INDUSTRIAL LOCATION OF INNOVATIVE ACTIVITIES AND TECHNO-INDUSTRIAL CLUSTERS: A STRUCTURALIST APPROACH TO NATIONAL INNOVATION SYSTEMS

Stéphane LALLICH* **and Christian LE BAS****

Abstract – *In this paper we suggest a description of National Innovation Systems (NIS) from a structuralist point of view. Two NISs are investigated (French and Italian) with patent data broken down into two dimensions: the industrial sectors which produce them and the technological fields in which the applications belong. Such a matrix provides a map of technological activities. The main results of our analysis are: the distribution of technological activities by industrial sector, the distribution of patents by technological field and the industrial concentration of technological knowledge are similar. Nevertheless, the technological concentration of industrial sectors are very different. NIS effects occur with each country organising its sectoral technological variety in a specific manner. A second body of results concerns techno-industrial "clusters". Three large groups emerge from the two NISs (chemical, electronics, mechanical equipment). They differ in terms of size, form and complexity.*

Key-words – PATENTS, TECHNOLOGICAL ACTIVITIES, INDUSTRIAL SECTORS, TECHNOLOGICAL KNOWLEDGE, LOCALISATION OF INNOVATIONS.

JEL Classification: L16, L24, L52.

A first draft of this paper was presented at AEA Conference "Econométrie de l'Innovation: le brevet", Luxembourg, 28-29 November 1996. We wish to thank Daniele Archibugi and Pari Patel for valuable comments. The first was written with the collaboration of Sophie Bergeron.

* ERIC, Université Lyon 2, 5 avenue Pierre Mendès France, 69676 BRON Cedex.

** Institut des Sciences de l'Homme, 14, avenue Berthelot, 69363 LYON Cedex 07, mél: lebas@univ-lyon2.fr

1. A STRUCTURALIST APPROACH TO NATIONAL INNOVATION SYSTEMS

By bringing to the fore economic, social and institutional specificities of each country, research on national innovation systems (NIS) has allowed a greater understanding of technology creation mechanisms, direction and pace of technical progress, and "technological advantages" particular to each country. This approach is based on two sets of hypotheses (Lundvall, 1992). Firstly, that the fundamental resource of an economy is *knowledge* (the Knowledge-based Economy). Secondly, learning, which is regarded as an interactive phenomenon, forms the central process which largely determines economic "performance". Technological creation is largely collective, or more globally innovation is a social process. Within the National Innovation System approach there are two major views which can be distinguished:

– The "*Institutionalist*" perspective in which the institutional and cultural context are explicitly taken into consideration. More precisely, it is supposed that historical processes, education systems, actions of governments, and incentive systems for basic and applied research determine the direction and extent of accumulated technical progress. This view is largely dominant in two key works: Lundvall (1992) and Nelson (1993). It emphasises institutional mechanisms, relationships between firms (technological co-operation, "user-producer relations"), relationships between firms and research centres, universities, and networks of economic players.

– The "*Structuralist*" perspective, which is entirely complementary to the above, focuses on the understanding of technological creation and knowledge exchange mechanisms from the starting point of the *industrial structure* of the national economy. The Structuralist perspective is the basis of a number of important economic theories: input-output models, growth pole theory (Perroux, 1969), and more generally the theory of the effects of inter-industry linkages and vertically integrated systems (Pasinetti, 1965 and 1973). Rosenberg (1976 and 1982) was one of the first to notice that many of the aspects of technical progress are only visible at an intermediary (ie: neither macro nor micro) level. He was therefore also one of the first to emphasise the importance of input-output methods in reaching a better understanding of structural interdependence, though he emphasised that they only took into account part of these interdependencies, namely those related to markets.

If it is assumed that knowledge, and in particular technological knowledge, takes shape within the productive system (and that it has undeniably an institutional content), analysis of relationships between the production or the diffusion of knowledge and industrial sectors appears fundamental for a number of reasons:

– Firstly, it defines the nature of industrial structures, notably the technological specificities of each industry, and the type of technological interactions which take place across sectors.

– Secondly, it clarifies the context of technological production or diffusion: it identifies the economic players (firms or industries) which are at the origin of the production/diffusion of knowledge.

– Finally, it plays a major part in the search for the determinants of NIS "performance", the latter being defined as "the efficiency of the production, diffusion and use of industrially exploitable technological knowledge" (Lundvall, 1992).

The implications of such an approach can now be demonstrated. Let us suppose we have information on the number of innovations realised by a country's i industrial sectors (i = 1, 2,…, n). Furthermore, let us suppose that we have available information about other characteristics of these innovations such as:

1. The industrial sector k (k = 1, 2,…, n) in which the innovation will be used.
2. The technological field j in which there is a significant advance (j = 1, 2,…, p) (it is supposed that an innovation is assigned without any ambiguity to one and only one technological field).

We are then to obtain a figure in 3 dimensions (I_{nnp}) which give a picture of the NIS.

By connecting the originating sector with the destination sector, a square matrix of inter-sectoral technology flows (I_{nn}) is obtained. This allows the appraisal of the way innovations realised in certain sectors co-determine the productivity of others. It also measures the speed of inter-sectoral diffusion of an innovation, gives the sectors a typology (diffuser or dependant) and helps to evaluate the social returns of R&D. Bresson and al. (1994), for example, showed that in the case of Italy, the structure of such an innovation matrix has similarities with a matrix of supply coefficients, but not with a capital goods matrix. This nevertheless calls for technology flows to be thought of as being closely related to buyer-seller relationships (except for capital goods). This approach to inter-sectoral technology flows describes "in its own particular way" the structure of a NIS.

The rectangular matrix I_{np} provides us with another picture of the national innovation system. In a knowledge based economy I_{np} contains relevant information about the technological activities of sectors and the type of knowledge used by each industry to produce innovations. The accumulation of technological knowledge which takes place through R&D activities, design or production (learning by doing), is the determining factor of technical progress and endogenous growth (Romer, 1991). This type of matrix in particular shows how the structuring of industrial activities directs the production of technological knowledge. It can be used to construct knowledge proximity indicators (Bergeron, Lallich and Le Bas, 1998). Industrial sectors which share identical technological knowledge are able, formally or tacitly, to exchange knowledge more easily (spillovers). It is this approach (complementary to technology flows analysis) which is developed in this paper.

We intend to study the French and Italian NIS from the point of view of the industrial structuring of their technological knowledge. The same technological indicator and the same data base will be used, namely statistics of patents granted in the United States. This is plainly a Structuralist approach in terms of the industrial production of knowledge.

Using the SPRU data base of patents granted in the United States by four countries (Germany, France, the United Kingdom and Italy), between 1969 and 1986, broken down into 33 technological fields (or categories), Malerba and Orsenigo (1995) were able to show that:

– directions of innovative activities differ significantly according to technological field, but are in fact similar in different countries (in the same technological category);

– technological performance is strongly associated with the emergence and stability of a group of innovative firms which assure consistent and continuous technological production.

