Strategies Of European Smes In Biotechnology: The Role Of Size, Technology And Market*

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Abstract

Both the technological and market focus of 228 European biotechnology SMEs are analysed in this paper. Data from the Genetic Engineering catalogue provide a complementary representation compared to the patent publications that are most commonly used. Results of the analysis produce a new view of the development of biotech SMEs. First, no pattern of specialisation by country is observed, even though three types of company with different technological focus can be distinguished in the sample. Second, it is argued that the rapid technological evolution in this domain can hardly be explained by a rapid evolution of the technological basis of the companies, and should consequently be explained primarily by the creation of new SMEs. Third, four different patterns of linkage between technology and market focus are observed, by means of co-word analysis.

Introduction

Biotechnology is a set of key enabling technologies, which are now being applied in a wide range of industrial sectors. European biotechnology companies and public policy makers are faced with a number of crucial problems related to the development of biotechnology in Europe and the construction of a single market in this area. These difficulties have been highlighted by several recent studies. They include a lack of European industrial competitiveness compared to the USA (Sharp 1995; Orsenigo 1989), the relative under-exploitation of the European science base in biotechnology (de Looze, Coronini and Joly, 1999), poor technology transfer mechanisms and difficulties in starting 'spin-off' firms (Walsh and Galimberti 1993; Senker and Sharp 1997) and, lastly, the technology transfer mechanism between public labs and SMEs on the one hand and large companies and SMEs on the other (Senker and Sharp, 1997).

However, despite these studies done on European biotechnology, the way in which firms have developed over the past twenty years has still not been clarified. While the small percentage of firms that have boomed owing to venture capital and entry into the stock market is well known, most high tech SMEs in Europe are developing slowly although they employ the majority of the workforce.

Based on Genetic Engineering[1] data in 1998, this paper aims to describe the different strategies of a sample of biotech SMEs regarding the technology/market twosome. The Genetic Engineering database is a worldwide database on biotech firms. Although it is a US database, firms from France, the UK and Germany are significantly present in it. It is therefore possible to compare development trajectories in these three countries. Does specialisation of each country appear when the focus is on technologies in use rather than on patent application (de Looze and Ramani, 1999)? The data describes the technology used in or developed by firms and the market focused on. It also contains information about the age of the firms and their size. Compared to the DBA database[2], the Genetic Engineering database focuses only on private SMEs. It provides us with precise information about the technologies SMEs are developing and using and the markets on which they are focusing.

Biotechnology is an emerging field in which large firms, academic labs and SMEs co-exist. **The mapping of these networks of scientific production and innovation raises the question of the organisation of research at the national, supra-national or sectoral levels** (section 2). Most scientometric contributions are based on available data, i.e. patent applications. The results of these contributions are very useful. **However, patent application depends on patent policy, which differs in large firms and SMEs, and from one country or continent to the next. Using scientometric tools (co-word analysis)** on data provided by the Genetic Engineering database, it is possible to map out the scientific and technological base of biotech SMEs (section 3-4). Although biotechnology is a tiny industrial sector, the coverage of each source (patents or directories of firms) is different and the picture obtained for each country depends on the source used by analysts. Such a result may have some implications for public policies in favour of innovation in biotechnology (final section).

Emerging technologies and dynamics of SMEs

The role of SMEs has been analysed from two main perspectives. First, in the Shumpeterian tradition, several authors have analysed the role of SMEs in industrial evolution. **Second,** more recent developments **in knowledge-based theory highlight the complementarities between different types of actor and the contribution of each to the division of labour in the research sector**.

SMEs and industrial dynamics: developing the Schumpeterian hypothesis

Schumpeter identifies two main patterns of innovative activity. The **first** is proposed in the "Theory of economic development" (Schumpeter Mark I) where the pattern of innovative activity is characterised by creative destruction. In that framework, entry is easy. Start ups, new firms and entrepreneurs play a key role in innovative activities. The **second** pattern, proposed in "Capitalism, Socialism and Democracy" (Schumpeter Mark II) emphasises the role of industrial R&D laboratories for technological innovation. Thus, large firms play a key role in innovative activities. This pattern of innovative activities is **characterised by creative accumulation**. The presence of entry barriers for new innovators explains the prevalence of large firms. **Malerba and Orsenigo** (1996) refer to these two patterns as ‘widening’ and

[1] Genetic Engineering News is published by Mary Ann Liebert Inc. (Larchmont, NY)

[2] Derwent Biotechnology Abstracts (DBA) is a data base on patents and literature updated every tree months since 1982.

'deepening'. In the widening pattern, the innovative base is continuously enlarged by the entry of new innovators. They explore new fields of innovation, which can erode the competitive and technological advantage of established firms. By contrast, deepening patterns of innovation are based on accumulation of technological and innovative capabilities.

Malerba and Orsenigo point out that very little is known about the empirical relevance of this characterisation. Their paper provides empirical evidence on the relevance of the model. Characteristics of this industry (concentration, entry, etc.) differ systematically across technological categories, and less significantly across countries. They point out that the **"technological imperative and technology-related factors (such as technological regimes, defined in terms of opportunity, appropriability, cumulativeness and knowledge-base features) play a major role in determining the specific pattern of innovative activities of a technological class across countries**" (p 470).

