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An analysis of innovation strategies and industrial differentiation through patent applications: the case of plant biotechnology [1]

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Abstract

The main result of this study of patent applications in plant biotechnology showed that a low level of technological differentiation explains a weak regime of appropriability. We consequently propose a complete reversal compared with traditional approaches. Whereas patents are generally considered as a decisive factor, we suggest that alone they cannot induce a dynamic of technological differentiation. It is because they do not play the role attributed to them by Kitch (the co-ordination of actors' plans) that they do not fulfil the function traditionally allocated to them (an incentive to innovation).

Given this relation of weak appropriability to a low level of technological differentiation, the dynamics of plant biotechnology seem to be more closely related to the introduction of new tools into specific fields of application via vertical integration, than to the autonomous development of generic technologies. Industrial organization is seen as being characterized by a dynamic of differentiated oligopoly, with a high level of vertical integration rather than intense horizontal specialization and quasi-commercial relations between firms.

1. Introduction

Since the early 1980s, there has been a considerable revival in the economic analysis of patents. Before that, traditional analyses had seen patents as the instruments of a compromise between static efficiency (pure and perfect competition) and incentives to research. This type of approach was then progressively completed by an analysis of relations between regimes of appropriability and industrial dynamics. Nelson and Winter's analysis of the Schumpeterian trade-off illustrates the method very well. We know that it consists of analysing, in a dynamic framework, relations between the degree of appropriability and the level of industrial concentration (Nelson and Winter, 1982).

This model was a significant step forward compared with analyses which focused on the optimum life-span of patents (Nordhaus, 1969) or with models of the patents race (cf. Reinganum, 1989, for a complete survey). Yet, it paid little attention to highly significant aspects of industrial dynamics, notably the diversity of products and that of industrial struc-

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tures. More recent approaches have progressively been addressing such issues.

From his analysis of strategies for creating value for innovation, Teece clearly shows the link between the nature of an appropriation regime and the degree of vertical integration (Teece, 1986). Articles by Kemplerer (1990) and Waterson (1990) consider the fundamental problem of the scope of patents. In their view, the main impact of a patent is not so much the creation of a monopoly situation as the patent's influence on rival firms' differentiation strategies. Such an approach can usefully be completed by the historical work of Merges and Nelson (1990) on relations between the impact of patents and the dynamics of technological development.

In a certain sense, these different contributions renew Kitch's prospect theory of patents (Kitch, 1977) which considers that the main role of a patent lies in its ability to co-ordinate the plans of different firms. Nevertheless, they are all based on the same presupposition: the nature of the regime of appropriability is considered as an exogenous variable on which forms of co-ordination and industrial structures depend. At no point is it assumed that the causality could be inverted. But what if the characteristics of the regime of appropriability were themselves dependent on the technological differentiation of firms?

The present article is based on this hypothesis of inverting the analysis. Can patents induce the technological differentiation of firms? If the level of differentiation is low, what about the regime of appropriability? In such cases, what can be said about firms' strategies and resulting economic and technological dynamics?

These questions are considered by means of an original method based on the use of scientometric tools in an emerging but fast-growing technological field – that of plant biotechnologies. Section 2 is a recap of the general characteristics of patents in that field, so as to identify clearly the pros and cons of the approach. Section 3 is devoted to an analysis of the positions of different actors, as revealed by scientometric tools. We first analyse the concentration of patent applications before considering the role of major patents and the key problem of technological differentiation. In Section 4, after developing further the analysis of the link between technological differentiation and appropriability, we consider the area of corporate strategies. This enables us to build a general hypothesis of the evolution of the technological field.

2. Describing the context in order to analyse the role of patents in biotechnologies

In order to interpret information on biotechnology patents accurately, the specific legal context must be considered. We recall that the patent was originally designed to protect mechanical inventions. Yet, from the 1970s, the biotechnological revolution created new needs for protection. The period of observation is thus marked by major uncertainty concerning the adaptation of patent rights to living organisms. This context impacts on the behaviour of the organizations involved.

2.1. Emergence of 'patentability' of biotechnologies in the American and European systems

Given the characteristics of innovations in biotechnology, protection through patents *is expected to* act as a significant incentive for R&D. No matter how long and complex it is, an R&D programme generally results in the creation of a new enzyme, gene, micro-organism, animal or transgenic plant. These new living organisms are characterized by a specific genetic heritage, that is, *codified information that can easily be reproduced.* The biotechnologies do of course also include a collection of processes which are generic to a greater or lesser degree. However, whether the final products are new or not, the production process systematically spawns new genetic information, which brings the problem of the appropriability of the innovation into sharp focus. Because of this basic characteristic of biotechnologies, the best way to prevent imitation is by protecting, through patents, not only the processes but also in many cases the products obtained by these processes.

Owing to the central role of the patent as a means of protecting inventions in plant biotechnologies, it can be used a priori to characterize research programmes. In contrast with other areas of

Table 1
Description of the classes of IPC for biotechnologies

Class	Description
A01G	Horticulture; cultivation of vegetables, flowers etc.
A01H	New plants or processes for obtaining them; plant reproduction by tissue culture techniques
A01N	Preservation of bodies of humans, animals or plants or parts thereof; biocides...plant growth regulator...
C12M	Apparatus for enzymology or microbiology
C12N	Micro-organisms or enzymes; compositions thereof; propagating, preserving or maintaining micro-organisms; mutation or genetic engineering; culture media
C12P	Fermentation or enzyme-using processes to synthesize a desired chemical compound or composition or to separate optical isomers from a racemic mixture
C12Q	Measuring or testing processes involving enzymes or micro-organisms; composition of test papers; processes for preparing such compositions; condition-responsive control in microbiological or enzymological processes

technology, [2] the other factors involved in the appropriability of the innovation (such as secrecy, advances on the experience curve, the importance of commercial efforts, etc.) play only a very complementary and secondary role here. Patents are likely to provide a representative indicator of the output of research programmes, which makes it possible to overcome one of their traditional limitations highlighted in other articles (Pavitt, 1988).

For both products and processes, the new problem posed by biotechnology patents is the appropriation of microbiological compounds (genes, vectors, micro-organisms, etc. that intervene in the different phases of a process) and, above all, the patenting of living organisms (plants and animals).

In fact, the patent is used here in an area which was formerly foreign to it. The questions posed are not only the classic technical ones (definition of the inventive activity, patent applications for micro-organisms, role of compulsory licences, etc.), but also questions of principle concerning the patentability of living organisms. Thus, during the 1980s there still existed numerous uncertainties which influenced the behaviour of firms with respect to their patent applications.

Even if questions of principle are no longer an issue today, several uncertainties remain concerning the effective conditions of the exercise of intellectual property rights. [3] Because of a lack of jurisprudential experience, it is not possible to foresee how important issues, for example those concerning the effective scope of a patent, will be settled in the future. The results of patent data bases must therefore be interpreted with caution, especially when one works on *patent applications*, as we have done here. One can assume that uncertainty has increased the propensity of certain firms to patent (firms specialized in biotechnology, the dedicated biotechnology firms (DBFs), and certain diversified corporations (DCs)) in order to rapidly secure positions of technological leadership and to carry weight in the debate on patents. The same phenomenon probably produces an under-representation of incumbents.