This type of analysis takes into account only one dimension of the location of innovative activities: the field of technological knowledge in which the firms realise their technological investments. It is supposed, implicitly at least, that one industrial sector is associated with each technological field. The use of the U.S. Patent Office's technological classification to categorise industrial activities is permissible by way of a first approximation. A much richer and more accurate view is obtained if a second dimension of the location of innovative activities, the industrial location (the sector or industry which produced the innovation), is introduced. This would then allow the validation of the hypothesis, namely that it is factors *specific to technological knowledge and basic technologies which principally determine the tendencies of innovative activities*.

From data comparable with that used by Malerba and Orsenigo (1995), it is our intention to examine if their main conclusions:

1. remain valid for the period after 1986;
2. are still verified if the location of industrial activities is explicitly introduced.

There is a second reason for the inclusion of the industrial location of innovative activities, namely to study how types of technological knowledge within the same industry are distributed and to highlight technological-industrial clusters. Do they differ in respect to differences in industrial structures or are they identical between countries?

After having clarified the advantages and limits of the data in section 2 (statistics of patents granted in the United States), we will show where technological activities are located in section 3. Then, with the assistance of an algorithm, in section4 the technological structure of industrial sectors will be analysed.

2. THE DATA

The data used here is that of American patents (U.S. Patents Office) granted to firms located in France and Italy.

2.1. American Patents and the Measuring of Technological Activity

Following the pioneering work of Schmookler (1966), numerous economists use patent statistics as an indicator of technological activity[1]. What is meant by technological indicator is a reliable, though imperfect, measure of innovative activities which allows the understanding of the state, changes, tendencies or directions of a nation's technological effort. It's limits are well known. Firstly, not every patent gives rise to an innovation and neither is every innovation patented. Secondly, patents can't be considered as an intermediate output of R&D (Griliches, 1984). There are, in particular, large sectoral disparities in technological appropriation procedures (Freeman, 1982; Scherer, 1983) which depend both on the nature (product/process) and the intensity of the innovation. Moreover, patents are not exclusively the result of social demand and economic growth (Schmookler, 1966).

Being involved in every phase of the innovation process (Basberg, 1982), we also consider them an indicator of *technological competence* (Barré and Laville, 1994; Grandstand and others, 1997). Using the definition of Carlsson and Eliasson (1994), we define technological competence as the ability to transform technological and market opportunities into an activity or into (technological) knowledge which has the potential to be industrially exploitable. As the codified and diffused result of a largely cognitive and tacit process, a patent is in effect the result of an accumulation process and the production of technological knowledge. Since the pioneering work done by Pavitt and Soete (1980), the use of American patents[2] (in the sense of patents granted in the United States) rather than domestic ones has become standard in all economic studies devoted to technological production and accumulation. The reasons for this are simple: American patents statistics are rich in information given the rigour and homogeneity of granting procedures, and the global dimension of the American technology market. American patents are considered as better technological indicators than domestic patents because inventions of lesser commercial and technological value are supposedly eliminated (Archibugi, 1988; Basberg, 1983). Finally, the reliability of the same legislation in terms of industrial property rights

[1] K. Pavitt (1985) records three analytical approaches behind the use of patent statistics: the bibliometric analysis of citations and co-citations of patents or the study of interrelations between technological fields, the study of causative relations between the activity of patenting and productivity, and finally the one which is adopted here, the analysis of national technological activities broken down by sector of activity and/or technical field.

[2] Since the creation of the OST in France, numerous studies also focus on the European patent. The European Patents System came into effect in 1978, but has only been fully effective since 1985. Over a prolonged period, from 1979 to 1988, the U.S. Patent and Trademark Office (U.S.P.T.O.) has received the largest amount of foreign patents.

allows for international comparisons (except with the United States which possesses a domestic advantage). The fact of patenting in the United States means that firms are seeking to exploit international markets and notably the American market. *In each country there are technology specific competencies which produce a "lock-in" or inertia effect. These are embodied in distinct inter-industry specialisations from where national technological advantages originate* (Porter, 1990; Freeman, 1995). These results are consistent with the national innovation systems approach.

2.2. The Data Base of Italian and French Patents

The American patent represents a good indicator of sectoral technological competencies. The data bases examined in this paper contain more than 11,000 American patents granted to French inventors between 1985 and 1990, and close to 7,000 granted to Italian inventors between 1969 and 1984. These figures call for three observations. Firstly, it is necessary to have available a large database in terms of both the number of patents and the period over which they were granted. This is in order to lessen the problem of patent "quality" due to fluctuations in the number of patents by year caused by reasons to do with patent administration (Freeman, 1982). The patent can be used strategically as a signal aiming to fool opponents about the technological orientation of research. We regard such a use of patents as largely marginal within large, highly innovative, industrial groups. The "Law of Large Numbers" allows the importance of this phenomenon to be reduced. Secondly, there appears to be a large difference in technological production between the two countries. Over the same period of time between 1980 and 1986, the number of patents granted to France were nearly three times more than the number granted to Italy, but one third of the German total, and approximately the same as Great Britain. The technological level indicator for each country, constructed by Fagerberg (1987), is more precise than the number of patents granted in the United States by country of origin. It takes account of the fact that the propensity of a country to patent abroad depends on the size of its internal market and the importance of its external markets. This indicator is expressed as the number of patents granted to country i abroad divided by the product of the population of country i and its export rate. The technological level of France, using this indicator for the period 1980-1986, is around twice as high as that of Italy, half as much as that of Germany and equal to that of Great Britain. The same tendencies are found as before: in technological terms, of these 4 European countries, France and Great Britain hold the median position, with Germany in top position and Italy last. The third observation results from the difference in scale and time periods (1985-1990 for France, 1969-1984 for Italy) between the two data bases. There is the possibility that our comparison of the French and Italian national innovation systems could produce biased results, in the sense that it is impossible to determine if the differences and similarities of the two systems are due to a country or a time effect. Evolutionary theory throws interesting light on this point. The paradigmatic form of technological knowledge implies that firms' and sectors' innovative activities are highly selective, result oriented and cumulative (Dosi, 1988). Therefore their development isn't random, it is on the contrary constrained by firms' and industries' existing economic and technological activities. We can thus believe that sectoral technological structures in each NIS are relatively stable, notably in terms of the capacity of sectors to appropriate technological knowledge or to diversify into several different technological fields.

