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Country-Specific Characteristics of Patent Applications in France, Germany and the UK in the Biotechnology Sectors

SHYAMA V. RAMANI & MARIE-ANGELE DE LOOZE

ABSTRACT *Given that institutions are highly country-specific, the differences in the national systems of innovation in the different countries of Europe are likely to give rise to country-specific patterns in new technology investment. The objective of this paper is to identify such differences, in the biotechnology sectors, in France, Germany and the UK. The results, based on an analysis of patent applications, indicate that France is focused on the 'dominant' technology of genetic engineering and its public laboratories and collective patent applications play an important role. Germany is leading in the total number of patent applications but is focused on 'intermediate' and 'residual' technologies with a significant number of individual depositors. The UK is leading in the 'dominant' technology. Its public laboratories and firms are strongly involved in depositing patents with a marked strategy of international protection.*

Introduction

The commercialization of innovations in a new science-based sector is a collective process, whereby the creation, development, adoption and diffusion of innovations, depend on the existence and functioning of networks, between a variety of agents in the economy. The principal agents are the public laboratories, the firms, the consumers, the financial institutions and the government. At the level of a nation, often the creation of innovations is considered to be embedded within a system called the national system of innovation (NSI), which refers to all the institutions within the country, involved in the creation, adoption and diffusion of a new technology.

The NSI approach was spearheaded by the seminal work of Freeman, Lundvall and Nelson,[1] as a possible alternative to the macroeconomic models of growth. Both approaches share the basic premise that the key to realizing national growth lies in *investment in knowledge accumulation* rather than *investment in physical capital*. However, the objective of the macroeconomic theories of growth is to examine the impact of knowledge accumulation on national growth, while the purpose of the NSI approach is to understand the process of knowledge creation and accumulation. Another basic distinction of the NSI approach is its central assumption that knowledge creation takes place within a system, composed of knowledge producers such as firms, laboratories, individuals and

Shyama V. Ramani and Marie-Angèle de Looze are Senior Researchers at the Department of Economics and Social Sciences, Institut National de la Recherche Agronomique (INRA), Université Pierre Mendès France, BP 47, 38070 Grenoble cedex 9, France. (Tel: +33-4-76825439; Fax: +33-4-76825455; E-mail: shyamar@grenoble.inra.fr, delooze@grenoble.inra.fr). Please address correspondence to Shyama V. Ramani.

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other institutions. Knowledge creation need not be linear as there can be feedback loops and externalities in the form of knowledge spillovers or barriers. Knowledge creation by these producers depends on the prevailing incentives and the rationality of these producers, which determines their response to such incentives. Two conclusions can then be inferred. First, the national environment will influence knowledge accumulation. Second, knowledge accumulation will be path dependent. The first result stems from the fact that institutions and state policy, which generate the incentives for knowledge creation, are highly country-specific. The second result follows as a corollary of the first, given that as different nations pursue different strategies for knowledge accumulation, they attain different results. It is also due to the evolutionary features of innovation systems such as knowledge accumulation following particular trajectories (given country specific innovation systems), and changes in the composition (and output) of the system, resulting from the creation of new varieties and a process of 'selection' based on adaptation criteria that eliminates some existing varieties.[2]

The NSI approach helps us to explain certain phenomena that are difficult to do using the standard macroeconomic theories. According to the latter, there should be a tendency for convergence in growth rates of national income, or at least rates of knowledge accumulation between nations, a fact that remains unconfirmed. Moreover, it has been documented that during certain periods, countries with similar resource structures and investment patterns, have had different rates of knowledge accumulation and different patterns of specialization in knowledge production. Such features can be explained by the NSI approach as being the result of nation-specific, evolutionary trajectories of knowledge accumulation. Policy makers are also increasingly attracted to the NSI approach, because an understanding of national specificities in terms of knowledge production helps them to 'develop approaches for enhancing performance in the knowledge based economies of today'.[3] Nevertheless, the NSI approach remains a conceptual framework rather than a theory, open to many forms of interpretation, and many forms of investigations.[4] In order to move towards a workable theory of NSI and arrive at a typology of systems, with an understanding of their concomitant impact on knowledge accumulation, more empirical studies are called for. The present article may be considered as a step in this direction.

The objective of this paper is to identify the national specificities of the knowledge base, in the biotechnology sectors,[5] of the three European leaders: France, Germany and the UK, as embodied in their patent applications. The biotechnology sectors have been chosen for study because they are important employment and innovation generating high-tech sectors, whose evolution is greatly influenced by the national system of innovation. The three countries considered are the leaders in Europe in terms of their R&D expenditure and patent applications in all fields.[6] In the above context, the two central questions addressed are:

(1) What are the common features of the biotechnology patent applications in France, Germany and the UK?
(2) What are the country-specific characteristics of the biotechnology patent applications in France, Germany and the UK?

Thus, the purpose is to identify and describe national patterns in biotechnology patent applications, so that new prospects for future theoretical and empirical research may be opened.

The present paper makes four kinds of contributions to the NSI literature. First, it confirms the basic hypothesis of the NSI approach that even countries with similar macroeconomic performances, can exhibit markedly different patterns of national technological specialization. Second, it identifies the national specificities of France, Germany and the UK in new technology creation (as embodied in patent applications), in the biotechnology sectors. Third, it assembles a set of indicators, which are well known but dispersed in the economics literature, to evaluate the performance of the NSI of a country as embodied in its patent statistics. Fourth, it introduces co-word analysis, a scientometric method used to study multidimensional systems or variables, to create indicators of the network structure of technologies and collaborating actors underlying the innovation system.

The data on patent applications was extracted from the *Derwent Biotechnology Abstracts*[7] containing biotechnology patents that were applied for either in France, Germany or the UK between 1992 and 1996. The data was used in its aggregated form. Given the short time period considered, evolutionary trends were not identified.

The implications of our study are however subject to some caveats. Our database contains patent depositions that have been published. These patents may or may not have been actually granted. In Europe, a patent application is published within 18 months of application, whether or not it is granted. For the purposes of our study, this does not pose a problem since we are using patent applications as an indicator of knowledge creation rather than market competition. We are also trying to distinguish the national strategies of France, Germany and the UK in the biotechnology sectors by examining the patents that were first deposited in these countries. Our database excludes patent applications by French, German and British agents that were not deposited first in France, Germany or the UK. However, this does not seem to be a significant limitation as most European firms and laboratories tend to deposit their patents initially in their own country. Finally, we identify the national strategies in terms of patent applications and our findings cannot be used to make predictions on the present economic impact or the future value of the patents of the three countries concerned. The actual economic value of a patent depends on the capacity of the innovating agent to exploit the patent and generate revenue through selling the patent or licensing the patent to others and such investigations are beyond the scope of this work.

The paper is organized as follows. Section 2 presents the methodology. It discusses patent applications as indicators of new technology creation, the scientometrics approach and the construction of the database. Section 3 presents the indicators used and the results of their application. Section 4 concludes by proposing explanations in terms of the national systems of innovation of these countries.

Methodology

Patents as Indicators of New Technology Creation

Patents applications were chosen as the indicator of new technology creation as they clearly reflect the commitment of agents to the new technology and they contain a large quantity of information. Firms, laboratories and individuals can apply for a patent to protect a new technology, to signal technological competence or simply to mark technological territory. Whatever the strategic motivations, a patent can be applied for, only if it has an industrial utilization as a target. Other indicators such as R&D expenditures, structure of R&D personnel, creation of new firms, etc., that permit the evaluation of new technology creation could also have been considered. However, to our knowledge, the biotechnology sectors are so extensive that it is not possible to recover data on such indicators at a disaggregated level, by firm, laboratory or country. In fact, Grilliches in his survey on the uses of patent statistics to measure research and innovative capacity concludes: 'In spite of all the difficulties, patents statistics remain a unique resource for the analysis of the process of technical change. Nothing else even comes close in the quantity of available data, accessibility, and the potential industrial, organizational and technological potential'.[8] A wide range of information on the scientific fields and industrial sectors to which a patent is pertinent is included, and it is a clear indication of the technology strategy of the patentee.

