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Industrial districts, innovation and I-district effect: territory or industrial specialization?

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Abstract: The I-district effect hypothesis establishes the existence of highly intense innovation in Marshallian industrial districts due to the presence of external localization economies. However, industrial districts are characterized by specific manufacturing specializations in such a way that this effect could be due to these dominant specializations. The objective of this research is to test whether the effect is explained by the conditions of the territory or by the industrial specialization and to provide additional evidence of the existence and causes of the highly intense innovation in industrial districts (I-district effect). The estimates for Spain of a fixed effects model interacting territory and industry suggest that the high innovative performance of industrial districts is maintained across sectors whereas the industrial specialization behaves differently depending on the type of local production system in which it is placed. The I-district effect is related to the conditions of the territory more than to the industrial specialization. The territory is a key variable in explaining the processes of innovation and should be considered a basic dimension in the design of innovation and industrial policies.

Keywords: industrial districts, innovation, external economies, district effect

JEL: O14; O31; R12

1. Introduction

The Marshallian industrial district and its subsequent rediscovery and theorization by Italian scholars (Becattini 1991; Brusco 1975) has generated a huge amount of literature for or against its importance as an analytical category, as a central piece in the theories of local development, and as a break from the traditional economic paradigm since it proposes a new way of interpreting economic change at the very heart of the local society, where economic forces interact and evolve.

Several theories in economic literature pose obstacles to the acceptance of industrial districts as economically efficient entities. They include the initial criticisms to the existence of external economies (Sraffa 1926), the principle of asymmetry between small and large firms (Steindl 1945) or the dominance of large monopolistic firms as the best innovators (Schumpeter 1942). Recent criticisms has questioned the efficiency of industrial districts or argued that this efficiency is static and based on lower costs due to over-exploitation of hired labour, self-exploitation of small entrepreneurs and precarious living conditions, whereas the district is not innovative or creative enough to generate dynamic efficiency (Becattini and Musotti 2004; Capello 2007).

Most of these criticisms were overcome by the studies dealing with the "district effect", which proved the static efficiency of the industrial district regarding higher productivity and lower inefficiency (Signorini 1994; Fabianini et al. 2000), and dynamic efficiency in terms of competitiveness (Gola and Mori 2000; Bronzini 2000) or innovation (Brusco 1975), even if there were objections to the results regarding the use of particular case studies and truncated datasets (Staber 1997).

Boix and Galletto (2008a) provided additional evidence for the study of dynamic efficiency in industrial districts and local production systems (LPS) by centring their research on the “innovation district effect” (I-district effect). The I-district effect hypothesis establishes the existence of highly intense innovation in industrial districts due to Marshallian external localization economies. The authors proved that industrial districts were the most innovative local production systems (LPS) in Spain as they produce 31% of Spanish patents and have an innovative output per capita that is 47% above the national average.

Although in Boix and Galletto (2008a) a highly detailed patent database is used and the results are compared with other periods and indicators, the possibility of an “industry-effect” in addition to the territorial explanation is not taken into account. Since industrial districts are characterized by specific manufacturing specializations, is the I-district effect really related to the conditions of the territory or to the industrial specialization? The industrial district theory suggests the hypothesis that the I-district effect is related to the characteristics of the territory more than to the industrial specialization. Thus, the objective of this research is to test whether this effect is explained by the conditions of the territory or by the industrial specialization.

The research contributes additional evidence of the existence and causes of the highly intense innovation of industrial districts (I-district effect), and an empirical procedure to differentiate the territorial and industrial effects when both are correlated. Deep down and under the cover of the Marshallian industrial district paradigm, this research contributes empirical evidence of one of the most important topics in economics: the determinants of innovation, shifting it from the firm or the sector to the territory.

The paper is structured as follows. The second section introduces the theoretical framework relating to industrial districts, the district effect and innovation. The third section proposes the indicator for the measurement of innovation and the typology of

LPS and specializations. The fourth section presents the basic results by territory, specialization and their interaction. The fifth section introduces a modification of Griliches' empirical model in order to measure the I-district effect and the division of the territorial and sectoral effects, and the results of the econometric estimates. The sixth section presents the conclusions.

2. District effect and innovation

2.1. Industrial districts

The industrial district is "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 1990). The industrial district proposes a new approach to economic change departing from the fact that this can not be understood in isolation from the local, territorially embedded society, where economic forces work and evolve (Sforzi and Lorenzini 2002). Thus, the unit of analysis is transferred from the "firm" or the "sector" to the "local production system" and one of its expressions is the industrial district.

Industrial districts have been identified as a general phenomenon in industrialized countries such as Italy (ISTAT 2006), Spain (Boix and Galletto 2008b), Portugal (Cerejeira 2002), the United Kingdom (De Propris 2005), Germany (Schmitz 1994); Denmark (Illeris 1992), Russia (Levin 2006), Japan (Okamoto 1993), the United States (Scott 1992), and Mexico (Rabellotti and Schmitz 1999). Similar figures have been found in emerging countries like China (Fan and Scott 2003), Brazil (Rabellotti and Schmitz 1999) and India (Holmstrom and Cadene 1998).

The social organisation of production in specialized localities produces external localization economies (Marshall 1890), which depend on conditions that are external to the firm and internal to the place. These advantages lead to reductions in costs, continuous innovation and higher levels of technical efficiency producing the so-called "district effect", which explains the competitiveness of industrial districts.