The two original data bases, *provided by the SPRU*, identify patenting firms and classify each patent granted in a technological field, but they provide no indication of the firm's sector of activity. The technological classification identifies groups of technical fields according to two criteria between which it is difficult to distinguish: the patent's technical function and its industrial application. Thus it defines the fields of technological knowledge, the industrial appropriation of knowledge being the sign of the acquisition of technological competencies. *The fact that a firm patents in a precise field means that it has technological knowledge in this domain and is capable of transforming its technological and market opportunities into knowledge suitable for industrial application*. Such a classification has been previously used to identify the proximity or distance between technologies (Jaffe, 1986), but has often been mistaken with sectoral classification. However there is no strict connection between these two types of data (Archibugi and al., 1987). Archibugi (1988 and 1991), in the case of Italy, and ourselves for France, have enriched the SPRU data base by finding for each of the patents, the industrial sector of the enterprise granted the patent. Globally, the French and Italian techno-industrial matrices we analyse in this paper account for respectively 82% and 76% of American patents granted to firms and institutions.[3] Having available the classifications for each patents, *by industrial sector and by technological field*, we can define the technological profile of industries, identify the nature of technological knowledge produced by sectors and techno-industrial clusters, which show the "convergence" (Rosenberg, 1976) or the "fusion" (Kodama, 1990) of technological knowledge which comes about between certain industries. We are also able to study the similarities and differences in industrial structuring of technological knowledge between the two NIS, and finally how this proximity or divergence explains the efficiency of each national innovation system[4].

3. THE INDUSTRIAL LOCATION OF TECHNOLOGICAL KNOWLEDGE

An initial synopsis of the industrial location of technological activities and knowledge can be established by identifying the technological production of each sector, the distribution of patents by field of technical knowledge, the technological concentration of industries and finally the sectoral concentration of technologies (Herfindhal index).

3.1. Technological Production and Concentration of Industrial Sectors

Over the period 1985-1990, the sectoral distribution of patents in France is

3 It wasn't possible to allocate the remaining patents to an industrial sector. Therefore were removed from the data base.

4 See Annexe for more information concerning data base.

relatively skewed: 9 of the 21 industries account for close to three quarters of total patents. These are the chemicals, energy production, telecommunications, drugs, electrical equipment, mechanical equipment, aircraft and automotive sectors. With the exception of the mechanical engineering sector, these are all the industrial sectors where the intensity of internal R&D expenditure is high. The mechanical engineering sector takes out less than half as many patents as the chemicals sector, but as many as the electrical equipment, electronics and aircraft industries. Often under-estimated in R&D statistics, this sector comes out well as a technology producing industry (Patel and Pavitt, 1994). The production of patents Italy is even *more skewed*. Eight industries are above the mean, a figure which is close to that of France, but they account for 85% of all Italian patents. Chemicals represent 14% of technological activities in France against 25% in Italy. A quarter of French sectors individually account for less than 2% of patents, whereas in Italy more than half of the industries (12 out of 21) are beneath this threshold. *Thus France has a profile which is more generalist than that of Italy*. Like France, the Italian chemicals, mechanical engineering, pharmaceutical, energy production and telecommunications sectors are those which have a high level of technological activity. The main differences are those concerning:

– office and computing equipment, and automotive industries; in Italy each one produces more than the sectoral mean, whilst this is by no means the case in France;
– automotive, electrical and electronic equipment, and aircraft sectors, whilst weak technological producers in Italy are strong in France.

The technological concentration of a sector (the opposite of technological diversity) was measured by calculating the Herfindhal index for each industry. In France 6 of the 21 industries are more concentrated than the mean (0.203). It is essentially the drugs, chemicals, telecommunications and automotive sectors that are the big patent producers. Inversely, 4 sectors which also account for a large number of patents are particularly diversified: the automotive, energy production, mechanical equipment and aircraft sectors. The mean technological concentration of sectors in Italy is slightly more than that of France. This could result from there being a little less technological diversification in this country. Nevertheless it is less asymmetric: half of the sectors are less concentrated than the mean against a third in France. Certain sectors which are large technology producers are mono-technological (chemicals, drugs, telecommunications, energy production and office and computing equipment). Others are multi-technological (the automotive or rubber and plastic products sectors are much more diversified than the Italian sectoral mean), or moderately diversified (in the case of mechanical equipment).

Table 1: Correlation between technological production and technological concentration of the industries

	French NIS	Italian NIS
Pearson Correlation	0.195	0.583
Spearman Correlation	0.033	1.158

Source: calculated by the authors.

Herfindahl Index: The Technological Concentration of Industrial Sectors and The Industrial Concentration of Technologies

Let b_{ij} be the number of patents taken out in the technological field j(f = 1,…, p) for the industrial sector i(i = 1,…, n). Let the total number of patents taken out by the sector i be b_i. The "Index of Technological Concentration of Industrial Sectors" for the sector i is given by calculating the Herfindahl index: H_i=?(bij/bi)^2 which measures the technological diversity of the sector i. By definition $0 < H_i < 1$. We have two limit cases. When $H_i=0$ the industrial sector has taken out patents in a large number technical fields, reflecting a large block of technological competencies. The sector is consequently said to be a "multi-technology" sector. When $H_i=1$ the industrial sector has taken out patents in only one field (a limit case). The sector is consequently labelled a "mono-technology" sector. For each country we have n values of H_i.We can thus calculate the correlation coefficient between n pairs of H_i (See Table 3).
We now do the same exercise for the industrial concentration of technical knowledge.

The largest differences between Italy and France are those concerning the:

– aircraft or the energy production sectors, which are 3 times more concentrated in Italy;
– mechanical equipment sector, twice as concentrated in Italy;
– automotive sector, twice as concentrated in France.

Table 1 shows the Pearson and Spearman correlation coefficients calculated between the technological production and concentration of the industries of each NIS.

It is clear that in each of the NIS, technological production of the industries is in no way linked to the degree of technological concentration. Certain industries that produce many patents are diversified in several fields of knowledge while others are mono-technological. This is to say that technological trajectories are specific to each sector (Pavitt, 1984).

3.2. The Distribution of Patents by Technological Knowledge and Sectoral Concentration of Technologies

Another indicator, traditionally used in studies dedicated to technological accumulation, concerns the quantity of patents granted in each field of technological knowledge. In France, a third of the categories are below the mean and account for around two thirds of the patents produced: these are the chemicals, drugs, instruments and mechanical equipment sectors. Inversely, transport equipment and energy production technologies, along with a highly disparate group, which includes metallurgical processes, textiles, rubber and food and beverages, account for a very small number of patents. As for the sectoral distribution of patents, their distribution by technological field is much more asymmetric in Italy than it is in France: technologies relating to chemical processes and the fabrication of chemical products account for 30.5% of patents in Italy, twice as many as in France. Only 3 of the 26 fields represent individually less than 1% of patents granted in aircraft, food, beverages and tobacco products and processes, and power plants). In Italy, 8 technologies are below this threshold. In addition to the three mentioned above there are mining and wells equipment, induced induced nuclear reactors, image and sound equipment, textile, leather and wood products, and other transport equipment.