United States patent statistics were used by Pavitt and Patel to analyze the relative competitiveness of countries and to construct 'an index of revealed technology advantage'.[9] At the same time, some authors noted that as indicators of new technology creation, patent applications do not cover the different industrial sectors in an equally efficient manner.[10] In fact, firms do not deposit as many patents in the food sector as in chemistry, pharmacy or electronics. Therefore, our analysis is pertinent to new technology creation, in the biotechnology sectors, to the extent that such knowledge is patented and can be compared to patent applications in each field in the biotechnology sectors.

This is indeed the case, because given the innovative and lucrative nature of the science and technology involved, in the biotechnology sectors, it is necessary for firms to ensure protection through patenting. Otherwise, if the products are released into the market place they can be easily imitated. New knowledge cannot be guarded as a secret between employers and scientists because these sectors are characterized by mobility of researchers between firms (and universities). Therefore, barring fields like 'diagnostics' in which innovations have short lives (e.g. 5 years) most new technology is protected by patents. The positive 'signalling' impact of patent applications is also considered to be particularly strong in the biotechnology sectors, not only for the large firms but also for small- and medium-sized firms.[11]

Co-word Analysis in Scientometrics: A Brief Introduction

The origins of scientometrics can be traced to the 1960s in the USA. In 1964, Eugene Garfield created the 'Science Citation Index' (or SCI) at the 'Institute for Scientific Information' (or ISI) in Philadelphia, USA under the aegis of the 'National Science Foundation'. The objective of the SCI was to provide an index, which permitted the rapid identification of the most important authors in a scientific domain, using references from publications (citing) and the aggregate bibliographies (cited) obtained from these publications. This new method of presenting the publications of researchers created a new culture that some referred to as the 'culture of citations'.[12] Using the database of ISI, Eugene Garfield and Henry Small developed a methodology to identify research frontiers in various scientific fields using citations and co-citations.

While he was creating the SCI, Eugene Garfield also began interrogations on patent references that eventually led to the creation of heavy and unwieldy methods for the treatment of patent citations (citations of literature, patent to patent citations, citations of authors, citation of examiners, citations of technologies involved etc.). It was difficult to apply the citations method developed for publications on patents, for several reasons. In patent texts, citations can be present in different sections, they can refer to publications or to other patents and finally, they can be ranked according to different criteria of importance. Indeed, the investigations along these lines were never completed by the ISI. However, very recently, the Derwent company brought out a new product that contains all the citations included in patents. Even more recently (Summer 2000), Derwent connected this database to the 'Science Citations Index' on the Web of Science (WOS) of the ISI. Thus, Eugene Garfield's dream has finally come true.

Francis Narin, is another pioneer, who has worked extensively on the methodology of 'citations'. Initially, he used the SCI to identify the frontiers of various fields and he made a number of suggestions for the improvement of the SCI so that it could signal the creation of various types of knowledge better, notably the distinction between science-based and application-oriented papers. Among his many contributions to the field, an important one with respect to patents, is his examination of *citations of scientific data or scientific knowledge within patents*. He has developed methods involving citations from one patent to another and from a patent to publications and shown that the creation of new technology is strongly determined by the creation of new knowledge in the sciences. More recently, he has developed a method based on citations and the technology cycle time (and patented it as a business method) to identify the leaders in an industrial sector, as he finds that certain patent indicators have a strong positive relationship with stock market evaluations.[13]

During the 1980s in France, sociologists from the school 'Ecole des Mines', were studying how to analyze emerging systems. Their objective was to characterize evolving systems, through identification of the role of the different variables and the agents associated with the variables. In this context, they began to examine the role of words and networks of words in literal texts describing evolving systems.[14] Their interrogations on words gave rise to the creation of a methodology close to that of the SCI. The distinguishing feature of the French method, termed 'co-word analysis', was that the citation–co-citation method was applied to the *words* themselves in the literal text and not only to *authors*. This gave rise to two advantages as compared to the 'co-citation analysis' developed by the ISI. First, it could be applied to any corpus of words, including the patent texts, unlike the ISI method, which could only be applied to citations on their own database. Second, citations pertain to events of the past, whereas there can be literal texts that describe the present, which bring us closer to the reality being formed. Thus, the above method can be used to analyze the present in order to predict the future more credibly. The co-word analysis has been further developed by a number of authors.[15] The applicability of this method also increases as the treatment and analysis of literal texts becomes more and more automated with computers and linked with the linguistic treatment of information.

In economics, the co-word analysis is used to describe the structure of a multidimensional variable in the form of a network. Consider a multidimensional variable that can be represented as a vector with many components, where each component is a binary variable (either present and given by 1 or absent and given by 0). Suppose a database contains many observations of such a multidimensional variable. Then application of the 'co-word analysis' represents these observations in the form of a graph or network. A network consists of a set of nodes connected by arcs. Each node represents a component of the vector, i.e. a component of the multidimensional variable, and each arc represents a co-occurrence of the corresponding pair of components in the database. In other words, the co-occurrence of two components is their joint frequency in the database or the number of observations of the variable, in which both these components were present. There are computer programs,[16] which indicate the actual number of co-occurrences of each pair of nodes above each arc in the network.

The 'co-word analysis' is of use in the study of national systems of innovation (NSI), because according to the NSI approach, the creation of new knowledge depends not only on the magnitude of the investment in the creation of new knowledge, but also on the networks supporting the NSI. Such networks determine the nature of circulation and transfer of knowledge within the innovation system. From the patent applications of a country, it is possible to formulate two types of multidimensional variables that can then be represented by a network. First, each patent is associated with a number of technologies. Therefore, the technology affiliations of a patent application are considered as a multidimensional variable, where each dimension indicates a possible application in a particular technology. Application of the co-word analysis to this variable then permits the depiction of the technology network underlying the knowledge base as embodied in the patent applications. Second, patent applications are filed collectively by a group of depositors. In this case, co-word analysis is used to depict the networks that exist between the collaborating knowledge producers.

Construction of the Data Base

From the '*Derwent Biotechnology Abstracts*' (DBA) all the patent applications for the years 1992–1996 were first extracted.[17] Then a second extraction yielded a list of patent applications filed in France, Germany and the UK during the years 1992–1996. The year associated with each patent was the year of submission and not of publication. This information was extracted from the priority number of the patent, which identified the first country where the patent was filed and the first date of application. Thus, considering the time between performing experimental work and filing a patent, we could suppose that the data reflected the situation at the beginning of the 1990s.

The final database contained 2650 patent publications of which 216 were collectively deposited. The latter posed a problem because the number of patent applications was then less than the number of patent participants or depositors. Therefore, 'fractional counting' was applied on the collective depositions. Each collective patent application involved a set of participants and each such participant was accorded a patent participation equal to 1 divided by the number of patentees in the group. In this manner, the sum of the patent participations was made equal to the sum of the patent applicants. For each patent application, the database provided the following information: (i) the technologies to which the patent was affiliated;[18] (ii) the name of the patentee (iii) the country in which the patent was first deposited and (iv) the region for which protection was sought at the moment of publication of the patent.

Using the information obtained from the DBA, two types of variables were considered to describe each patent participation. The first type was a qualitative,[19] one-dimensional variable, which associated each patent participation with one possible state of the variable. The second type was a qualitative, multidimensional variable, given by a vector corresponding to each patent participation. Each component of this vector could assume one of two possible values, either 0 or 1 (indicating either absence or presence of the corresponding component of the vector in the observation of the variable). Both these types of variables are detailed below.

One-dimensional Variables

Six types of uni-dimensional qualitative variables were constructed for the statistical analysis.

National affiliation of participant V1. In order to carry out national comparisons it is necessary to identify the 'nationality' of each patentee. The database DBA did not provide this information. A number of experts were consulted[20] and the internet was also used to attribute one of four possible 'national affiliations' to each participant: British, French, German or other.

Type of participant V2. Each patentee was classified as being one of three possible types of agents: a private firm, a public laboratory or an individual. In the biotechnology sectors, public laboratories are as active as private firms in the creation of new technology. The DBA does not indicate whether a patentee is a firm or a laboratory, and hence, we again identified this characteristic with the help of experts and the internet. Whenever an individual was mentioned along with a firm or a laboratory, he or she was assimilated to the firm or laboratory. Only when no firm or laboratory was mentioned, was an individual noted as such.