2.2. The "district effect"

The term "district effect" was coined by Signorini (1994) to explain the higher rates of efficiency of firms located in 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".

Empirical research of the "district effect" has relied on several categories of indicators where the most suitable are productivity/efficiency, competitiveness/exports and innovation (Table 1)[1]:

1. The main line of research seeks to quantify the differential performance of industrial districts on productivity and efficiency and includes Signorini (1994), Fabianini et al. (2000), Soler (2000), Hernández and Soler (2003), Brasili and Ricci (2003), Cainelli and de Liso (2003), Becchetti et al. (2007) and Botelho and Hernández

[1] The difference is noted between the "district effect" (productivity/efficiency, competitiveness, innovation) and other "characteristics of districts" such as the degree of vertical integration, smaller size of establishments or a premium on wages. The existence of a financial premium on the rates of interest (lower rates) could represent an additional and separate family of district effects although it is not central to the presented arguments.

(2007). Results vary depending on the country, sector and type of measurement although in general they provide evidence of the district effect in the form of higher productivity and higher efficiency (lesser inefficiency).

2. The district effect on competitiveness is directly addressed in Costa and Viladecans (1999), Becchetti and Rossi (2000), Gola and Mori (2000) and Bronzini (2000). Aggregated results for manufacturing as a whole suggest the existence of a large positive district effect on the export ratio (70% to 228%), a positive but slower effect on the probability of being an exporter (5%) and the existence of revealed competitive advantages. Data disaggregated by sectors is not conclusive although it suggests the existence of a district effect in more than half of the sectors.

3. The existence of a district effect on innovation has been addressed by Santarelli (2004), Muscio (2006) and Boix and Galletto (2008a). The former uses a fixed effects model by firm to explain the determinants of the number of EPO patents of firms located in the Italian region of Emilia-Romagna, where the localization in an industrial district is introduced as a dummy variable. Results are inconclusive since for the first period considered in the analysis (1985-1990) the dummy coefficient was positive (0.82) and for the second period (1991-1995) was negative.

Muscio (2006) centres on the industrial districts identified by Garofoli (1989) in the Italian region of Lombardy. He uses firm data taken from the author's survey of eight manufacturing sectors and a probit estimation. Results suggest that location in industrial districts increases the probability of being innovative by 14%.

Boix and Galletto (2008a) use as unit of analysis 806 LPS divided into seven typologies identified by applying to Spain the Sforzi-ISTAT (2006) methodology. The I-district effect is contrasted using national and international patents per employee and LPS and a fixed effect model by typology of LPS. The results prove that industrial districts are the most innovative LPS with an innovative intensity that is 47% above the mean and the results are robust to other periods and indicators.

Although no research to date has simultaneously relied on the three indicators (productivity, competitiveness and innovation), the separate finding of large positive district effects on the three magnitudes suggests the existence of a "magic triangle" where high innovative capacity (I-district effect) generates higher levels of productivity, pushing competitiveness. Changes in markets and the search for new market niches stimulate new incremental and radical innovations in such a way that the triangle performs a loop[2].

2.3. Industrial districts and innovation

Moulaert and Sekia (2003) differentiate six typologies of territorial innovation models: industrial districts, their generalization as localized production systems, *milieux innovateurs*, clusters of innovation, regional innovation systems and learning regions. The literature on industrial districts highlights the way that the district model fosters the innovative ability of firms and helps promote a spiral process of generation and adoption of innovations producing the I-district effect:

1. Innovation is the "genetic ability" of industrial districts (Piore and Sable 1984; Bellandi 1996), a vital condition for confronting continuous and discontinuous change. From an evolutionary point of view, industrial districts are economic multicellular organisms embedded in a process of economic selection. Districts change their traits through innovation in an attempt to survive to the process of creative destruction.

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[2] Innovations affect static efficiency reducing costs but also dynamic efficiency since they allow for changes and improvements in products and their introduction into markets.

2. Several types of mechanisms lead to new knowledge and innovations (Bellandi 1992): R&D, learning-by-doing, learning-by-using, entrepreneurship and the a breaking up of the productive chain into many phases. R&D is carried out by a few firms and technological institutes although it does not constitute the main source of innovations[3]. The main amount of innovations seems to proceed from "spontaneous creativity" (Becattini 1991) or "decentralized creativity" (Bellandi 1992), this is, practical knowledge generated in learning-by-doing and learning-by-using mechanisms and involving a large number of actors. Another factor are spin-off mechanisms of entrepreneurship, where new ideas or conceptions of the production process lead to the creation of new firms or vice versa. Finally, due to the competitive atmosphere the breaking up of the productive chain into phases is more dynamic than in other enviroments and this fact fosters innovation.