Table 2: Correlation between the distribution of patents by technological field and the sectoral concentration of technologies

	French NIS	Italian NIS
Pearson Correlation	-0.190	0.040
Spearman Correlation	-0.350	-0.200

Source: calculated by the authors.

Concerning sectoral concentration of technologies, the data show that in France technologies that other sectors find difficult to appropriate are the induced nuclear reactors, mining and wells equipment, power plants, aircraft equipment and organic chemicals technologies. These technologies are more concentrated in a small number of industrial sectors. Inversely, mechanical equipment and instrumentation technologies are multi-sectoral, while electronic and land transport equipment technologies are moderately appropriable. Relatively similar tendencies can be found within the Italian technological production system over the period 1969-1984.

In both countries there is absolutely no linear (Pearson) or rank (Spearman) correlation between the quantity of patents granted in each knowledge field and the sectoral concentration of each technology.

3.3. Similarities and Differences between the two NIS

Finally, we can summarise the proximity or the distance between the two innovation systems in table 3.

Table 3: Dependence and Interdependence of the Two National Innovation Systems

	Characteristics of NIS	Pearson Correlation Coefficient	Spearman Correlation Coefficient	Results
1	Technological Production of Industrial Sectors	0.70	0.50	Dependence. Sector Effect
2	Technological Concentration of Industrial Sectors (or Technological Diversity of Sectors)	0.47	0.01	Independence. NIS Effect

3	Distribution of Patents by Knowledge Fields	0.82	0.73	Highly Interdependence Technology Effect
4	Industrial Concentration of Technological Knowledge	0.60	0.55	Dependence. Technology and Sector Effect

Source: calculated by the authors.

1 – The fact that sectoral technological production in the two countries is similar means that *the sector effect is more important compared to the country effect*. What is meant by sector effect is that a sector which is more innovative than another one is so in both of the countries. Here, this phenomenon is exaggerated by the fact that patents, which are used as an innovation indicator, have a sectoral bias: innovations are only effectively protected by patents in certain sectors and not at all in others.

2 – There is no correlation between the two countries in terms of technological concentration or diversity of industrial sectors. In other words, the same sector can be highly diversified from the point of view of technological activities in one country (low Herfindhal Index) and highly concentrated around one or two technological competencies in the other (high Herfindhal Index). *The sectors' technological trajectories are different in Italy and in France*. This result is perhaps dependent on the way in which the data is constructed. However it can equally be explained by a NIS effect, in other words by each country's history, by the way which the sectors appropriate activities, products and technologies, by their techno-industrial specialisation and interdependence (market and non-market relationships), and by the way that their state and R&D institutions interact, etc.

3 – Concerning the distribution of patents by knowledge field, the two countries provide pictures that are quite similar *and this despite the difference in time periods*. This is to say that there are factors which are specific to the nature and type of *knowledge* (captured here by the patent). These explain the differing propensity to patent (Scherer, 1983).

4 – The industrial concentration of technological knowledge can be presented as similar in the two countries. *The sectoral trajectories of technological knowledge are globally the same for the two innovation systems*. The appropriability effect of the technology interacts in parallel. In our opinion this reflects certain properties of the R&D process: R&D indivisibility, the critical mass effect in terms of competencies, etc., which interact in the same way in both countries. Induced nuclear reactor technology is thus practically concentrated in a single sector, whilst innovations relating to metallurgical products are much more dispersed. Here, it isn't the country effect which is in operation, but the technology production effect[5].

Finally, the most notable difference between the two NIS is that of the technological profile of the industries. It is possible that the same sector

[5] With the firms being categorised in a single sector, that of the principal activity, intra-firm diversity could explain some of the sectoral diversity.

is more or less diversified because it is more or less part of an inter-industrial network which creates technological knowledge.

In our opinion, the fact that several industries are capable of producing abundantly in the same knowledge field is a necessary condition for the existence of technological externalities across these industries. Such a phenomenon reflects the existence of a network of (potential) technological externalities or a techno-industrial cluster.

4. SUB-SYSTEMS IN NATIONAL INNOVATION SYSTEMS

4.1. The Concept of Techno-industrial Clusters

A techno-industrial cluster is made up of chains of interdependencies linking *industrial sectors* with types of *technological knowledge*, which are brought together through the principe of proximity. It is this aspect which allows them to be differentiated from the concept of *filières* which summarise the existence of linkages between different industrial sectors and which are characterised by the intensity of market relationships (buyer-seller) and linkage effects. These clusters incorporate complementary technologies (non market technological interdependencies) which, in other words, are knowledge flows that don't necessarily give rise to pecuniary transactions. These correspond with a structured set of technological externalities (notably of technological knowledge) which act as "focusing devices" (Rosenberg, 1976), and industry specific assets. The definition of a techno-industrial cluster is close to the concept of a technological system put forward by Carlsson and Stankiewicz (1991): a network of actors that interact in a technological field and a specific industrial infrastructure producing technological knowledge[6]. We think that a NIS can be "broken down" into different clusters associating industries and technical knowledge. We have constructed an algorithm which allows us to do this.

4.2. The Zig Zag Algorithm for Determining Clusters

For the entirety of the patents from the SPRU-LESA data base, the sector of the patenting enterprise was connected to the patent's technological field. This allowed us to put together a contingency table X. Row i is the technological destination of the patent granted in sector i, whilst column j corresponds with the sectoral origin of patents granted in the technological field j. From table X we can identify techno-industrial clusters.

To do this we designed Zig Zag (Lallich, 1995), an algorithm which

---

[6] Whereas B. Carlsson and R. Stankiewicz emphasise institutional dimensions, including those at an international level, we strongly emphasis here the underlying national *industrial structures*. Behind our notion of cluster stands the idea of technological proximity. Jaffee (1989) has tempted to characterise the technological position of firms while E. C. Engelmann and van Raan (1992) have made a patent-based map of technology. Here we develop a sector-based view of technological proximity. We consider two sectors are closed when they are a part of the same techno-industrial cluster.

simultaneously produces a two-way classification of sectors and technological knowledge based on the row modal link ("best technological outlet") and the column modal link ("best sectoral outlet") criteria. This was applied to the analysis of the French NIS (Bergeron, Lallich and Le Bas, 1996).

4.3. Techno-industrial Clusters and the Structuring of the French and Italian Innovation Systems

When the algorithm is applied to the two NIS 10 techno-industrial clusters appear in France and 9 in Italy (see Fig. 1 and Fig. 2). In France, these clusters account for more than 60% of patents produced. Nearly 50% of them are in three *complex* clusters:

– electronics, which account for 17.5% of patents in the techno-industrial matrix;
– chemicals (16.2%);
– mechanical and transport equipment sectors (15%).

The Zig Zag Algorithm

Let S be the set of sectors and T the set of technological fields, with Card S = n and Card T = k.

