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Industrial Location Patterns In Catalonia: Industrial Mix And Human Capital

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**INDUSTRIAL LOCATION PATTERNS IN CATALONIA:
INDUSTRIAL MIX AND HUMAN CAPITAL**

ABSTRACT

The aim of this paper is to study location patterns in Catalonia in recent years (from 1986 to 1996). Particular attention is paid to the importance of the skill level of human capital in the different sectors.

The most important aspect of this work is that it uses local data so as to better portray phenomena such as agglomeration economies (normally studied at a regional or national level). The results show that the characteristics of each region have an important influence on the location decisions of industrial establishments (which are different in each of the sectors considered).

Key words: industrial location, cities, and human capital

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INTRODUCTION

The relationship between industry and cities is similar to the relationship between firms and inputs:¹ that is to say, cities are a form of input. Therefore, one way of approaching the economic results of firms is to consider both the tangible and intangible assets that are provided by the urban environment. This means that the competitiveness of a firm can depend on the characteristics of the territory in which it operates.²

This argument implies that territories influence the economic activities that occur within them and, as a result, these activities have specific characteristics (intensity of land use, use of energetic inputs, human capital requirements, distance from dynamic urban centres, etc.) which require a specific environment because different territories provide different inputs (in other words, the resources available in a big city are not the same as in a smaller one). This, however, is a static approach and, nowadays, location is regarded as being a dynamic process. Duranton & Puga (2000) argue that it is more important to study how innovative firms can relocate in space (dynamic perspective) than study location patterns (static perspective). In this way, efficiency can be improved by determining the advantages of the territorial inputs which will depend on the product cycle.

All this firm-city circular causality takes place at a local level which means that it can be explained better by local data and not by regional or national data. We believe that a group of economic interactions can be studied with greater precision in small territorial units and not large ones. Because of the scarcity of other studies on a local level, this paper aims to identify territorial patterns that act on industrial location from a local point of view. It is divided into four sections. The first section describes the previous work done by other researchers; the second section presents the data and the model used; the third section shows the main results and, the final section provides a brief conclusion which is followed by two methodological appendices.

REVIEW OF PREVIOUS WORKS

In recent years there has been a widespread belief that, in the more advanced countries, industrial production has developed to a greater extent in peripheral smaller cities than in central areas (Chapman & Walker, 1991; Delisle & Lainé, 1998; Scott, 1982). Industrial relocations can be easily observed in the city of Barcelona where, for several years now, industrial activity has been leaving the centre because firms prefer to relocate in places with a greater availability of land which is cheaper to rent. There were 304,209 industrial workers in Barcelona in 1964 and only 134,541 in 1995. In terms of percentages, 55.6% of all the workers in the city were employed in the industrial sector in 1964 and only 20.3% in 1995 (Trullén, 1997).³

Firms that decide to move out of the CBD⁴ (Central Business District) (White, 1999) must face a trade-off -some costs increase while others decrease. When firms decide to decentralise their plants to the periphery, there is less commuting. This means that the commuting costs of workers will fall and firms can benefit by paying lower wages. At the same time, land rents decrease as distance from the centre increases and the transport costs of inputs and outputs also decrease because of the lack of congestion in transport infrastructures. On the other hand, when firms move out of the CBD productivity falls because they lose the agglomeration economies. The decision of a firm to relocate will depend on the result of this trade-off.

All in all, schemes like this only work if wages are adjusted when commuting costs fall. Likewise, the percentage of the total costs made up by wages depends on what companies produce. This means that only labour-intensive firms will relocate from the centre to the periphery. Another way of approaching this phenomenon is to study the geographical patterns of new industrial establishments and this is the approach we have chosen in this paper.

In spite of the changes mentioned above (the capacity of medium and small cities to attract industrial investments), it is clear that larger cities can attract firms, too. The main forces behind the agglomeration of economic activity in a metropolitan region are the availability

of resources or the accessibility to transport networks, the indivisibility of production, scale economies, externalities and historical and institutional elements (Junius, 1997). There are, however, other forces (mainly proximity-linked costs such as congestion, pollution, land rents, etc.) which pull in the opposite direction (Duranton & Puga, 1999; Fujita et al. 1999) and lead to the dispersion of economic activities. So, agglomeration forces rationalise the existence of cities while dispersion forces decrease their size. As Carlino says (1988, p. 14): “Agglomeration economies lead to concentration, but congestion costs pave the way for deconcentration”.

