COLLECTIVE INVENTION and EUROPEAN POLICIES

"COLLINE"

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ABSTRACT

Our central concern is with the problems of information shari ng and technical coordination raised in the context of collective R&D. Public policies in this area need to be built upon a strong empirical foundation of how knowledge sharing and collaborative arrangements operate. In addition, and also key to our conce rns, is the need for and value of documenting, generalising, and diffusing knowledge of successful rules and norms among the different domains of scientific and technological research to reduce the costs of "reinvention" and to promote "best practices" in such arrangements wherever possible.

The key practical motivation of *Colline* is that the proliferation of experiments and new patterns of collective invention within the framework of European programmes - as well as within private consortia and other (less formal) forms of collective invention - is generating many new rules, methods, and mechanisms of coordination whose value should be recognised and more broadly diffused. Many of these innovations are occurring spontaneously and some are being formalised to solve the problems posed by collective invention.

In our case studies (carried out in various fields), we have identified rules, guidelines and institutional devices which allow solutions to some of the practical problems of collective invention :

- the problems of building the instruments and methods for ensuring technical coordination as well as the circulation of data and research materials among the participants of the project;
- the problems of establishing balances between the need for rapid acc ess to knowledge for participants in projects and the need for maintaining some degrees of excludability and private appropriation for those participants who have invested private resources in the enterprise;
- the problems of managing the dissemination o f knowledge beyond the boundaries of the project.

While some of these new practices seem to perform very well, they are most often local solutions designed in the particular context of a project. Very frequently these rules and practices are emerging spontaneously from the search by scientists and technologists for "better organisations" to solve the three classes of problems described above. They are thus very difficult to generalise and to transfer to other contexts; and thus there is a potential for un derperformance in institutional learning (selecting "the best practices" and generalising them) in the European context.

The main result of the project is the identification and documentation of these local solutions. We assessed their usefulness and perf ormance in order to select those that appear to be exemplary in various ways, to explore the possibilities for their generalisation and to implement a schema in order to facilitate and accelerate their practical generalisation among various contexts. As a feasibility study, one important outcome of the work is to show that it would be of considerable value to implement the *Colline* approach on a larger scale in order to establish a "permanent" observatory of best practices and a platform for the transfer and learning of these pratices.

Chapter I

Background and Objectives of the project

I.1 – What is "collective invention"

I.1.1 – Towards definition

The development of empirical research on the innovation process began with a critique of the 'lone inventor' model of invention process. By recognizing that invention and innovation was increasingly an organised activity the path was open to examine how contributing factors could be productively combined, what the limits were to the institutionalizati on of innovative activity and how companies organised the process.

These analyses were fundamentally concerned with establishing the context of innovative activity within the organisation. Inter-organizational issues were confined to questions of the "mak e versus buy" decision: how contract research operated or failed to operate, how users shaped and influenced the innovation process, how the context of scientific knowledge might influence innovative activity (science-based industry).

A fundamental depart ure occurred when it became recognized that the knowledge generated for innovation was not solely an intra-organizational conversion, combination, adaptation, and extension process but was a process that was collectively organised by industries and other l arger domains of interfirm or government-industry relations. The collective nature of innovation is in the first instance a recognition that the domain of innovation is larger than the organisation and the unit of analysis must therefore be larger as well.

The growing appreciation that a broader unit of analysis is appropriate based upon understanding of particular research communities and networks has been augmented by efforts to identify and enumerate the institutional forms of various inter-organisational forms supporting knowledge creation. Thus technology development agreements taking the form of joint ventures, technology exchange agreements and university-industry linkages provided persuasive evidence that collective invention is a rapidly growing co mponent of national innovation systems.

All of this can be fairly characterized as advance in knowledge about how the innovation process works. It also is about the fact that the innovation process is itself evolving.

There is, nonetheless, a gap in our understanding. The 'forms' of collaborative arrangements do not adequately describe their content or process. Moreover, when we return to examine specific organisations in the original innovation studies tradition we find the firms are engaged in collaborative processes that are not implemented in the formal structures of joint ventures or strategic alliances. This suggests that the collaborative invention process is even larger than some of the indicators would suggest. What happens in the process of colle ctive invention is therefore becoming a more pressing issue. Before we can develop broader and more inclusive measures of the activity and the determinants of its successes, we need to develop a deeper empirical knowledge of the varieties and purposes of c ollective invention. In effect conceptual advance and empirical knowledge generation must be developed simultaneously and interactively. This is what we have done in the *Colline* project. The level of activity is much smaller than would have been needed to empirically characterise the evolving features of collective inventions. It has, however, been large enough to provide the basis for a substantive analytical framework useful for guiding further research.

