Regional Innovation and Small High Technology Firms in Peripheral Regions

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ABSTRACT. This paper highlights the difficulty of developing HT firms in a peripheral region of Spain. Although the endogenous development of HT firms in these regions is possible, their evolution depends on more central regions. The firm's geographical location and the type of HT production are the most important endogenous factors governing the firm's success.

I. Introduction

High technology (HT) firms are usually defined as those which simultaneously devote more resources to R&D (R&D/Sales) and have higher percentages of qualified personnel (scientists and engineers) than the overall average for manufacturing industry. These industries are taking on increasing importance in the analysis of technological change, since they represent the origin and application of technological product and process innovations which contribute to regional and national economic growth (Freeman, 1986).

HT industries are one of a region's assets in achieving desired economic growth. Besides HT industries, other assets which are required for economic development are public research and training centres, communication and transport facilities, financial services, a diversified economy and so on. Regions can be classed as "central", i.e., more developed, and "peripheral", i.e., less developed, depending on the amount of these assets which they possess and the level of economic development already achieved.

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Various studies reveal that the industrial structure of peripheral regions differs from that of central regions. In central regions, there is a predominance of firms which are more research and technology-intensive, whereas in peripheral regions, more mature labour-intensive industries predominate. For example, in Italy HT industries are concentrated mainly in the more developed northern regions, whereas in Great Britain they are concentrated in the south-east. Townsend *et al.* (1982) concluded that the less developed regions of Britain produced much fewer innovations in the post-war period than the most developed regions, and this tendency has increased with time. According to Cicciotti (1986), in Italy, the introduction of new products and the adoption of new technology is much lower in the south of Italy than in the region of Lombardy in the north. It appears, therefore, that HT firms arise spontaneously in or are attracted by regions, in which there is a higher level of development and more R&D infrastructure.

In peripheral regions, the implantation of HT firms tends to follow two types of exogenous development: either (1) depending on efforts of the regional or national government to attract HT investment; or (2) depending on the location strategies of the parent companies of HT firms in other regions indirectly benefiting the peripheral region by the establishment of a subsidiary. This second alternative is rare, so that public sector promotion policy is the main instrument in developing HT activities.

One example of this exogenous development is Scotland's so-called Silicon Glen, the corridor between Edinburgh and Glasgow, which American electronics firms found to be an attractive site for production subsidiaries in the 1950s, as a base for sales in the European market (Haug, 1986). Later, when competition became tougher in the

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European market, these multinationals added R&D facilities to their Scottish production plants to enable them to respond more rapidly to changes in the market. They started to build up relationships with the Scottish universities, which led to a fertile environment in the 1970s for the endogenous development of HT firms in the region. Therefore, this process took a long time, even though the region already had universities, transport infrastructure and large urban areas.

Nevertheless, the norm is that peripheral regions' low level of technological development hinders the endogenous development of HT firms, and therefore peripheral regions depend on exogenous investment to attract high technology activities. Although a region's technological progress does not depend only on the presence of R&D, but also on the other variables which contribute to the innovation process (qualified labour, information systems, etc.) empirical evidence shows that less developed regions are not rich in these resources either. For example, the qualified labour which HT industries require is scarce in peripheral regions and, even if there are technological training centres, their graduates tend to migrate to more prosperous regions (Goddard *et al.*, 1987).

Therefore, given peripheral regions' limitations with regard to endogenous development of HT firms, it is interesting to study the HT nuclei which arise in these regions. This paper studies Aragon, a region located in the north-east of Spain, which in technological terms is a peripheral region but which has the peculiarity of being surrounded by regions which are central in both economic and technological terms like Catalonia, Madrid and the Basque Country. This particular geographical structure has enabled it not to attract exogenous HT investment, but to endogenously develop small HT firms.

II. Regional technology imbalance

Economic analyses of Spain show that the regions with greatest prospects of growth in the short and medium term are distributed along two "Economic axes": the Mediterranean coastline, and the Ebro valley, as well as the province of Madrid (Cuadrado, 1988). These provinces and regions are those which have highest percentage GDP growth, and where industries of the future have concentrated. Between 1975 and 1985, four provinces (Madrid, Barcelona, Valencia and Vizcaya) absorbed 61% of all investment in HT industries. Between these four provinces, and on the intersection of the two Axes is the region of Aragon, but this position has not apparently led it to attract HT investment (Giraldez, 1988).

HT industries have located in the regions with highest technological intensity. In 1986, three regions — Madrid, the Basque Country and Catalonia — absorbed 73.1% of total R&D spending, and also had the highest concentration of HT activities, although they only account for 39.5% of Spain's GDP. Aragon contributed 2.1% of total R&D spending (Table I), which places it sixth in technological intensity (R&D/GDP) with a figure of 0.36% behind Madrid (2%), the Basque Country (0.74), Catalonia (0.57), Castille-Leon (0.43) and Navarre (0.42). Therefore, Aragon's participation in the national research efforts is lower than would correspond to its share of the national GDP and to its growth prospects. Table I also shows that Aragon's participation in national and EEC R&D programs is much lower than its share of the Spanish economy.

The fact that Aragon's participation is lower than its economic potential is explained by the lower participation of its firms in the region's technological intensity and by the regions's industrial structure. In Aragon, companies' R&D spending amounts to 79% of public sector R&D

TABLE I
Economic-technological indicators for Aragon

Indicator[a]	Mean value
Aragon's GDP/Spain's GDP	3.5%
Aragon's active population/ Spain's active population (1989)	3.1%
Aragon's R&D/Spain's R&D	2.1%
R&D/GDP	0.36% (Spain = 0.61%)
Private R&D/Public R&D	79.0% (Spain = 142%)
R&D per capita (Pts)	8968 (Spain = 13426)
Participation in national technology projects (1989)	3.0%
Participation in EEC technology projects (1987—1990)	0.6%

[a] The data baseline is 1986 unless otherwise specified.

spending, compared with the average figure of 142% for Spain as a whole (Table I). On the other hand, university research in Aragon has a greater share in the region's R&D than the national average. Whereas Aragon accounts for 2.1% of national R&D spending, the figure for university research is 4% of the country's total university R&D spending, and that for company R&D is only 1.6%.