Organization of the patent deposition V3. When a patent involved a single patentee it was termed as a single or non-collective deposition. When a patent involved more than one patentee, it was termed a collective deposition.

Technology type of the patent participation V4. The database contained 29 main technological classes and most (about 90%) of the patent applications were associated with more than one technology class. Then, each patent participation was accorded one of three possible technology types: 'dominant technology', 'intermediate technologies' or 'residual technology' as detailed below.[21]

The technology that most often occurred was genetic engineering (A1 in 66.8% of the patent applications). This was considered as the 'dominant' technology. Then came four technologies: peptides and proteins (D3), clinical genetic techniques (D7), animal cell culture (J1) and biocatalysis applications (K2), which were present in between 10 and 25% of the patent applications. These four technologies were taken as the 'intermediate' technologies. The rest[22] occurred in between 0.5 and 10% of the patent applications and were classified as 'residual' technologies.

The technology type of a patent application was taken as 'dominant' if it involved genetic engineering as one of the associated technologies. Then, all these applications were removed. Among the rest, the technology type of a patent application was taken to be 'intermediate', if it involved one of the intermediate technologies. The technology type of the rest of the patent applications was taken to be 'residual'. Thus, each patent application was associated with one of the three technology types: dominant technology (involving genetic engineering), intermediate technologies (not involving genetic engineering, but involving either peptides and proteins, clinical genetic techniques, animal cell culture or biocatalysis applications) and residual technologies (not involving genetic engineering or any of the intermediate technologies).

Initial region of protection V5. This referred to the region over which protection was sought at the time of application. There were five possibilities: France, Germany, UK, regional or world.[23] The category 'regional' indicated an area larger than a single nation (e.g. EU).

Final region of protection V6. This referred to the region over which protection was sought at the time of patent publication, as the patentee could revise the region over which protection was sought during the first year after deposition. The states were the same as that for variable 5, namely France, Germany, UK, regional or world.

Multidimensional Variables

For each type of national affiliation (French, German or British), two types of multidimensional variables were formulated for the scientometric analysis.

Technologies vector V7. A 29 component vector was attributed to every patent application (affiliated to one of the three countries). Each component stood for a technology class. It was 1 if the patent was affiliated to that class and 0 otherwise. This corresponded to the original technology attributions of the DBA for each patent participation.

Co-depositors vector V8. A vector with as many components as patent participants was associated with each collective deposition of each country. Again, a component of this vector was 1 if the patent was affiliated to the corresponding patent participant and 0 otherwise.

Indicators Used and Results

Two types of indicators identify the country-specific characteristics of patent applications. The first type ranks and compares the magnitude of new technology creation in the three countries in terms of six unidimensional variables (national affiliation, type of patentee, organization of patent deposition, technology type, initial region of protection and final region of protection). The second type analyzes the structure of two networks supporting the new technology creation in the three countries. The networks are constructed by applying the 'co-word analysis' on multidimensional variables (technology vector and co-depositors vector).

Indicators of Knowledge Stocks Based on One-dimensional Variables

In order to rank and compare new technology creation in the biotechnology sectors as given by patent applications, the following indicators based on frequency counts of the one-dimensional variables V1–V6 are defined.

(i) *Distribution over the three countries*: The frequency distribution of the patent participations affiliated to the different technologies (V1, V3) and the frequency distribution of the patent participants (V2) over the three countries. The higher the percentage of patent participations or participants affiliated to a particular country, the better its ranking.
(ii) *Internal structure of the three countries*: The frequency distribution of the different possible states of the variables V2–V6 for each country. The higher the percentage of patent participations in a certain state of a variable, the greater the importance of that state for the country concerned.
(iii) *Country profile*: The characteristics (i.e. the set of states of the different variables V1–V6) which are most representative of a country and which distinguish it the most from the others. This is obtained using the standard statistical method of cluster analysis.

Network or Knowledge Flow Indicators using Multidimensional Variables

Consider a multidimensional variable v with n components. Each component of v can be either a quantitative or a qualitative entity. Suppose that in a database, there are m number of observations of this multidimensional variable. Then, these m observations of the n-dimensional variable v, form a scatter plot in n-dimensional space. The application of the co-word analysis, reduces this scatter plot in n-dimensional space to a graph in two-dimensional space. Such a network is made up of n nodes, where each node corresponds to one of the n components of the variable v. The nodes are connected through arcs. For instance, the nodes that are connected to a particular node through arcs, are those with which the component has a positive joint frequency in the database.

Thus, the structure of the multidimensional variable *v* is cast as a network map in which the position of each component is portrayed.[24]

Recall that we had formulated two multidimensional variables for each type of national affiliation: the technologies vector of the patent applications (V7) and the co-depositors vector of the collective applications (V8). Application of the co-word analysis on these two variables yields two maps for each country, a network of technologies supporting the knowledge base (as given by patents) of each country, and a network of collaborating knowledge producers. The nodes in the technology network map represent the different technologies and the arcs joining pairs of nodes indicate the joint frequency of the corresponding pairs of technologies. Similarly, in the network map of co-depositors, the nodes represent agents and the arcs indicate the number of co-depositions by pairs of agents.

For each node and network, the following characteristics can be identified.

- *Centrality of a node*: The number of nodes with which it has a connection or with which its joint frequency is non-zero. This is indicated on the network map by the number of arcs issuing from the node.
- *Density of a node*: Sum of the joint frequencies with other nodes. It is equal to the sum of the joint frequencies associated with the arcs issuing from the node.
- *Centrality of a map*: Number of pairs of technologies which are connected or whose joint frequency is positive. It is also equal to the number of arcs in the map.
- *Density of a map*: The sum of the joint frequencies of every pair of technologies. It is equal to the sum of the joint frequencies of technologies associated with each arc in the map.

Using the concepts of centrality and density, the position of each country *vis-à-vis* the others can be ranked as follows. The centrality of a technology (or of a map) in a country is taken to be 'high', if it is greater than the average centrality of that technology (or the maps) computed for the three countries. The centrality of a technology (or of a map) in a country is taken to be 'low', if it is smaller than the average centrality of that technology (or the maps) computed for the three countries. Similarly for density.

Then the following two indicators on the nature of networks and particular nodes can be formulated.

(iv) *Relative maturity of a node*: A high centrality of a node indicates that the node is well connected to other nodes (with respect to the corresponding connection in other countries). A high density implies that the node is strongly connected to the other nodes (with respect to the corresponding connection in other countries).

(v) *Relative maturity of a network*: A high centrality indicates that the network is well developed (with respect to the corresponding network in other countries). A high density implies that the network is strong (with respect to the corresponding network in other countries).

Evidently the terms 'well connected', 'well developed or 'strong' networks are ad-hoc terms, but they serve to designate a high centrality or a high density. Furthermore, these indicators are important because of the following assumption of the NSI approach that the returns to any investment in the creation of knowledge is a function of the networks underlying the innovation system, as the networks designate the flows of knowledge between the nodes, whenever there is knowledge creation.

Assumption: *A network represents the flows of knowledge between the nodes comprising the innovation system. Whenever there is knowledge creation at a node* v_k, *there is a spillover of knowledge to all the* *nodes connected to node v_k, with a positive probability (such that the sum of the probabilities over the connecting nodes is less than or equal to 1).*

Given the above assumption on networks, it can be inferred that the returns to any investment in a technology (or in a country) is a function of the maturity of the concerned node (or the maturity of the network of the concerned country). For any investment in a technology, the higher its centrality, the greater the number of other technologies to which there is a spillover of knowledge. For any investment in a technology, the higher its density, the greater the magnitude of the spillover to the connected technologies. Similarly for a country given the maturity of its network. Thus, if a country has lower knowledge stocks today, but more mature networks, by investing the same amount as its competitors, it can catch up with the others.

This completes the presentation of the five indicators used and now we go on to the results obtained by their application.

Ranking of the Three Countries According to the Different Variables

The distribution of the different states of the variables V1, V2 and V3 over the three different national affiliations is given in Table 1. The table has to be read horizontally and each line gives the percentage of participations in that category according to national affiliation.

