are in parentheses and asterisks represent statistical significance at 1% (***), 5% (**) and 10% (*); (d) Within group effect model estimates; (e) Fixed effects provided under the restriction that $\sum \alpha_i = 0$, so that he dummy coefficients mean deviations from the averaged group effect (intercept); (f) Heckman adjusted coefficients; (g) Robust Huber-White estimators when slight problems of heteroskedasticiy, collinearity or outliers are detected.

Figure 1. Typology of Local Production Systems in Spain

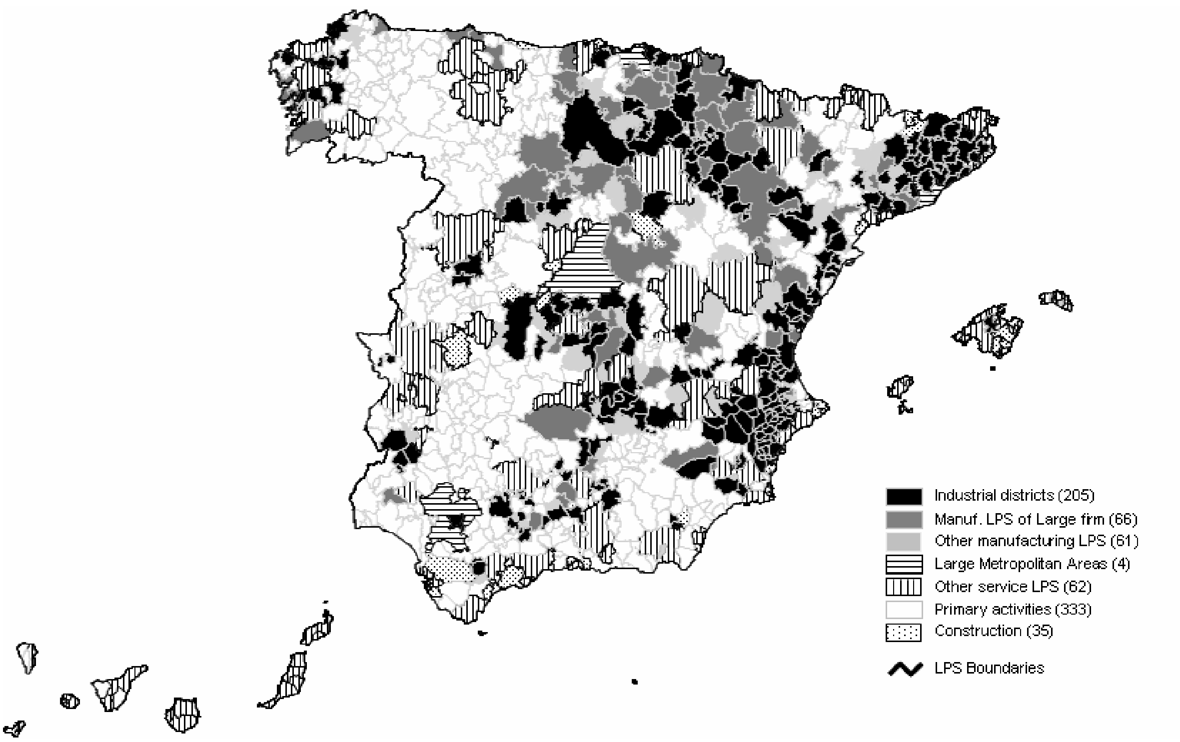
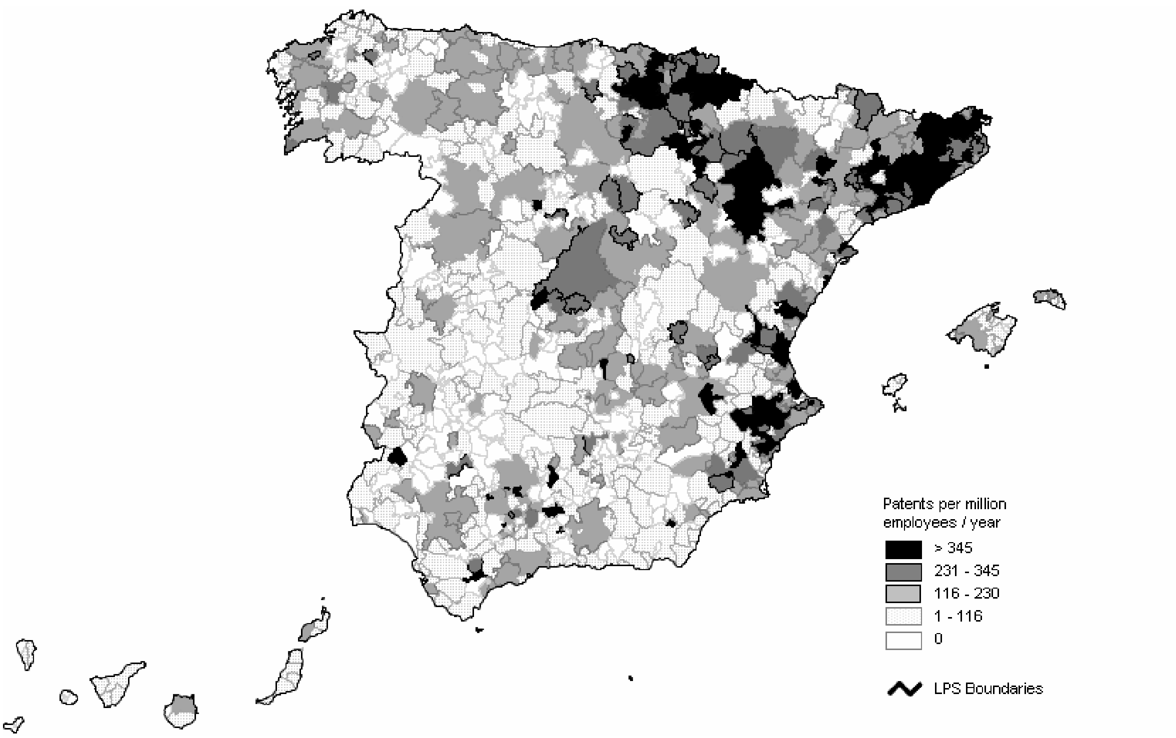
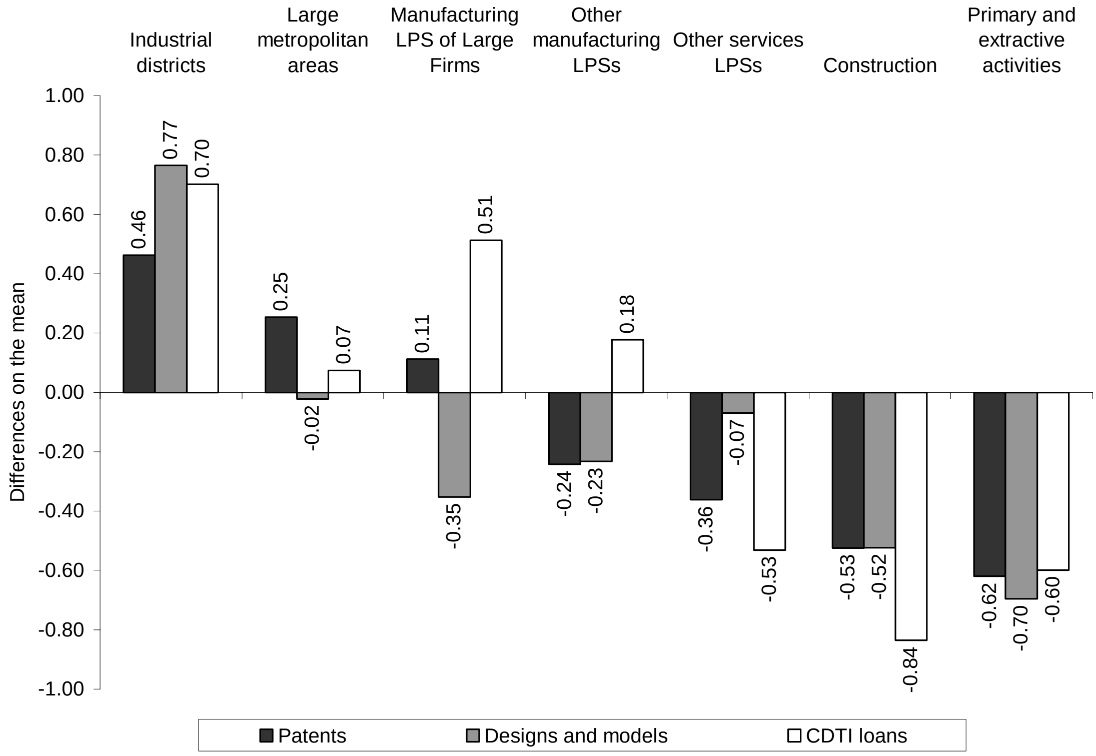