Various approaches have shown that the growth of territories depends on the comparative advantages of either the number of inputs or self-reinforcing agglomeration processes caused by historical accidents. It has also been said that manufacturing goes to where markets are important and that markets are important where manufacturing is located (Krugman, 1991 & 1992).

Glaeser (1999) explained that cities are successful because they generate knowledge. He designed a theoretical model in which people acquire skills (knowledge, technical training, experience, etc.) from interacting with other people who command these skills. Cities are an ideal environment for this process to be successful because dense urban areas make these interactions easier and provide more opportunities for learning (Glaeser, 1999, p. 255): “Dense urban agglomerations provide a faster rate of contact between individuals and each new contact provides an opportunity for learning.” In this model, the probability of acquiring new knowledge and skills depends on the number of skilled workers in a city and the size of the city. This argument suggests a distribution of activities in which sectors that are more technologically advanced would tend to locate in places where they have easier access to the human capital they need to run the firms (in these kinds of firms innovation is very important and innovation requires skilled labour): these places are cities, more specifically big cities.

There are several studies on industrial location and the creation of firms in Spain. Herrero & Pedroso (1997) limit their analysis to the inland Spanish regions between 1985 and 1994

and they show not only that industrial investments were moving from metropolitan regions to medium-sized cities, but also that rural towns had little capacity of attracting this kind of activity. Callejón & Costa (1995, 1996 and 1997) studied the effect of external economies on location patterns in Spanish industry while Viladecans (1997) made a similar analysis for Catalonia. Soy (1997) showed that the urban nature of the services that firms provide can determine subsequent industrial locations. Galán et al. (1998) showed that decisions about location are not always taken under perfectly rational assumptions. Finally, Costa (1997) made an excellent review of the literature on industrial location and Alonso Teixidor (1999) provided an overview of the changes in the predominant activities in Spanish cities over time.

THE MODEL

The aim of this work is to study the territorial dynamics that act when economic agents decide to enter a market by opening an industrial establishment. These agents face the following dilemmas:⁵

- In the first place, they must decide whether potential profits are big enough to enter a specific sector. This decision also involves choosing a specific technological level (the sector level).
- In the second place, they must decide where to locate the new establishment. This decision involves choosing the best territory for the new activity.⁶

This model represents the process by which some individuals decide to set up an industrial establishment in a specific territory and sector. According to Henderson et al. (1995), in a sector i aggregate production level can be approximated by:

$$Q_i = A_i \cdot f(L_i, VT_i)$$

where VT_i is a vector of different variables that can be associated to each territory and L_i is the number of jobs. VT_i includes population concentrations⁷ that may or may not be

included in wider dynamic urban areas⁸ and the diversity and specialisation of the local industrial mix. It also includes variables of the urban environment in which the firm is located; that is to say, variables that are external to the firm. Likewise, A_i measures technological level and includes both general and local components:

$$A_i = A_{gen} \cdot A_{loc}$$

Variables such as diversity (DIV), specialisation (ESP), workers⁹ (L) and skilled workers (CH), all related to external economics, are represented by A_{loc} :

$$A_{loc} = A(DIV, ESP_i, L_i, CH_i)$$

We assume that the rate of skilled labour is different in each sector and is directly linked to the technological level of the sector. This means that the technological level of each sector is determined by the degree of skill of the labour force and this, in turn, determines the level of production of the sector.

As Glaeser says (1999), the probability of learning in a city j depends on the existence of skilled labour and the size of the city.

$$\text{Probability of learning} = f(CH_j, POB_j)$$

Given that less skilled workers learn through interaction with skilled ones, the bigger a city is, the more opportunities there will be for interaction and, consequently, learning. This means that skill levels will be higher in cities:

$$CH_j = f(POB_j)$$

At equilibrium, the amount of work is the point at which the value of the marginal product is equal to its price (wages). That is:

$$w_i = A_i \cdot f' (L_i, VT_i) \cdot P_i$$

where w_i is wage and P_i is output price.