The problem of the time taken by patents offices to process applications is only a partial consequence of more fundamental debates in this area. It can also be attributed to the difficulties which these offices experience in recruiting suitably qualified examiners. This problem was emphasized by the Office of Technology Assessment (OTA) in its report on biotechnology patents:

As of July 1988, 5850 biotechnology applications had not been acted upon. Currently, it is approxi-

[2] On the estimation of the relative importance of different means of protecting innovation, we refer to the results of the Yale survey which show that, with the exception of pharmaceuticals, patents systematically play a less important role than alternative means of protection (See Levin et al., 1987).

[3] For a general overview, see Eisenberg (1992) and Barton (1991).

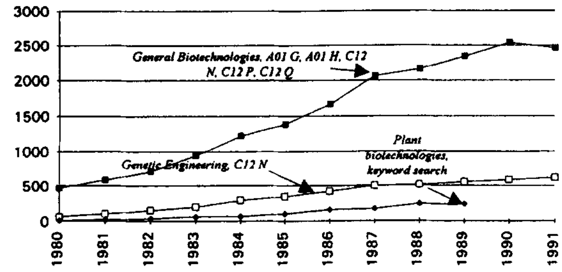

Fig. 1. Evolution of patent applications in the biotechnology field.

mately 15.5 months, on average, before the examination of a biotechnology application is initiated, and an average of 27 months before the examination process is completed by the granting of the patent or the rejection of the patent application (OTA, 1988, p. 60).

The length of these delays explains why, in order to retain a maximum of information, we chose to analyse patent applications rather than patents actually granted by the offices. Because the European system permits the publication of a patent 18 months after its application, American patents can be found at the European Patents Office even before they are published by the US Patent and Trademark Office (USPTO). [4]

2.2. *Biotechnologies: retrospective analysis and macro comparisons*

Patents in general biotechnology concern all aspects of biology, whether they are traditional biotechnologies (fermentation, microbiology, enzyme engineering, etc.) or modern biotechnologies (related to recent developments in molecular biology) (Table 1). The number of patent applications rose from 500 to over 2500 year^{-1} during the 1980s (Fig. 1). The rapid increase in the number of applications in all categories shows the effect of renewal related to interaction between traditional techniques and modern approaches.

Patents in genetic engineering (belonging to Class C12N) progressed from a negligible level at the beginning of the period under study to more than 500 year^{-1} at the beginning of the 1990s, that is, 20% of all applications in the biotechnologies. This rapid growth corresponded to the investments made in the late 1970s by American DBFs and DCs, and then from the 1980s by big European and Japanese industrial groups. In this area, the first patent accepted was that of Stanley Cohen and Herbert Boyer of Stanford University ("Process for producing biologically functional molecular chimeras" 2/12/80). With more than 200 user licences and an annual income of US$1.7 million, it is the record-holding patent of Stanford University.

The biotechnologies are characterized by strong complementarity between fundamental and applied research. This often results in the hybridization of roles at the laboratory level. It is not unusual for articles written by scientists from industrial research laboratories to appear in prestigious journals like *Science* or *Nature*; on the other hand, public research laboratories often have a systematic strategy of obtaining protection through patents. The study conducted by Collins and Wyatt (1988) shows that a patent related to a genetic engineering process cites on average 8.8 articles of which more than 80% have been published in journals of fundamental research (Class 4 of CHI Research, Inc. [5]). According to Narin (1992), DBF patents (Genentech, Genex, Genetics Institute, Cetus, Chiron, etc.) cite on average 15.6 scientific articles as opposed to only 3.72 for the patents of large pharmaceutical companies. [6]

It is therefore not surprising that the participation of the different zones of the Triad (USA, Europe, Japan) in patent applications reflects their scientific production. The United States accounts for 35% of

[4] On this point, see also Schmoch et al. (1992) whose results are similar. It is also due to the fact that USPTO publishes patents only when they are granted.

[5] Pinski and Narin (1972). F. Narin, excerpt from Science Indicator Final Report, for the NSF, pp. 95–109, CHI Research Inc.

[6] In 1992, Genentech scientists published 292 articles in scientific journals. The firm also obtained 218 additional patents, which brought its collection of patents to a total of 1210 (Genentech, *1992 Annual Report*).

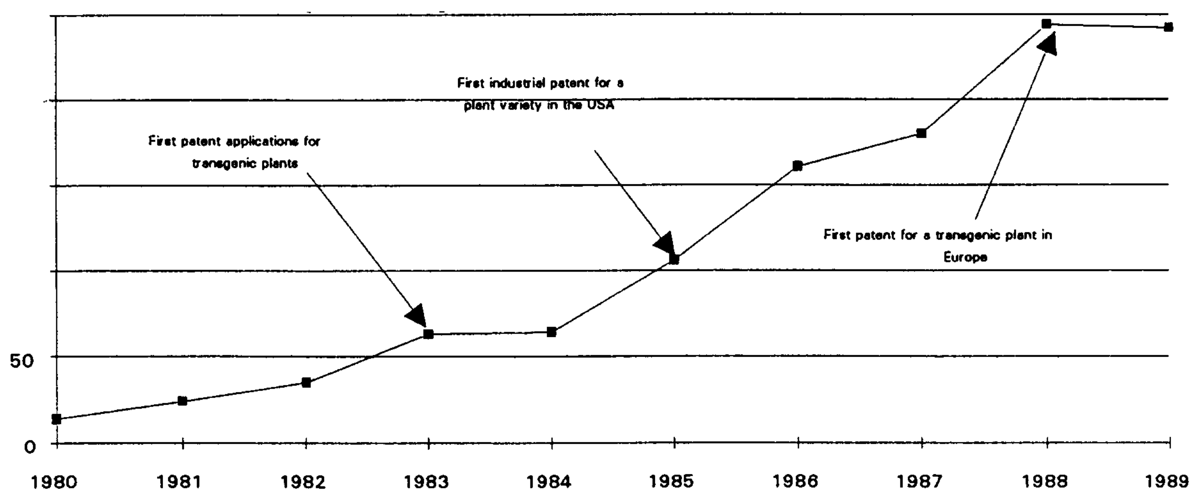

Fig. 2. Evolution of patents in plant biotechnologies.

the international scientific production in biology; their share of patent application in biotechnology (International Patent Classification: C12N) at the European Patent Office is 41.9%. For the European Union countries, these shares are 27.7% and 37.1% respectively.

2.3. Patents in plant biotechnologies

The results of analyses carried out during the 1980s show that, from the viewpoint of innovation strategies and industrial dynamics, biotechnologies cannot be considered as a homogeneous entity. Each field of application has to be analysed individually.