I.1.2 - An "*original*" form of co-ordination providing particular mechanisms to the production and appropriation of knowledge

Collective invention is an *original* mode of coordination of economic actors, which completes or is superimposed on the private and public research sectors. We recall that Allen (1983) considered collective invention as an institution in its own right, alongside the scientific institution, the industrial laboratory and the individual inventor. Collective invention is everywhere: between private firms, between public organizations a nd, of course, between the private and public sectors.

The originality of collective invention as an institution is threefold:

- above all, it is an original mode of knowledge production, based up on the advantages of collective action (organization of t he division of labour, combination of scattered elements of knowledge) in intellectual and technological creation;

- secondly, it is a form of regulation of knowledge exchange that is distinct from both the private and the public research domains and is e ven, in some cases, a combination of characteristics from both these domains. Collective invention defines areas of knowledge sharing in which private appropriation is temporarily, and to a very slight degree, suspended. This pooling of knowledge in a conf ined circle is different from the release to the public sphere in which knowledge may circulate freely and that, by definition, is open to all potential users.
- finally, it is an original form of diffusion of knowledge throughout the economic fabric, in s o far as it delimits a circle in which knowledge is pooled (internalization of externalities) and organizes its diffusion beyond that circle. The scope of that diffusion is a matter of negotiation

(e.g. how will knowledge diffusion policy of European cons ortia be implemented in the fifth framework programme, given the firms' direct participation?).

Thus, collective invention is an original mechanism which transforms the nature of relations between independent agents in the production, distribution and use of knowledge.

Addressed in this general report are issues about why and to what extent collective invention is an important instrument for technology and innovation policy, and how the implementation of a collective invention schema can regenerate and en rich the way in which knowledge activities are organized in both the private and the public sectors.

I.1.3 – Economic rationality of collective invention

Whatever the precise form of collective invention (see section I.2), the underlying economic rationality is governed by two principles. The first is the creation of co -ordinated procedures for exploration and learning, motivated by the advantages of collectively organized research or innovation. These procedures allow the linking up and assemblage of dispersed and divided knowledge, and avoid duplication, redundancy and useless imitation in a specific domain. The second principle is the extension of the boundaries of the field in which the knowledge is freely disseminated (internalization of externali ties). This determines the creation of collective areas which temporarily suspend technological secrecy and private exclusivity on knowledge.

According to these two principles, collective invention is a mechanism which – temporary and locally – provides s olutions to the so -called “knowledge dilemma” in Box 1.

Box 1 – The knowledge dilemma

In so far as knowledge transfers define positive sum games (owing to the at tribute of non -rivalry, the agent transmitting knowledge does not lose it, and the cumulative nature of knowledge implies that it is potentially useful in a multitude of new projects), all non -distributed knowledge is wasted to a very large degree. Thus, m aximum efficiency in the use of knowledge implies that there is no restriction on its use and that the price of its use is nil. Knowledge ought to be a "free" good; that is the condition for optimum use of a non-rival good (Machlup, 1984). From a concrete point of view, rapid dissemination of knowledge facilitates coordination between agents and reduces chances of duplication between research projects. Above all, by propagating knowledge throughout a mixed population of researchers and entrepreneurs, the probability of discoveries and inventions being made is increased, and the chances of this knowledge being retained by agents incapable of exploiting its potential is reduced.

The mere fact of technological non -rivalry does not assure economic non -rivalry. Assessing the latter involves recognising that while the simultaneous use of knowledge may be costless as an input it may also

effect the value of the output. For example, the use of superior knowledge may dramatically increase the availability of a goods that previously was costly and scarce (e.g. aluminium or plate glass). This is a major benefit to the final consumer but may create substantial adjustment costs to incumbent firms. In areas where the new knowledge destroys existing accumulated competence (competence destroying technical change) the consequences may involve substantial private losses. Even though society benefits, particular economic actors may loose. Under conditions where these losers have a means to suppress the new knowledge they may do so even if they would benefit if using the new technique would involve the eventual loss of control of it. Again, this is a specific feature of cumulative technological systems that does not apply to non-cumulative innovations.

However, while maximum effi ciency in the use of knowledge implies rapid and complete distribution, and therefore requires that its price be nil, the same does not apply to its production. Producing knowledge is expensive and in some cases very much so. That is why maximum efficiency in the use of resources to create new knowledge requires that the costs of all necessary resources be covered by the economic value of the knowledge created. Private agents must therefore be given the means to harness or requisition financial benefits der ived from the use of knowledge. This means that a price must be paid for this use, but that is possible only if it is limited. The solution therefore lies in the creation of control mechanisms.