Other developments have been addressed in the framework of the technology life cycle first developed by Abernathy and Utterback (1978). Anderson and Tushman (1990) further developed the analysis by distinguishing between two kinds of rupture: competence-enhancing and competence-destroying. The role of SMEs is especially important in the latter case when technology leads to the destruction of the main existing competencies. Evidence from different historical cases shows that these new entrants expand at the expense of large companies, which are progressively pushed out.

To sum up, from such a perspective the central questions are: do SMEs wish to become large firms in the long run? Do the characteristics of the technological regimes tend to maintain a constant flow of new small firms, which will remain small? Within such a framework, the coexistence of large and small firms is only conceivable during the transition stage corresponding to the emergence of a new technology. Moreover, the authors concerned generally do not consider that the structure of the sectors might evolve. What pattern of development (widening or deepening) of the biotechnology sector is involved**? Is the development of the sector based on new firms or on the creation of new technologies by existing firms?**

The role SMEs in the knowledge-based economy

The analysis in terms of knowledge-based economy is especially relevant for new emerging technologies such as biotechnology**. Because of the characteristics of the learning process, the knowledge base of a firm limits its own extension (Saviotti 1998).** Consequently, incumbents are not the best actors to develop radically new technologies. This interpretation is coherent with the analysis of Anderson and Tushman. However, **developments within the knowledge-base theory focus more particularly on the organisation of research activities, as shown by the analysis of National System of Innovations (NSI).**

Niosi (1999) defines a national system of innovation as "a set of inter-related institutions. Its core is made up of those that produce, diffuse and adapt new technical knowledge, be they industrial firms, universities, or government agencies. The links between these institutions consist of flows: knowledge, financial, human (people being the bearers of tacit knowledge and know-how), regulation and commerce". An NSI includes the activities of firms, government departments and agencies, the education and training system, universities and the science base, and banks and financial markets, which together provide the knowledge and resources for the development of a new technology. The features of a national system therefore both constrain and facilitate the activities of biotechnology firms.

When an NSI is empirically defined, patent application is the main proxy used to describe the strength or weakness of a technological field. In a recent study, de Looze and Ramani (1999) compare the characteristics of patents from three leading European countries in the biotechnology sector (France, Germany and the UK). They highlight two main features. First, institutional differences are pointed out: in France, two thirds of patent applications are issued from public research organisations, compared to one third in the UK and Germany. Second, they show a national specialisation in micro-specialised biotechnology fields.

Such differences can be explained by different domains of expertise in the three countries, but also by different funding mechanisms, as shown by Walsh et al. (1995). Their analysis underlines, more particularly, the role of public policies concerning innovation, and other funding **mechanisms (e.g. venture capital). A variety of instruments have been developed in each country to promote both the development of biotech SMEs and the creation of networks between firms and public laboratories[3].**

The institutional characteristics of the countries concerned suggest that different biotechnology development trajectories can be adopted. Firms, and particularly SMEs, are the driving force behind such developments. This analysis warrants comparison with empirical data.

The empirical analysis proposed in the next section is part of this second framework on the knowledge-based economy. The focus is limited to the technological part of the knowledge base of each SME and ignores the managerial part. Based on a sample of SMEs from three countries, we analyse the leading technologies in each country as well as the different combinations of technologies that are usually made by SMEs. This analysis follows the one proposed by Saviotti et al. (1998) which was limited to France (in Europe).

The database

Most of the time, the study of an actor's technology base draws on patent or article production (McCain 1995, Joly and de Looze 1995; Joly et al. 1996, de Looze and Ramani 1999). This method is biased when studying SMEs because most of them do not file for patents to protect the results of their research, even in high-tech sectors such as biotechnology. Moreover, this type of selection may lead to some bias when studying technology bases because one particular technology might be more easily patentable than others[4].

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[3] Powel et al. (1996) analyse in great detail the dynamics of biotech networks. In particular, they show that when a knowledge base of an industry is both complex and expanding and the sources of expertise are widely dispersed, the locus of innovation will be found in networks rather than in firms.

[4] As suggested by Levin *et al* (1987), all process innovations are generally less patented than product innovations.

The alternative is to use databases based on surveys (Bioscan, Dibner, Genetic Engineering, etc.). Most of the time, these databases are more exhaustive for US firms than for European firms, both because they are built in the United States and because biotechnology has developed more recently in Europe. Moreover, very few databases use a unique classification of technologies for the description of all the firms in the database. Non-standardised information generally prevents any transversal analysis. For all these reasons, the Genetic Engineering database has been selected for this study because it provides a good, standardised description of firms (especially concerning the technology base and targeted markets). This database was published in 1998 but it mainly covers companies set up before 1996.