The situation described above with respect to the biotechnologies in general also applies to the plant biotechnologies in particular: it is an emerging field, characterized by strong legal uncertainties and by intense interaction between scientific discovery and technological innovation. On the other hand, given the high level of market segmentation, specialized complementary assets play an essential role in the creation of value for innovation.

In order to constitute a corpus of analysis for the plant biotechnologies, one cannot in this case limit oneself to a direct utilization of the International Patent Classification (IPC). It is necessary to implement search strategies which intersect several categories of the IPC with selected keywords. That is what we did in this research. [7]

The period of observation (1980–1989) corre-

[7] Methodology for constituting a corpus of patents in plant biotechnologies:
In order to compile a corpus of patents in plant biotechnologies, we first brought together a group of INRA biologists who were asked to draw up lists of keywords and authors in the field of plant biotechnologies. (INRA is the French National Institute for Agronomic Research with 8000 employees, of whom 3000 are researchers. A large part of its research activity is devoted to biology.) This first stage was completed by several meetings with information science specialists who have considerable experience in this domain. We were thus able to define the field by means of search strategies that used keywords related to one another by Boolean operators, and to generate a list of themes. Our search provided the principal keywords which were subsequently intersected with classes of the international patent classification as shown in Table 1. We used the Derwent WPI and WPIL data bases. After several iterations we obtained around 1000 relevant patents.
Once these different operations were complete (and the data downloaded), an index of the patents cited was drawn up (CT field). Re-examination showed that 10% of the patents cited were not in our file. We therefore carried out a direct search for these patents on WPIL from the patent number. One can therefore say that in the current state of the corpus the rate of non-reply is at most around 10%.
The data base was verified at the different stages by two experts in plant biotechnologies. Finally, it was compared to an equivalent base constructed by a large chemical company.

sponds to a revolution in the field of plant biology, which explains the dramatic increase from an insignificant number of patent applications to a regular level of 250 patents $year^{-1}$. This is a very high level considering that it is related to the anticipation of a technological breakthrough, rather than to the current economic importance of this area of activity (Fig. 2). We note that the first patent concerning genetic transformation of plants by *Agrobacterium tumefaciens* was filed in 1983.

3. The position of different actors in plant biotechnologies

Besides general trends, the information contained in patents makes it possible to identify the position of different actors. An initial approach consists of taking into account only the number of patents per firm. In spite of its simplicity, it shows that many organizations probably play a marginal role. When the analysis is taken further at the level of the most important organization, original results are obtained. Some of these are fairly predictable (for example, the somewhat marginal position of academic research [8]) while others are more surprising (the participation of large firms in patenting is twice as high as that of firms specialized in biotechnologies).

A more sophisticated approach allows us to refine these results by giving them a more strategic content. This is the approach by 'major patents'(Section 3.2).

Finally, the application of co-word analysis by means of Leximappe enables us to analyse the degree of technological differentiation of firms working in the plant biotechnologies (Section 3.3).

3.1. Concentration of patent applications

A total of 532 organizations (firms, universities, public institutions, etc.) participated in the application for 1133 patents in the plant biotechnologies

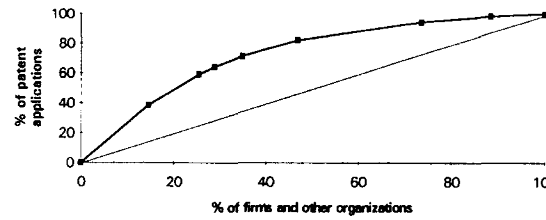

Fig. 3. The concentration of patent applications by firms.

between 1980 and 1989. [9] This is a very low ratio which can be explained by the heterogeneity of the technological area chosen. A large number of firms (353, or 66%) appear on the fringe, with just one patent application; they account for 25% of all applications. At the other extreme, 53 organizations (10%) account for 50% of all applications. The first ten organizations (those that filed more than 20 patent applications during the period under consideration) account for 21% of the total number of applications. The distribution of patent applications is therefore highly asymmetric (Fig. 3).

A study carried out at the level of the first 110 organizations, accounting for 65% of the patent applications, enabled us to develop a more precise analysis. At this level, academic research accounts for only 25% of all patents, even though each of the organizations (universities, public institutes) applied on average for more than seven patents during the period under consideration. [10] As far as industrial

[8] In spite of recent incentives to patent, the dominant mode of valorizing results is understandably by means of scientific publications. See Footnote 10 for further comments on this point.

[9] These are 1133 patents gathered together in a 'family'. (Applications filed in several different offices for the same patent, called a "basic patent", as well as patents related to the basic patent of a particular invention, called "equivalents", are counted only once.) If joint applications are taken into account, the number of participants in the 1133 applications is 1404.

[10] Note, however, that the increasing participation of academic research in patent applications is the result of a radical change in direction during the 1970s. In the United States, for example, the patent and trademark amendments of 1980 (Public Law 96-517) (the Bayh–Dole Act) gave universities the right to retain property rights to inventions derived from federally funded research. The Bayh–Dole Act thus confirmed a new doctrine by considering that patenting inventions financed by the government is positive since it increases the probability that firms use such inventions, owing to exclusive licences. In a recent paper, Henderson et al. (1995) show that this change is one of the causes of the increase in university patents: between 1965 and 1988, they increase 15-fold while real university research spending only tripled.

Table 2
Patent applications by categories of firms

	Number of organizations	Number of patents	Patents (%)	Patents per organization
DBF	17	183	21,71%	10,76
DC	44	451	53,50%	10,25
Public Institute (PI)	15	115	13,64%	7,67
Universities	15	94	11,15%	6,27
Total	91	843	100,00%	9,26

NB: 19 organizations totalling 65 patents (7 percent) could not be taken into account because of a lack of information.
Source:INRA/SERD.

research is concerned, each firm applied on average for 10.5 patents. There does not seem to be a significant difference in this respect between the behaviour of firms specialized in biotechnology (DBFs) and diversified corporations (DCs). On the other hand, given the strong representation of the latter category in the sample, it is not surprising that it accounts for 53% of all patents (Table 2).

The above results lead us to rethink a prevailing view which sees the DBFs at the heart of developments in the biotechnologies. These firms have probably played a considerable role in the learning process of the entire industrial fabric of advanced countries. Certain DBFs' lead in investments has allowed large firms progressively to enter this area by an active strategy of competitive intelligence. The same analysis for the period 1980–85 would probably have shown the DBFs in a more central position, partly because some of them have since been absorbed by diversified corporations (e.g. Agrigenetics by Lubrizol in 1984, Allelix by Pioneer in 1990). However, this role of providing an 'open window on technology' has probably been less important than in the application of biotechnologies to human health.

3.2. *Strategies for creating technological bottlenecks: an analysis by major patents*

During the emergence of a new technology, the strategies adopted by firms vary considerably. One such strategy consists of playing a role of 'technological leadership'. This implies substantial or even exclusive control of the technological barriers through which all firms in the industry have to pass.