Table II shows that total R&D spending by Aragonese industry in 1989 was 9,524 million pesetas, which is 1.16% of sales. Five industries accounted for 67.8% of R&D spending in Aragon: Electrical and electronic machinery and equipment (20.6% of the total industrial R&D spending in Aragon), Automotive and other transport equipment (13.2%), Food industry (12.7%), Mechanical machinery and equipment (11.9%), and Metal products (9.4%). Table II also shows that the Aragonese industries with the greatest technological effort (R&D/%Sales) in 1989 were: Electrical and electronic equipment (4.7%), Mining (4.1%), Printing (4%), Mechanical machinery and equipment (3.5%), Metal products (2.8%) and Basic chemicals and chemical products (2.7%).

The concentration of R&D in these Aragonese industries is related to their importance in economic terms. Manufacturing industries in which Aragon is more specialised than the country as a whole, and which are the largest employers, are (Table II) Automobiles and spares (13.8% of total employment in manufacturing in Aragon), Metal products (12.4%), Electrical and electronic machinery and equipment (8.3%) and Mechanical machinery and equipment (8.3%). The five biggest researching industries account for 52.9% of total industrial employment.

The concentration of R&D in a few industries partly reflects the combined effects of external control and the size of manufacturing industry in Aragon. Firstly, almost all the manufacturing industries in Aragon with more than 500 em-

TABLE II
Technological intensity of Aragonese industry in 1989

Industry	R&D spending (Million Ptas)	%	R&D Sales	IM[a]	ID[b]	% Employment
Mining of ferrous and non-ferrous metals	414.3	4.3	4.1	—	—	4.2
Building materials, glass and ceramic industries	108.8	1.1	0.4	—	60	4.1
Basic chemicals and chemical products	972.0	10.2	2.7	—	86	7.6
Primary metal transformation, foundries and forges	239.0	2.5	0.8	43	71	4.6
Metal products	895.4	9.4	2.8	16	21	12.4
Food production	1214.4	12.7	1.1	—	18	10.8
Footwear	35.5	0.4	1.7	—	—	2.5
Textiles	100.0	1.0	2.5	—	—	2.3
Clothing	152.8	1.6	1.7	30	10	7.3
Paper	103.4	1.1	0.4	—	40	2.2
Printing	155.9	1.6	4.0	—	25	1.9
Wood industry	148.5	1.5	1.7	17	—	3.1
Furniture	0.0	0.0	0.0	—	—	2.5
Plastics, rubber and products	238.1	2.5	1.9	—	33	1.9
Mechanical machinery and equipment	1134.0	11.9	3.5	22	42	6.3
Domestic appliances	390.0	4.1	1.1	100	—	2.7
Electrical and electronic material and equipment	1961.4	20.6	4.7	—	56	8.3
Automotive and other transport equipment	1260.5	13.2	0.3	30	62	15.1
Total	9524.0	100.0	1.1	—	—	100.0

[a] IM is the percentage of firms in each industry which use innovative technology acquired in the market.
[b] ID is the percentage of firms in each industry which use innovative technology developed in-house or by the group to which they belong.
Source: CREA, 1990.

ployees are controlled by capital from outside the region, including foreign capital, which tends to restrict the development of activities other than assembly and production. Secondly, enterprises in Aragon are predominantly small, since 96.1% of manufacturing firms have less than 50 employees. Small firms are an important indicator of the dynamism of a region's economy. Regions with a diversified economy and a high participation of small firms are better able to resist the fluctuations in the economic cycle than regions in which employment is concentrated in a few of sectors and firms. The interest of economic recovery policies in the 1980s in small firms is even greater in the case of small HT firms, since they have the greatest potential for growth and, therefore, for economic benefits for their region.

III. Small high technology firms

A. *Spatial and sectorial distribution*

Following the criteria laid down by Giraldez (1988) in her study of HT industries in Spain and the definition given in the Introduction of the paper, Table III shows the sectorial distribution of Aragonese HT firms in 1990, in terms of number of firms and employees.[1] High technology industry in Aragon is very small, since it represents only 2.2% of manufacturing firms, and 8.3% of industrial employment, which are far below the figures for regional HT complexes (Breheny and McQuaid, 1988). The degree of diversification of HT in Aragon is low because the participation of two of the six industries (Aeronautics and Computing) is merely symbolic. Aragonese HT firms are concentrated mainly in manufacturing electronic products and instrumentation. Firms in these industries mainly produce short runs with a high added value, belong to private capital from the region, and were founded less than fifteen years ago.

There is also a high degree of spatial concentration (Table IV). HT industry in Aragon is concentrated mainly in the city of Zaragoza. This could be expected, since HT industries normally have a lower degree of geographical dispersion than other industries due to the fact that the new firms normally arise in cities with research centres or with communications infrastructure with important industrial centres (Aydalot and Keeble, 1988). The city of Zaragoza contains half the region's population, is the centre of specialized service firms (finances, consultancy, computing, . . .), contains 80% of the regions' university teachers and students, it is the hub of transport networks (air, rail, motorway) with adjoining central regions, it contains 70% of the region's employment, and is the seat of the regional government and other public administrations.