3. Short physical, social and cognitive proximities between the district's agents make fast and efficient processes of diffusion and absorption of innovations possible. Alliances and direct cooperation between firms are not the usual ways of diffusing innovations. This takes place through (Becattini 1991; Bellandi 1992; Asheim 1994): (1) a social process where there is informal exchange of information in public spaces or domestic life between the workforce and, sometimes, the same entrepreneurs or managers; (2) inter-firm mobility of workers; (3) the chain of specialized suppliers by

[3] Bagella and Becchetti (2000) propose a theoretical model based on a game where proximity reduces the appropriability of knowledge, positively affects the imitative capacity of firms and fosters knowledge spillovers from firms with R&D expenditures to other firms in the neighbourhood. As a result, the expenditure on R&D of individual firms and aggregated R&D effort are lower in industrial districts although other forms of technological innovation take on the same role.

means of the needs of the final integrator; (4) the innovations of the phase suppliers; (5) imitation mechanisms.

4. Production of incremental and disruptive innovations. The main body is made up of incremental innovations due to small variations in processes, products, or gradual integration in new markets (Garofoli 1989, p.81). Furthermore, disruptive innovations emerge in some districts, providing important market advantages (Albors and Molina 2001).

Several models can partially explain the innovative performance of industrial districts and therefore the existence of the I-district effect: the cognitive spiral (Becattini 2001), the model of collective inventions (Allen 1983), the knowledge barter and the horizontal diffusion model (von Hippel 1998 and 2002), and the network models of innovation (Cowan 2004). However, there is no integrated theory of innovation for industrial districts which allows for a comprehensive explanation of the processes of generating and diffusing innovation in industrial districts, their impact on local development processes and the district effect on innovation.

Empirical research of the links between industrial districts and innovation has contributed important findings regarding these linkages. Brusco (1975) finds that small metal-mechanical engineering firms around Bergamo have similar levels of technology to similar large firms, which contradicts the theory that technological innovation originates exclusively from internal investment. Russo (1986) shows that the high rates of technical progress in the ceramic district of Sassuolo can not be explained by R&D activities performed in individual firms but rather by the links between the users and producers of machinery in the ceramic industry. Molina (2002) finds that knowledge spillovers are important for the innovative dynamic in the Spanish ceramic district of Castellón. Cainelli and De Liso (2003) find that the change in added value for innovative and non-innovative firms in industrial districts is higher than for firms outside districts. Muscio (2006) finds that 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 internal and external R&D activities. Departing from the observation of the high innovative performance of industrial districts regarding other types of LPS, Boix and Galletto (2008a) proposed the existence of the I-district effect and contrasted its relationship with external economies.

3. Measurement of innovation and typology of local production systems in Spain

3.1. Measurement of innovation

The measurement of innovation is a widely discussed topic in the literature and there is no agreement as to which indicator is the most appropriate (Grilches, 1990; Acs *et al.*, 1992). Innovation indicators are usually divided into "input indicators" (R&D expenditure or jobs) and "output indicators" (patents, new product announcements). The main inconvenience of the former is that they fail to take into account activities related to contextual knowledge, which are more important in smaller firms, underestimating their innovative capacity. On the other hand, patents and new product announcements represent the outcome of the innovation process. As long as granted patents imply novelty and utility, and also an economic expenditure for the applicant, it is supposed that patented innovation is of economic value (Griliches, 1990). Furthermore, patent documents contain such highly useful data as the applicant's address, name, date and technological classification. For these reasons patent indicators are the most widely employed indicators of innovation (Khan and Dernis, 2006). The use of patents as innovation indicators offers the additional advantage of being able to compare and discuss the results regarding the most extended empirical line.

In order to avoid yearly fluctuations and take into account the lags in the outcome of innovation processes, it is common practice to consider data about innovation over periods of 4-5 years (Griliches, 1992). As in Boix and Galletto (2008a), data for the 2001-2006 period (both inclusive) was used[4]. Patent data is not restricted to a single register as is the usual practice but instead covers several sources to produce more precise counts: Spanish Patent and Trademark Office (OEPM), European Patent Office (EPO), United States Patent and Trademark Office (USPTO) and World Intellectual Property Organization (WIPO), and covers applications with at least one applicant with an address in Spain per year of application[5]. The treatment of the data avoided double-counting (patents first applied for at the Spanish office and then extended by means of the European or World treaty, or vice-versa). The final database covers 22,500 documents for the whole 2001-2006 period.

3.2. Typology of local production systems in Spain and their specializations

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[4] The complete patent database includes 70,000 documents from 1991 to 2006. Patent counts include "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 Portugal. Employment data comes from the 2001 Census of the Spanish Institute of Statistics (INE).

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

Data on innovation was compiled by address so that any level of territorial aggregation is possible. The territorial units are the 806 local labour markets in Spain (Boix and Galletto, 2008a) identified using the Italian Sforzi - ISTAT (2006) methodology. The territorial typologies by LPS coincide with Boix and Galletto (2008a) whereas the identification of the dominant specialization comes from the third stage of the algorithm (Annex 1). Departing from this methodology, seven types of LPS and sixteen dominant specializations are identified:

1. Three types of manufacturing systems which cover 332 LPS: 205 Marshallian industrial districts specialized in manufacturing and basically composed of SME; 66 manufacturing LPS specialized in large firms; and 61 LPS obtained as a residual since they specialized in manufacturing although they are not classified as industrial districts or manufacturing LPS of large firms. Manufacturing LPS have nine specializations: Food and beverages; Textiles and textile products; Leather and footwear; Paper, publishing and printing; Chemistry and plastics; Products for the house; Machinery, electrical and optical equipment; Metal products; and Transport equipment.