The output price is determined by the inverse demand function (which includes the number of workers and several variables that account for the local industrial mix). These variables refer to external economics (degree of concentration or diversity of local industry, for instance):

$$P_i = P (L_i, DIV, ESP_i)$$

If we substitute A_i and P_i in the wage equation, we get:

$$L_i = L (DIV, ESP_i, CH_i, VT)$$

The factors that account for the output level (human capital, workers, external economics, etc.) are not spread homogeneously over space. In cities they are discontinuous and they also depend on the size of the city.

At this point, we require workers and firms to behave rationally. We can distinguish two groups of workers: skilled and unskilled:

- The members of the first group are concentrated in bigger cities, they earn above average wages and they also pay above average prices.
- The members of the second group are more widely spread over the territory. They live in smaller cities with lower densities of population, earn below average wages and pay below average prices.

Firms can choose between minimizing inputs or maximizing outputs. Minimizing inputs involves locating where the workers from the second group (unskilled) are to be found, that is to say in the smaller cities. Maximizing outputs means locating where the workers of the first group (skilled) are to be found, that is to say the bigger cities. Should they decide the

latter, the results are high technology activities; should they decide the former, the results are labour-intense activities (with lower wages).

Individuals can choose to go to a bigger city, where they can improve their skills and get a job in a high technology sector, or they can choose to remain in their own towns and never improve their skills to any great extent.

Given that we have no data about output at a local level, we can use the variable “job creation” as a proxy of production. This is justified by the fact that we know the aggregate industrial data of production of the economy (and we also know the amount of labour used in this production). This information makes it possible for the different industrial productivities of labour to be obtained so that the number of jobs can be used instead of production:

$$\text{we know that } \frac{Q_i}{L_i} = q_i, \text{ and this implies that } Q_i = q_i \cdot L_i$$

For all the reasons given above, job creation in sector i can be accounted for by the same variables that account for the production of this sector. Therefore, on the basis of the consequences in terms of job creation in a specific group of industries and cities we can proxy firms decisions related to profit maximisation.

On this premise, and by analysing the variables that influence output levels, individuals decide whether to enter the market and, should they decide to do so, in which place and sector. In this study, we do not attempt to explain the production level of the economy in terms of entry decisions; we attempt to explain how many jobs are created by this phenomenon.

The model which is going to be estimated is:

$$L80-96_{ij} = \alpha + \beta_0 DIV_j + \beta_1 ESP_{ij} + \beta_2 CH_j + \beta_3 POB96_j + \beta_4 DENSI96_j + \\ + \beta_5 DI_j + \beta_6 D2_j + \beta_7 DENSI*DI_j + \beta_8 DENSI*D2_j + v$$

To sum up, the dependent variable is:

- Job creation between 1980 and 1996 (L80-96): this variable includes the jobs collected by REI in new industrial establishments.

The explanatory variables are:

- Diversity Index¹⁰ (DIV) this index shows, for each city, to what extent industrial jobs are concentrated in a few sectors or spread over all of them. Results are between 0 (maximum dispersion) and 1 (all the jobs are only in one sector).
- Specialisation Index¹¹ (ESP): this index is the ratio between the number of jobs in each sector and total number of industrial jobs, thus showing the specialisation of each city.
- Human Capital (CH): this index measures the skill level of human capital in a city. It shows the number of people with medium and high levels of education¹².
- Population in 1996 (POB96): this variable measures the size of cities.
- The population density in 1996 (DENSI96): this variable acts as a proxy of agglomeration economies, because it shows the intensity of land use.
- *Dummy 1* (DI): this variable compares job creation in high technology sectors with job creation in medium technology sectors.
- *Dummy 2* (D2): this variable compares job creation in low technology sectors with job creation in medium technology sectors.
- Crossed variable 1: (DENSI*DI): this variable shows the impact of population density and job creation on high technology sectors
- Crossed variable 2 (DENSI*D2): this variable shows the impact of population density and job creation on low technology sectors.