Result 1: Strategic positions

- *France is not a leader in any category.*
- *Germany leads in terms of the total number of patent participations and the total number of patent participants. Germany also leads in the intermediate and residual technologies. Germany is further distinguished by a high proportion of individuals depositing patents.*
- *UK leads in patent depositions in the dominant technology of genetic engineering and in the number of laboratories depositing patents.*

This positioning of the three countries in terms of the total number of patent applications is slightly different from their global positioning. The 'Observatoire des Sciences et des Techniques' (functioning under the aegis of the French government) has reported patent publications in all sectors for the different countries of Europe for the two years, 1990

Table 1. Distribution of patent applications over the three countries

	French partici-pations	German partici pations	UK partici-pations	Other partici-pations	Total number of partici-pations
v1. National affiliations	592	1054	720	284	2650
	22.34%	39.77%	27.17%	10.72%	100%
v2. Type of agent					
2.1 Firms	21.19%	38.19%	26.19%	14.44%	1600
2.2 Laboratories	29.91%	30.04%	34.35%	5.70%	789
2.3 Individuals	6.51%	78.93%	11.49%	3.07%	261
v4. Type of technology					
4.1 Dominant technology	24.22%	31.00%	33.78%	11.01%	1726
4.2 Intermediate technologies	19.74%	50.86%	17.38%	12.02%	466
4.3 Residual technologies	17.90%	61.57%	12.23%	8.30%	458

and 1997.[25] Since patents are published 18 months after submission, the figures for 1997 fall within the time period studied in our paper. According to their report, Germany accounts for 40%, UK 14.3% and France 15.7% of all published patents involving European patentees. Thus, while France has about half as many patent applications as Germany, it has more than the UK. This is however not the case in our sample, which indicates a better positioning of the UK in the biotechnology sectors.

The above table can also be used to construct the 'Revealed Technology Advantage index' (RTA index) similar to the one used by Pavitt and Patel.[26] The RTA index is defined as a particular country's share of patents within a technology class divided by the country's share of patents within the database. A value greater than one shows the relative strength of a country within a sector. Then the RTA of France lies only in the dominant technology (RTA index equal to 1.08). The RTA of the UK also lies only in the dominant technology (RTA index equal to 1.24). However, Germany has a RTA in the intermediate and residual technologies (RTA index of 1.28 and 1.55 respectively).

Internal Structure of Patent Applications in France, Germany and the UK

The internal structure refers to the distribution of the different states of the variables V2–V6 in the patent participations of each country. The results are given in Table 2. It should be read vertically and it leads to the following inferences.

Result 2: Internal structure of patent applications

- *The common features of patent applications in the three countries are the following*:
  1 Firms are the most active agents in patent applications.
  2 Collective patent applications are far less common than non-collective applications.

Table 2. Internal Structure of patent depositions by national affiliation

	French participations (%)	German participations (%)	UK participations (%)
v2. Type of agent			
2.1 Firms	57.26	57.97	58.19
2.2 Laboratories	39.86	22.49	37.64
2.3 Individuals	2.87	19.54	4.17
v3. Type of organisation			
3.1 Single or non-collective	85.47	96.02	91.67
3.2 Collective	14.53	3.98	8.33
v4. Type of technology			
4.1 Dominant technology	70.61	50.76	80.97
4.2 Intermediate technologies	15.54	22.49	11.25
4.3 Residual technologies	13.85	26.76	7.78
v5. Region of initial protection			
5.1 France	98.31	0.00	0.28
5.2 Germany	0.34	98.48	0.28
5.3 UK	1.35	1.52	99.44
v6. Region of final protection			
6.1 Protection in France	33.28	0.00	0.28
6.2 Protection in Germany	0.51	71.44	0.56
6.3 Protection in UK	0.84	0.66	6.94
6.4 Regional protection	11.99	13.76	5.97
6.5 International protection	53.38	14.14	86.25

3 The technology focus is on the dominant technology i.e. genetic engineering.
4 The region of application is mainly the country of origin of the participant.[27]

- *The country-specific features of patent applications are the following*:
  1 French participants deposit a higher percentage of their patents collectively.
  2 German participations are marked by a much higher proportion of individuals. They are more focused on intermediate and residual technologies. They protect a much greater percentage of their patents at a national level.
  3 UK participants protect a much higher percentage of their patents at an international level.

In all three countries, about 58% of the patent participations come from firms. Since firms are the agents that appropriate the maximum benefits from the commercialization of new technologies, they are the most active in the pursuit of patents. Another striking feature is that less than 10% of the patents have been deposited collectively. This moderates the generally held view that R&D co-operation is strengthening due to the increasing complexity, costs and risks of research. Firms may prefer to deposit alone, because the sharing of proprietary rights constitutes a source of conflict and weakness.[28]

In the three countries, more than 50% of patent applications are affiliated to genetic engineering.

The initial region of protection is the country of origin of the participant in more than 98% of patent participations in the three countries. The deposition of patents in a country is related to the existing intellectual property rights regime. Since this regime is not homogenized within the different countries of Europe, it is easier for most agents to deposit patent applications in their country of origin.

Coming to the country-specific features, patent applications in France are characterized by a higher proportion of collective depositions (15% as compared to 4% in Germany and 8% in the UK). This is probably related to its NSI as will be explained later.

The German participations are marked by the presence of individuals (20%), which is much higher than in France (3%) and in the UK (4%). One must note that in Germany, the universities cannot deposit their patents in their name, it is the university researchers and teachers who have to deposit it personally. This could be the reason for the high number of individuals as patentees.

The German participations are less focused on genetic engineering (51% as compared to 71% in France and 81% in the UK) and more focused on the intermediate technologies and residual technologies, as compared to the UK and French participations. When it comes to the region of final protection, national protection is preferred the most by German participants (71.44% with Germany as final region of protection).

The UK participations are distinct in their aggressive policy of patent protection. International patenting protection is sought in 86% of the UK participations as compared to 53% of French participations or 14% of German participations.

National Strategy Profiles

Though the internal structure of the patent applications gave a preliminary view of the country-specific features, it was necessary to examine whether these results were statistically significant. Given that all the variables were qualitative, (or variables that can take one of several states), the χ^2 test was first used to identify the relations between the variables and test the hypotheses of independence for each pair of variables. It revealed that all the variable were interdependent. Evidently, the results obtained by the χ^2 meant that it was not possible to formulate statistical models of the three countries or of the

Table 3. Results of the cluster analysis

Typology by protection at the moment of publication	State in the class	Frequency of the class	Percentage of the state in the class (%)	Representa-tivity of the state (%)	Percentage of the state in the population
Class 1	International protection	1190	89	**83.26**	48
	Dominant technology		**94**	64.94	65
	UK affiliation		45	**74.84**	27
	Laboratories		48	**71.85**	30
	Collective depositions		12	67.36	8
	Other participations		12	53.89	10
Class 2	Protection in UK	88	**100**	**100**	3.3
	UK affiliation		56.25	6.91	27
	Other participations		29	8.75	11
Class 3	Protection in France	211	**95**	**94.55**	8
	Affiliation France		**95**	34.38	22
	Laboratories		50	13.27	30
	Collective depositions		18	17.92	8
Class 4	Protection in Europe	362	74	**91.90**	11
	Firms		**93**	21.17	60
	Intermediate technologies		43	34.55	17
	Single or non-collective		98	14.71	91
Class 5	Protection in Germany	799	**84**	63.32	30
	Affiliation Germany		**84**	**87.44**	40
	Individuals		29	**68.68**	10
	Residual technologies		41	43.55	18
	Intermediate technologies		26	31.79	17
	Single or non-collective		**97**		92

Representativity of a state in a class $= \left(\frac{\textit{frequency of the state in the class}}{\textit{frequency of the state in the population}}\right) . 100$

different types of agents using regression analysis. Then multiple correspondence analysis was used to understand the relationships between the different states of the different variables and to identify the main factors representing the information. The variable 'initial region of protection' was left out as it was highly correlated to the variable 'national affiliation' of participants. On the basis of the first five factors,[29] a cluster analysis was carried out to identify the groups of states of variables that were related to one another. The results are given in Table 3.