To solve creators' problems, they must be allowed to establis h a "fence" around the new knowledge, thus raising its private value and creating an incentive to invest. However, in the domain of science and technology, restrictions on the circulation of knowledge reduce not only individual use by a few "consumers" but also and, above all, collective accumulation and progress, that is, the myriad of opportunities afforded by new combinations between diverse bits of knowledge.

Thus, we see how the contradiction worsens between the aim of increasing the private value of knowledge (which involves restrictions on its use) and that of maintaining its social value (which involves free use). The more cumulative the knowledge, the more the control mechanisms – intellectual property rights – tend to generate losses to society. T hat is the dilemma: only the anticipation of a positive price on the use of knowledge can guarantee the allocation of resources for its creation, yet only if the price is nil can the efficient use of the knowledge, once it is produced, be guaranteed. On th e one hand, there is the social aim of ensuring that knowledge is used efficiently once it has been produced and, on the other, there is the aim of offering the private producer the best incentives. This dilemma exists fully only with the concept of cumulativeness of knowledge, which moves knowledge from the sphere of consumer goods to that of production.

The dilemma produces a positive externality, created by a non-rival and cumulative good, that cannot be rectified like a negative one (or, more precisely , actions aimed at rectifying a positive externality cannot be the exact opposite of those aimed at reducing a negative one). In the case of negative externalities (e.g. noise, pollution), the problem is relatively simple: action must be taken against the transmitter of the externality, either by demanding rectification at the source or through taxes. In the case of a positive externality, the problem is not to reduce the externality, since it is positive; it is far more complex and the path is narrow betwe en safeguarding a creator's interests and maintaining benefits for society.

Positive externalities are not a "problem" as such. But they may create problems such as premature "lock in" to technological standards or the suppression of variety in the searc h for new technological solutions. These problems arise from the irreversibility of commitments that are solely a property of cumulative technological systems. If the system is not cumulative then the ordinary arguments concerning "sunk cost" are relevant and costs of switching can be appropriately assessed at the margin.

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I.1.3-a – Efficiency analysis of collective invention

Two efficiency effects can be achieved through the coordination of research activities in collective organizations: i) the linkage and assemblage of dispersed and divided knowledge, which promotes complementarity, collection and externalities; ii) the ordering and organ ization of exploration and learning within a field so that problems of duplication, redundancy and imitation can be reduced.

• A special form of assembling divided and dispersed knowledge

- *Division and dispersion of knowledge*

Knowledge bases are esse ntially dispersed and divided, a souce of efficiency loss. These two concepts were defined by Machlup (1984). The division of knowledge stems simply from the extension of the division of labour into processes of knowledge production, while the dispersion o f knowledge is due to the local character of learning and to agents' strategies aimed at restricting access to it. Now, in many cases, it is important to connect and assemble divided and/or dispersed elements of knowledge. This may have positive efficiency effects of complementarity, collection and externality.

- *Structures of knowledge which require the assemblage of divided and dispersed elements*

The structure of knowledge has three common features, so that its exploitation requires the creation of link ages and the assemblage of diverse elements.

The first feature is that knowledge is often physicaly distributed among different locations or institutions but is complementar and therefore benefits may be reaped from combination and further distribution. T his feature explains the multiple ties that are established between the knowledge of suppliers and that of customers, the knowledge of academic laboratories and that of industrial firms, the knowledge of one firm and that of others, and the knowledge of a discipline or sector and that of another discipline or sector. In all cases, collective invention creates conditions for the assemblage of complementary knowledge [WP 02 and 09] (WP XX means *Colline* Working Papers N° XX – see list of Colline Working Papers in Annexe 1). It proves to be particularly appropriate when innovation systematically follows the recombination of existing knowledge elements [WP 04, 05].

The second feature involves the production of information and knowledge through comparison and synthesis of dispersed knowledge. Either the assembly of a collection of data or a sufficiently large sample produces knowledge of a better quality, or the coordinated organization of experiments and the exploration of different paths of research makes it pos sible finally to select the best solution in a context of uncertainty. In these different cases, collective invention is manifested

in the combination of different systems of knowledge, and in the collective and concerted performance of evaluations and syntheses [WP 02]. This second feature also involves complementarity but since the value of combination does not appear readily nor can the contribution of any single piece of information or element of knowledge be readily distinguished as being "key" to generating value.

The third feature is generally expressed in terms of network externalities. The key characteristic of a network technology is that the value of a particular component to a particular user depends on the network of users and the network of supporting products and services [WP 07]. These characteristics of network externalities result in forms of collective adoption by users, related to the benefits that each party will derive from the generalized choice of a particular network or technology. But these characteristics will also generate forms of coordination on the supply side of products and components, which fit entirely into the scope of collective invention. These forms of coordination will help to guarantee the levels of compatibility, inter-operability and inter-connectivity, aimed at enhancing the integration of systems and networks. This form of collective invention will be concretized in the creation of standards and interfaces [WP 04, 05, 06 and 07].