The Genetic Engineering directory of biotech companies covers information on approximately 2,200 companies world-wide, of which 440 are in Europe, including 228 SMEs[5] in the three leading countries (the UK, Germany and France). Compared to other sources, this sample seems representative: Ernst and Young (1998) report 550 SMEs in the same countries[6], and Bioscan reports 106 companies. Only 33% of the firms described in Genetic Engineering have published a patent. Five types of variable can be drawn from this database: year of creation, number of employees, number of scientists**, technologies used or developed, and market targeted by the company**. Information on technology and market were available for all the firms, information on creation date and number of employees were available for about 90% of the companies, and only 50% of firms gave information on the number of scientists. The rates are approximately the same for all the countries under study.

Results

First a description of the sample of firms under review is presented. The technology base of the firms is then analysed in more detail, and leads to the identification of three groups of firms. In the last sub-section, **patterns of association between technologies and markets are analysed, using scientometrics tools.**

- **Descriptive statistics for each country**

A first **set of descriptive statistics is given in Table 1.** The number of companies in France and Germany is similar, and more than three times smaller than in the UK, as recognised by most empirical analyses. The recent emergence of new companies in Germany is not captured here because the sample contains only one firm created in 1997 and seven firms in 1996. Interestingly, the number of employees per firm in Germany is 50% lower than the number in France or in the UK (32 compared to 50 and 61). A similar difference also exists for the number of scientists[7].

The average year of creation is 1984 for the whole sample, and ranges from 1982 in France to 1985 in the UK. The median of the creation date is higher compared to the mean because only 33% of the companies were created before 1984. A very regular trend of creation

[5] The SMEs were defined as having fewer than 500 employees.

[6] According to Ernst & Young, 150 companies out of the 550 were founded after 1997, and are probably not recorded in Genetic Engineering.

[7] Information on the number of scientists was available for only 50% of the sample, and has to be taken with more caution.

of about 5% per year in relative terms (percentage of the final number in 1997) is observed for each country[8].

This database is a declarative one. The firms characterise their technologies and targeted markets themselves by answering a questionnaire sent by Genetic Engineering. In the questionnaire, a pre-determined list of 33 technologies and 33 markets is proposed. Amongst these 33 items, the number of technologies or markets chosen is not limited. For the whole sample, the average number of technologies is 4.8 and the average number of markets is 5.2.

Table 1. General caracteristics of the sample used for the analyses

	UK	Germany	France	Total
Nb of SMEs	145	42	41	228
Creation year (mean)	1985	1983	1982	1984
Nb of employees (mean)	50	32	61	49
Nb of scientists (mean)	24	8	25	22
Nb of technologies/company (mean)	4.67	4.52	5.37	4.77
Nb of markets/company (mean)	4.96	5.64	5.66	5.21

The countries do not appear to be specialised with respect to either their technologies or their markets (tables 2 and 3). The three main technologies are ranked in the same order in each country: (1) purification/separation, (2) cell/tissue culture, and (3) fermentation. The three main markets are also identical but ranked differently: biologicals, pharmaceuticals, and diagnostics. The seven main technologies or markets for the full sample are all ranked in the first 10 places in each country. Consequently, if a National System of Innovation exists, it does not lead to the use of specific technologies or to the targeting of specific markets by SMEs.

Table 2. The 15 main technologies used in the biotech SMEs in each country

Rank	UK		Germany		France		Total	
1	Purification/ separation	66	Purification/ separation	22	Purification/ separation	23	Purification/ separation	111
2	Cell/tissue culture	59	Cell/tissue culture	22	Cell/tissue culture	17	Cell/tissue culture	98
3	Fermentation	44	Fermentation	13	Fermentation	14	Fermentation	71
4	Bioprocesses	42	Recombinant DNA	11	Recombinant DNA	13	Recombinant DNA	60
5	Recombinant DNA	36	Enzymology	11	Synthesis	11	Bioprocesses	59
6	Computer hardware/ software	30	Synthesis	11	Large-scale purification	10	Large-scale purification	46
7	Large-scale purification	27	Sequencing	11	Bioprocesses	9	Enzymology	45

[8] These figures have to be interpreted carefully. Firstly, the Genetic Engineering database is a cross section database and ignores the cases of firms which disappeared before 1998. The rate of creation is probably under-estimated. Secondly, this database represents a sample, and consequenlty the figure can be given only in relative terms.

8	Polyclonal antibodies	26	Large-scale purification	9	Enzymology	9	Computer hardware/ software	42
9	Enzymology	25	Bioprocesses	8	Gene amplification	9	Synthesis	42
10	Gene amplification	23	Gene amplification	8	Computer hardware/ software	7	Sequencing	41
11	Sequencing	23	Polyclonal antibodies	8	Sequencing	7	Gene amplification	40
12	Hybridoma/ cell fusion	23	Drug discovery	8	Hybridoma/ cell fusion	7	Hybridoma/ cell fusion	37
13	Combinatorial chemistry	22	Hybridoma/cell fusion	7	Combinatorial chemistry	6	Polyclonal antibodies	36
14	Synthesis	20	Drug delivery	7	Drug discovery	6	Combinatorial chemistry	32
15	Small molecule chemistry	18	Computer hardware/ software	5	Peptide isolation and synthesis	6	Drug discovery	28