Result 3: National strategy profiles

- *France does not have a well defined country profile.*
- *Germany is distinguished by its investment in the residual and intermediate technologies, with a strong participation of individuals (i.e. its university researchers) and a passive protection strategy.*
- *UK is characterized by a strong investment in the dominant technology of genetic engineering with a strong participation of its laboratories and an aggressive protection strategy.*

The fifth column of Table 3 indicates to which degree a class is representative of the strategy of a country. For example, around 75% of the UK participations are captured in the first class. The first class could then be considered as being representative of the strategy of the UK. It is more difficult to identify the French strategy, because even though it is present in class 3, this class itself represents only 35% of the French participations. Nevertheless, class 3 confirms the characteristics already noted for France: the important role of laboratories and the propensity for co-deposition. In addition, French participations are attracted to national protection, but it must be recalled that this class only represents 35% of the French participations. The internal structure of French participations given in Table 2 reveals that international protection is largely sought (in 52% of participations).

Germany is clearly represented by class 5, which makes it easy to identify its country-specific characteristics. Germany is strongly committed to the development of the intermediate and residual technologies and its depositions are mainly non-collective. The non-collective nature of patent depositions is due to an important number of depositions by individuals, certainly the university researchers evoked earlier. The preferred strategy of protection is national protection. This seems to indicate that their national legislation is favourable to national protection and is efficient enough to persuade German participants not to seek international protection. Since a significant proportion of the German participants are individuals, one can also understand that they prefer a national protection, because it offers a good quality to price ratio. International protection would be much more costly for individuals and the defence of their interests would be more complex, costly and long.

As has been noted already, class 1 is the most representative of the British strategy. It illustrates clearly that the UK participants aim at protecting their patents at the international level and this is particularly so in genetic engineering. Laboratories are also active in this technology, which explains the inclusion of collective depositions in this class. The UK is also distinct in being able to attract the patent depositions of foreign firms.

The second class is a small class representative of a small number of British patents and a small number of patents from other countries seeking the UK as their final region of protection. For Britain, this class represents the least valuable patent applications, as they are only protected locally. The patent applications from other countries shows that the UK attracts agents coming from outside of the three countries.

Class 4 seems to be the most representative of patents having Europe as its region of protection. This class shows that most of the European depositions are by firms submitting alone. The fact that depositions are not collective, whether they are by individuals or by firms, is not surprising.

Maps of Networks: Application of Co-word Analysis

Technology networks. The application of the network indicators on the technology maps of the three countries, and on certain technology nodes in the three countries: the dominant technology, each of the intermediate technologies and the most central residual technology, yielded the results given in Table 4.

Result 4: Nature of the technology networks (Figures 1–3)

- *France is a potential leader in all three technology networks.*
- *Germany is a follower in the network of the dominant technology and most of the intermediate technologies, but is a specialized leader in the network of the most central residual technology.*
- *The UK is the uncontested leader in the network of the dominant technology and in most of the others, as its networks are either well developed or strong or both* vis-à-vis *those of the two other countries.*

It is clear that in terms of technology networks, the strategic positions are different from those indicated in terms of patent frequencies given in Table 1. The UK and not Germany emerges as the leader in terms of the entire technology network, as well as in the specific fields of genetic engineering, peptides and proteins and animal cell culture. Both its centrality and density are higher than the average for the countries in these fields.

Germany's technology networks are less developed and less strong in the dominant

Table 4. Centrality and density of technologies

	France	**Germany**	**UK**
Total map	Well developed but not strong	Not well developed and not strong	Well developed and strong
	The dominant technology		
A1, Genetic Engineering	Well developed but not strong	Not well developed and not strong	Well developed and strong
	The intermediate technologies		
D3, Peptides and Proteins	Well developed but not strong	Not well developed and not strong	Well developed and strong
D7, Clinical Genetic Techniques	Well developed but not strong	Not well developed and not strong	Not well developed but strong
J1, Animal Cell Culture	Well developed but not strong	Well developed but not strong	Well developed and strong
K2, Application	Well developed but not strong	Not well developed but strong	Not well developed and not strong
	Most central residual technology		
M1, Waste Disposal	Not well developed not strong	Not well developed but strong	Well developed but not strong

Note: 'Well developed' indicates that the corresponding centrality is higher than the average centrality over the three countries. 'Strong' indicates that the corresponding density is higher than the average density over the three countries.

technology and most of the intermediate ones. However, the network is strong in biocatalysis and waste disposal. Thus, while Germany is leading in the intermediate and residual technologies in terms of frequency counts (Table 1), these technology groups are not connected much to other technologies and they form an isolated specialization.

As may be recalled, France was behind Germany and the UK in all three technology groups in terms of frequency counts (Table 1), but in terms of its technology networks it emerges as a potential leader. In all the fields considered, its networks are well developed, exhibiting a higher centrality than the others. If there is more investment, then the spillovers between the technologies will be higher given the greater number of connections and it can emerge as a leader in these technologies.

Next the co-word analysis was applied to the patentees of all collective depositions and this revealed the networks in which the agents had collectively deposited their patents. Here the nodes were the agents and the arcs represented the number of collective depositions between partners. While it must be kept in mind that the collective depositions represent only 10% of the total number of observations, it gives us an idea of the nature of the co-operative networks in the three countries. Then we have the following result.

Result 5: Nature of co-deposition networks (Figures 4–6)

- *The network of co-depositions in France is well developed and strong. It has three poles formed by its national research organizations: INRA, INSERM and the CNRS.*
- *The network of co-depositions in Germany is not well developed or strong. Germany is marked by two networks between agents, and two poles made of the national research organization, the Max Planck Research Institute and the firm BASF.*
- *The network of co-depositions in the UK is not well developed but it is strong. Its central pole is 'The Medical Research Council'.*

The centrality and density of the French map are 46 and 83 respectively while those of the British map are 23 and 38 respectively. The German map exhibits the least centrality

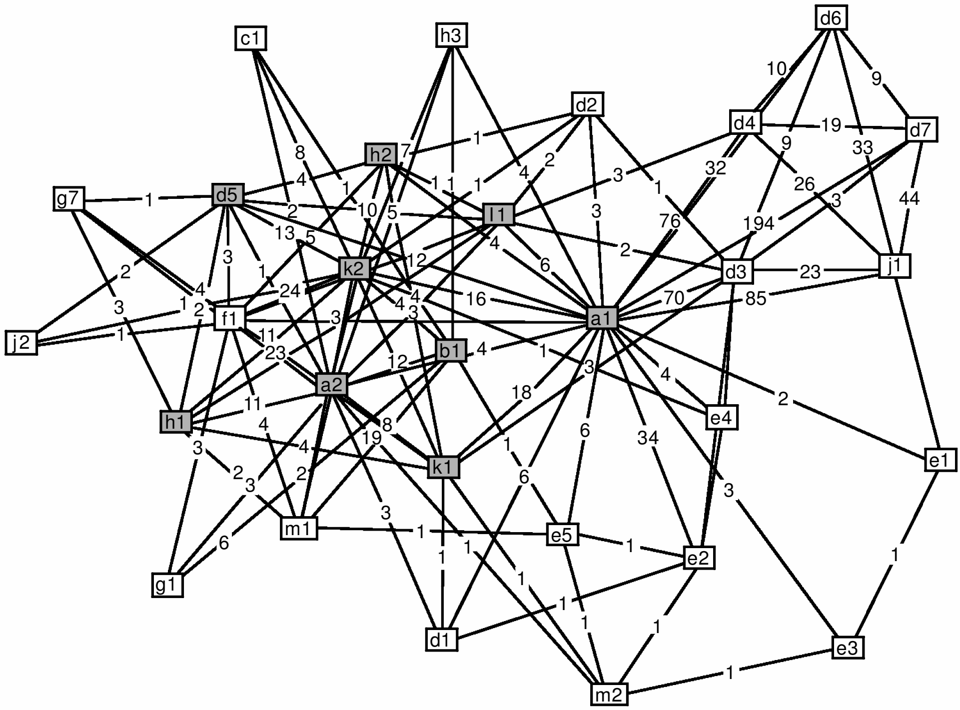

Figure 1. Technology network of France.