The data used in this study are essentially for new industrial establishments in Catalonia between 1980 and 1996 (obtained from the Spanish Industrial Establishments Register, REI) and the territorial distribution of jobs and population (obtained from the Catalan Statistical Institute).

The REI is a database from the MINER (Spanish Ministry of Industry) and is an administrative register of several variables related to the opening and enlargement of industrial establishments. Because it is an administrative register it has several drawbacks which should be taken into account when the results are analysed. The two main drawbacks are that it attempts to hide information from firms and takes little interest in being up to date. Mompó and Monfort (1989) describe the REI database and its advantages and disadvantages in considerable detail.

The desaggregation level of the data is CNAE-93 in two significant figures, only for industrial sectors. It is very important to use data with an appropriate level of industrial desaggregation, because the differences in the activities in each sector lead to differences in location patterns.

As far as territorial grouping is concerned, we considered that urban environments influence industrial location process, and that this influence is not the same for all sectors or all kinds of cities. From this initial hypothesis, we considered that the size of a city would be an appropriate variable for portraying this situation so we divided the cities into five groups¹³ according to their population in 1996.

RESULTS

First, we present the descriptive statistics, and then the econometric contrasts.

The REI includes 27,833 industrial establishments that were new in Catalonia between 1980 and 1996. Most of these were in the region of Barcelona (21,224) and some considerable way behind Tarragona (2,495), Girona (2,428) and Lleida (1,686). This territorial pattern is very similar to the distribution of population (and economic activity) in Catalonia.

These new establishments were not spread uniformly over the urban system. In particular, smaller cities were overrepresented in terms of new industrial establishments, while bigger cities were underrepresented. For example, cities with fewer than 50,000 inhabitants received a greater percentage of new establishments than their percentage of the total population of Catalonia¹⁴. The situation of cities with more than 50,000 inhabitants was the opposite. If we consider job creation (instead of new establishments) results are mainly the same.

This location pattern, however, is not the same in all industrial sectors. In the first place, we should differentiate between those activities which are closely linked to the residential population (and which are therefore of little interest from a locational point of view) and extractive activities (such as mining) which usually take place in small towns where there is plenty of land available. This analysis has the problem that there is an excessive degree of disaggregation (29 industrial sectors)¹⁵, but it can be overcome by grouping the 29 sectors into only 3 without losing any explanatory power. The sectors can be grouped into three categories according to their technological level: high, medium and low technology (see Appendix 1). We have assumed that the location patterns are similar in each industrial grouping.

Table 1
Distribution of new industrial establishments: 1980 to 1996*

	Industrial grouping			Total sectors	% population
	High technology	Medium technology	Low technology		
Lower than 2,000 h.	3.8	7.6	11.0	10.4	6.4
From 2,000 to 10,000 h.	13.7	20.4	22.0	21.6	14.0
From 10,001 to 50,000 h.	18.4	27.3	26.6	26.6	23.3
From 50,001 to 100,000 h.	10.6	12.7	9.6	10.1	10.8
From 100,001 to 1,500,000 h.	16.1	17.0	18.2	18.0	20.8
More than 1,500,000 h.	37.5	15.0	12.4	13.4	24.8
<i>Total</i>	<i>100.0</i>	<i>100.0</i>	<i>100.0</i>	<i>100.0</i>	<i>100.0</i>

*Population data are for 1996.
Source: own elaboration with data provided by REI and IDESCAT (Catalan Statistical Institute).

These industrial groupings show that the environmental needs of firms depend on the kind of activity in which they are involved and that these needs cannot be provided for by all cities. In short, firms from different industrial sectors will decide to locate in cities of different sizes because the size of a city affects the kind of input that it can provide (for example, the skill level of human capital, availability of specialised services, transport, etc.).

Most new establishments belong to low-technology sectors (82.9%), followed by medium-technology sectors (14.8%) and, finally, high-technology sectors (2.3%). This distribution, however, is not homogeneous for all population sections, as table 1 shows.