Table 3. The 15 main markets targeted by biotech SMEs in each country

Rank	UK		Germany		France		Total	
1	Biologicals	87	Pharmaceuticals	25	Pharmaceuticals	31	Pharmaceuticals	138
2	Pharmaceuticals	82	Biologicals	24	Biologicals	24	Biologicals	135
3	Diagnostics	65	Diagnostics	22	Diagnostics	18	Diagnostics	105
4	Agriculture	45	Chemicals	14	Cosmetics	18	Agriculture	66
5	Reagents	38	Reagents	12	Veterinary products	15	Veterinary products	63
6	Veterinary products	37	Veterinary products	11	Clinical tests	13	Reagents	61
7	Instrumentation	35	Agriculture	10	Agriculture	11	Clinical tests	53
8	Clinical tests	31	Clinical tests	9	Reagents	11	Chemicals	51
9	Environmental technologies	31	Instrumentation	9	Chemicals	11	Instrumentation	51
10	Contract manufacturing	30	Environmental technologies	9	Food processing	10	Environmental technologies	45
11	Chemicals	26	Cosmetics	9	Instrumentation	7	Contract manufacturing	41
12	Contract research / CTM	25	Food processing	8	Contract research / CTM	7	Food processing	41
13	Food processing	23	Vaccines	8	Vaccines	7	Contract research / CTM*	39
14	Human genome project	23	Contract research / CTM	7	In vitro toxicology testing	6	Cosmetics	37
15	Vaccines	18	Human genome project	7	Environmental technologies	5	Human genome project	34

* CTM = Clinical Trial Management

- **Analysis of the technology base of SMEs**

For each technology, the characteristics of the firms using it can be analysed (Table 4). The year of creation of companies appears to be very different, and interestingly those with the most recent date of creation are also the ones that develop the more recent technologies. Thus, companies work mainly on the technologies originally chosen when they were created. The rapid evolution of technologies observed at the sectoral level is mainly due to the creation of new SMEs. **The internal renewal of technologies within each company**[9] **does not appear to be a key force of technology creation.**

Table 4. Caracteristics of technolgy use: age of companies and association of technologies

Technology	Nb of companies	Mean creation date	Mean association number
High throughput drug screening	21	1990,2	7,1
Drug delivery	23	1990,0	4,6
Tissue engineering	9	1989,4	4,4
Bioinformatics	20	1989,4	6,8
Drug discovery	28	1989,1	7,2
Transgenics	17	1989,0	5,0
Small molecule chemistry	27	1988,0	7,0
Combinatorial chemistry	32	1987,2	5,7
Peptide isolation and synthesis	27	1986,6	6,7
Anti- fungals	10	1986,2	8,2
Recombinant DNA	60	1986,1	6,2
Peptidomimetics	9	1985,8	8,9
Computer hardware/software	42	1985,3	3,9
Gene amplification	40	1985,1	5,8
Synthesis	42	1984,8	7,0
Sequencing	41	1984,7	6,7
Robotics	21	1984,0	6,0
Hybridoma/cell fusion	37	1983,9	5,5
Antisense	20	1983,8	8,0
Chiral chemisrty	18	1983,5	8,9
Purification/separation	111	1983,3	5,4
Apotopsis	45	1982,9	7,1
Enzymology	21	1982,9	6,3
Chimeric compounds	4	1982,7	11,0
Cell/tissue culture	98	1982,5	5,2
Large-scale purification	46	1982,5	5,8
Fermentation	71	1982,1	5,5
Gene therapy	17	1981,9	6,9
Bioprocesses	59	1981,8	5,7
Polyclonal antibodies	36	1981,1	5,2
Blood substitutes	3	1980,0	8,0
Carbohydrate biotechnology	17	1978,8	7,9
Process monitoring control	15	1978,6	5,5

[9] Results concerning evolutionary patterns always have to be considered with caution when drawn from cross-sectional data A better level of confidence could be reached with panel data, but this kind of data is unfortunately not available on large samples.

Are technologies combined or does a firm use only one technology? The association between technologies has now to be analysed. Firms generally use about 5 technologies (Table 1), and only 30 firms out of 228 use only one technology. The number of associations is then broken down (Table 4). The average number of technologies associated with a particular one ranges from 3.9 (Computer hardware/software) to 8.9 (Peptidomimetic and Chiral Chemistry) and even 11 (Chimeric compounds). These differences cannot be explained by the other variables. In particular, the average date of creation has no effect on the rate of association.

We then tried to identify different types of firms, based on the combination of technologies they are using. The analysis is based on a data analysis method called Multiple Component analysis, with the 33 technology variables as explicative variables. The first axis explains 12% of the variance and mainly compares use and non-use of any technology[10]. When the technologies are projected on the axes 2 and 3, we clearly observe that non-uses are concentrated in the centre, with uses all around. Three groups of firms were finally distinguished, based on their coordinates on axes 2 and 3: INST (south-east), CHEM (north) and GENE (south-west).