In the biotechnologies, such a strategy may rely on patents. In the different regions of the OECD, patent offices accept applications for broadly defined patents, provided they are highly inventive. In the case of a new function in a process or product, general claims which cover its utilization in a large number of processes are accepted, even if these have not been realized at the time of application. Such processes can be developed independently and may even be patented by another firm. However, the utilization of this patent will be possible only with the authorization of the holder of the first patent. [11] When Beachy and co-workers first created a transgenic tomato that was resistant to the tobacco mosaic virus (TMV), they laid claim not only to the new plant thus created, but also to the totality of plants that would acquire resistance to any virus by using coat protein expression technology. The same applies to Calgene's antisense RNA technology: its patent lays claim not only to 'long life' tomatoes (obtained by the inhibition of polygalacturonase), but also to all the future applications of the generic technology. Owing to the wide range of potential applications, these major patents are very likely to be cited by other patents.

The identification of major patents is carried out by an automatic procedure in which the number of citations of such patents by other patents in the corpus is counted. This technique, introduced by Narin, has been tested in different areas (Narin et al., 1987). When results obtained by this method are compared with experts' analyses, which are slow and costly, its validity is usually demonstrated. [12] We shall return to this point.

[11] On this point and on the debate on dependency licences, see Joly (1992).

[12] As far as problems of the difference in the nature of citations is concerned, the study carried out by Schmoch (1993) shows that the bias introduced by processing without distinguishing the type of citation is not significant. Research conducted by Schmoch (1993) and Narin et al. (1987) revealed that a patent that is cited extensively is not systematically a major patent; on the other hand, a major patent systematically receives a large number of citations.

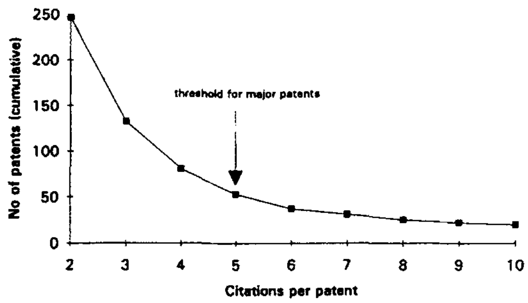

Fig. 4. Distribution of patents by the number of citations (cumulative).

On the level of five citations per patent, 53 major patents can be identified, that is, 5% of the whole corpus (Fig. 4). This corresponds to a restrictive definition of major patents (in other studies, major patents accounted for around 10% of all patents – cf. Schmoch, 1993).

The analysis of the distribution of major patents shows a strengthening of the leading position of the United States whose share increases from 42% of the entire corpus to 68% at this level. This takes place at the expense of Japan, whose share declines from 22% to 6%, while that of Europe remains stable (Table 3). We are tempted to conclude that the value of patents applied for by Japanese firms is lower than that of other countries' patents, something which would hardly be surprising given the practice of applying for single-claim patents (on this point, see in particular Ordover, 1991).

The analysis of major patents by type of organization reveals a slight increase in academic research (Table 3). But the most remarkable phenomenon is in industrial research where the DBFs carry far more weight, with one third of the major patents as opposed to only one fifth of all patents. The average number of major patents is 1.17 for the DBFs against only 0.57 for the DCs. These results correspond closely to the differences in the strategies adopted from the end of the 1970s. From the outset, the DBFs deployed an offensive strategy based on the utilization of recent scientific discoveries. On the other hand, the DCs, apart from certain notable exceptions such as Monsanto, first applied a strategy of competitive intelligence before moving on to a more original phase of research activity in 1983/84 only.

There is a fairly close correlation between the total number of patents and the number of major patents (see Table 4); a large number of patents generally corresponds to a significant number of major patents. We also note that certain organizations have numerous patents without having any major patent: e.g. Pioneer, INRA, Hoechst. This can generally be explained by a lag effect in investment.

These organizations have generally carried out research in a context of dependency on major patents. Situations of conflict and litigation are therefore likely to arise when the firms that have secondary patents reach the stage of marketing their new products. It is difficult to predict what the attitude of the courts will be because of the lack of jurisprudence.

Table 3
Distribution of major patents by type of organization in the different zones of the Triad

	Diversified corporation	Dedicated biotechnology firms	University	Public institute	Total	Major patents (%)	Total corpus (%)
EU [a]	7	3	0	6	16	25.40	26.70
USA	14	17	10	2	43	68.25	42.75
Japan	4	0	0	0	4	6.35	21.98
Total	25	20	10	8	63 [b]	100.00	
%	39.68	31.75	15.87	12.70	100.00		

[a] European Union, including Switzerland.
[b] The total is 63 because there are ten joint applications.
Source: INRA/SERD.

In a recent judgement concerning biopharmaceuticals (Amgen Inc. vs. Chugai Pharmaceutical Co.), the US Federal Court of Appeal rejected broad claims to a whole group of molecules whose biological effects were said to be close to those of Erythropoietine. However, this was not a question of principle, but a refusal due to the lack of adequate descriptions provided (Eisenberg, 1992).

Table 4
The main R&D organizations in plant biotechnologies in the world

Name	Type of organization	Country	Number of patents	Number of major patents	R&D budget in plant biotechnologies (88 in million of $)
Firms that have at least one major patent and have filed at least four patents during the period					
Lubrizol	DC	USA	62	7	12
Mycogen	DBF	USA	28	6	n.d.
Monsanto	DC	USA	23	6	15
Calgene	DBF	USA	30	4	11.5
Ciba-Geigy	DC	Switzerland	37	3	17
Agracetus	DBF	USA	11	3	n.d.
PGS	DBF	Belgium	20	2	8.5
Agri Microbiology	DBF	USA	11	2	n.d.
Cornell Research Foundation	UNI	USA	10	2	n.d.
Akad Landwirt DDr	PI	Germany	8	2	n.d.
Washington University	UNI	USA	4	2	n.d.
Mitsui Chemical	DC	Japan	4	2	n.d.
ICI	DC	UK	26	1	17
DNA Plant Technology	DBF	USA	23	1	11.5
General Hospital	UNI	USA	16	1	n.d.
Max Planck Inst.	PI	Germany	13	1	n.d.
Du Pont de Nemours	DC	USA	13	1	20
Rhône-Poulenc	DC	France	9	1	3
Boriinsho KK	DC	Japan	8	1	n.d.
Mogen	DBF	Japan	7	1	n.d.
Firms and laboratories with at least ten patents but no major patent					
INRA	PI	France	23	0	n.d.
Pioneer	DC	USA	20	0	3.5
Hoechst	DC	Germany	19	0	n.d.
Mitsubishi Chemical	DC	Japan	16	0	n.d.
Akad Wissenschaft DDR	PI	Germany	15	0	n.d.
Mitsubishi Corp.	DC	Japan	15	0	n.d.
Mitsui Toatsu Chemical	DC	Japan	15	0	n.d.
USDA	PI	USA	15	0	n.d.
Sumitomo Chemical	DC	Japan	14	0	n.d.
Lion Corp.	DC		12	0	n.d.
AGC	DBF	UK	11	0	n.d.
Bayer AG	DC	Germany	11	0	n.d.
Univ. of California	UNI	USA	11	0	n.d.
Rijkuniv Leiden	UNI	Netherlands	10	0	n.d.
Teijin KK	DC	Japan	10	0	n.d.