Best technological outlet criterion. With each sector i, i = 1, 2,…, n is associated a technological field j (i), j (i) XX {1, 2,…, k} which represents its most important outlet. The case x_j, j(i) corresponds with the row i of X, the flow matrix. Thus, an application c of S in T is defined which is necessarily non surjective (here where n < k), and not necessarily injective. The arrowed representation of this application c makes up a two-part flow line G_c.

Best sectoral outlet criterion. With each technological field j, j = 1, 2,…, k, is associated the sector i (j), i (j) XX {1, 2,…, n}, which is its most important outlet. The case x_i (j), j corresponds with the max. of column j of X. Thus, an application f of S in T is defined which is necessarily non injective (here where n < k), and not necessarily surjective. The arrowed representation of this application f makes up a two-part flow line G_f which has the same peaks as G_c.

Strong form. If flow lines G_c and G_f are merged, while distinguishing between the two types of lines (unbroken lines for c and broken lines for f), a two-part flow line G is obtained which has n + k lines. a pair of peaks (i, j) is linked by a maximum of 2 lines. In the case of 2 lines, these are necessarily distinct (unbroken and broken lines). Such a sector – technological field pair will be considered as the strong form of the two-part flow lines: each one is the reflection of the other in the best client-best supplier relationship that the flow line represents. The corresponding value x_{ij} of X is the maximum in row i and in its column j.

Zig Zag Algorithm. When a pair doesn't constitute a strong form, a chain of the type i1, j1, i2, j2,… is seen to appear, where j_h is the best client of i_h, whilst i_{h+1} is the best supplier of j_h. All chains are concluded by a strong form. For each sector i, i = 1, 2,…, n and for each technological field j, j = 1, 2,…, k, the chain of which it is part and its end form are investigated. The relationship R "to be associated with flow arrow G which results from the merger of flow arrows G_f and G_c.the same strong form" defines an equivalent relationship on the peaks of G as well as on the paths G S and G T. The equivalent categories modulo R are the connected parts of the flow line G. Their intersections with S and T make up the two-way classifications of S and T.

The application of this algorithm is undertaken in two steps:
– the table bringing together the nearest neighbouring chains starting from each sector and technological field is drawn up.
– these chains are used to represent the two part.

Source: Lallich (1995 and 1999).

In Italy the 9 techno-industrial clusters represent 66% of patents granted, 4 of them are complex: chemicals/drugs (38.2% of patents); mechanical equipment cluster (8.4%); electrical/electronic equipment cluster (6.4%); finally, the transport equipment cluster (4.7%).

Figure 1: French Techno-Industrial Clusters

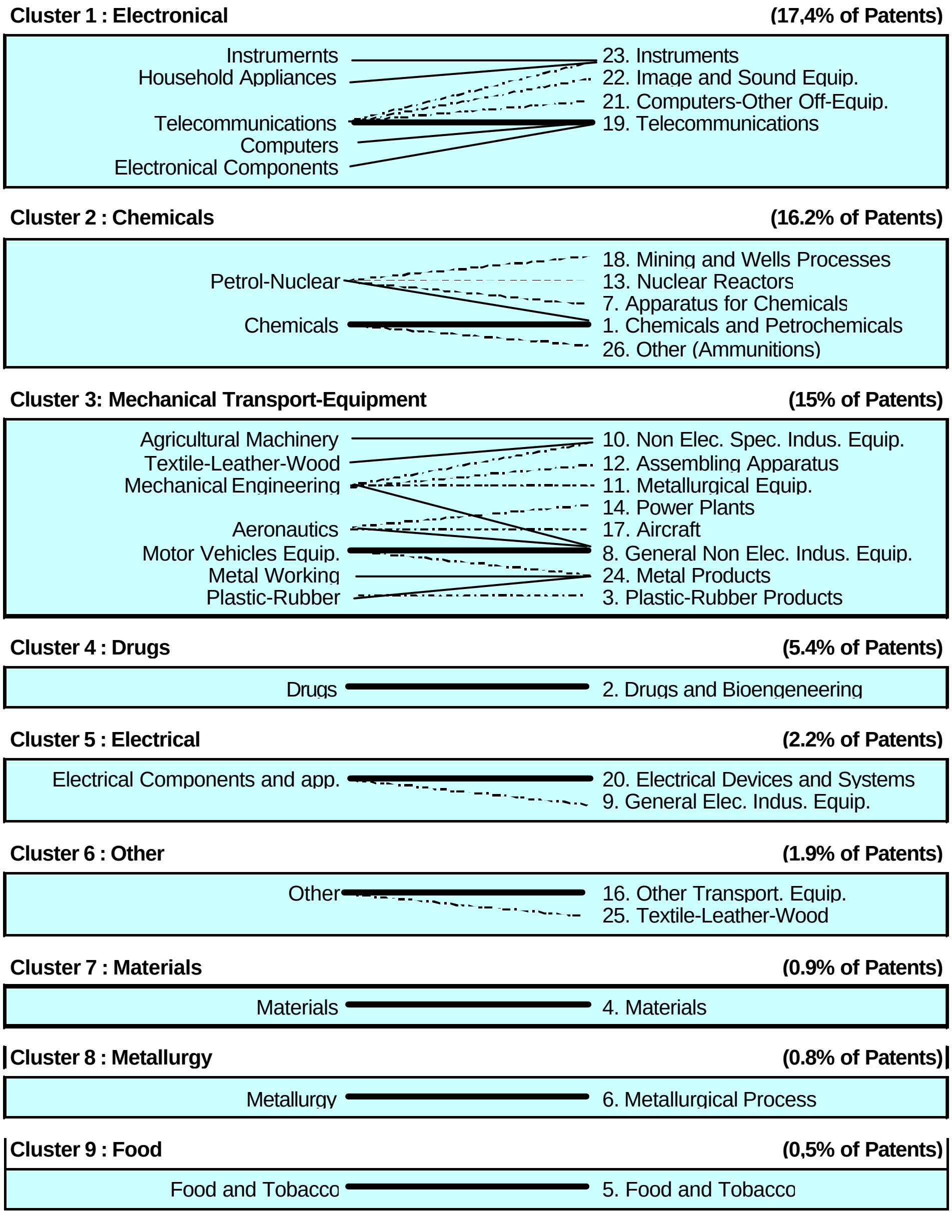
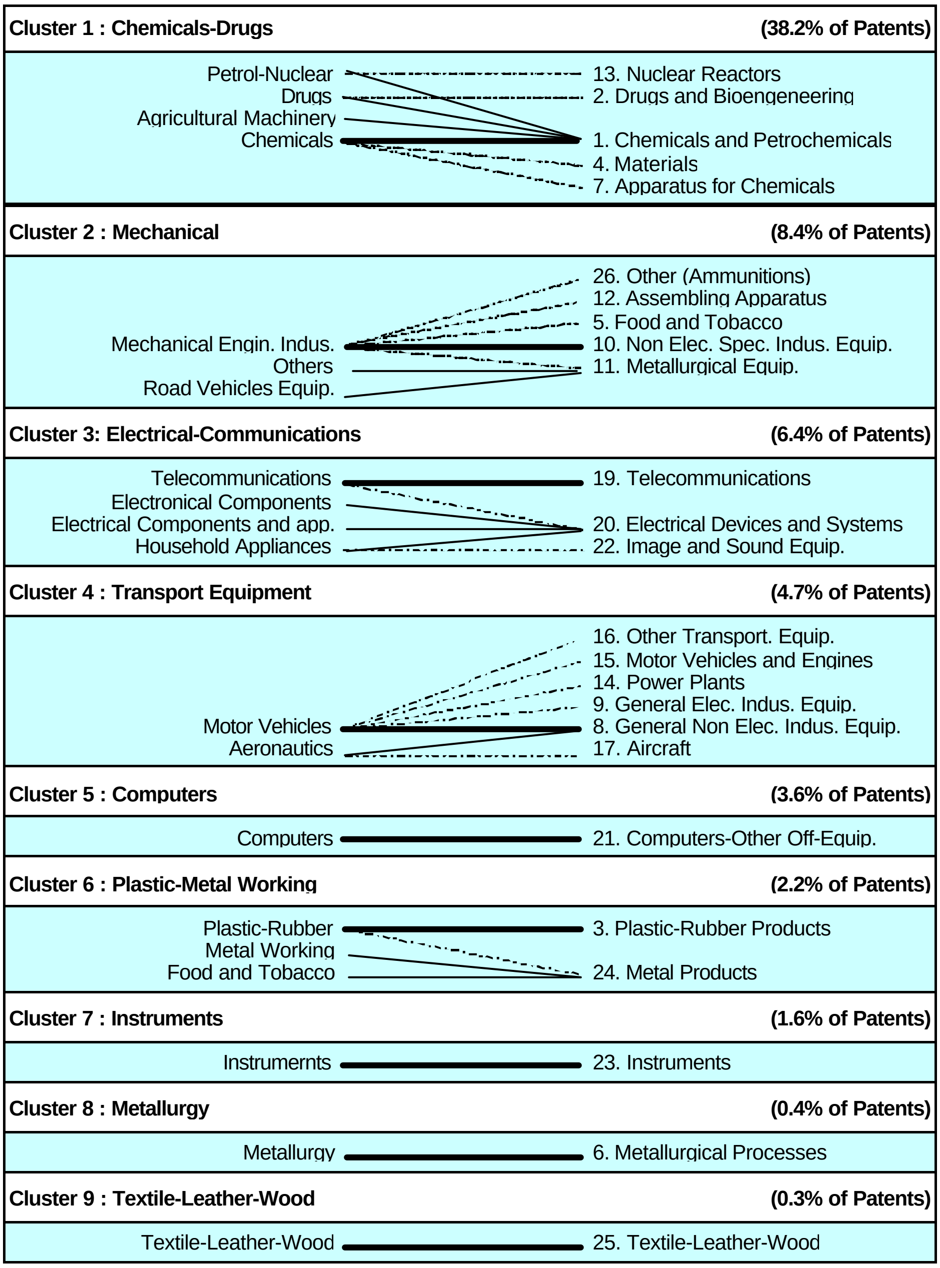