The frequency of technologies within each group is reported in Table 5. Membership of technology groups is the factor differentiating firms the most. A firm's country of origin is not a discriminating variable (Table 2). Only four common technologies are ranked in the first fifteen places of the three groups (instead of 7 in the first 10 places of the three countries). The technological orientation of a group can then be determined:

- the INST group is oriented towards instruments (computer hardware/software, robotics, high throughput drug screening, bioinformatics);
- the CHEM group is oriented towards more classical chemistry and process improvement (fermentation, bioprocesses, large-scale purification, drug discovery, drug delivery);
- the GENE group focuses on genetic and genomic research (gene amplification, recombinant DNA, polyclonal antibodies, gene therapy)

These classifications confirm the clustering of technologies obtained by Saviotti et al. (1998) on the basis of French companies only. Five groups are obtained in their research, three of them (production, diagnostics and proteins) being closed to the CHEM group identified here.

Table 5. The 15 main technologies used in the three groups of biotech SMEs

Rank	INST (66 SMEs)		CHEM (120 SMEs)		GENE (42 SMEs)	
1	Computer hardware/software	34,8%	Purification/separation	57,5%	Purification/separation	71,4%
2	Cell/tissue culture	30,3%	Fermentation	50,0%	Cell/tissue culture	71,4%
3	Robotics	19,7%	Cell/tissue culture	40,0%	Gene amplification	64,3%
4	High throughput drug screening	18,2%	Bioprocesses	39,2%	Recombinant DNA	61,9%
5	Purification/separation	18,2%	Large-scale purification	33,3%	Sequencing	50,0%
6	Sequencing	16,7%	Enzymology	27,5%	Polyclonal antibodies	38,1%

[10] Axis 2 explains 9.4% of the variance, and axis 3 explains 7.3% of the variance.

7	Synthesis	16,7%	Recombinant DNA	20,0%	Hybridoma/cell fusion	35,7%
8	Gene amplification	15,2%	Combinatorial chemistry	19,2%	Fermentation	26,2%
9	Recombinant DNA	15,2%	Hybridoma/cell fusion	18,3%	Gene therapy	26,2%
10	Small molecule chemistry	15,2%	Synthesis	17,5%	Synthesis	23,8%
11	Bioinformatics	15,2%	Peptide isolation and synthesis	16,7%	Antisense	23,8%
12	Combinatorial chemistry	13,6%	Drug discovery	15,0%	Bioprocesses	21,4%
13	Transgenics	12,1%	Drug delivery	15,0%	Apotopsis	21,4%
14	Drug discovery	10,6%	Polyclonal antibodies	13,3%	Transgenics	21,4%
15	Tissue engineering	9,1%	Computer hardware/software	12,5%	Enzymology	19,0%

Frequencies are relative to the number of companies in the group

The proportion of each group in each of the three countries is reported in Table 6. Companies in the INST group develop more frequently in the UK, those in the CHEM group in Germany and those in the GENE group in France. However, these tendencies do not preclude development of other groups in each country, as can be observed when figures are considered in absolute terms. The number of companies in the GENE group is more important in the UK (20) than in France (12), simply because there are twice as many companies in the UK as in France[11]. Finally, a pattern of specialisation is observed in each country, but because of different total numbers, a group ranking second in one country can be larger than a group ranking first elsewhere.

The size of firms seems to be influenced specifically by the technology base. SMEs in the INST group are significantly smaller (40 persons), even if this group is dominant in the UK where the medium size is fairly large (50 persons). Conversely, companies in the CHEM group are larger in all countries. The number of technologies used by each SME also differs far more within a group than within countries: **GENE companies combine more technologies (6.7) compared to CHEM (5.0) and INST (3.17).**

The group also has a net effect on the propensity to patent. When companies are working on a gene, patenting is a major tool for appropriability and most of the companies involved are patent owners (57.1%). Patenting also concerns classical research in pharmaceuticals, and we observe a number close to the average propensity to patent (i.e. for the whole sample). Conversely, the propensity to patent is weak in the INST group: firms working on instruments seem to find other ways to appropriate the benefits from their innovation.

[11] Absolute values could be contested because they are compiled for a sample of companies. However this precise comparison between France and the UK on the GENE group is probably true because it is generally acknowledged that biotech SMEs in the UK are more numerous than in France.

Table 6. Characteristics of the three groups of firms

		INST	CHEM	GENE
Factor 2		-		+
Factor 3		+	+	-
Frequency of SMEs	Total	29.0%	52.6%	18.4%
	UK	35.9%	50.3%	13.8%
	Germany	14.3%	61.9%	23.8%
	France	19.5%	51.2%	39.3%
Nb of employees	Total	39.6	56.9	41.6
	UK	42.2	59.3	36.7
	Germany	16.5	37.1	26.9
	France	37.8	70.4	61.4
Nb of technologies		3.17	4.98	6.67
Propensity to patent*		18.2%	32.5%	57.1%

* Percentage of companies with at least one patent in the DBA database.