Source: INRA/SERD.

A verification by experts of the validity of major patents (as revealed by the citation method) showed a strong correlation between these experts' views and results obtained by bibliometric tools. Only a few patents were missing, including the particle gun and the 35S promoter. However, since these patents had been filed as recently as 1989, other patents which might still cite them had not yet been published. This delaying effect is a fairly obvious limit of the citation method if one wants to use it for competitive intelligence. We also found that certain extensively cited patents were abandoned after some time by their holders. Indeed, although patent citation is well correlated with 'patent quality' (Trajtenberg, 1990), one has to be extremely careful when using this method to identify single 'major patents'.

3.3. Strategies of technological differentiation: a quantitative approach based on scientometric methods

The study of technological differentiation is significant for the following reasons. In an initial period of scientific innovation, the common technological know-how of the firms in an industry is very important. If these firms have similar technological profiles and their patents overlap partially, the probability of litigation is strong and the expected private

Table 5
The main research programmes [a] in plant biotechnologies according to Leximappe

Programme	Keyword	No. of patents	No. of major patents	Average age	USA	Japan	Europe
1	*Bacillus thuringiensis*	74	7	87.20	44	10	17
2	Transformed plant cells with *Agrobacterium*	22	1	84.70	7	8	6
3	Gene expression, gene promoters...	166	18	86.64	73	27	58
3.1	Regeneration, plant tissue culture	34	0	86.00	15	12	2
3.2	New DNA encoding protein	36	1	87.50	7	2	10
4	Nitrogen fixation	74	1	84.90	20	23	1
5	Hybrid plants	12	0	87.50	11	1	0
6	PCR	9	0	88.66	7	0	2
7	Regeneration of sunflower and other plants	24	0	86.10	7	5	3
8	Control of soil fungal disease	85	0	85.80	22	23	20
9	Protoplast fusion, male sterility	48	2	86.30	14	19	10
11	Resistance against viral infection			70	4	86.60	27
12	Herbicide resistance	25	4	86.70	12	6	4
13	Inoculum and inoculating plants	40	2	85.70	17	9	10
14	Propagation of somatic embryo	37	0	86.70	15	10	7
14.1	Seed coated	28	0	86.40	11	8	7
15	Plant propagation by root formation	18	0	87.20	3	3	2
16	Foreign DNA	11	0	86.90	2	0	7
17	Cloning DNA to transform plants	29	0	86.86	11	3	11
18	Haploïd seeds...	76	1	86.30	29	13	24
20	Plant gene recombination	70	4	86.60	25	15	24
22	Ripening fruit	9	1	88.00	3	1	5
24	Disease	17	0	86.50	5	8	3
26	Monoclonal antibodies	6	0	87.30	4	1	1
	Total	1020	46	86.51	391	229	250
					38%	22%	25%

[a] Note that the patents concerning transversal techniques (such as polymerase chain reaction (PCR)) are definitely under-represented because the search strategy links the different classes and the keywords to the plants in an exclusive manner.

value of innovations low. This problem of technological differentiation is compounded when, for the same technological objective, different alternatives can be envisaged. The risk is not only one of weak incentives but also of a situation developing in which a heterogeneous collection of local solutions prevents the accumulation of the effects of experience. [13] In order to make the transition from 'craft' biotechnologies (a varied collection of local solutions) to 'industrial' biotechnologies (a set of standardized solutions based on optimized procedures), a sufficiently high level of technological differentiation in the industrial sector is necessary. Otherwise all the firms in the sector tend to do more or less the same thing.

In order to deal with the problem of technological differentiation, we must be able to measure the similarity of technological profiles of different firms. This measurement can be obtained by adopting a two-stage method: (1) divide the plant biotechnology into different homogeneous 'programmes', using a scientometric method applied to patent applications; (2) analyse the profile of patent applications of each firm in the different programmes identified in (1).

First stage: In this stage we use co-word analysis to divide research in plant biotechnologies into homogeneous 'programmes'. From the indexed titles of patents, the Leximappe software constructs co-word matrices. By processing these matrices we are able to group together words whose frequency of co-occurrence is the highest (Callon et al., 1986). One thus obtains aggregates of terms which are supposed to represent homogeneous research programmes because they are based on the association of terms taken from titles established by inventors.

Second stage: This stage involves the construction and processing of the table that, for each firm chosen, sorts patent applications according to the research programmes identified. [14] Construction of the table is immediate because Leximappe indicates the relation between the patents and the research programme. The processing of the table is based on methods of data analysis (factorial correspondence analysis (FCA); hierarchical classifications). The objective is to see if different technological profiles can be identified. A measurement of technological differentiation as the 'distance' between firms' patent profiles is thus defined, with these profiles being built on the themes defined by the co-word method.

In our study co-word analysis has been used for the entire corpus. [15] It has allowed us to obtain 26 distinct programmes whose principal characteristics are reported in Table 5.

A number of programmes concern the different tools in plant genetic engineering:

- sequencing, expression of genes, promoters, creation of chimeric genes, etc. (3, 3.2, 6, 16, 17, 20);
- techniques of transformation by *Agrobacterium* (2);
- regeneration (3.1, 7).

Transversal techniques also include applications that are specifically related to in vitro techniques:

- fusion of protoplasts (9), propagation of somatic embryos (14), haplomethods (18), artificial seeds and seed coating (14.1).

Four programmes concern specific applications of genetic engineering: resistance to insects (1), resistance to virus (11), resistance to herbicides (12) and control of the maturation of fruits (22).

Other applications include techniques for the diagnosis of diseases (24, 26), nitrogen fixation (4, 13) and the creation of hybrid plants.

An analysis of these results by several experts shows that, besides the technology of molecular markers (e.g. RFLP, RAPD, AFLP) or certain transformation techniques such as the particle gun for which patent applications are still too recent, the major programmes in plant biotechnologies are all

[13] In plant biotechnologies, we would cite many examples of situations where the firms have similar knowledge bases and pursue the same objective, although in different ways. For example: genetic engineering techniques (use of the particle gun, *A. tumefaciens*, electroporation, etc.); insect resistance with different kinds of *Bacillus thuringiencis*; virus resistance (via the coat protein gene, use of satellite RNA, etc.) and so forth.

[14] The 35 organizations chosen are those featured in Table 4.

[15] For more details on the utilization of Leximappe, see Callon et al. (1986). For an in-depth report on the methodology and results, see de Looze et al. (1993).

represented. Plant breeding techniques are under-represented because, other than for exceptional cases, they are not protected in their existing form. Plant varieties are generally protected by plant breeders' rights.