In this respect, low-technology sectors are more important in cities with fewer than 50,000 inhabitants and high-technology sectors are less important in these cities. The distribution of new establishments in cities with more than 50,000 inhabitants (except Barcelona) is close to the average of the whole country, whereas Barcelona clearly specialises in high-technology sectors. Although the number of new industrial establishments in Barcelona is only 13.4% of the total number in Catalonia, the number of new establishments in high-technology sectors is 37.5% of the total for this grouping. The tendency for job creation is the same, even though the magnitude of the phenomenon is not as great: new jobs in Barcelona are 17.7% of the total for Catalonia but 31.7% of the total for high-technology sectors.

An analysis of the activity of new establishments in relation to where they are located suggests that firms in the low-technology sectors prefer smaller cities, while firms in high-technology sectors are overrepresented in Barcelona. It is also noteworthy that the ability of cities with more than 100,000 inhabitants (excluding Barcelona) to attract firms from high-technology sectors is not proportional to their size. Of the eight cities in this group¹⁶, six are in the Barcelona area (Badalona, L'Hospitalet de Llobregat¹⁷, Mataró, Sabadell, Santa Coloma de Gramenet and Terrassa) while two (Tarragona and Lleida) are not. An analysis of the territorial pattern of new, high-technology industrial establishments shows that they

are concentrated around Barcelona but not such that the concentration is directly proportional to the distance from Barcelona.

Moreover, the new industrial establishments are usually very small (in terms of number of workers). More than 80% of establishments had fewer than 10 workers (see table 2).

Table 2
Size of new industrial establishments (1980 to 1996)

Number of workers	Establishments	% establ.	Workers	% workers
<10	23,051	82.82	79,834	37.87
10 a 19	3,101	11.14	40,698	19.31
20 a 49	1,364	4.90	38,839	18.43
50 a 99	204	0.73	13,572	6.44
100 a 500	103	0.37	18,512	8.78
> 500	10	0.04	19,340	9.17
TOTAL	27,833	100.0	210,795	100.0

Source: own elaboration with data from REI.

The pattern of industrial location is clearly influenced by the size of new industrial establishments¹⁸. Previous empirical studies (Galán et al., 1998; Cotorruelo & Vázquez Barquero, 1997, etc.) show that the analysis of alternative locations is only important for bigger firms. This means that microfirms are normally located in the same town as the entrepreneur and variables such as agglomeration economies, availability of specific services and industrial environment are not considered. It may be argued, however, that these variables act to create an environment that encourages entrepreneurial activities and, therefore, the creation of firms even though they are heavily linked to territory.

To test the model, we chose four basic specifications, one for each industrial grouping (high, medium and low technology) and another specification for whole sectors.

The data obtained from the four estimated models reinforce the main conclusions obtained from the descriptive data and give additional information about local determinants of industrial location patterns in Catalonia.

Table 3

Econometric results

	D I V	ESP A	ESP M	ESP B	POB	DENSI	CH	D1	D2	DENSI *D1	DENSI *D2	F	R ²
HT sector	-	.027			.249	.044	.623*					114.149*	.835
	.	(.772)			(1.001)	(.763)	(2.692)						
	0												
	8												
	6												
	*												
	(
	-												
	2												
	.												
	3												
	1												
	9												
)												
MT sector	-		-.042*		.687*	-.055*	.274*					636.815*	.902
	.		(-2.672)		(6.261)	(-2.056)	(2.709)						
	0												
	6												
	2												
	*												
	(
	-												
	3												
	.												
	8												
	9												
	8												
)												
LT sector	-			.021*	1.772*	-.028**	-.835*					1852.202*	.934
	.			(2.323)	(27.214)	(-1.702)	(-13.970)						
	0												
	3												
	4												
	*												
	(
	-												
	3												
	.												
	6												
	1												
	4												
)												