Of the 140 HT firms in Aragon, 125 (89.3%) are located in Zaragoza; i.e., the region's capital contains 89.3% of the HT firms and 92% of HT employment in the region. The remaining 10.7% of HT firms are distributed in the region's other two provinces. Table IV shows that 92% of

TABLE III
Composition of Aragon's high technology industry in 1990

HT industry[a]	No. firms	%	No. workers	%
Pharmaceuticals	34	24.3	359	4.5
Advanced electrical equipment	51	36.4	4613	57.9
Electronics	26	18.6	1356	17.0
Computing	6	4.3	81	1.0
Aeronautics	1	0.7	4	—
Instrumentation	22	15.7	1559	19.6
Total HT industry	140	100.0	7972	100.0
Percentage of manufacturing industry	2.2	—	8.3	—

[a] High Technology industries in Aragon are defined as those which simultaneously devote more resources to R&D (R&D/Sales) and have percentages of qualified personnel than the overall average for Aragonese manufacturing industry.

TABLE IV
Size distribution (number of employees) and location of high technology firms in the provinces of Aragon in 1990

	Zaragoza	Huesca	Teruel	Total	%
Small (1—49)	116	8	6	130	92.9%
Medium (50—499)	6	1	—	7	5.0%
Large (+500)	3	—	—	3	2.1%
Total firms	125	9	6	140	100.0%
%	89.3%	6.4%	4.3%	100.0%	—

Aragonese HT firms are small and 5% are medium-sized, which indicates that HT industry in Aragon consists essentially of small firms.

Aragon is not one of the areas where HT industry concentrates; these industries have particular preference for the Centre and Mediterranean coast regions. For example, Aragon does not have any HT subsidiaries of multinational firms or firms from other regions. Therefore, it would be interesting to study the development of HT industry in this peripheral region. Data are available from a survey performed in the first half of 1990 among 54 small HT firms in Aragon. The sample represents 39% of HT firms and 67% of HT employment in Aragon, which are similar to the figures for other studies. The firms surveyed belong to the electrical, electronic and instrumentation sectors.

B. *Innovation in HT firms*

HT firms stand out from other firms in two ways: they devote a greater proportion of their resources to R&D, and they have a higher growth rate. The firms surveyed devote between 3 and 12% of their sales to R&D, with an average of 4.9%. This percentage is four times the average technological intensity of Aragonese industry as a whole, which highlights the difference between the two groups of industries. The percentage of graduates in the staff varies from 10 to 32%.

With regard to the higher growth rate, this will be maintained since the majority of firms surveyed expect to increase their market, sales, R&D, etc., in the short term. A total of 48.4% of the firms will need more physical space, 81.5% are going to increase investment in equipment and installations, and 85.2% are going to increase resources devoted to R&D in the short term. The number of products also tends to increase (59.25% of firms) although not so significantly as investment in R&D, which means that the normal product line will be maintained or expanded, but R&D will be intensified to increase the products' technological content.

Technological change in small HT firms occurs with product and/or process innovations. These two forms of technical progress have different regional effects. Process innovation guarantees the HT industry's competitiveness as it evolves from high cost, low volume production towards later stages which require progressive cost reduction. Product innovation guarantees the firm's survival and permits economic growth and increased employment in the firm and in the region. Although small firms have fewer resources and lower capacity to innovate, they have various advantages due to their greater flexibility, adaptability and organizational simplicity. In his analysis of innovations in Great Britain from 1945 to 1983, Harris (1988) found that there is a regional difference in the distribution of innovations. Thus, he found an increase in the proportion of process innovations in peripheral regions, whereas product innovations tended to be concentrated in Britain's central regions.

The degree of innovation of the products made by the HT firms in our survey can be described as average, which agrees with the technological evaluation of Aragonese industry, as a whole, which has similar or lower values. Apart from incremental innovations, which are found in nearly all firms, it is noteworthy that less than half of these firms developed new products with advanced

TABLE V
Types of product innovation in HT firms in Aragon

Type of product innovation	% of firms
Improvements to existing models	92.0%
New models of existing products	55.5%
New products with standard technology	48.1%
New products with advanced technology	44.4%

manufacturing technologies (Table V). A study by Torres *et al.* (1985) showed that, apart from the Mechanical machinery and equipment industry, Aragon's manufacturing industry had a low to medium technological level, as measured by a basket of criteria (R&D, patents, adoption of new technology, etc.). Table II showed the level of use of innovative technologies developed in the firm or acquired in the market. The sectors with the highest proportion of firms using innovative technologies acquired in the market are: Domestic appliances (100%) and Primary metal transformation (43%). The sectors using the highest proportions of innovative technologies developed in-house or by the group to which they belong were: Basic chemicals and chemical products (86%), Primary metal transformation (71%) and Automotive and other transport equipment (62%). There was a correlation between technological intensity and the use of innovative technologies in most of Aragonese industry.

C. *Origins and motivations of HT firms*

There is a clear difference between the origin of Aragonese HT firms and those in other regions with greater HT activity. Thus, none of the Aragonese firms had arisen out of an academic project, i.e., the phenomenon of firms arising out of academic research did not exist. The percentage of spin-offs is relatively low, since only 11.2% of the firms surveyed were formed from another firm, either by the parent firm itself, or by managers who had previously worked in another firm. The rest of the surveyed firms did not arise as spin-offs from university or business.

A survey in the province of Madrid (Gamella, 1988), which is one of the two regions with the highest concentration of HT firms in Spain, showed a different situation. Of the surveyed firms, 14.3% had arisen from an academic project, and 35.7% came from other firms in the sector; i.e., the survey found that half of the HT firms created in Madrid in recent years were due to university or business spin-offs, compared with a figure of 11% for Aragon. The difference between a central and a peripheral region, in terms of HT, is clear.