Given the importance of patent protection in genetic engineering, it is not surprising that this technique holds a strategic position in plant biotechnologies as a whole. It is both central and very well structured.

An analysis of the table showing the distribution of patents for each firm and each programme (Appendix A) yields the following results: [16]

Factorial correspondence analysis (FCA) shows that the cluster of points is fairly compact: the first four axes account for only 48% of the total variance. In other words, none of the dimensions linked to the research programmes enables us to discriminate between the firms. The technological profiles are not particularly heterogeneous; a continuum links one extreme to the other and 'typical profiles' cannot be clearly identified. Thus, we observe the equal distribution of firms throughout the technological sphere. An ascending hierarchical classification of the first seven factors of the FCA (63% of the variance) confirms this result. There are four clearly distinct classes, the most central [17] among them having 24 organizations out of 35 focused on the different basic techniques of genetic engineering and on its principal applications.

Most firms are currently working on the same technologies. Intra-industrial diversity is essentially a result of being in advance or of lagging behind, rather than the product of distinct technological profiles. This is apparent both at the level of generic technologies and of specialized applications, and can be explained partly by the reduced importance of these applications. Yet, when they appear they are systematically chosen by several firms.

Even though we do not have an absolute measurement of technological distance, we can conclude from this analysis that there is a low level of technological differentiation in the industrial structure. The quantitative analysis is effectively confirmed by more qualitative elements characterizing firm's strategies.

4. Economic and technological dynamics

4.1. Technological differentiation: an essential element for the characterization of regimes of appropriability

In his article on profiting from technological innovation, Teece identifies two elements for qualifying a regime of appropriability: legal instruments and the nature of the technology (product or process, tacit or coded) (Teece, 1986). Let us look at two examples from Teece:

- the formula for the Coca Cola syrup is an example of a 'tight' regime of appropriability: in this case protection relies on the fact that the formula involves tacit knowledge, that it can be kept secret and that the brand itself is protected;
- the Simplex algorithm in linear programming is an example of a 'weak' regime of appropriability: since the knowledge is coded and, by definition, cannot be protected by a patent or copyright, the protection of such technologies is impossible.

Teece's argument can be refined. We know, for example, that when an innovation is continuous and the potential pace of productivity increase is high, the innovator is naturally protected by an advance on the learning curve. This phenomenon can be observed in the field of semi-conductors where it has been discussed extensively in relation to historical analyses (Merges and Nelson, 1990) and to surveys in industry (Levin et al., 1987).

We shall, however, remain on a general level for analytical purposes. It seems that, from a viewpoint of industrial dynamics, the exogenous variables of Teece's analysis (the 'regime of appropriability') must be partially 'endogenized'. This seems clear both for legal instruments and for the nature of the technology.

Arguments relating to tacit knowledge and se-

[16] The statistical processing was carried out on SAS by Nadine Mandran (INRA Grenoble).

[17] The Leximappe software calculates a centrality index for each programme by taking the sum of the external links between this programme and other programmes.

crecy lose some of their weight in cases where firms have similar technological profiles. When firms have a common technological base, the probability of them producing similar innovations is high, even in the absence of spillovers or of the possibility of imitation. In fact, even though it is in principle localized and its evolution dependent on cumulative learning processes (Dosi, 1988), tacit knowledge is in this case 'common knowledge'. Firms cannot base their appropriation strategies on such knowledge. In terms of appropriation and differentiation strategies, it is therefore not enough for knowledge to be local; it also has to be original. Thus, from this point of view, a problem of the *co-ordination of the different actors' plans* arises. Joly and Lemarié (1993) show, in the context of a horizontal differentiation model, that the co-ordination of plans is all the more difficult when the actors are similar. In the extreme case where the actors are completely the same, they tend not to differentiate themselves, and, consequently, to produce the same innovation.

Clearly, in this context patents must be seen not only as an incentive but also as an element of co-ordination. We find here Kitch's argument in the formulation of his prospect theory of patents (Kitch, 1977). Nevertheless, we can show that, in the case observed, (1) patents do not play the role attributed to them by Kitch (co-ordination of actors' plans) and (2) they therefore only partly fulfil the function generally assigned to them (protection of innovation). Let us consider these two arguments:

1. The inadequacy of the patent as a means of co-ordination: In the case observed, the technological profiles of firms are similar despite the existence of patents. In other words, patents alone have not induced a strong dynamic of mutual specialization. Until now, co-ordination mechanisms have proved to be very weak compared with the convergence of research programmes. We can assume that the weak differentiation of profiles is due to the large size of a common knowledge base, which can in turn be explained by the central role played by academic research. With respect to this last point, we may assume that both the relative investment of public research and its high density of relationships with firms, have a limiting effect on technological variety.
2. The second point is also established from empirical observations. A low level of differentiation leads firms to apply for very similar patents, which reduces each of the holders' scope for exploitation. One finds, for example, 'cosmetic differentiation' of patents based on different procedures but aimed at the same applications. It applies both to tools and to their applications. Even with respect to the approval of identified programmes, the simultaneous application by numerous firms in a single programme can often be noted (see Appendix A). In this context firms devote considerable resources to duplicating their efforts, to circumventing others' patents or to dealing with conflict and litigation. [18]

In any event, the problem is complex. Large scope patents could be recommended as a possible solution to the problem of co-ordination. Yet, it is also a tricky solution from the viewpoint of legal doctrine since it means granting wide-ranging rights in the case of few differences, something which is not easily conceded. Moreover, the question of efficiency is not easy to analyse. [19]

Since no judicial precedents exist, we have to wait for the outcome of current cases to have a clearer picture of the situation. [20] However, given these two elements (problem of doctrine and effectiveness) it is scarcely likely that wide scope patents will be generalized in this domain.

Indeed, although Kitch (1977) was right when he considered that the first function of a patent system

[18] The negotiation of licence contracts offers a good illustration of this point: the price of such licences is decreasing sharply over time. Take the case of the negotiation for a licence on a patent for an insect-resistant gene based on the use of *Bacillus thuringiensis*. The first agreement was for a $3 million lump-sum fee. Eighteen months later, it was possible to obtain the gene for only $1 million because several firms offered the same type of gene.

[19] Different analyses underline the dangers of large scope patents. Scotchmer clearly shows that, in the case of innovation sequences, one has to ensure a balance between incentives for the pioneering innovator and incentives for the actors who produce subsequent innovations (Scotchmer, 1991). From this point of view, broad-ranging patents can have negative effects on innovation dynamics. Such effects are confirmed by the historical analysis of Merges and Nelson (1990).

[20] For a general overview of the question of the scope of patents, see Ko (1992).