Figure 2: Italian Techno-Industrial Clusters



Simple, Complex and Composite Clusters

Each cluster is based upon a *strong pattern (heavy line)*. A strong pattern links an industrial sector with a field of technological knowledge according to two criteria, the criteria of the best technological outlet of the sector and the best sectoral supplier of knowledge. This reciprocity of industry-knowledge relationship defines the strong pattern. A cluster's outline can be limited to the strong pattern type. In this case the cluster is qualified as a *simple cluster*. It illustrates a simple reciprocal linkage between an industry and a knowledge field. The frontiers of a cluster can be larger than the simple strong pattern. *Composite* and *complex clusters* are therefore distinguished. Composite clusters are made up of one or two industries, and one or two fields of technological knowledge. A number of unilateral relationships can be added to the strong pattern based on the criterion of the row modal link or the column modal link. As for complex clusters, these are much larger than the latter.

Globally it is the same industries and fields of technological knowledge which structure the chemicals, electronic and mechanical equipment clusters. Here we find the results arrived at by empirical studies on inter-industry externalities: technology creation is concentrated in certain sectors such as chemicals, mechanical equipment and electronic products (Mohnen, 1991). Nevertheless, three main differences between the two NIS are of note. First and foremost, the clusters differ in volume. In Italy, the chemicals/drugs cluster is huge.

This is without doubt due to the fact that in Italy chemicals and drugs are linked, *which is not the case in France*. Is this be the result of the different structuring of industrial activities in France and Italy, notably in the make up of the larger groups? In France there is a simple drugs cluster: the drugs industry producing principally in its "natural" technological field, whilst in Italy the focus is on knowledge relating to the fabrication of chemical/organic chemical products. A second difference concerns the mechanical equipment/transport equipment cluster. Whilst in France this cluster is associated with the aircraft and automotive sectors, thus with a larger "transport" industry, in Italy two distinct complex clusters appear which separate the mechanical equipment and automotive/aircraft sectors. The third difference concerns electronics. In France this sector is cut off from the electrical equipment cluster, whilst in Italy both of them form a single cluster. Furthermore, the electronics cluster in the French NIS is dense in the sense that there are distinct links between scientific instruments and electronics. In the Italian NIS, on the contrary, the complex electronic/electrical equipment cluster is cut off from the simple cluster linked to office and computing equipment and from the simple cluster relating to instruments for industrial processes.

More generally, these differences in clusters, that is to say the sub-systems in the NIS can be explained by:

– a country effect, namely the composition of different industrial groups or the different structuring of industries;

– a period effect: the two NIS are being effectively studied at different moments in time. The hypothesis can be made that this represents two different moments of the same evolutionary tendency (e.g. dissociation electrical/electronic equipment and dissociation chemicals/drugs sectors)[7].

To conclude, it is clear that:

– definitions of clusters depend on sectoral and technological classifications. Their outlines thereby need to more definitely clarified. In this respect, our work must not give rise to the idea that the sub-systems in the NIS are intangible.

– a result can be found here which has already been established: Patel and Pavitt (1995) effectively found that four clusters tended to emerge, each one based on a very distinct group of competencies which were the source of new technologies: the mechanical equipment cluster, based on design and engineering, the chemicals cluster, based on R&D and fundamental chemistry research, the electrical equipment/electronic cluster based on R&D and fundamental physics research, and software which it wasn't possible to examine here with patent data. It is interesting to note that the results obtained (confirmed we believe by other studies) are produced on the basis of an algorithm which isn't founded on any a priori assumptions concerning the nature of the technologies and the specificities of the sectors.