- **Analysis of the links between technologies and SME markets**

Coword analysis is used to detect linkages between technologies and markets[12]. This method is described in Callon et al. (1991). In this paper, the graph results are obtained through the Sampler© software[13]. Sampler is a "text meaning" environment combining linguistic technology with the algorithm of co-occurrences. **The analysis produces four clusters technologies and markets, presented in Graphs 1 to 4**. Although the results of are of real interest, they must be analysed with caution. The definition of markets in the Genetic Engineering Database is not homogeneous. Some markets seem highly generic (pharmaceuticals, diagnostics, agrifood, etc.) while others are far more limited (biosensors, human genome project, etc.). This is particularly true for Cluster 1. The quality of data does not enable us to be more precise.

Cluster 1 corresponds to generic technologies and markets. The number of co-occurrences between variables is high (generally more than 20). Pharmaceuticals, biologicals, diagnostics and veterinary products seem to be the leading poles, while reagents, clinical tests, bioprocesses, agriculture, food processing, and environmental technologies are less generic and appear to be more specific markets (niches). Techniques that are linked are the most frequent techniques shown by the preceding results; they are "classical" techniques in the field.

Cluster 2 corresponds to markets and technologies involved in supplying hospitals. The linkages are weaker than those in Cluster 1: the number of co-occurrences is usually less than 10. Biomaterials, vaccines, contract-research-clinical-trial-management are the most attractive poles. The linked technologies are gene therapy, transgenics, and tissue engineering, used for heath care, hospitals and other forms of care. The linked techniques are fairly new.

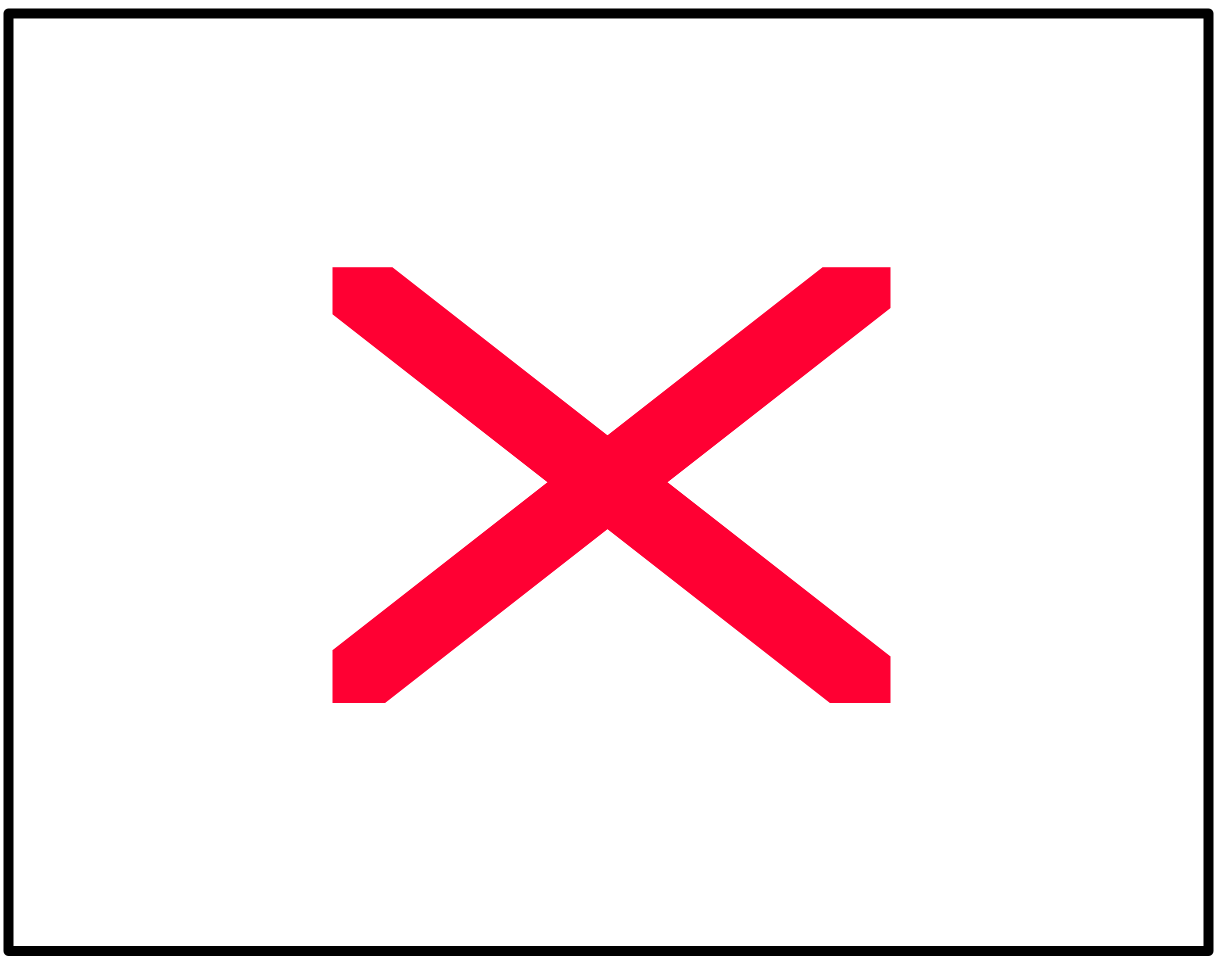
[12] This method was used because the specialisation of the groups INST, CHEM and GENE with respect to the market was very weak.