Total (i)	-	.017	-.034*	1.072*	-.015	-.297*				317.719*	.624	
	.	(1.038)	(-1.996)	(8.955)	(-.516)	(-2.693)						
	0											
	3											
	8											
	*											
	(
	-											
	2											
	.											
	1											
	5											
	6											
)											
Total (ii)	-	.019	-.042*	1.137*	-.007	-.358*	-.102*	.096*		275.585*	.649	
	.	(1.173)	(-2.521)	(9.814)	(-.257)	(-3.360)	(-5.704)	(5.322)				
	0											
	6											
	6											
	*											
	(
	-											
	3											
	.											
	8											
	4											
	6											
)											
Total (iii)	-	.019	-.037*	1.133*	-.115*	-.337*	.004	.030**	-.198*	.317*	399.326*	.767
	.	(1.400)	(-2.768)	(11.977)	(-3.948)	(-3.875)	(.229)	(1.938)	(-10.197)	(16.496)		
	0											
	4											
	6											
	*											
	(
	-											
	3											
	.											
	2											
	7											
	4											
)											

t is shown between brackets, and *significant at the 5% level and **significant at the 10% level.

The results are different for each of the three sectors considered. This shows that the factors that affect the location of industrial establishments are different for each sector. The characteristics of each city, therefore, serve to attract (or not) establishments in one sector or another. Taking into account that different urban environments (in terms of city size) have different kinds of input (human capital, agglomeration economies, spillovers, etc.)¹⁹

and that each sector requires a specific combination of these inputs, it is logical to assume that territories with this specific combination would have a greater chance of attracting this kind of establishment. This means that research into industrial location that does not take into account the differences between the sectors will not be able to provide reasonable explanations. From a policy point of view, research should focus on what sorts of establishments are attracted by what sorts of cities, not whether a city can attract an industrial establishment.

Although each sector has different requirements, the results as far as the diversity of industrial jobs is concerned are very similar. In the three sectors analysed, there is a preference for industrial diversity; that is to say, job creation is favoured in cities in which there is a greater dispersion of jobs between the three sectors. Individuals should begin their industrial activities in a diversified urban environment²⁰. These results do not coincide with others obtained by other researchers²¹, like Viladecans (1997) for Catalonia, or Callejón & Costa (1997) for Spanish provinces. The differences should be put into the context of the different territorial units studied because it is clear that this variable will increase when the territorial unit is bigger. More specifically, diversity will be greater in bigger cities than in smaller ones (the more firms there are, the more sectors there are in the city). Finally, another difference with previous work is that the industrial units considered are not the same²².

According to the above results it would be logical to expect that fewer jobs will be created in cities that are heavily specialised in each of the three sectors. However, when we analyse models from each sector it is obvious that this is not the case (except in the medium-technology sector), and even in the low-technology sector job creation is stimulated by relative specialisation in this sector.

This could be explained by Duranton & Puga's conclusions (2000). The authors suggest that there is a relationship between industrial location patterns and the product cycle, in such a way that in their initial stages firms would prefer diversified environments. Subsequently, once they have decided on their technological level and requirements²³, they

try to relocate in specialised territories where other firms with the same technology work. This situation has been observed in France. According to this pattern, it seems reasonable that sectors which use mature technology should prefer to locate in cities or regions specialised in this technology.

Population and population density do not measure the same phenomenon. Population refers only to the people in an administrative unit (we know nothing of its size) and may suggest the stronghold of a local market, the existence of workers or a network of services for firms. Population density, on the other hand, shows the size of human concentration in one specific place and can be a good proxy for agglomeration economies. We should point out that the trends of the two variables are not the same (we may intuitively imagine that density would arise from size, but this is not the case). Therefore, as stated above when discussing industrial activities and the move from the centre of big cities to the periphery, we should expect that the density variable will be negative, with the exception of knowledge spillovers (in high technology sectors) which need to be territorially concentrated²⁴. Even so, it should be pointed out that knowledge spillovers created by a high population density can also increase firms' profitability and this can save jobs (Coombes, 2000); or, in other words, congestion caused by density could annul the positive effects of knowledge spillovers.

Indeed, in estimations of medium and low technological levels, and in three extensions of the whole model, the density variable is negative. This means that the consequences of the concentration of people and activities in a few cities will be different in different sectors. Broadly speaking, in some sectors the benefits of proximity (knowledge spillovers, etc.) are greater than the drawbacks (congestion, cost increase, etc.) while mature-technology sectors (and those which incorporate few innovations) find it difficult to assimilate these positive effects and they would only be affected by the costs of being close to the centre. As a result of this, they would relocate in cities with lower agglomerations.