CONCLUSION

The Structuralist analysis of NIS that we have put forward allows us to establish certain results:

– The two systems studied (French and Italian) have *highly dependent* distributions of technological activities by knowledge field. Whilst the time periods studied are different, the same tendencies of technological accumulation are at work in both of the countries. This largely results from the effectiveness of patents as a mean of protecting innovations, which varies according to technological field and not according to country.

– Industrial concentration of technological knowledge in the two countries seems quite *similar*. This results from certain properties of the R&D process, design systems in terms of critical mass and system complexity.

These phenomena have been emphasized by other studies (Pavitt and Patel, 1995; Malerba and Orsenigo, 1995).

– Technological production of sectors is quite dependent. It can be inferred from this that the sector effect is more important than the country effect: the difference between sectors within the same country is greater than the difference between the same sector in two different countries.

– Technological concentration of industrial sectors is different in the two countries. *The sectoral technological diversity characteristic of evolutionist environments isn't the same in the two countries*. Since the sector is fixed, it is

[7] Others explanations are also pertinent: the size of each national economy can drive to different specialization patterns, the kind of links between large and small firms, and so on.

a country effect which is observed here. This result has a real originality. It is linked to our main methodological contribution, namely to the joint use of 2 classifications (technological field and industrial sector). This tends to confirm (or explain) the result found by Archibugi and Pianta (1994): the sectors converge in terms of their productivity levels, but diverge in terms of their technological specialisation profiles.

– We have presented an algorithm allowing the breakdown of the NIS into "techno-industrial clusters" (several industrial sectors linked by common or communally shared technological knowledge) without a priori hypotheses about the nature of the technologies or the position of the sectors in the production system. Our results confirm the existing work on "clusters". Three large groups clearly emerge from the two NIS: chemicals, electronics and mechanical equipment (associated with transport equipment). Nevertheless, according to the country they present different configurations: in terms of size (amount of innovations realized), form (sometimes associating different sectors) and complexity (number of associated sectors or technological fields). In the final analysis, factors relating to each country's history are involved here: the way the industrial fabric is structured by firms, State Policy in respect to "national champions", etc. The importance of the three large complex clusters *is similar* in France showing its *generalist* profile. On the contrary, in Italy chemicals/drugs is the techno-industrial cluster which is very *largely dominant* and the electronics cluster regroups a smaller number of patents than the mechanical equipment cluster. Italy has therefore a more specialized (from the point of view of the production of technological knowledge) and more traditional (mechanical equipment) profile than France.

ANNEX
Information concerning the data base

SPRU has made available to the LESA data relating to patents granted by the US Patent Office, between 1985 and 1990, to France based firms and scientific and technological institutions. LESA had available the following information: the name of the company and the technological field in which the patent is granted. After correcting for errors and on the basis of the names of industrial and service sector firms, with the assistance of the INSEE Rhone-Alpes Regional Office, we identified the SIRENE (official registration number) code of each parent firm and APEN code at the NAF700 level specifying the sector to which the firm belongs. When dealing with industrial firms in which research is undertaken in a subsidiary (which appears under the title 731Z, Research and Development), the subsidiaries were allocated to the industrial sector of the patenting firm on the basis of the information relating to the subsidiary's establishments. When this was not possible, the subsidiaries concerned were not included in the analysis. The same procedure was used in the case of holdings. In total, of 14 374 patents, 95% were allocated a SIRENE code and 76% of the original patents were allocated to a *manufacturing industry*. As the NAF 700 classification was too detailed for our statistical analysis, the data was pooled. This was done by using different levels of aggregation of the NAF classification while respecting the specificity of sectors' technological profiles (S. Bergeron and alii 1996). Finally, the patents were broken down into 26 industrial sectors. Being now a matter of technological classification, we are able to use the US Patent Office 34 category classification without modification. Compared to previous work on French patents using US data (Patel and Pavitt 1990, Malerba and Orsenigo 1995), our database has three advantages: i) it covers a more recent period 1985-1990, ii) it includes all firms located in France regardless of their size and iii) it allows an analysis of technological specialization schemes at a sectoral level. In other words, *we make a clear distinction between the field of technological knowledge on the one hand, and the main industry group of the firm (industrial sector) on the other hand. Such a distinction is very important for understanding our model of clustering. This has never been done in previous studies using data concerning patents granted to French firms in the US*. The studies by Patel and Pavitt (1990) and Malherba and Orsenigo (1995) assimilate technological and industrial classification. On the other hand, this double dimension (technological field x industrial sector) was adopted by D. Archibugi (1988) for American patents granted to Italian Firms.

REFERENCES

Archibugi D., 1988, "The Inter-industry Distribution of Technological Capabilities. A Case Study in the Application of the Italian Patenting in the U.S.A.", *Technovation*, 7, 259-274.

Archibugi D., 1991, *The Sectoral Structure of Innovative Activities in Italy – Results and Methodology*, Ph. D. Thesis, University of Sussex.

Archibugi D., et al., 1987, "Innovation, recherche-développement, et dépôt de brevets : résultats de l'enquête sur la diffusion de l'innovation en Italie", *S.T.I. Revue*, 2, 141-156.

Archibugi D., Pianta M., 1994, "Aggregate Convergence and Sectoral Specialization in Innovation", *Journal of Evolutionary Economics*, 4, 17-33.

Basberg B., 1982, "Technological Change in the Norwegian Whaling Industry", *Research Policy*, 11, 163-171.

Barré R., Laville F., 1994, "La bibliométrie des brevets : une mesure de l'activité technologique", *Économie et Statistique*, n° 275-276, 71-81.

Basberg B., 1983, "Foreign Patenting in the U.S. as a Technology Indicator", *Research Policy*, 12, 227-237.

Bergeron S., Lallich S., Le Bas C., 1998, "Location of Innovating Activities, Industrial Structure and Techno-Industrial Clusters in the French Economy, 1985-1990. Evidence from US Patenting", *Research Policy*, 26, 733-751.

Carlsson B., Stankiewicz R., 1991, "On the Nature, Function and Composition of Technological Systems", *Journal of Evolutionary Economics*, 1, 93-118.

Carlsson B., Eliasson G., 1994, "The Nature and Importance of Economic Competence", *Industrial and Corporate Change*, 3(3), 687-711.

Chesnais F., 1994, *La mondialisation du capital*, Syros.

De Bresson C. and al., 1994, "Structure and Location of Innovative Activity in the Italian Economy, 1981-1985", *Economic Systems Research*, 6(2), 135-158.

Dosi G., 1988, "Sources, Procedures and Microeconomic Effects of Innovation", *Journal of Economic Literature*, 26, 1120-1171.

Fagerberg E., 1987, "A Technology Gap Approach to Why Growth Rates Differ", *Research Policy*, 16 (2-4), 87-99.