2. Two types of service LPS which cover 106 LPS: 4 LPS belonging to the central labour markets of the largest Spanish metropolitan areas; and the other 102 LPS specialized in services. Service LPS are specialized in Business services; Traditional services; Consumer services; and Social services.

3. Two other categories including 333 LPS specialized in Agricultural and Extractive activities, and 35 LPS specialized in Construction.

4. The measurement of the territorial and specialization effects

4.1. Territorial effects

The results can be analyzed regarding three axes: territory, industry and a combination of both. Regarding the interpretation of the results by territory (Tables 2 and 3), Marshallian industrial districts and the core of the largest metropolitan areas are determinant for the innovative capacity of the country. Marshallian industrial districts (21% of national employment) generate 30.6% of Spanish innovations and a ratio of 337 innovations per employee, 47% above the national average, being the most innovative LPS in Spain. The four cores specialized in services of the largest metropolitan areas (28% of the employment) generate 35% of Spanish innovations and a ratio of 288 innovations per employee, which is 25% above the national mean (230 innovations per employee).

Manufacturing LPS of large firms (10.9% of employment) account for 12.1% of innovations. Their innovative intensity is 256 patents per million employees a year, which is 11% above the national average but 32% below the industrial districts.

The remaining LPS account for 22% of innovations generated in Spain and their innovative intensity is below the national average. Thus, the remaining manufacturing LPS account for only 0.6% of national innovations and their innovative intensity is 24% below the national average. Service LPS which do not pertain to the core of a metropolitan area have 16% of innovations and the innovative intensity is 36% below the national average. LPS specialized in Construction generate 1.1% of total innovations with an innovative intensity that is 53% below the national average. Despite accounting for 41% of total LPS, those 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. Furthermore, 64% of these LPS do not have any innovation

4.2. Specialization effects

The LPS specialized in services concentrate 51% of the innovations and 53% of the employment (Table 1). The metropolitan LPS specialized in Business Services (Madrid, Barcelona and Bilbao) have 33.5% of innovations and 25% of the employment. LPS specialized in Traditional Services have 10.5% of innovations and 17.5% of the employment. The remainder concentrates 6.9% of the innovations and 10% of the employment. Only the three metropolitan LPS specialized in Business Services (304 patents per million employees) have an innovative intensity larger than the Spanish average (230 patents per million employees) (Table 2).

The LPS specialized in manufacturing concentrates 43.3% of innovations and 32.6% of the employment (Table 1). The most important concentrations of innovations regarding the total Spanish innovations are in Products for the house (10.3%), Textiles and textile products (8.1%) and Transport equipment (7.4%). Other important concentrations can be found in Food and Beverages (4.6%), Machinery, electrical and optical equipment (4.8%), and Chemistry and plastics (4%). Manufacturing specializations have a rate of patents per employee above the mean (except for Metal products and Food and beverages), where the most significant cases are Machinery, electrical and optical equipment (376 innovations per million employees), Textile and textile products (360), Chemistry and plastics (348), Leather and footwear (343), and Products for the house (331) (Table 2).

Thus, despite the large amount of innovations concentrated in service LPS, the higher rates of per capita innovation are mainly related to manufacturing specialization and to the business service LPS.

4.3. Breaking down simultaneously by territory and industry

By simultaneously separating the effects by territory-industry, it is found that in most cases it is the territory and not the specialization which explains the innovative intensity. Centring on manufacturing, where the typology makes in-depth analysis possible, this causality is clearly evident in half the cases.

In Food and beverages, industrial districts have 263 innovations per million employees while the other manufacturing LPS are below 130; as a result, the total performance of the sector is above the total mean for Spain. In Chemistry and plastics the innovative intensity of industrial districts (454 innovations per million employees) is four times larger than the manufacturing LPS of large firms (105). In Products for the house and in Textiles and textile products, the innovative intensity of industrial districts (341 and 372 respectively) is also twice that of the other LPS. In other cases, like Leather and footwear, the territorial and industrial typologies are indivisible, due to the fact that 23 of the 25 LPS are industrial districts.

Manufacturing LPS of large firms show a clear superiority in Transport equipment (281 innovations per million employees versus 126 in the industrial districts), and better results in Machinery, electrical and optical equipment (399 versus 341), as well as in Metal products (177 versus 112).

Thus, the breaking down of the effects interacting industry and territory suggest that there is a strong correlation between the type of LPS and their dominant specialization[6]. However, when there are several types of LPS specialized in the same

[6] This was indeed expected because the procedure to divide the LPS by typology is based on the characteristics of the industry in the territory.

industry, the territorial dimension usually overcomes the sectorial one and strong evidence about the I-district effect arises in six of nine manufacturing specializations.

5. Parametric modelling of the I-district effect

5.1. The model

To test the existence of a district effect on innovation (I-district effect) and model its determinants, Boix and Galletto (2008a) depart from the knowledge production function introduced by Griliches (1979) and implemented by Pakes and Griliches (1984). Their enhanced function relates innovation to R&D inputs and to idiosyncratic effects associated to each typology of LPS so that the equation is specified as a fixed effects model:

$$\log i_j = \gamma + \beta \log r_j + \delta^* + \varepsilon_j \quad (1)$$

, where *i* is the average innovation per worker, *r* is average R&D per worker in the LPS *j*, and δ^* are the fixed effects by typology of LPS. After subtracting the effect of inputs, the remaining differential is due to the characteristics associated to each type of production system. The seven fixed coefficients capture the different performances of each typology of LPS and inform whether they are statistically significant[7].