With regard to the motivation for forming the firms, (Table VI), only 9.1% were formed to exploit the research, which is far below the figures for the US and other countries. In a peripheral HT region, this motivation is not so frequent because of the lower amount of resources devoted to HT activities, both in absolute terms and in comparison with industrial activities as a whole, in relation to central regions which are more intensive in HT activities. The most important motivation was identification of a gap in the market, but this was not due so much to prior research as to experience.

These entrepreneurs had a technical background, mainly engineering, and had no knowledge or experience of management when they started the firm. For this reason, the biggest problems they faced in the early years were in obtaining financial resources, opening up distribution channels, and finding suppliers and more qualified technical staff as the firm's technological level rose. These results agree with the findings of other studies, in which these problems are cited as the most important, even in HT firms which benefited from public aid for R&D. For example, in a study of 177 HT firms located in 31 Innovation Centres in Germany, Sternberg (1990) found that the order of importance of the problems encountered by these firms in their beginnings (Table VII) was similar to that found in other

TABLE VI
Motivations for setting up HT firms in Aragon

Motivation	% of firms
Identification of an opportunity to commercialise knowledge in the market	51.5%
Desire for independence	21.2%
Economic reasons	18.2%
Exploitation of the results of a research project	9.1%

TABLE VII
Most important problems to be solved by HT small firms located in Innovation Centres in Germany

Problem area	% of firms
1. Marketing of new product(s)	60.0%
2. Acquisition of highly qualified employees	45.3%
3. Technical problems (R&D)	40.6%
4. Finding financial resources	33.5%
5. Business management	23.5%
6. Obtaining materials	15.9%

Source: Sternberg (1990).

studies of firms which had had no public support for innovation.

Therefore, the most important location factors when setting up the firm, i.e., the reason why the firms located in one region and not in another, were those which enabled them to exploit their situation to the fullest (Table VIII), including personal motives, low industrial conflict, image, etc. An outstanding location factor is the presence of qualified personnel in the area, particularly in view of the tendency of the technical professions to migrate to other regions (mainly Madrid and Catalonia) where R&D and HT activities are concentrated.

Table IX shows that the most important location factors in other countries are similar to those given by the surveyed firms, the main factors being the presence of qualified labour, and the area's level of business development. Most of these factors are the basis for development HT complexes such as Cambridge in the UK or Route 128 in the US. In contrast, other factors may differ depending on the HT complex in question. For example, in Silicon Valley, HT firms have little interaction with the university (Oakey, 1984), whereas in the Edinburgh area Heriot-Watt university has been the main source of development and attraction for small HT firms. The "quality of life" in the area is another ambivalent factor, since although the qualified personnel of HT firms prefer urban areas with health services, amenities and educational facilities, the increase in labour and housing costs in the San Francisco area has led several HT firms to relocate (Malecki, 1987).

Therefore, there are location factors which take on more importance as the firm develops. For example, in the surveyed firms, some of the factors which were avoided in the beginning were later viewed more positively, although less than 25% of the firms would take these factors into account now (Table X). These results reflect the different problems the firms have experienced in their development, such as lack of qualified personnel and problems with suppliers, which are now appearing in the surveyed firms. For example, almost a quarter of the firms cited as a negative factor the lower amount of public subsidies available in Aragon compared with other adjoining regions, although only 11% of the surveyed firms had considered this factor to be important when they set up in the region.

A survey performed in 1988 among the 60 most innovative firms in Aragon (Martínez and Navarro, 1989), which included HT firms, revealed

TABLE VIII
Location factors considered to be very important or important by HT firms installing in Aragon (percentage of firms)

Location factor	Very important	Important
1. Personal reasons	44.4%	22.2%
2. Qualified personnel in the area	25.9%	44.4%
3. Ease of communications	18.5%	59.2%
4. Low industrial conflict	18.5%	44.4%
5. Prosperity in the region	18.5%	44.4%
6. Image	14.8%	37.0%
7. Presence of Universities and Research centres	11.1%	51.8%
8. Proximity to clients	11.1%	11.1%
9. Proximity to a large city	7.4%	48.1%
10. Low installation costs	7.4%	63.0%

TABLE IX
The four location factors considered to be most important by HT firms in the US, Canada and Scotland

Country	Location factor
United States	— Qualified labour
	— Labour costs
	— Taxes
	— Universities
Canada	— Business activity in the area
	— Founder lives in the area
	— Easy access to markets
	— Qualified labour
Scotland	— Proximity to clients and markets
	— Building and land costs
	— Qualified labour
	— Labour costs

Source: Premus (1982), Christy and Ironside (1987), and Haug (1986), respectively.

TABLE X
Percentage of Aragonese HT firms who believe they did not give sufficient importance to the above factors when setting up, and who would give them more important now

Location factor	% of firms
Qualified personnel in the area	27.0%
Proximity to suppliers	22.3%
Public aid	22.2%
Proximity to clients	18.5%
Low industrial conflict	18.5%
Ease of communications	14.8%
Existence of similar firms in the area	11.1%

the main barriers to innovation in Aragonese firms (Table XI). The two greatest barriers were lack of medium and long-term planning, and the difficulty in finding qualified staff and firms to hire or subcontract, respectively.

The finance used to set up these firms did not differ essentially from the used by other firms with a lower technological level. Table XII shows that more than half the firms were initially financed by the contributions of capitalist partners and with the savings of the founders and their families. In contrast with other regions with more HT activities, public or private venture capital was not used. Since only a tenth of the firms had considered the need for finance to be an essential factor when locating in Aragon, it can be deduced that the lack of venture capital was not an important barrier to the rest of the firms. On the other hand, the source of finance to be used by these firms for their expansion in the short term was self-financing in 44.44% of cases, and borrowing (37.03%).