Freeman C., 1982, *The Economics of Industrial Innovation*, Pinter Publishers.

Freeman C., 1995, "The national System of Innovation in Historical Perspective", *Cambridge Journal of Economics*, Vol. 19 (1), 5-24.

Engelsmann E. C., Van Raan F.J., 1992, "A Patent-based Cartography of Technology", *Research Policy*, n° 23.

Grandstand O., Patel P., Pavitt K., 1997, "Multi-technology Corporations: Why They Have Distribuded Rather than Distinctive Core Competences", California *Management Review*, n° 39.

Griliches Z. (ed.), 1984, R&D, *Patents and Productivity*, Chicago Press.

Jaffe A.B., 1986, Technological Opportunity and Spillovers of R&D: Evidence from Firms'patents, Profits and Market Value, *American Economic Review*, 76(5), 984-1001.

Jaffe A.B., 1989, "Characterising the «Technological Position» of Firms, with Applications to Quantifying Technological Opportunity and Research Spillovers", *Research Policy*, n°18.

Kodama F., 1990, "Vers un nouveau paradigme techno-économique? Essai d'analyse empirique et quantitative", *STI Revue*, 7, 111-143.

Lallich S., 1995, "ZigZag, un algorithme du lien modal pour la recherche de deux partitions associées", *Working Paper*, LESA.

Lallich S., 1999, "ZigZag, a New Clustering Algorithm to Analyze Categorical Variable Cross Classifications Tables", in *Proceedings of the 3th European Conference on Principles and Practice of Data Mining and Knowledge Discovery*, J.M. Zytkow, J. Rauch, editors, PKDD'99, Prague, LNAI, Springer-Verlag, 398-405.

Levin R. and al., 1987, "Appropriating the Returns from Industrial Research and Development", *Brookings Papers on Economic Activity*, 3 (Special Issue), 783-831.

Lundvall B.A., 1992, National *Systems of Innovation, Towards a Theory of Innovation and Interactive Learning*, London, Pinter Publishers.

Malerba F. Orsenigo L., 1995, "Schumpeterian Patterns of Innovation", *Cambridge Journal of Economics*, 19(1), 47-66.

Mohnen P., 1991, "Survey sur les externalités technologiques", in J. De Bandt and al., *L'évaluation économique de la recherche et du changement technique*, CNRS.

Nelson R.R., 1993, *National Innovation Systems: A Comparative Analysis*, Oxford University Press.

O.S.T., 1993, *Science et technologie indicateurs* 1994, Economica.

Patel P., 1995, "Localised Production of Technology for Global Markets", *Cambridge Journal of Economics*, 19(1), 141-154.

Patel P., Pavitt K., 1990, "L'accumulation technologique en France. Ce que les statistiques de brevets tendent à montrer", *Revue d'Économie Industrielle*.

Patel P., Pavitt K., 1994, "The Continuing, Widespread (and Neglected) Importance of Improvements in Mechanical Technologies", *Research Policy*, 23, 533-545.

Patel P., Pavitt K., 1995, "Patterns of Technological Activity: Their Measurement and Interpretation", in P. Stoneman (ed.), *Handbook of the Economics of Innovation and Technological Change*, Basil Blackwell, 14-51.

Pavitt K., Soete L., 1980, "Innovative Activities and Export Shares", in Pavitt K. (ed.), *Technical Innovation and British Economic Performance*, Macmillan.

Pavitt K., 1984, "Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory", *Research Policy*, 13, 343-373.

Pavitt K., 1985, "Patent Statistics as Indicators of Innovative Activities: Possibilities and Problems", *Scientometrics*, 7(1-2), 77-99.

Perroux F., 1969, *L'économie du XX^{ème} siècle*, Paris, PUF.

Pasinetti L., 1965, "A New Theorical Approach to the Problems of Economic Growth", *Pontificae Academiae Scientiarum Scripta-Varia*, 28, Cité du Vatican, 571-696.

Pasinetti L., 1973, "The Notion of Vertical Integration in Economic Analysis", *Metroeconomica*, 25, Avril, 1-30.

Porter M., 1990, *The Competitive Advantage of Nations*, Mac Millan.

Romer P., 1991, "Progrès technique endogène", Traduction française, *Annales d'Economie et de Statistique*, 22, 1-32.

Rosenberg N., 1976, *Perspectives on Technology*, Cambridge University Press.

Rosenberg N., 1982, *Inside the Black Box,* Cambridge University Press.

Scherer F., 1983, "The Propensity to Patent", *International Journal of Industrial Organization*, 1, 107-128.

Schmookler J., 1966, *Invention and Economic Growth*, Harvard University Press.

LOCALISATION INDUSTRIELLE DES ACTIVITÉS INNOVANTES ET CLUSTERS TECHNO-INDUSTRIELS : UNE APPROCHE STRUCTURALISTE DES SYSTÈMES NATIONAUX D'INNOVATION

Résumé – *Cet article suggère de décrire les systèmes nationaux d'innovation (SNI) d'un point de vue structuraliste. Deux SNI sont considérés (français et italien) à l'aide de données de brevets distingués selon les secteurs industriels qui les produisent et les champs technologiques dans lesquels les brevets sont déposés. De là, la matrice obtenue permet de cartographier les activités technologiques. Il apparaît que la distribution des activités technologiques par secteur industriel, la distribution des brevets par champ technologique et la concentration des connaissances technologiques sont similaires dans les deux pays. La concentration technologique des secteurs est par contre très différente. Chaque pays organise de façon spécifique sa variété technologique sectorielle. S'agissant des "clusters" techno-industriels, trois grands groupes émergent (chimie, électronique, mécanique). Ils diffèrent entre les deux pays en termes de taille, de structure et de complexité.*

LOCALIZACIÓN INDUSTRIAL DE LAS ACTIVIDADES NOVADORAS Y GRUPOS TECNO-INDUSTRIALES: UNA APROXIMACIÓN ESTRUCTURALISTA DE LOS SISTEMAS NACIONALES DE INNOVACIÓN

Resumen – *Este artículo sugiere una descripción de los sistemas nacionales de innovación (SIN) de un punto de vista estructuralista. Se consideran dos SIN (francés e italiano) con datos de patentes dadas en función de los sectores industriales que les producen y los campos tecnológicos en los cuales las patentes se depositan. De allí, la matriz que se consigue permite cartografiar las actividades tecnológicas. Vemos que la distribución de las patentes por campo tecnológico y la concentración de los conocimientos tecnológicos son parecidas en los dos países. La concentración tecnológica de los sectores es en cambio muy distinta. Cada país organiza de forma específica su variedad tecnológica sectorial. En lo*

que se refiere a los grupos tecno – industriales, tres grandes grupos se destacan (químicos, electrónicos, mecánicos). Son distintos en los dos países en lo que se refiere al tamaño, la estructura y la complejidad.