[7] In a posterior step Boix and Galletto (2008a) relate the fixed effects to the existence of external economies: $\delta^* = f(Z_j)$.

Two modifications to this model are proposed. First, if it is assumed that the innovation effect is caused by the dominant specialization of the LPS and not by their territorial typology, the territorial fixed effect δ^* should be replaced by the specialization-industry effect λ^*:

$$\log i_j = \gamma + \beta \log r_j + \lambda^* + \varepsilon_j \quad (2)$$

Second, to contrast the hypothesis of dominance of the territorial effect, it is necessary to separate the territorial typology and the specialization of each LPS. The estimation of a two-way fixed effect model including δ^* and λ^* is not a good strategy because territorial typology and specialization are correlated. A better approach is to introduce a combined fixed effect $\delta\lambda$ so that for each specialization it is possible to compare the performance of the different territorial typologies or vice versa:

$$\log i_j = \gamma + \beta \log r_j + \delta\lambda^* + \varepsilon_j \quad (3)$$

5.2. Variables

The dependent variable is the innovative intensity (innovation per employee) in LPS, expressed as the annual average of patents per employee between 2001 and 2006 and using 2001 as the base year for employment. 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 LPS, which cause problems with the logarithms, the data was grouped into two categories: private and public R&D. Since there are 206 LPS without innovations for which logarithms can not be computed, the problem is treated as a censured sample by means of a Heckman estimate of the fixed-effects model.

5.3. Results of the fixed effects by territory

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 4). The coefficients and statistical significance of the fixed effects (Table 5) provide robust evidence of 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. The other manufacturing LPS also show a high fixed effect (0.43 to 0.31). With the exception of the large metropolitan areas (the coefficient is positive although not statistically significant) all the other typologies show negative differential effects ranging from -0.18 for Other service LPS to -0.52 for Primary and Extractive activities.

5.4. Results of the fixed effects by specialization

R&D coefficients are statistically significant and range between 0.13 and 0.28 for business R&D and between 0.08 and 0.24 for public R&D (Table 4). They are similar to those obtained with the fixed effects model by typology of LPS.

Fixed effects by dominant specialization are positive and statistically significant for five of the nine manufacturing specializations (Table 5): Machinery et al. (0.69), Leather and Footwear (0.68), Products for the house (0.49), Textiles and textile products (0.44), and Food and beverages (0.17). For the remaining manufacturing sectors the coefficients of the fixed effects are small and statistically non significant. In services, only Social services have a statistically significant fixed effect, which is negative (-0.30). Construction (-0.51), Agriculture and Fishing (-1.15) and Extractives (-0.29) have negative and statistically significant coefficients.

The explanatory capacity of both models is similar regarding the adjusted R2: 0.28 to 0.29 for the territorial model and 0.29 to 0.32 for the specialization model. Since the specialization model has more parameters, Akaike and BIC criteria slightly prefer the territorial model although the differences are not conclusive.

5.5. Results of the combined fixed effects by territory- specialization

R&D coefficients are statistically significant and range between 0.13 and 0.27 for business and between 0.08 and 0.24 for public R&D (Table 4). They are similar to those obtained with the other models.

For the detailed interpretation of the fixed effects, a table of results is proposed where the combined effects are in the central part, and the separated territorial and specialization effects are in the margins (Table 5).

Regarding manufacturing sectors, the coefficient is positive and economic and statistically significant for the industrial districts in Textiles and textile products (0.37), Products for the house (0.41) and Leather and footwear (0.69). In the latter, the territorial typology and specialization are basically the same because only two specialized LPS are not industrial districts.

In Chemistry and plastic, the opposite performance is observed between the specialized LPS which are industrial districts (0.47) and those of large firms (-0.68), in both cases statistically significant. Since the two effects cancel each other out, this explains why the aggregated fixed effect by specialization is close to zero and statistically non significant. The performance favourable to the industrial districts can be also observed in Food and beverages (0.19), and in Paper, publishing and printing (0.62), although in these cases the coefficients are statistically non significant.

On the other hand, in Machinery the averaged fixed effect is positive and statistically significant for all the manufacturing LPS and the strongest and most robust effect belongs to the manufacturing LPS of large firms (0.69). In this case, it is possible to conclude that there is more of a specialization than a territorial effect.

Analysing the coefficients by column (territory), for the industrial district column six of the nine possible specializations are positive and statistically significant and the other two are positive although statistically non significant (Table 5). For manufacturing LPS of large firms, no robust evidence of a significant aggregated innovative effect was found: the signs are indistinctly positive or negative and only two effects are statistically significant although with opposite signs: Machinery et al. (0.69) and Chemistry and plastics (-0.68). The other manufacturing LPS also show conflicting signs depending on the specialization although the aggregated territorial effect is positive and statistically significant.

Regarding services, the evidence again suggests that the territorial dimension is the one that explains the negative and statistically significant (or non significant) coefficients more than the type of services in which the LPS are specialized. For the other categories (Construction and Primary activities), no distinction is possible.