Therefore, no HT firms were formed with support from the national or regional government, no venture capital was available for these firms, no subsidiary HT plants of multinational firms or firms from other regions were established in Aragon, and there were no university spin-offs. These results suggest that Aragon should be considered more as a sectorial model of endogenous HT development, rather than a model of regional development, in the same way as Giaoutzi (1990) argued for the case of Greece. This sectorial

TABLE XI
Factors which hindered innovation in Aragonese industry

Type of barrier	Index[a]
Lack of medium and long term planning	2.80
Lack of financial resources	2.73
Lack of suitable scientific and technical personnel	2.36
Uncertainty in the commercial appraisal of the idea	2.27
Inability to detect demand in the market	2.23
Lack of external stimuli	2.12
Client's reluctance to adopt the innovation	2.02
Difficulties in obtaining the necessary technological information	1.93
Fear of excessive risk	1.86
Lack of information about financial aid	1.85
Difficulties in interpreting the available technological information	1.67
Low motivation on the part of management	1.66

[a] Scale from 1 (Not important) to 4 (Very important).
Source: Martinez and Navarro (1989).

TABLE XII
Sources of finance used by HT firms in Aragon

Financial source	% of firms
Capitalist partners	54.3%
Founder's and family's savings	25.7%
Private loans	11.4%
Public aid	8.6%

model implies that HT firms and industries initially arose and developed as an extension of the existing traditional industries, and independently of their regional location. Thus, for example, the electronics and instrumentation firms in Aragon have arisen indirectly from electrical equipment and metal transformation firms. Twenty per cent of these HT firms evolved and diversified from electrical and metal firms when they began to manufacture HT products in the middle 1970s. Later the HT products replaced completely the mature products and the firms became "high-tech".

Given that the percentage of business spin-offs is small, the small HT firms in the electronics and instrumentation sector did not arise from other existing HT firms, but were mainly formed in the 1970s by people in the region with technical training and experience in the electromechanical industries besides the HT firms which evolved from existing manufacturing firms. The technological content of these firms' products was generally in the middle-low range of HT activity. It was not until the 1980s that the influence of the recently established Engineering School in Zaragoza began to be felt, and some of its graduates participated in the process of creating HT firms or joined existing ones. Thus, one explanation for the endogenous of this HT industry in Aragon is the presence of certain industries in which the HT firms' founders were trained.

D. *Linkages of HT firms*

An analysis of the spatial relationships of the surveyed firms reveals that they are not very closely linked with the overall economic fibre of the region. Table XIII shows that Aragon is not an important supplier of raw materials nor is it an important market for its HT firms. This is consistent with other studies. For example, Gripaios *et al.* (1989) found that HT firms in the peripheral region of Plymouth bought and sold little in the local area, and complained of the lack of local suppliers due to the small size of the HT industry in the area. Besides that, Hoare (1985) argues that the importance of regional input-output linkages in agglomeration processes has decreased over time and some empirical studies (Hagey and Malecki, 1986) have shown them to be weaker than stated in early studies.

TABLE XIII
Percentage distribution of sales and purchases by Aragonese HT firms

	Purchases	Sales
Aragon	20	30
Rest of Spain	72	65
Abroad	8	5

It is also noteworthy that the HT firms have a small foreign market, smaller in fact that the average for Aragonese industry as a whole. The main destination for their sales is the rest of Spain, mainly Catalonia, Madrid, Valencia and the Basque Country, i.e., the central regions adjoining Aragon, and which are equidistant from Zaragoza, which is where Aragon's HT firms are located.

Nevertheless, this dependence does not mean that these firms should be considered as mere subcontractors or dependent suppliers of firms in the central regions. Of the surveyed firms, 78% make products which they sell themselves like automation equipments or autogiros, and in the remaining 22%, the main component of their order books was special designs like computer software for production management. The small size of the HT market in Aragon is the main reason for the low regional economic relation between HT firms, but the surveyed firms made their own designs and product innovations and they do not work as subcontractors. The Aragonese HT firms usually find their customers through marketing activities like advertisement in technical magazines or business visits to firms. There are also HT firms which work as engineering firms because they can develop an automation plant project besides manufacturing the necessary equipment. For example one of the Aragonese HT firms is a robot supplier firm in Zaragoza but 77.61% of robots which were working in the spanish industry in 1990 were located in firms of adjoining regions so the market for this and other HT products is inevitably outside Aragon.

Aragon's HT industry is concentrated in the city of Zaragoza, from which it has easy access to the markets from which its supplies come and to which its products go. The traditional theory on

the location of HT industry states that these activities are highly concentrated to take advantage of labour and raw materials. Nevertheless, Oakey and Cooper (1989) note a new possible tendency of HT firms towards peripheral regions, provided that the economic conditions do not jeopardise the survival of HT firms after their establishment. These conditions (universities, communications, etc.) have been promoted during the 80s by the creation of Technology Parks in many European regions, but no endogenous HT sector has arisen in these Parks. The case of Aragon reveals that these concentrations of HT arise when two conditions are met:

(1) the firm's founder has strong links with the peripheral region where the firm is established, and accepts the restrictions on personnel and industrial services in the area;
(2) the firm's type of production is economically viable in the region.

Both these conditions are met in the HT firms surveyed, given that their founders are from the area, and the technological level of their products does not require agglomeration with other HT firms. This agglomeration, which has been so fruitful in HT complexes such as Silicon Valley, permits the informal circulation of information, and the contacts and exchanges which are vital for cutting-edge R&D activities. When technological requirements are much lower, the need for information is commensurately lower. In the sample analysed here, the firm works to a great extent with large outside firms, to which it sells intermediate components.