Figure 2. Patents per million employees. Annual average 2001 - 2006



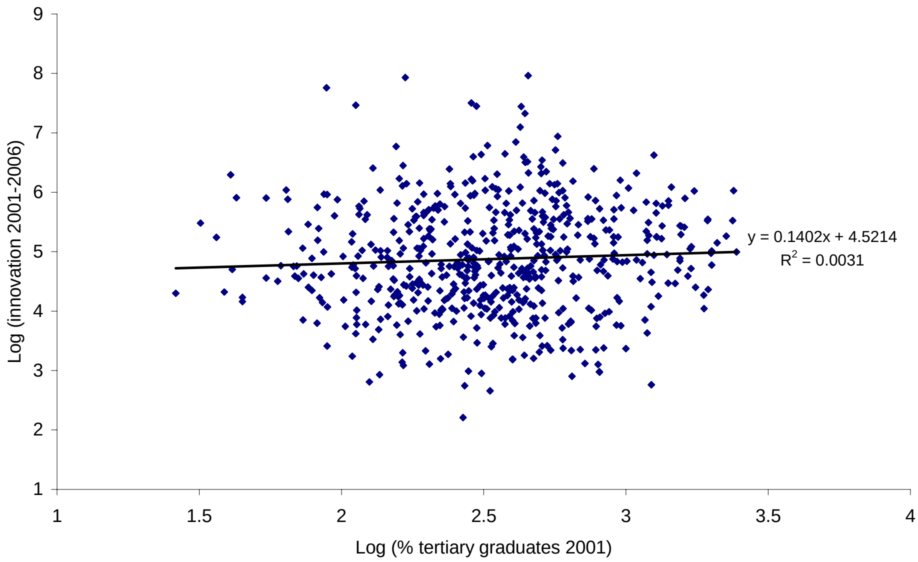
Source: Elaboration from OEPM, EPO, WIPO, USPTO and Census 2001 (INE).

Figure 3. Innovative performance by typology of LPS and indicator. Innovations per million employees a year in differences on the mean of each indicator. 2001-2006



Source: Elaboration from OEPM, EPO, WIPO, USPTO, CDTI and Census 2001 (INE).

Figure 4. Innovation versus human capital (% of university graduated employees on total employees)



Source: Elaboration from OEPM, EPO, WIPO, USPTO, CDTI and Census 2001 (INE).

Annex 1. Correlation matrix

	Patents/ million jobs	R&D firms	R&D public	Specialization	Specialization in manufact.	Suppliers	Social capital	SMEs	Population	Density of jobs
Patents/ million jobs	1,00									
R&D firms	0,34	1,00								
R&D public	0,16	0,22	1,00							
Specialization	-0,21	-0,34	-0,30	1,00						
Specialization in manufacturing	0,56	0,39	0,05	-0,36	1,00					
Suppliers	0,08	-0,09	0,17	-0,21	-0,09	1,00				
Social capital	0,41	0,43	0,21	-0,31	0,41	0,27	1,00			
SMEs	-0,18	-0,15	-0,02	0,15	-0,19	0,01	-0,13	1,00		
Population	-0,02	0,08	0,52	-0,46	-0,05	0,08	0,00	-0,01	1,00	
Density of jobs	0,32	0,36	0,29	-0,15	0,22	0,19	0,65	-0,14	0,14	1,00

Annex 2. Probit regression on the probability to innovate

Marginal effects	(A1)	(A2)
R&D firms	0.0393 **	0.0163
	(0.016)	(0.340)
R&D public	0.0597 **	0.0395
	(0.023)	(0.121)
Population	0.1802 ***	0.1756 ***
	(0.000)	(0.000)
Specialization in manufacturing	0.1184 ***	0.1020 ***
	(0.000)	(0.000)
Average firm size	-0.1435 **	-0.1659 ***
	(0.026)	(0.008)
Suppliers	0.1424 ***	0.0864 *
	(0.008)	(0.098)
Density of jobs		0.3726 ***
		(0.000)
Log pseudo-likelihood	-328.30	-317.37
Pseudo R2	0.283	0.307
% predict = 1	0.856	0.865
Number of obs	806	806

Notes: (a) Dependent variable = Patents on employment in the period 2001-2006); (b) All variables are natural logarithms; (c) Probabilities are in parentheses.