Thus, the interactive fixed effects specialization-territory supports the evidence that, although both are correlated, the territorial effect (typology of LPS) prevails over the industrial specialization.

5.5. Robustness and other issues

The basic results by territory are robust to different time periods and indicators. In the previous periods, 1991-1995 and 1996-2001, the innovative intensity of industrial districts was 33% and 35% above the national average. Regarding the sensitivity of the indicator of innovation (patents), the results are maintained with another two indicators that are available on a microdata level covering the same period: (1) industrial designs and models from the databases of the Spanish Patent and Trademark Office (OEPM), which is another indicator of output innovation; (2) and grants and loans provided by the Centre for the Development of Industrial Technology (CDTI), which can be interpreted as an input indicator (demand for public loans to innovate). Industrial districts show in the three cases the most important differential effect in relation to the Spanish average, clearly above that of 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.

Following Boix and Galletto (2008a), the models were re-estimated including the external economies in the function of production of innovations. In this case, and as was expected, all the fixed effects were statistically non significant except two effects for Machinery et al. and Chemistry in the manufacturing LPS of large firms.

Additional controls of the functional form of the model and the relationship between the dependent and explanatory variables were introduced, although the log-linear specification without quadratic or interactive terms proved to be the most suitable specification. Spatial correlation in the form of lag and error models on the basis of a matrix of contiguity was considered although no robust evidence of these effects was found.

6. Conclusions

The I-district effect hypothesis establishes the existence of highly intense innovation in the Marshallian industrial districts due to the presence of external localization economies. However, industrial districts are characterized by specific manufacturing specializations in such a way that this effect could be due to these dominant specializations. The objective of this research was to test whether the effect is explained by the conditions of the territory or by the industrial specialization and to provide additional evidence of the existence and causes of the highly intense innovation in industrial districts (I-district effect). The most relevant conclusions are:

1. The I-district effect is related to the conditions of the territory more than to the industrial specialization. The estimates for Spain of a fixed effects model interacting territory and industry prove that the innovative performance of industrial districts is maintained across sectors whereas the industrial specialization behaves differently depending on the type of local production system in which it is placed.

2. The territory is a key variable in explaining the processes of innovation and should be considered a basic dimension in the design of innovation and competitiveness policies. In most cases, innovation policies centred on the sector might be not be appropriate because the heterogeneous response of the different territorial profiles could cancel their effects.

3. In the same way, horizontal policies focusing on the districts as homogeneous entities could be misleading since different types of districts produce different innovative responses.

4. Different responses suggest the provision of an adaptive framework where each LPS, departing from its particular characteristics, proposes its strategies or makes a differentiated use of the available resources. An example of flexible strategy is the policy on "Innovative Business Groups" (MITYC Order ITC/2691/2006 and Order ITC February 2007) issued by the Spanish Ministry of Industry on the basis of EU recommendations (COM 2005-121; COM 2005-488) and which takes this approach. This policy reconciles bottom-up oriented industrial policy with innovation and territory by departing from a comprehensive label which collects industrial districts, territorial clusters and other types of territorial industrial business networks.

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Annex 1. Typology of local production systems and identification of the dominant specialization

The procedure to divide the LPS by typology is based on the Sforzi-Istat (2006) procedure for the identification of industrial districts and uses the different filters and information on each stage to assign each LPS to a typology:

1. Identification of LPS specialized in manufacturing: on the basis of their ISIC/NACE codes, the productive activities are grouped into Agricultural activities; Extractive industry; Construction; Manufacturing; Business services; Consumer services; Social services; and Traditional services. These groups serve to calculate a location quotient and a prevalence index (location quotient in absolute value) for each local labour market. The Istat (2006) procedure considers an LPS to be specialized in manufacturing when it presents a location quotient larger than 1 (above the national mean) for Manufacturing activities, Business services or Consumer services, and the prevalence index for Manufacturing is larger than those for Business services or Consumer services. If the LPS is not specialized in manufacturing, it is assigned to the group in which it maximizes its LQ.

2. Classification of manufacturing LPS into industrial districts, large firms LPS and others:

a) If the LPS is specialized in manufacturing, it is tested whether it is specialized in small and medium enterprises or in large firms. A location quotient is computed by firm size, adopting the three intervals used by the EU (small firms with up to 49 employees, medium firms with between 50 and 249 employees, and large firms with above 250 employees). A local labour market is specialized in SME when the maximum value of the location quotient corresponds to small or medium enterprises, and is otherwise specialized in large firms.

b) Identification of the dominant industry. As in the Sforzi-Istat algorithm (2006), manufacturing activities are divided into 11 groups: Textiles and textile products; Leather and footwear; Products for the house; Jewellery, musical instruments and toys; Food and beverages; Machinery, electrical and optical equipment; Manufacture of basic metals and fabricated metal products; Chemicals and plastics; Transport equipment; and Paper, publishing and printing. Location and prevalence quotients are computed for each manufacturing group in each local labour market. The dominant industry corresponds to that industry with a location quotient above 1 and the largest value in the prevalence index.

c) Firm size of the dominant industry. The dominant industry is mainly composed of SME when the employment in SME in the dominant industry is larger than 50% of the employment of the industry in the local labour market. The case of only one medium firm in the local dominant industry when this firm shares more employment than the remaining small firms is considered an exception to the criteria. Otherwise, an LPS is considered to be composed of large firms.

d) Departing from the previous quotients, a manufacturing LPS is considered to be an industrial district if it is specialized overall in small or medium enterprises, its dominant industry is mainly composed of SME and its dominant industry has at least 250 employees in the LPS (similar to a large firm) (Boix and Galletto 2008b). A manufacturing LPS is considered to be a manufacturing LPS composed of large firms if it is specialized in large firms and its dominant industry is mainly composed of large firms. The remaining manufacturing LPS are assigned to a residual category.