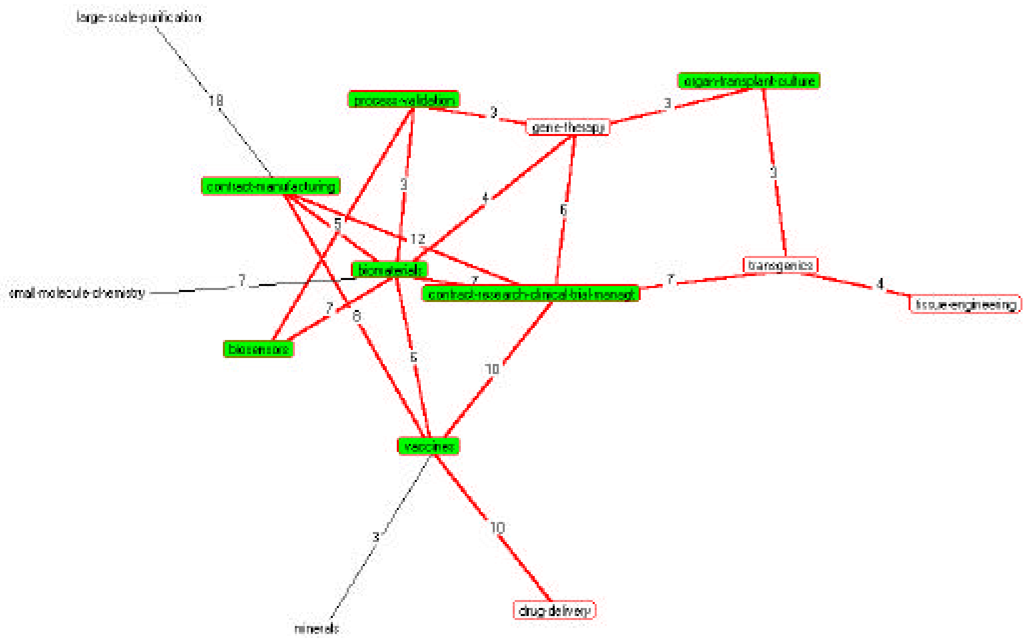
[13] Sampler© was developped by the CISI (3, rue Le Corbusier, Silic 232, 94528 Rungis Cedex, France).

Cluster 3 is dominated by the environmental markets and contains very few technologies. Links with technologies are difficult to map out with the algorithm of co-occurrences because the market frequency is very low. Large companies generally occupy these markets.

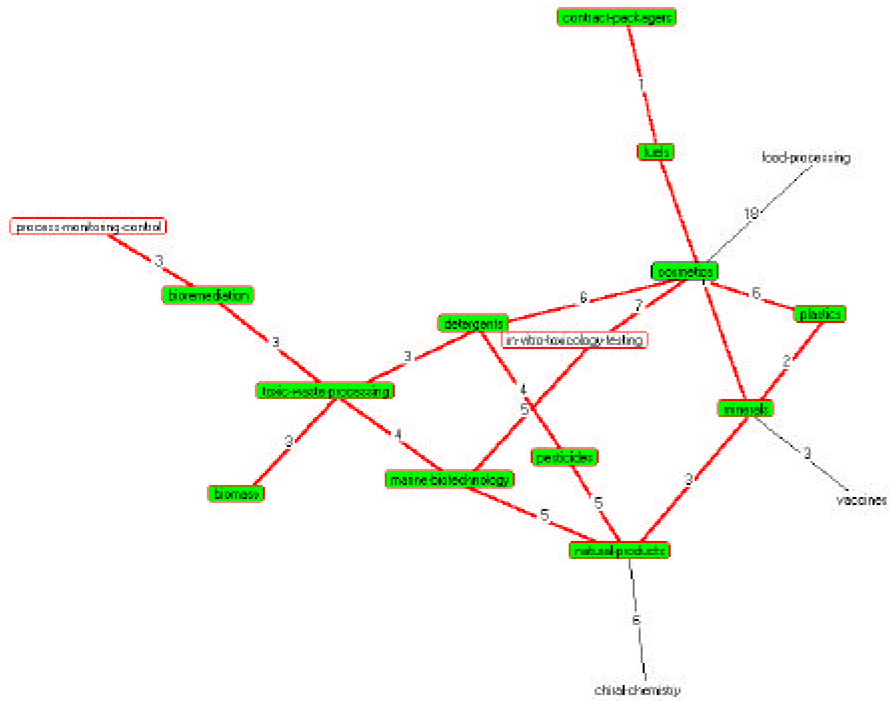
Cluster 4 comprises relatively new technologies and very few markets. The graph can be divided into two parts, with small co-occurrence numbers on the left and high co-occurrence numbers on the right. Technologies with significant co-occurrences (right hand side) are fairly new (e.g. bio-informatics, peptidomimetics). The firms that produce these technologies anticipate new technologies and new markets. This cluster contains only two markets linked together: instrumentation and human-genome-project.