This type of product does not require such complex information systems as those required to produce high technology consumer goods, and this enables these firms to locate in areas which are distant from existing R&D complexes. It is then necessary that the distance from the markets should not be an economic disadvantage. In HT products such as electronics and instrumentation, with a high added value and low unit weight, transport costs are not normally a barrier or a competitive advantage, so that their manufacturers are free to locate in the periphery. The firms surveyed in Aragon meet these requirements, and the fact that they are equidistant from the four adjoining central regions (Catalonia, Madrid, Valencia and the Basque Country) gives them rapid access (less than 5 hours by road and rail, and less than one hour by plane) to 80% of Spain's HT market.

In their analysis of industry in Israel, Bar-El and Felsenstein (1989) suggest that the variable used to define the technological level of industries affects the geographical distribution of HT industries. In particular, the nature of the product, and the industry's spatial relations have not been a serious obstacle to the development of sophisticated industry in peripheral regions of Israel. At a similar level of R&D, an industry requiring very qualified staff tends to concentrate in central regions, whereas one which uses advanced manufacturing technologies more intensively tends to spread out towards peripheral regions in search of other economic advantages. As with the peripheral regions of Israel, the HT industry analysed in Aragon is less intensive in highly qualified personnel than the industry in the central regions (Gamella, 1988), and is located in more advanced stages of the sector's life cycle.

Finally, the relations between HT firms and the university can be said to be slight. Only 22% of the surveyed firms had performed R&D projects in collaboration with the university, although this figure is greater than that for Aragonese industry between 1982 and 1989, which was 5.8%. Several of the surveyed firms complained of the difficulties they had found in the early 1980s in establishing collaboration with the university, principally due to the lack of university personnel to work on these R&D projects. The foundation of the Engineering School has partly solved this problem, and proof of this is the fact that 55.3% of the R&D contracts between industry and the university in Aragon were signed with this school.

IV. The public sector and high technology in peripheral regions

Given the positive effect of technology and innovation on a region's economic development (Harrison and Hart, 1987), national technology policies have progressively included a regional dimension and, in turn, regional development policies have gradually included a technological dimension. Thus, during the 1980s, local and regional government has used different instru-

ments to promote technology (Table XIV). One of these instruments' common objectives is to stimulate innovation at a regional level by improving the technological level of small industrial firms and promoting the development of small HT firms (Oakey *et al.*, 1988).

TABLE XIV
Public instruments for regional technological (RTD) promotion

RTD Mechanism
Technological universities
Public R&D centres
Technology Parks
Innovation Centres
Offices for the Transfer of Research Results
Technical and business information centres
University-business relations centres
Training programmes for innovators
Programs for mobility and exchange of research personnel
Technological cooperation networks
Fiscal and financial incentives for R&D projects
Supply of venture capital
Public procurement

The promotion of high technology is one of the priorities of technology policy. It is government's responsibility to choose the instruments which are most appropriate to each region. Because of their lower supply of qualified personnel, R&D centres, etc., peripheral regions require more intensive public support than central regions, which already have more technological dynamism. On the other hand, however, in peripheral regions the opportunity cost of promotion resources for HT activities is much higher because — as the case of Aragon reveals — HT firms make up such a small percentage of the region's production, and they have more relations with the outside economy than with the region's economy. Furthermore, in peripheral regions there may be more divergence between public R&D centres and HT firms because of the small size of the HT industry. Local firms cannot exploit R&D centres to the full, and the personnel working or being trained in such centres tend to migrate to central regions where there are more opportunities.

Therefore, peripheral regions must find a difficult compromise between improving, the technology of their industrial base and promoting new technology activities. Furthermore, there is more empirical evidence of the application of certain technology promotion instruments in central regions than in peripheral regions. For example, Technology Parks arose initially in prosperous regions, or in developed regions suffering from industrial decline, and only after their effects were observed was it proposed to use them in peripheral regions. Although one useful function of Technology Parks is to attract HT companies which are leaders in their activity, which will in turn attract other firms, the firms by themselves are not capable of developing HT complexes, and the Park may fail if certain preconditions are not met; peripheral regions do not normally meet these conditions (Martínez, 1987). Table XV contains examples of different mechanisms which generate and maintain HT complexes.

Aragon's experience shows that its regional technology policy is one of improving the technology of the region's industry, but it has not yet given specific support to HT industry. The regional government's action has been directed to the diffusion among the region's firms of national and EEC technology programmes so as to increase their participation in such programmes. In 1984, the *Instituto Tecnológico de Aragon* (Technological Institute of Aragon — ITA) was set up to promote the application and development of new technology among the region's firms. Although the number of R&D projects performed by the ITA has increased progressively, between 25 and 35% of these projects have been financed by firms from other regions.

In Aragon there are three types of direct public aid to private R&D. Since 1985, soft loans have been available for R&D projects in certain areas of technology; since 1988, there have been grants to cover part of the cost of specific R&D projects, and since 1987 the interest rate on loans to any R&D project has been subsidised to the extent of 5 percentage points. The first two measures are provided by the central government, and the third by local government.