3. Due to the special features of the centres in largest metropolitan agglomerations, service LPS are divided into metropolitan and non metropolitan. Metropolitan LPS are considered the centres of the largest metropolitan areas that are specialized in services: Madrid, Barcelona, Seville and Bilbao. The metropolitan area of Valencia (the third largest area of the country) is specialized in manufacturing and is included in the industrial districts group.

The procedure generates a basic division into seven territorial categories and sixteen dominant specializations:

- Agricultural, Extractive and Construction LPS, where the three are monospecialized.

- Manufacturing LPS, divided into industrial districts, manufacturing LPS of large firms and the rest. They can be specialized in Textiles and textile products; Leather and footwear; Products for the house; Jewellery, musical instruments and toys; Food and beverages; Machinery, electrical and optical equipment; Manufacture of basic metals and fabricated metal products; Chemicals and plastics; Transport equipment; Paper, publishing and printing.

- Services LPS, divided into metropolitan and non metropolitan. These can be specialized in Business services; Consumer services; Social services; and Traditional services.

Table 1. The measurement of the district effect in quantitative research

Research	District effect (differential above the mean)
Productivity/Efficiency	
Signorini (1994)	- Productivity (added value/worker): 29% - Operating profits and financial effects
Camisón and Molina (1998)	- Return on investment: 200% - Financial returns: 850% - Return on sales: 300% - Growth of payoffs: 191%
Fabianini et al. (2000)	- Profitability: return on investment (17%) and return of Equity (60%) - Productivity (added value/worker): 1% - Financial effects: leverage (5%) and cost of debt (2.4%) - For 8 of 13 industries, being located in an ID significantly improves firm efficiency → median -2.01
Soler (2000)	Benefits/active: above the mean in the 4 sectors considered Productivity (added value/worker): above the mean in 3 sectors (doubtful in furniture)
Hernández and Soler (2003)	Efficiency - Furniture: -0.20 (statistically non significant) - Ceramic tiles: 71%
Brasili and Ricci (2003)	- ROI: between -37% and 28% - ROE: between 31% and 280% - Productivity: between -13% and 53% - Technical efficiency: between -14% and 37%
Cainelli and De Liso (2003)	Change in value added in simple ratios: non-innovative firms (42%) and innovative firms (35%) Change in value added in econometric regressions (innovative and non-innovative firms): 16%
Becchetti et al. (2007)	- Exports per worker: 79% - Value added per worker: 37% - Leverage: 119% - Return on investment: -36% - Return on equity: - 162% - Return on assets: 253%
Botelho and Hernández (2007)	- Benefits per establishment: 137% - Productivity (added value/worker): 108% - Efficiency: 28%
Competitiveness/Exports	
Costa and Viladecans (1999)	Competitiveness (exports/sales): - Positive differential to specialized LPS in 12 out of 21 industries→ median: 75% - Negative in 9 industries→ median: -58%
Becchetti and Rossi (2000)	Competitiveness: - Probability of being an exporter: 5% - Export intensity (export/sales): between 179% and 228%
Bronzini (2000)	Competitiveness (exports/jobs): 70% of aggregated manufacturing. and statistically significant in 11 out of 17 manufacturing industries
Gola and Mori (2000)	Revealed competitive advantages (X/X+M): $\beta = 0.0034$ and statistically significant
Innovation	
Santarelli (2004)	Number of patents by firm: - 1986-1990: 82% - 1990-1995: - 52%
Muscio (2006)	Product innovation → probability of being an innovative firm: 14.4%
Boix and Galletto (2008)	Innovation (patents per employee): 47%

Table 2. Distribution of innovation (patents) by local production system typology and specialization. 2001-2006

	Industrial districts	Manufacturing LPS of Large firms	Other manufacturing LPS	Large metropolitan areas	Other service sectors	Construction	Primary activities	Total
Food and beverages	**3,98%**	0,53%	0,11%					4,62%
Transport equipment	0,47%	**6,94%**	0,01%					7,42%
Machinery, electrical and optical equipment	1,88%	**2,86%**	0,07%					4,81%
Metal products	0,02%	**0,98%**	0,00%					1,00%
Chemistry and plastics	**3,61%**	0,36%	0,01%					3,98%
Paper, publishing and printing	**0,11%**	0,06%	0,07%					0,24%
Leather and footwear	**2,72%**	0,01%	0,01%					2,74%
Products for the house	**9,97%**	0,19%	0,17%					10,33%
Textile and textile products	**7,88%**	0,16%	0,12%					8,16%
Business services				33,52%				33,52%
Social services					2,74%			2,74%
Consumer services					4,16%			4,16%
Traditional services				1,51%	9,07%			10,58%
Construction						1,06%		1,06%
Agriculture and fishing							4,38%	4,38%
Extractives							0,26%	0,26%
Total	30,63%	12,10%	0,57%	35,03%	15,97%	1,06%	4,65%	100,00%