Classification scheme used by Derwent for the data base: A1, Nucleic Acids; A2, Fermentation; B1, Biochemical Engineering; C1, Sensors and Analysis; D1, Antibiotics; D2, Hormones; D3, Peptides and Proteins; D4, Vaccines; D5, Other Pharmaceuticals; D6, Antibodies; D7, Clinical Genetic techniques; E1, Biological Control (Agriculture); E2, Plant Genetic Engineering; E3, Pesticides; E4, *In-Vitro* Propagation; E5, Agricultural, Other; F1, Food and Food additives; G1, Biofuels and Solvents; G2, Mining and Metal Recovery; H1, Polymers; H2, Chiral compounds; H3, Chemical Miscellaneous Compounds; J1, Animal Cell Culture; J2, Plant Cell Culture; K1, Biocatalysis—Isolation and Chararacterization; K2, Biocatalysis—Application; L1, Purification—Downstream Processing; M1, Industrial Waste Disposal; M2, Environmental Biotechnology

(7) and density (9). In France, among the three poles, only INSERM is directly linked to a firm. In the UK, the Medical Research Council is directly linked to only one medium-sized firm. In Germany, even though the network is sparse, the large laboratories are directly related to large firms. In all three countries, the public laboratories (rather than the firms) are the leaders in the creation of new technology through cooperative networks, as they form the most central nodes in the networks.

Conclusions and Explanations

The objective of this paper was to identify the characteristics of patent applications in the biotechnology sectors, in France, Germany and the UK in order to gain some insight on the impact of their national systems of innovation. They yielded the following main

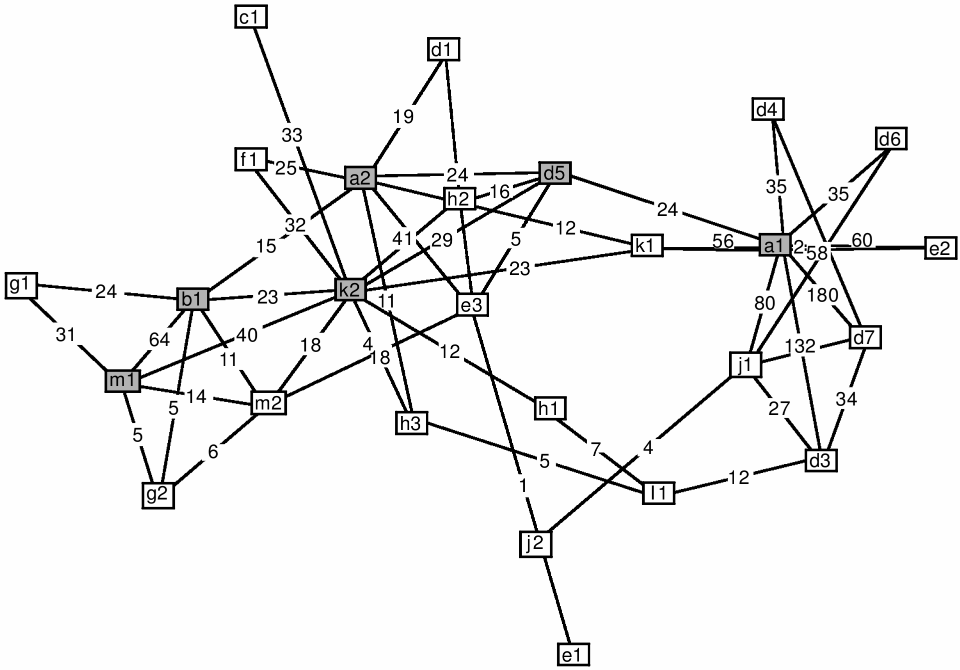

Figure 2. Technology network of Germany. (For DBA classification scheme see Figure 1.)

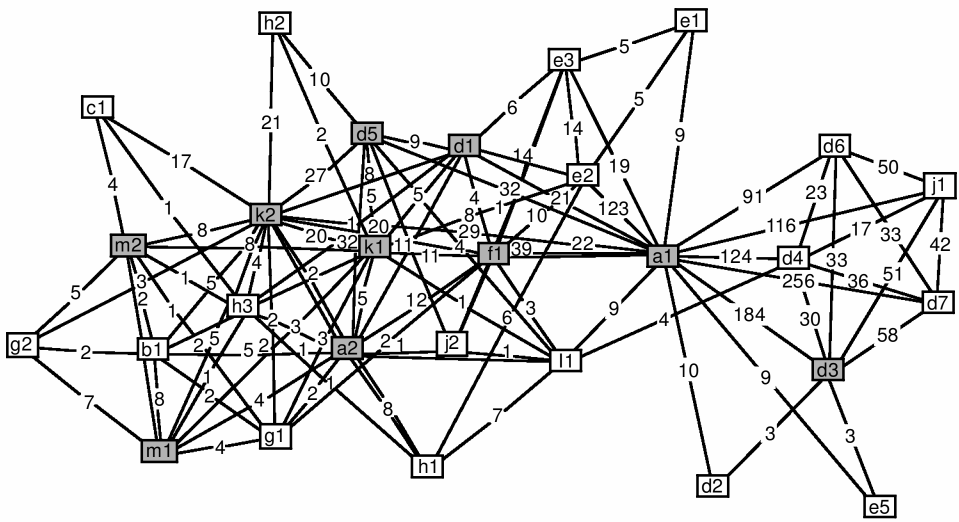

Figure 3. Technology network of the UK. (For DBA classification scheme see Figure 1.)

results on the common and distinct features of their patent applications in the biotechnology sectors.

- All three countries are focused on the dominant technology of genetic engineering, they prefer non-collective applications to collective ones and their firms are the most active patent participants.