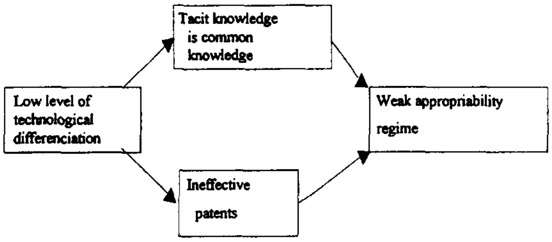

Fig. 5. Level of technological differentiation as a determinant of the regime of appropriability.

is the co-ordination of actors' plans, we cannot agree with his assumption that the patent system effectively resolves co-ordination problems whatever the situation. Thus, the following proposition: when the level of public research and the number of firms engaged in a technological race are high, and when the relevant technology is scarcely differentiated, then patents are relatively unsuccessful in creating technological differentiation (thus the problem of appropriability).

If our reasoning is accurate, it seems that the characterization of appropriation regimes proposed by Teece (1986) is valid only in a context where there is a high degree of technological differentiation. If the latter is low, traditional factors of appropriation (nature of knowledge, legal resources) are of little relevance (Fig. 5). From an analytical viewpoint this is a significant about-turn since the aim is to focus on all the factors of technological differentiation rather than on the characteristics of the appropriation regime alone.

In this context, the decision to patent should be considered more as an option to enter into an economic activity than as the acquisition of a monopoly right. [21] Indeed, it is necessary to analyse the complementary strategies which allow firms to profit from their technological innovations.

[21] In a context of intense uncertainty on the evolution of the plant biotechnologies and the patent issue, a patent has an 'option value'. This is because, in a case where it is useful to have patents, a firm which has decided not to apply for one may well find itself in a highly unfavourable position. This intuitive analysis can easily be formalized in the framework of option value models.

4.2. Which strategies can offset the shortcomings of weak appropriability?

When the level of technological differentiation is low, the patent in itself is not sufficient to ensure satisfactory protection of innovations. Following the analysis of Teece (1986), we can predict that protecting one's competitive advantage will depend on the *control of complementary assets*. However, such a strategy is not entirely adequate when the protected technologies are generic. A wide range of potential applications cannot be exploited through vertical integration. One strategic option in this case is to impose a de facto standard, via a policy of wide-ranging diffusion (by open licences at a low cost).

In the following section, we first consider the strategy of 'technology suppliers' before analysing strategies for the control of complementary assets. The former involves the standardization of 'technical products' which are transferred to the user (in general the seed companies) in the framework of quasi-market relations. The latter strategy consists of targeting the end users, which implies not only the conception of products adapted to their needs but also the co-ordination of a number of heterogeneous activities: the creation of variety, the production of seeds, agricultural production, transformation, stocking and distribution.

In Section 4.2.3, we attempt to give an overall view of technico-economic dynamics by synthesizing the various elements concerned.

4.2.1. Supplier of technologies: is it possible to impose de facto standards?

Given the close dependence on a rapidly expanding scientific base, the biotechnologies are characterized by a considerable amount of common technological know-how. There are around 40 organizations in the world that know how to clone a gene, create a chimeric gene, transfer it to a plant and multiply the transgenic plant. Given the numerous organizations that have these techniques in hand, the viability of the strategy of supplying technology is uncertain. In such a context, the patent essentially serves a purpose of protecting firms from rivals' patents or of enabling them to negotiate the utilization of certain key technologies on an equitable basis. In order to position itself as a technology supplier, a firm must adopt a policy of diffusion and so impose a de facto standard for extending the zone of effective protection, before trying to protect its rights too restrictively. A tactic that first aims at imposing one's rights is very likely to fail because it encourages other firms to develop local alternatives, i.e. to position themselves as competitors when it was intended that they should be users.

Several examples allow us to illustrate this idea.

Du Pont de Nemours, which had acquired the exclusive licence on the particle gun (the patent belongs to Cornell University), opted for a policy of extensive diffusion at a low price. In fact, a restrictive policy would have prompted laboratories to create their own guns or to use alternative transformation techniques because of the fear of possible litigation. This strategy was based mainly on an increase in the technical complexity of the machine (switching over to helium powder, adjusting the pressure, etc.) in such a way that it became difficult to think of a particle gun made by a craft industry.

After having filed a patent application, Monsanto diffused the 35S promoter widely, leaving it open to free utilization for research, notably in the academic milieu. This super-promoter came to be used regularly by biologists. Those users who now want to commercialize the fruits of their research are required by Monsanto to obtain a licence. Theoretically, other promoters could be used; however, it would be necessary to re-do the genetic constructions and carry out numerous tests. The organizations that depend on the Monsanto patent often discover their position with surprise and sometimes with resentment. It is, however, in their interests to buy the licence.

Mogen has a policy of offering initial launching prices for its binary vector derived from *Agrobacterium*. The patent has been filed but has not yet been approved. During this intermediate period, this Dutch DBF offers non-exclusive licences at advantageous prices. Around 15 firms have already obtained the licence.

Such strategies of standardization through diffusion are well known in information technology and electronics. Their efficiency depends on increasing returns to adoption (Arthur, 1989): returns to scale in production, learning through utilization, network externalities and development of complementary techniques. These effects explain why a technology becomes even more efficient as its utilization increases.

4.2.2. Construction of networks for integrating user needs and controlling markets

Strategies for profiting from innovation in the biotechnologies by means of a more vertical approach can be contrasted with the previous method. In this case, the protection of the innovation depends on the control of complementary assets such as production capacities, marketing, distribution networks and so forth (Teece, 1986).

These assets can be controlled in two ways: by acquiring financial control or through contractual relations. The control of assets can stop at the stage of the seed market or can go as far as the end-user market.

When the seed market is the target, vertical integration or partnerships may be mobilized, depending on the firm. For example, Monsanto and PGS have a well-tested strategy for creating value by means of contracts. The seed firms (e.g. Pioneer, Limagrain, KWS) and certain chemical companies that have important assets in the seed industry (e.g. Sandoz, Upjohn, Zeneca) create value for their innovations principally by means of their seed subsidiaries. In this case, appropriability depends on the conditions of competition in the seed industry.

Final markets are, however, increasingly becoming the major targets. This evolution corresponds to the conjunction of two factors. First, it is fairly obvious that the total added-value is much higher in the final stages than at the seed stage, particularly for dedicated products (one can easily count a factor of 1 to 10). Second, it is also clear that plant biotechnologies offer more and more extensive possibilities for producing tailor-made products: oils for industrial use, cereals with a high content of amino-acids (e.g. methionine), 'long life' fruits and vegetables and so forth. With maize, for instance, those types which are rich in amylopectine, amylose, oils or threonine can easily be distinguished. Different types of maize have different uses; their utilization requires a shift from a system of mass production to the production of dedicated products. This implies a different organization of the production subsidiaries so as to guarantee the identity of the product from the beginning of the chain to the end user. The choice of the final market as the target thus corresponds to an organizational necessity. This choice is generally made through alliances with agro-food firms that control a considerable part of the final markets (e.g. the alliance between Calgene and Campbell Soup concerning tomatoes). Firms like Nestlé, which are very well positioned in the agro-food business and have considerable research capacity, are particularly well-suited to this role. In the case of the industrial use of agricultural products, it could involve the creation of new industrial and commercial entities (for example, the technical oils developed by Calgene, by Lubrizol or by DNA Plant Technology in collaboration with Du Pont).