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

Table 3. Innovation intensity by local production system typology and specialization. 2001-2006

	Industrial districts	Manufacturing LPS of Large firms	Other manufacturing LPS	Large metropolitan areas	Other service sectors	Construction	Primary activities	Total
Food and beverages	**263**	123	129					228
Transport equipment	126	**281**	**233**					**261**
Machinery, electrical and optical equipment	**341**	**399**	**592**					**376**
Metal products	112	177	0					175
Chemistry and plastics	**454**	105	**299**					**348**
Paper, publishing and printing	**258**	211	**232**					**238**
Leather and footwear	**351**	57	66					**343**
Products for the house	**341**	189	174					**331**
Textile and textile products	**372**	**234**	151					**360**
Business services				**304**				**304**
Social services					133			133
Consumer services					179			179
Traditional services				133	140			139
Construction						109		109
Agriculture and fishing							87	87
Extractives							103	103
Total	**337**	**256**	174	**288**	147	109	88	**230**

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

Table 4. Estimates of the input coefficients in the I-district fixed effects.

	(1.1)	(1.2)	(1.3)
Constant	5.1464 ***	5.5055 ***	5.5861 ***
	(0.000)	0.000	0.0000
R&D firms	0.2635 ***	0.2825 ***	0.2751 ***
	(0.000)	0.000	0.0000
R&D public	0.1902 ***	0.2441 ***	0.2485 ***
	(0.001)	0.000	0.0000
Fixed effects	Territory	Industry	Territory and Industry
Fixed effects F-test	0.000 ***	0.0000 ***	0.000 ***
LR selection (lambda=0)	0.000 ***	0.0001 ***	0.0002 ***
R2-ajd / Pseudo R2	0.297	0.3225	0.3283
Log-L	-681.46	-670.24	-658.20
Akaike	1370.91	1378.473	1390.40
BIC	1388.50	1462.015	1553.08
Number of obs	806	806	806

Notes: (a) Dependent variable = Patents per employee in the 2001-2006 period; (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 the dummy coefficients mean deviations from the averaged group effect (intercept); (f) Heckman two stages coefficients adjusted for sample selection; (g) Robust Huber-White estimators when slight problems of heteroskedasticiy, collinearity or outliers are detected.

Table 5. The breakdown of the I-district effect. Interaction fixed effects by typology and specialization of the LPS compared with the non disaggregated fixed effects

	Industrial districts	Manufact. LPS of large firms	Other Manufact. LPS	Large metropolitan areas	Other service sectors	Construction	Primary activities	Fixed Effects by industry
Food and beverages	0,1991	-0,1425	-0,0304					0.1781
	(0,170)	(0,495)	(0,906)					(0.100)
Transport equipment	-0,4254	-0,0199	0,1622					-0.0853
	(0,114)	(0,935)	(0,824)					(0.617)
Machinery, electrical and optical equipment	**0,4859 *****	**0,6957 *****	**0,7470 ***					**0.6923*****
	(0,021)	(0,002)	(0,082)					(0.000)
Metal products	0,1764	-0,1179						0.0139
	(0,810)	(0,680)						(0.957)
Chemistry and plastics	**0,4720 ***	**-0,6880 *****	0,2783					0.0400
	(0,065)	(0,010)	(0,704)					(0.819)
Paper, publishing and printing	0,6232	-0,3297	-0,2322					-0.0271
	(0,396)	(0,527)	(0,586)					(0.926)
Leather and footwear	**0,6908 *****	-0,8573	-0,4082					**0.6877*****
	(0,000)	(0,241)	(0,580)					(0.000)
Products for the house	**0,4154 *****	0,6252	0,2783					**0.4988*****
	(0,001)	(0,231)	(0,209)					(0.000)
Textile and textile products	**0,3768 *****	0,1249	0,2084					**0.4463*****
	(0,005)	(0,810)	(0,496)					(0.000)
Business services				-0,0625				0.0283
				(0,886)				(0.946)
Traditional services				-0,1480	**-0,4210 *****			-0.1420
				(0,840)	(0,006)			(0.270)
Consumer services					**-0,2477 ***			-0.0556
					(0,082)			(0.771)
Social services					-0,1541			**-0.3094*****
					(0,451)			(0.024)
Construction						**-0,4022 ****		**-0.5153*****
						(0,012)		(0.000)
Agriculture and fishing							**-0,6229 *****	**-1.1510*****
							(0,000)	(0.000)
Extractives							**-1,2498 *****	**-0.2997****
							(0,000)	(0.041)
Fixed effects by LPS	**0.4840 *****	0.1039	**0.3167 ****	0,0994	**-0.1829 ***	**-0.2989 ****	**-0.5222 *****	
	(0.000)	(0.344)	(0.016)	(0.768)	(0.068)	(0.036)	(0.000)	

Notes: (a) Dependent variable = Patents per employee in the 2001-2006 period; (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 the 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; (h) In the combined interaction estimation, Other manufacturing LPS specialized in Metal products has been aggregated to Machinery because it caused problems in the restrictions for obtaining the fixed effects.