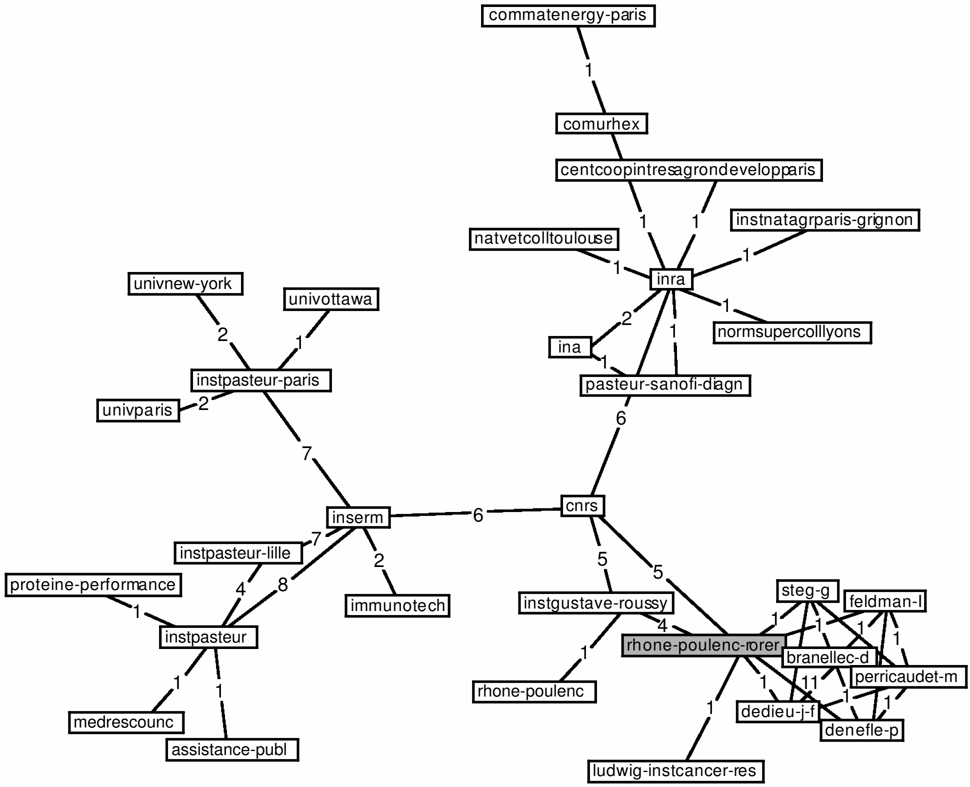

Figure 4. Co-depositions in France

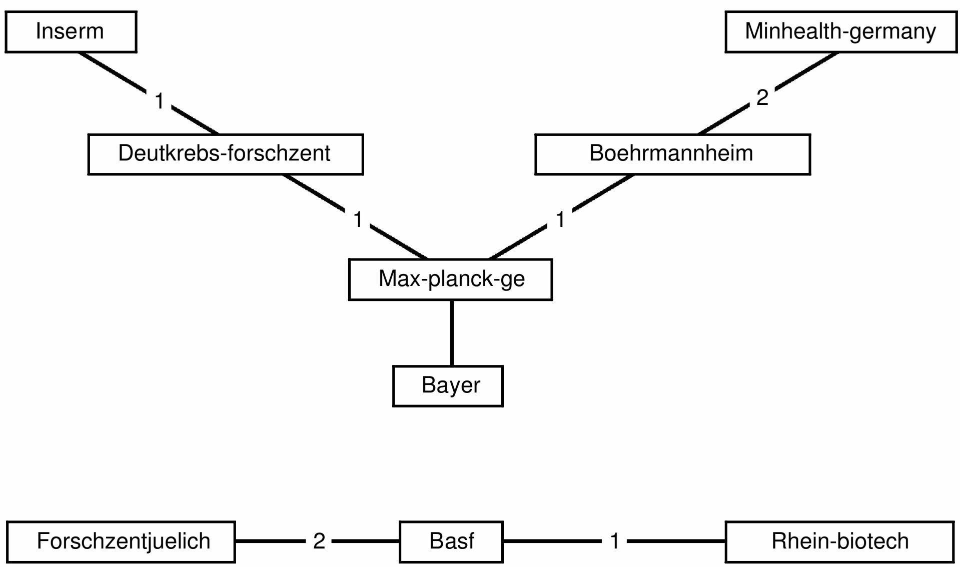

Figure 5. Co-depositions in Germany.

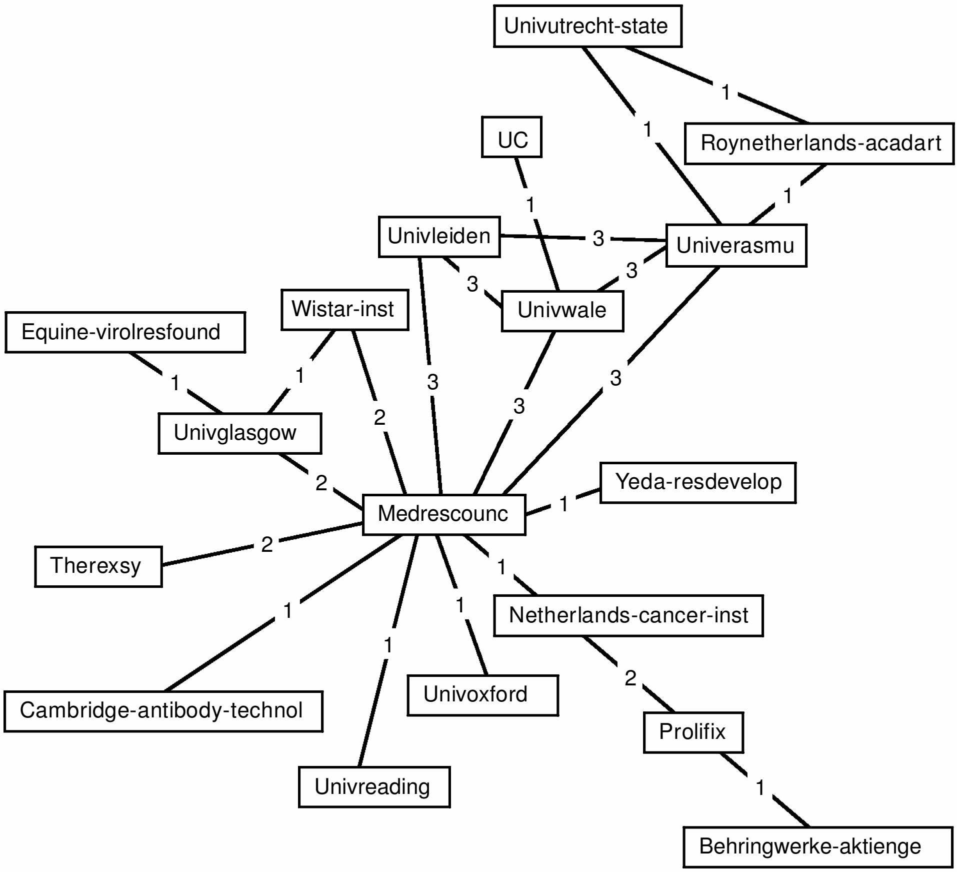

Figure 6. Co-depositions in the UK.

- France is trailing behind the other countries in terms of the total number of patent applications, but it has the potential to improve its position as its technology networks are well developed. It is marked by its dynamic laboratories and their capacity for creating new technology through co-depositions. Its relative technology advantage lies in genetic engineering.
- Germany is leading in terms of the total number of patent applications, as well as in the number of patent applications in the intermediate and residual technologies. The last two fields are also its sources of comparative advantage. If these residual and intermediate technologies take root and become more important in the future, Germany will have a leading edge. Its technology networks are not well developed, but in some fields they are strong. It has adopted a passive strategy of national patenting.
- The UK is the uncontested leader in terms in the dominant technology of genetic engineering both in terms of the total number patent applications and in terms of the well developed and strong supporting technology network. Its competitive advantages lies in its dominance in genetic engineering, its active public laboratories and its aggressive policy of international patenting.

Now we will briefly attempt to explain the above results in terms of their national systems of innovation.[30] At the outset itself, it must be noted that the creation of the biotechnology sectors in France and Germany were largely the outcomes of strong state intervention, while in the UK it was more led by the market. The main distinction between France and Germany at the initial stages, lay in the stronger participation of public laboratories in France and the stronger participation of large firms in Germany.[31]

According to Chesnai[32] the salient features of the French national system of innovation by the end of the 1980's were: (i) strong government funding of research and new technology creation; (ii) an alliance between the government, large firms and the elite educational institutes (which provide bureaucrats and industrial managers); (iii) among the high-tech sectors, focus on large mission mode technologies like space, telecommunications and transport meant for public markets (i.e. with public buyers and sellers); (iv) weak public laboratory–private firm collaborations and (v) weakly developed sector of small technology intensive firms. Thus, it is not surprising that in France, the impulse for the creation of the biotechnology sectors came from the state. The French government involved itself strongly in the creation of industrial competencies, through launching a series of national biotechnology programmes. The programmes provided funds to the national research organisms (INRA, CNRS, INSERM, Institut Pasteur, CEA, etc.) and promoted the initiation of co-operation between public laboratories and private firms.[33] This is clearly confirmed by our results, which show the importance of public laboratories and collective patent applications in the French participations.

However, during the 1990s the policy of the French government changed, focusing more on the large industrial groups (programme Bio-Avenir). Progressively, the French state ceased to be the major agent in the integration of biotechnologies, leaving its place to the large industrial groups such as Aventis, with which it continues to have a strong alliance. This change of policy could be one of the reasons for the retard of France *vis-à-vis* the other European leaders. Another explanation could lie in the dual structure of French patent applications. While some of the large French companies are well-established leaders in the biotechnology sectors (for example, the French firm Aventis, formerly known as Rhone-Poulenc, is the international leader in genetic engineering), the number of patent participations by its small- and medium-sized firms is lower than in the UK or Germany.[34]

Keck[35] characterizes the national system of innovation in Germany at the end of the 1980s in the following terms: (i) government policies designed to promote technical change and technology transfer; (ii) cost sharing of private and public R&D projects by the government; (iii) main burden of national R&D investment borne by firms (63%, which is higher than in the UK or France); (iv) weak higher education sector; (v) among the high-tech sectors, areas of strength in chemicals, pharmaceuticals, machinery and motor vehicles.