A priori, the skill level of labour is a factor that should have an unequal impact on job creation in industrial establishments and the impact would depend on the needs of firms in

each sector. It is to be expected that this factor would positively affect those sectors which use a greater amount of skilled labour (because of their technological level) but not the low-technology sectors or labour-intensive firms, which locate in cities with an abundance of unskilled and cheap workers. This result is expected for the whole model because of the importance of job creation in low-technology sectors (more than 70% of total job creation). We should point out that the results of this variable match forecasts and confirm Glaeser's results (1999) about the importance of job skills. It seems logical that firms which belong to high-technology sectors prefer to locate in cities with skilled labour (this factor is essential), while for low-technology firms this is not so important (they do not use as much skilled labour as other firms). Therefore, the amount of skilled labour in a city affects the kind of firms that locate there²⁵.

This is of considerable importance because it makes possible a process of dual growth, in which some cities have high concentrations of skilled workers (and specialise in high-technology activities) while the rest (which do not have this skilled labour) specialise in labour-intensive firms with low levels of technology. Human capital, then, is the factor that can change the growth model and it is in cities that this human capital can best be generated and trained.

Dummies 1 and 2 (calculated for the estimations ii and iii), and crossed variables (DENSI*D1 and DENSI*D2) give more information about a phenomenon that has previously been explained by other indicators: the greater importance of job creation in low-technology sectors.

Finally, we should point out that the values of R^2 are not only large but also that they increase in estimations i, ii and iii when more explanatory variables are added.

CONCLUSIONS

The results of studying the territorial patterns of industrial location in Catalonia reveal a pattern in which firms prefer to locate in medium-sized and small cities rather than large cities.

Cities are places in which more skilled workers can meet one another, searching for opportunities for their particular skills. At the same time, this concentration of human capital allows cities to attract more innovative activities and to create jobs in these sectors. In this respect, the reason for the success of medium-sized or big cities is their capacity for attracting and training skilled labour, an essential factor for innovative firms.

While bigger cities are becoming increasingly specialised in more technologically advanced activities (these activities need to cluster together), other industrial activities are experiencing the negative consequences of urban industrial agglomerations and are moving from the centre and relocating in smaller cities where they can use the infrastructure more efficiently and have greater access to industrial land at lower costs.

Further study could focus on how the size of new establishments affect industrial location patterns. Likewise, we believe that studying decisions to enlarge industrial establishments could improve our knowledge of the type of urban environment needed by these establishments.

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APPENDICES

<i>Appendix 1</i> Industrial grouping by technology level

Code CNAE93	Technology level
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<i>30, 32 and 33</i>	<i>High</i>
<i>24, 29, 31, 34 and 35</i>	<i>Medium</i>
<i>10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25, 26, 27, 28, 36, 37, 40 and 41</i>	<i>Low</i>

Appendix 2

CNAE93 industrial classification

Code	Name
10	Mining of coal and lignite; extraction of peat
11	Extraction of crude petroleum and natural gas
12	Mining of uranium and thorium ores
13	Mining of metal ores
14	Other mining and quarrying
15	Manufacture of food products and beverages
16	Manufacture of tobacco products
17	Manufacture of textiles
18	Manufacture of leather clothes
19	Tanning and dressing of leather
20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
21	Manufacture of pulp, paper and paper products
22	Publishing, printing and reproduction of recorded media
23	Manufacture of coke, refined petroleum products and nuclear fuel
24	Manufacture of chemicals and chemical products
25	Manufacture of rubber and plastic products
26	Manufacture of other non-metallic mineral products
27	Manufacture of basic metals
28	Manufacture of fabricated metal products, except machinery and equipment
29	Manufacture of machinery and equipment n.e.c.
30	Manufacture of office machinery and computers
31	Manufacture of electrical machinery and apparatus n.e.c.
32	Manufacture of radio, television and communication equipment and apparatus
33	Manufacture of medical, precision and optical instruments, watches and clocks
34	Manufacture of motor vehicles, trailers and semi-trailers
35	Manufacture of other transport equipment
36	Manufacture of furniture; manufacturing n.e.c.
37	Recycling

40	Electricity, gas, steam and hot water supply
41	Collection, purification and distribution of water

Source: INE (Spanish Statistical Institute).