Table XVI summarises the 168 applications made and the 82 granted in the period 1985—1989. The most popular instrument, in numerical terms is the subsidised interest rate, and in

TABLE XV
Mechanisms leading to the establishment of a HT complex

Mechanism	High Technology Complex[a]
Origin	
Locations through government decisions	Sophia Antipolis (France)
Attraction through government incentives	Silicon Glen (United Kingdom)
Attraction through the image of the area	Austin (United States)
Attraction through local demand for HT products	Paris Sur (France)
Internal spin-off	
from knowledge centres	Cambridge (United Kingdom)
from local firms	Route 128 (United States)
High rate of internal firm creation	
local socio-professional adapted structure	Aix-en-Provence (France)
local profit opportunities	Silicon Valley (United States)
Operation and growth	
Local customers	Bristol (United Kingdom)
Local suppliers	Milan (Italy)
Sub-contracting on a local basis	Silicon Valley
Local inter-firm co-operation	San Antonio (United States)
Local scientific/technical links	Tsukuba (Japan)

[a] The examples are illustrative only since the characteristics of HT complexes are not unique.
Source: Aydalot and Keeble (1988).

monetary terms it is the loans for R&D projects. Overall, public aid covered 7.3% of Aragonese industry's R&D spending in 1989, compared with 9.4% in 1986 (Table XVII). This fall in the percentage of R&D financed out of public funds is due to the fact that during these years of economic growth, industrial R&D has increased in real terms much more than public subsidies to R&D.

TABLE XVI
Public funding of R&D projects in industrial firms in Aragon

	Total no. firms	No. small firms	Thousand Pesetas	% funding small firms
1985	14	6	785700	11.8
1986	3	3	164750	100.0
1987	17	12	35956	12.9
1988	19	11	250066	20.6
1989	10	5	691772	3.2
1985—1989[a]	48	34	1718320	18.0

[a] The number of firms which were granted public funding for their R&D projects in the period 1985—1989 does not coincide with the sum of the individual years because some firms appear in several years. Total funding for the period 1985—1989 is expressed is constant 1985 pesetas.

The three industries with the highest percentage of firms applying for aid with R&D projects are Domestic appliances (67%), Automobiles and other transportation material (50%), and Electrical and electronic machinery and equipment (38%). The average number of Aragonese firms receiving public aid for R&D was between 10 and 20 in the period between 1985 and 1989. All the firms receiving aid, except one, are small firms, but the impact of these subsidies on innovation in Aragonese small firms has been small. For example, in 1989 in Aragon there were 6,218 manufacturing firms, of which 5,975 had less than

TABLE XVII
Public sector participation in funding industrial R&D in Aragon

	1986	1989
R&D in Aragonese industry (million pesetas)	1746.7	9524.0
Public funding of Aragonese industrial R&D (million pesetas)	164.7	691.7
Percentage of industrial R&D funded by the public sector	9.4	7.3

50 employees, but only 15 firms applied for aid for R&D, and only 10 were successful. This means that less than 1% of Aragon's industrial firms requested aid between 1985 and 1989, which is an extremely low figure.

This figure is higher in the HT sector since 15% of Aragon's HT firms applied for R&D aid. This difference is due basically to the greater technological intensity of HT firms, and to more active monitoring by the regional government. Nevertheless, in terms of the finance actually granted, HT firms received only 8% of the total in the period 1985—1989, which is slightly higher than the employment in HT industries as a percentage of Aragonese industry as a whole.

Medium-sized and large firms received 85% of total finance for R&D given to Aragonese industry between 1985 and 1989. As a result, finance for R&D projects allocated to small firms is too small because 96.1% of Aragon's industrial firms, and 92.9% of its HT firms are small. Despite the fact that the average finance received by firms has increased slightly in real terms, the number of firms being granted such aid has not varied significantly except for the year 1986.

Therefore, in Aragon, firms have basically used their own resources to finance R&D projects. Public funding does not appear to have helped expand technological innovation in Aragonese industry in general, and its HT industry in particular. In view of the low and practically constant number of firms using public aid for R&D and the low proportion of such finance going to R&D in small firms, it can be said that the R&D projects carried out by Aragonese industry would not have been substantially different if such aid had not existed. The trend has been to concentrate aid for R&D in larger firms. The reduced innovative capacity of existing firms and the type of products made by Aragonese HT firms have not stimulated the participation of small firms in public programmes of support for R&D.

The focus of these three grants was on product innovation. Besides there was another grant programme in Aragon in 1988 which consisted of subsidising the acquisition by small and medium-sized firms of numerically controlled machine tools (NCMT), with the condition that it was the first machine of its type to be installed in the firm and that it should be a machine produced by spanish manufacturers. Success for this programme was such that the limited number of goal had to be increased from 35 to 47 firms that year. The effectiveness of the programme allowed decisions regarding the adoption of NCMTs to be taken more quickly, also had an "imitation effect" on the other firms in the region and led to the introduction of more sophisticated technologies in smaller firms than would have been the case in the absence of public assistance. The Engineering School of Zaragoza have developed advanced software for the NCMTs introduced in Aragonese firms since then and even one CAD software company has been established for more advanced technologies like CAD/CAM equipment introduced after that. As these grants for process innovations have been more popular among Aragonese firms that grants for product innovations, it could be a more suitable mechanism for peripheral regions to update first the technologies adopted by firms in the region and later to stimulate R&D projects concerning those technologies in regional public research centres and HT firms.

As in many peripheral areas the public policy in Aragon must fight a little awareness of new technologies and lack of understanding of innovation in Aragonese small and medium-sized manufacturing firms. This is a long term battle and it is difficult to find the mechanisms which are best for particular peripheral regions. Sometimes those schemes which have diffused most rapidly have been the ones which have met least institutional resistance. For example the institutional environment in Aragon has greatly hindered the development of linkages between industry and university. In fact the main contractor within the local university between 1985 and 1989 has been the regional government. Besides 85% of cooperative R&D projects between industry and university in that same period have been performed by the bigger Aragonese companies. Changes in the institutional environment around both university and industry — more flexible mobility of personnel, less bureaucratization for contracting — have increased the cooperative contracts in Aragon from 75 million pesetas in 1986 to 261 million pesetas in 1989. The Government Industrial Promotion Service and the Technology Transfer Point in the university have continuously in-

creased their efforts to overcome companies' resistance to innovate and cooperate with the university through conferences, information campaigns and direct advisory assistant to the firms. The linkage between university and HT industry in Aragon has been very small so far as it was mentioned in the previous chapter.