As in France (but a bit later), biotechnology took off in Germany during the mid 1980s, with the help of the government, which first concentrated on creating scientific competence and promoting technology transfer from public laboratories to private firms.[36] Government backed technology promotion programmes continued throughout the 1990s, with the setting up of technology parks, incubator laboratories for creating spin-off firms from laboratories and public sector venture capital fund companies. The German stock market was also reformed to permit easier listing.[37]

The focus of Germany on intermediate and emergent technologies is due to a number of reasons. According to a number of authors,[38] the nurturing of the biotechnology industry, with the creation of entrepreneurial technology firms, albeit in a secure environment, led to a focus on the creation of incremental innovations in fields with a low scientific intensity and low technological risk. Funds are readily available from public sector venture capital companies, which nevertheless shy away from risky entrepreneurial projects. Scientists are available but the firms that hire them must guarantee them long term employment. Hence, scientists are allocated to do research on technologies that seem stable. The dominant position of Germany in the chemical based 'intermediate' technologies such as biocatalysis and biochemicals could be also explained by the fact that the majority of industrial R&D in biotechnology is conducted by Germany's large chemical and pharmaceutical multinational companies. Germany has long been a leader in chemical-based industries and it continues to invest in the creation of new technology in these sectors. Finally, the lower specialization on genetic engineering is in part due to the strong consumer resistance to transgenics that has been developing in Germany. Its strong investment in the waste disposal and environment sectors could be a response to its recent cultural and social history, which is strongly marked by an awareness of environmental problems and the enduring influence of the Green Party.

It is interesting to note that while in both France and Germany the evolution of the biotechnology sectors was nurtured by the state, the technology focus of the two countries is different. This differentiation could be due to the different types of knowledge producers mobilized in the two countries and the differences in their rationality. In France, the three main kinds of actors active in the biotechnology sectors are the large life science firms, newly created dedicated biotechnology firms (with strong links to public laboratories) and public laboratories. The large firms are interested in genetic engineering, because it is a generic technology with a potential for application in a variety of sectors, the new dedicated biotechnology firms have developed competencies in platform technologies involving genomics, and the public laboratories are drawn to genetic engineering because of its high scientific intensity.[39] In Germany, in addition to the reasons evoked earlier for their specialization in the intermediate and residual technologies, it must be noted that the large German firms woke up later than their French counterparts to the potential of genetic engineering. Though there are more small- and medium-sized firms in Germany, which are involved in biotechnology, they are more interested in readily applicable incremental innovations. Finally, the system of technology transfer is such that public laboratories work for firms rather than with firms, in applied research in traditional fields of use to industry.[40]

According to Walker,[41] the national system of innovation of the UK by the end of the 1980s was characterized by: (i) government investment on R&D bent on getting 'value for money' leading to a myopic view and short term objectives; (ii) strongly developed services sector, especially the international capital market (and a declining manufacturing sector); (iii) among the high-tech sectors, relative strengths in the pharmaceutical and chemical sectors (with British multinational firms as leaders), the aerospace sector (supported by government commitment to defense spending), motor vehicles and electronics (due to foreign direct investment); (iv) weak education and training system and (v) weakly developed sector of small technology intensive firms.

Despite the supposed weaknesses of the British education system, biotechnology in the UK was spearheaded by scientists during the 1980s. During Mrs Thatcher's term, the government's objective was to create a context similar to that of the USA. Public research received government subventions, but major industrial groups were expected to finance their own research and small- and medium-sized firms were to engage in research contracts. Thus, the policy of the British government was more oriented to providing market incentives for the creation of new technology rather than doling out direct subventions.[42] More recently, during the 1990s, the British government focused on improving the co-ordination between the different 'councils' involved in the promotion of biotechnology, on stimulating technology transfer between firms and laboratories and on promoting the development of the venture capital market.[43] The mobility of researchers and the incentives provided for the creation of new firms by researchers has reinforced this strength. The focus of the UK on genetic engineering could be due to the active participation of its laboratories attracted to this subject on account of its scientific intensity, and to the activities of its firms, which perceived this field as having an economic potential. Furthermore, the market environment in the UK was (and remains) the most conducive in Europe for investment in new science-based fields like genetic engineering. Today, the UK has the most developed biotechnology sectors in Europe, with the greatest number of firms, the greatest number of employees and the highest R&D investment.[44] This might be due to the fact that biotechnology is a market-based technology requiring the competencies of a variety of agents (financiers, scientists, industrialists, etc.) and though the British government cannot be lauded for its narrow focus on creating efficient markets, it could have provoked the creation of a competitive and open environment in which 'entrepreneurs' can emerge more easily than in other European countries.

Acknowledgements

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15. For surveys, see A.F.J. Van Raan (Ed.), *Handbook of Quantitative Studies of Science and Technology* (Amsterdam, Elsevier Science B.V., 1988) and Wouters, *op. cit.*, Ref. 12.
16. For example we used Sampler, a 'text mining' environment developed by CISI (CISI, 3, rue Le Corbusier Silic 232 DER Génie Informatique 94528 Rungis Cedex France). The software works under UNIX and Windows 2000.
17. The data base *Derwent Biotechnology Abstracts* covers the publications and patents related to the biotechnology sectors from 1982 onwards. The DBA covers 40 patent issuing authorities and for non-US issued patents it includes the first patent that comes to its attention. The main identification fields of a patent are present (priority year, the names of the depositors, the names of the inventors, publication number, etc.). The information is available on CD ROM with the information being updated every three months.
18. The DBA has very set selection guidelines for the inclusion of information. With respect to patents, the information is analysed by experts and their descriptions are summarized in résumés.
19. A qualitative variable is one, which can assume one of several possible states. For example, a ball can be described according to its colour, as being blue, red or yellow, etc.
20. Whenever the affiliation could not directly be inferred from the patent information, the internet was used to identify the corporate headquarters of the firm or the location of the laboratories. When this method did not yield the national affiliation, one of the following experts was consulted: Jackie Senker, Paul Martin (SPRU), Thomas Reiss (FhG, ISI), Bernard Bettel (OEB) and Lionel Nesta (SERD/INRA). The final results were sent to them again for confirmation.
21. We could have associated each participation with one of the numerous combinations of the 29 classes or the technology affiliation of a patent could have been taken as a multidimensional variable in the form of a vector. For statistical analysis, both solutions are cumbersome and therefore, the technology classes were reclassified according to their relative frequency under three technology types. However, the vector representation was used for the scientometric analysis.
22. A2, Fermentation; B1, Biochemical Engineering; C1, Sensor and Analysis; D1, Antibiotics; D2, Hormones; D4, Vaccines; D5, Other Pharmaceuticals; D6, Antibodies; E1, Biological control; E2, Plant genetic Engineering; E3, Pesticides; E4, *In vitro* Propagation; E5, Agricultural; F1, Food; G1, Biofuels and Solvents; G2, Mining and Metal Recovery; H1, Polymer; H2, Chiral Compounds; H3, Miscellaneous compounds; J2, Plant Cell Culture; K1, Biocatalysis Isolation of Enzyme; L1, Purification of proteins; M1, Waste disposal; M2, Environment.
23. Convention PCT (Patent Cooperation Treaty, Washington, 1970), corresponds to a protection which could be termed world-wide in the sense that it covers around 90 countries.
24. The limitation of this method is that only pair wise joint frequencies are considered and represented. In other words, it does not consider the joint frequencies of more than two components (not three, not four, etc.).
25. Observatoire des Sciences et des Techniques, *Science & Technologie Indicateurs* (Paris, Economica, 2000), pp. 214–215; 463.
26. Pavitt & Patel, *op. cit.*, Ref. 9.
27. This result is slightly biased given our mode of extraction of information.
28. P.-B. Joly & M.-A. de Looze, 'Copropriété de brevets et coopération en R&D: une analyse des biotechnologies', *Economie Appliquée*, *52*, 1999, pp. 183–197.

29. Representing 77% of the inertia.
30. Readers wishing to know more of the details on the national systems of innovation or the integration of biotechnology in these countries can look up the references given in this section.
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