Graph 1 The main markets with heavy links with technologies (cluster 1)

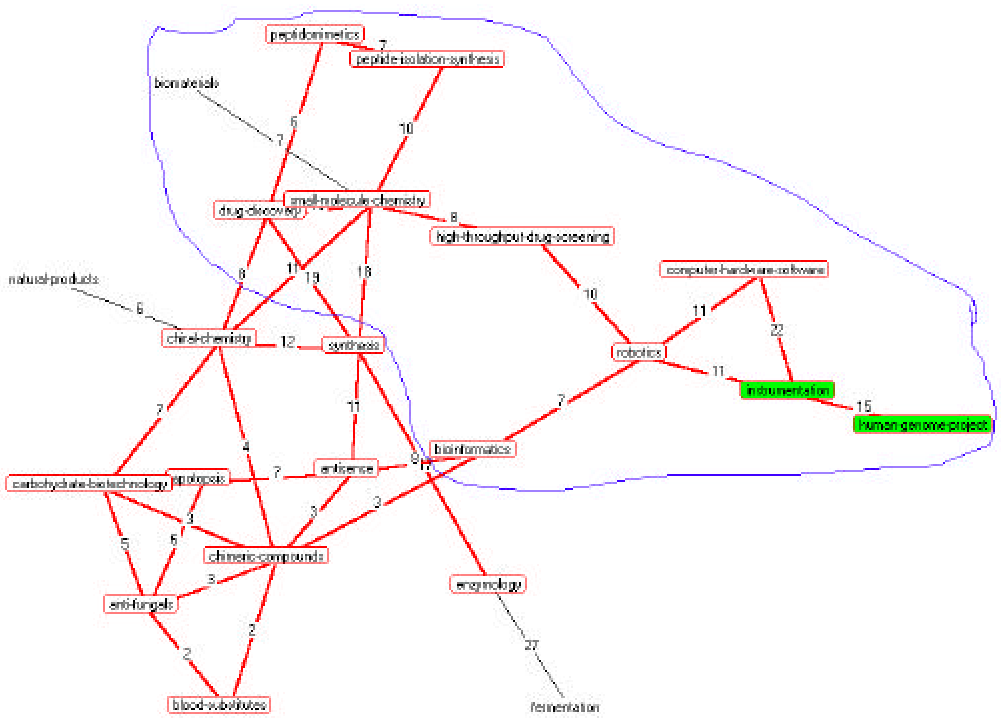




Graph 2 : The market of health (cluster 2)



Graph 3 : The markets of the environment (cluster 3)



Graph 4 : New technologies and few specific markets (cluster 4)

Based on the use of a specific database containing standardised information, scientometric tools and statistical analysis give a different picture of biotechnology sector dynamics, compared to patent-based analyses. SMEs in different countries are specialised and their specialisation depends on their period of creation. The dynamics and adoption of new technologies seem to be based more on the creation of start-ups than on the renewal of technology in existing firms. If a national specialisation exists, it must be analysed carefully as the number of firms involved in one area is more important than the relative proportion of firms in each scientific sub-field. Complementary scientometric tools identify the growing area, including markets and technologies. By means of this analysis it is possible to map out the leading technologies/markets combination.

Conclusion

To summarise, four main conclusions can be drawn from this study:

1) In order to study the technology base of SMEs, patent analysis may introduce some bias because the propensity of firms to patent differs significantly, depending of the technological

base of the SME. Only one third of the SMEs in our sample patent. Patent analysis would probably overestimate the importance of genetic-related technologies and underestimate technologies linked to instruments or process improvement. The alternative used in this paper is to develop a questionnaire-based database. However, these databases are generally incomplete (especially when studying European biotechnology), and generally contain cross-sectional data.

2) No specific national characteristics appear clearly. By analysing the technologies developed and used by firms, we obtain an image and conclusions that differ from those obtained in studies based on patents.

3) Biotech SMEs are frequently associated with their original technology. Their small size is generally a handicap in the adoption of new technologies. Consequently, the evolution of the technology base at the sectoral level is primarily due to developments in the number of SMEs. For the moment, in the biotechnology sector, the innovative base is continuously enlarged by the entry of new firms. The renewal of technologies is due to newcomers.

4) Four clusters of associations between technologies and markets can be observed. Some clusters clearly link technologies with markets (cluster 1 with leading market and technologies, and cluster 2 dedicated to health care). Other clusters are more market-based (cluster 3 concerns mainly the environment), or technology based (cluster 4 is dominated by emerging technology that does not yet have a corresponding market).

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Title: Strategies Of European Smes In Biotechnology: The Role Of Size, Technology And Market*

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