Shifting the analysis from technological profiles (derived from patent analysis) to complementary assets in order to understand the dynamics of corporate differentiation is directly related to the main conclusion reached above. Since a low level of technological differentiation limits the role of patents, firms rely on the control of complementary assets to profit from their innovations. Thus, these dynamics involve considerable specific investments: industrial development, creation of partnership networks, commercial investment and so forth. Such specific investments play an essential role in the protection of innovations because they constitute entry barriers to the relevant markets. A low degree of viability may therefore be expected in some of the DBFs which lack financial resources to invest in complementary assets.

4.2.3. Technico-economic dynamics

How is a choice made between vertical integration, the creation of common subsidiaries or the granting of licences? This will depend every time on the terms of negotiation. In situations in which patents make it impossible to exploit licence fees, the concession of licences is unsatisfactory (other than for the generic technologies mentioned above). When the balance of power is not in the offerer's favour, the creation of common subsidiaries can constitute an important first step in a value creation policy. That is the path which firms specialized in biopharmacy have generally followed. They find a partner to commercialize a first product and then, in a second stage, create their own means of production and marketing. The underlying idea is that whenever the balance of financial power allows a firm to invest in complementary assets, it should do so.

Why are such substantial resources devoted to complementary assets? Because technological differentiation takes place in relation to fields of application and not to basic technologies. That which gives a firm a determining advantage is not the control of a basic technology but the association of a set of technologies and a particular field of application.

Consequently, patents constitute only one of the elements 'marking' firms' territories. The main factors in differentiation dynamics are based on elements of competition in the sectors of application. If this reasoning is valid, it corresponds to M. Sharp's observations on the evolution of the bio-industry, i.e. in contrast with the scenario forecast in the 1980s of an autonomous bio-industry, the latter will be dominated by the dynamics of the sectors of application (Sharp, 1996).

5. Conclusion

To conclude, we shall summarize the contributions and limits of this paper by identifying, from results which have a broader scope, those which are peculiar to the field studied.

Given the weak appropriability related to a low level of technological differentiation, the dynamics of plant biotechnologies seem to be more closely related to the insertion of new tools in specific fields of application than to the autonomous development of generic technologies. This first result confirms other work concerning the development of bio-industries. Industrial organization is seen as being characterized by a dynamic of differentiated oligopoly, with a high level of vertical integration rather than intense horizontal specialization and quasi-commercial relations between firms.

As the lack of technological variety seems to be linked to the role of public research, it appears necessary to carefully consider such a role with respect to the type of work it should involve, as much as the modalities of its connections with industry.

On a general level, it is necessary to stress two points. First, this paper presents an original method for identifying technological profiles. The method can be replicated but it would need to be used in other technological fields in order to enhance its effectiveness. This development is a significant one, considering the fact that we need to characterize technological proximity in order to improve our understanding of the dynamics of firms' knowledge bases.

From a more analytical viewpoint, by showing that technological differentiation explains a weak regime of appropriability, we propose a complete reversal compared with traditional approaches. Whereas patents are generally considered as a decisive factor, we note here that alone they cannot induce a dynamic of technological differentiation. It is because they do not play the role attributed to them by Kitch (1977) (the co-ordination of actors' plans) that they do not fulfil the function traditionally allocated to them (an incentive to innovation). Such results should prompt us to analyse more systematically the mechanisms of technological differentiation, notably for science-based industries. We would need to analyse the role of different factors in the structuring of new technological fields and, in particular, that of public research.

Appendix A. Repartition of patents per firm and per research programme

Name	Code	Programmes										
		1	2	3	3.1	3.2	4	5	6	7	8	9
Agracetus	AGRA-	1	1	2								
AGC	AGRG	1		2							3	
Agri Microbiology	AGRI =										1	
Calgene	CALG-			4	1	2						
Ciba Geigy	CIBA	2		11	1	2					2	
Cornell Research F.	CORR			3	1							1
Akad Wissenschaft DDR	DEAK			5								
DNAPT	DNAP-			2		1		1			3	4
Du Pont de Nemours	DUPO	1		3	1	2					1	
Bayer	FARB			3							3	
Hoechst	FARH			8							1	
General Hospital	GEHO-			4		1			1			
ICI	ICIL	4		5		2			1			2
INRA	INRG			1		3					2	1
Akad Landwirt DDR	LAND-											
Lion Corp.	LIOY		5									
Lubrizol	LUBR	2	1	20	6	3		1		6	3	
Mitsui Chemical	MITS		1	3						1		5
Mitsubishi Chemical	MITU		1	3						1		5
Mogen	MOGE-			4								
Monsanto	MONS	4		5		2				2	1	
Mycogen	MYCO-	20				2					1	
Boriinsho KK	NORQ			1							1	
Pioneer	PIOE-				1			6			1	3
Max Planck Inst.	PLAC			1		1				1		
PGS	PLAN-	7	1	8		4						
Univ. of California	REGC		1									
Rhone Poulenc	RHON			2						1		
Sandoz	SANO	5		1								
Sumitomo Chemical	SUMO	4		4							1	1
Teijin KK	TEIJ			4	1					1		
Washington University	UNIW	1		2		1						
Upjohn	UPJO			4								1
USDA	USDA	1										
Rijkuniv Leiden	UYLE-		5	2								
Total number of firms in the sample (1)		53	16	117	12	26	0	8	2	13	24	24
General total per class (2)		74	20	166	34	36		12	9	24	85	48
(1)/(2)		0.7	0.8	0.7	0.4	0.7		0.7	0.2	0.5	0.3	0.5

11	12	13	14	14.1	15	16	17	18	20	22	24	26	Total
		3											7
		3		1				1	1		2		14
		1						1					3
	1		2	1				6		2			19
5	2		2	1			2	1	6		2	2	41
2				2			2	2					13
			1		1		1	4	2				14
1			2						4	1	1	2	22
	3						1		1				13
									1				7
1	2						1	1		1	1		16
	5						3		4				18
			1	1			4	2	4	4			30
2		2		1			2						14
								5					5
			1	2	1			2					11
5		3	5	2	2		3	2	7			1	72
2	2	1											15
2	3	1	1										17
	2							2	2				10
3				2					2				21
					1				1				25
			1					1	2				6
		1	1					3					16
			1			3							8
	1					2			4				27
					1								2
	3	3	2										11
													6
5				3	1			2			1		22
2			2	1					5				16
1									1		2		8
3				3			1	1					13
1		1									2		5
								1	2				10
35	24	19	22	20	7	5	20	37	49	8	11	5	557
70	25	40	37	28	18	11	29	76	70	9	17	6	944
0.5	1	0.5	0.6	0.7	0.4	0.5	0.7	0.5	0.7	0.9	0.6	0.8	0.6

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