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¹ In fact, it would be more correct to talk about cities as a vector of a group of variables which have different impacts on a firm's productivity.

² Fujita et al. (1999) and Ottaviano & Puga provide a summary of links between space and economics in "new economic geography". A recent, very synthetic revision of urban economics can be found in Alonso & de Lucio (1999).

³ On the other hand, aspects other than just relocation of industrial activities from centre to periphery should be taken into account: for example, labour-saving technological findings, the closure of establishments because of economic recession, the externalisation of services that had previously been provided by the firms themselves, deindustrialisation and relocation to countries with lower wages.

⁴ The economic activity is concentrated at the centre while the workers live on the outskirts.

⁵ In this study we only consider the last stage of the process.

⁶ It should be noted that optimal location is not always considered when an establishment opens, particularly in the case of smaller establishments. Galán et al. (1998) made a study in which 46% of cases did not consider an alternative location. Likewise, Cotorruelo & Vazquez Barquero (1997) made a similar study in which a third of medium-sized and small firms who had answered a questionnaire said that they had carried out previous location studies. As we shall see below, REI data show that 82.3% of new establishments have less than 10 workers and this small size means that there are close links with the place where the entrepreneur lives (from a locational point of view). This may cast some doubt on our conclusions, but we believe that the entrepreneur is created (and influenced) by the same phenomena (agglomeration economies, skill levels, etc.) that act positively on the location of industrial activities.

⁷ Population concentration can be expressed as the number of inhabitants of a city or as the population density per km².

⁸ Glaeser (1999, p.254) states that "individuals acquire skills by interacting with one another, and dense urban areas increase the speed of interactions (...) cities will have a higher mean and higher variance of skills, and will attract young people who are not too risk averse and who benefit most from learning (...)."

⁹ If a lot of workers are concentrated in the same place (Glaeser, 1999), there are more opportunities for learning and training.

¹⁰ The Hirshmann-Herfindahl index is defined as $DIV_j = \sum_{i=1}^n s_{ij}^2$, where i represents sectors, and j represents cities.

¹¹ The Specialisation index is defined as $ESP_{ij} = (L_{ij}/L_j)/(L_i/L)$, where i represents sectors and j represents cities.

¹² This is an absolute value and shows how cities can attract skilled labour (Glaeser, 1999).

¹³ The groups are the following: cities with fewer than 2,000 inhabitants; cities between 2,001 and 10,000 inhabitants; cities between 10,001 and 50,000 inhabitants; cities between 50,001 and 100,000 inhabitants; cities between 100,001 and 1,500,000 inhabitants and, finally, cities with more than 1,500,000 inhabitants (in Catalonia, only Barcelona has more than 1.5 million inhabitants).

¹⁴ The population data is from 1996.

¹⁵ This circumstance is magnified when, like in this work, we use both sector and city size.

¹⁶ Cities which, in 1996, had a population between 100,000 and 1,500,000 inhabitants.

¹⁷ This city is the only one in this group of 8 that has similar trends to Barcelona in order to attract new industrial establishments belonging to high technological sectors. It must be noted that L'Hospitalet is close to Barcelona (in fact, there is an urban continuity between both cities).

¹⁸ The average size of new industrial establishments during the reference period is 7.6 workers per establishment.

¹⁹ In other words, if variables like degree of labour skill, diversity of employment or agglomeration economies are directly linked to city size.

²⁰ If we consider the limitations of the model used (specifically, about small firms linked to a territory), the interpretation would be that this kind of urban environment influences the innovative entrepreneur.

²¹ Except in high-technology sectors where diversity can have positive effects on job creation.

²² Specifically, 3 sectors in this work, 23 in Callejón and Costa (1997) and 9 in Viladecans (1997).

²³ In this phase firms have stopped introducing innovations.

²⁴ See Glaeser (1999).

²⁵ Even so, differences between the place where people live and the place where people work means that we must hesitate about drawing conclusions in this direction (specially if we consider the growing importance of commuting). A possible way to improve the analysis is to use travel to work areas (areas in which most people both live and work).