In the capital of Aragon a relatively dense network exists, consisting among others of the University including the Technology Transfer Point, the Technological Institute of Aragon, some private training centres, the Government Industrial Promotion Service and the Industrial Development Company. However the number of HT firms created through the network has been very small: one or two firms each year since 1985. Although the network has improved the performance of other industries there has not been a close coordination and support for the materialization of HT initiatives. The network should play a more active role in the identification and utilisation of regional potentials which otherwise would insufficiently stimulate regional economic development. It seems that this active role will soon be played by the Business Innovation Centre (BIC) created in Zaragoza in 1991 and later by a Technology Park. Its objective is to provide temporally very cheap services and business space for individual innovators and very small high technology based firms in areas like microelectronics, software or precision engineering. The BIC will coordinate and integrate mechanisms already existing in the network and establish new ones in order to create HT companies able to compete in the marketplace after an "incubation" period in the BIC. So far a distinct public intervention for HT firms has not existed in Aragon. For example, the Government Industrial Promotion Service has assisted firms and evaluated the technological and financial viability of some of their projects but without a distinct focus on HT firms. Synergistic effects from combinations of mechanisms can be crucial to the success of public support for new HT firm formation. This support will be effective if it combines incubator premises, finance and demand stimulation. The evidence of other regions (Goddard *et al.*, 1987) suggest that the most successful initiatives, both technology parks and innovation centres, are in those areas where entrepreneurship is assisted and where public policy provides comprehensive support.

State owned utilities may also be able to play a role in peripheral regions. As major purchases of equipment and services of various technologies and technological intensity they may be able to trade with a wide range of firms and thus be more able to buy products from HT firms in peripheral regions. In Aragon a regional electricity state owned provider has established R&D contracts with the local university and some HT firms providing a high technology activity within the region.

Inward investment has not been taken into account in Aragon mainly because HT multinational plants have been attracted by other adjoining central regions where more technical and services infrastructure is available. Nevertheless branch plants are not dependent on their local environment for these inputs but rather are provided with resources via corporate contacts and linkages. For example, McDermott (1970) in a study of Scottish electronics enterprises found over 80% of the externally controlled enterprises surveyed were dependent on corporate technical support and direction. An inward investment strategy has certain potential benefits for peripheral regions — for example, job opportunities for local scientists and technicians, and components supply by local firms — but those regions likely to benefit most are firstly those which were amongst the first to do so, and secondly, those peripheral regions which have a relative science and technology base. As the availability of HT inward investment is always very small relative to the requirements of peripheral regions, there are only going to be a few regions which can benefit by adopting such a strategy. Regional and local governments in Aragon did decide not to allocate their scarce resources to beat the adjoining central regions but instead to create a technological base in the 1980s. Thus the Engineering School of Zaragoza has produced over 100 engineers each year since it was created in the late 1970s and although 40% of them have found their first job in big companies located in the adjoining central regions like Catalonia or Madrid they have come back after four or five years to settle down at small and medium-sized Aragonese firms with the

know-how and experience that they got outside the region. Besides Aragon has developed the network and technology infrastructure and HT industry mentioned in the paper. Nowadays the Aragonese regional and local governments are beginning to use these factors to attract foreign HT investment and so far two japanese electronics companies, one italian pharmaceutical company and one french computer company are going to set up branch plants in Aragon in 1991. In addition to benefit from location advantages — a new opened highway links Zaragoza to the capital of Spain and another one will link Zaragoza to France in a short term — the firms will create 800 qualified jobs and may help retain technical personnel trained in the region.

Public Research Establishments (PREs) like the Technological Institute of Aragon were created in order to rise the technology level of regional firms. However by orienting themselves exclusively towards local industry PREs in peripheral regions may not necessarily be doing the best for their own internal needs and goals. They may have to forego contracts with HT firms outside the region to avoid losing the ability to generate their own innovations if local firms have a mature technology which does not need the applied research and development projects carried out at PREs. Thus a certain technological mismatch or technology outflow from peripheral regions is inevitable in a short-term meanwhile the existing high education facilities settle into the area and their personnel and graduates establish a network of research and training linkages within local industry. For example the Technological Institute of Aragon has performed a slightly decreasing number of R&D projects for firms from other regions and has focused more on local industry after the public support has risen the technology level of some local firms — by R&D and new technologies acquisition grants — and the qualified manpower from Aragonese high education facilities have improved the management and production and innovation techniques used by local industry.

V. Conclusion

This paper reveals the difficulty of endogenous development of HT industry in peripheral regions. The case of Aragon reveals the low economic and technological relations between HT firms and the region's industry, and the dependence of HT small firms which have developed in the region on the adjoining central regions for their purchases and sales. Nevertheless, the paper also reveals that endogenous development of HT firms in peripheral regions is possible without public sector aid or foreign investment, provided certain favourable location conditions are met. Due to the proximity of, and good communications with, adjoining central regions, HT firms can arise when their production does not require economies of HT agglomeration.

Note

[1] There are three other industries in Aragon — mining, printing and basic chemicals — that partially apply to the definition given for a HT industry. They devote more resources to R&D but employ a lower share of qualified personnel than the overall average for manufacturing industry. Therefore they have not been taken into account for this study.

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