- *Collective invention as a way to assemble "sticky" information and knowledge*

Thus, collective invention is a special form of organization which allows "the assemblage of dispersed and divided knowledge". It is a particularly effective form when knowledge and information are "sticky"[1]. The sticky nature of information means that information transfer costs are a significant component of the costs of the planned problem-solving work. When the solving of a given problem requires access to sticky information located at two or more sites, problem-solving activities will sometimes move iteratively among these sites, leading to collective invention. It is a mode of collective learning used primarily in the context of relations between suppliers (or developers) and customers. Our empirical work clearly illustrates this quality of collective invention ([WP 09], and Appelyard et al., 1996).

• Co-ordination of activities when there is a tragedy of commons

Discovery of a gold mine or a rich fishing area can lead to an excessive allocation of resources to exploration and discovery in that area. This could result in a significant decline in the private and social returns of research and exploration. In certain conditions, this problem applies to the production of knowledge. Collective invention then seems to be a possible solution to this problem, known as the "tragedy of commons".

- *Regime and tragedy of common resources*

[1] - "Often the information used in technical problem-solving is costly to acquire, transfer, and use in a new location – is, in our terms, 'sticky' " (Von Hippel, 1994, p.429).

In this regime everyone has the privilege of using the resource and nobody can exclude anyone from that use. This property regime is clearly defined as a regime in which everyone has a single right: that of not being excluded. In it the tragedy may concern the over-exploitation of the resource. Examples are public hunting areas, fishing zones or communal grazing ground where entry is free (there is no license to pay for hunting, fishing or grazing), the rule of capture applies (whoever captures the resource owns it) and agents compete to consume the good. When too many people have these rights the resource is likely to be over-used. Standard examples are those relating to ecological problems: threatened species, air pollution and destruction of vegetation.

- *Tragedy of commons and economics of knowledge*

How can this tragedy be translated into the domain of the knowledge economy? It will be reflected in an excess of incentives to carry out the same type of work, leading to wastage and duplication. This excess results from a lack of coordination between independent agents working in the same field. From a theoretical point of view, this type of situation is produced by the combination of a shared resource – the research field – and the existence of property rights on the results. As in the fishing zone, the research field is a shared resource in which the rule of capture applies. It is necessary here to clearly distinguish between property rights on discoveries, and the right to discover (just as there is a distinction between rights to the fish caught and fishing rights). The fact of having a free field and property rights on discoveries is a very widespread condition. But the tragedy also depends on the exhaustibility of the resource, and knowledge is generally considered as an inexhaustible good (in the sense of non-rival). What can, to an extent, be considered as an exhaustible resource is precisely the research field when everyone is relatively close to the goal and there is only one invention to be found. The tragedy occurs in "innovation races" when several firms are competing for the same invention.

Thus, for the tragedy to occur,

- the research fields must be free,
- the rule of capture must apply (full property rights on new knowledge),
- there must be only one element of knowledge to discover – for which everyone is competing – and, finally,
- there must be no knowledge externalities between rival agents (for example in the form of scientific publications).

Cockburn and Henderson (1998) note that these hypotheses are strong. In their empirical studies on 21 discoveries of drugs in the US, they show that, even in cases of innovation races, there are usually knowledge externalities between rival agents (who carry on publishing) and that, in the end, the agents discover different knowledge. Moreover, it is clear that a research field is not automatically a common resource, even in the absence of formal property rights on it. The definition, identification and evaluation of a research field depend on the scientific capacities of agents and on previous research in related fields (David, Mowery and Steinmueller, 1992); and one could hardly characterize such resources as common. The situation of tragedy of commons is therefore rare, although contexts of innovation races, in a well-defined field where the object of the search is known and predictable (e.g. the race between the Pasteur Institute and the US firm Abbot to develop a test for the HIV) can correspond to this situation. The international breast

cancer consortium offers another example [WP 02]: imperfect coordination between groups working on the subject was a result of the race to pub lish first on the location and identification of the gene, and of the patent race (on the interpretation of this case, see also Dasgupta and David, 1994).

- *Solutions*

A solution to this problem, similar to classical solutions, might consist of auctioning research rights. However, uncertainty on the value of the right (due to uncertainty on the importance of discoveries not yet disclosed) makes this problematical. Nor does the solution lie in agents mutually informing one another, for this could have the o pposite effect to the one hoped for (as in the case of the discovery of a gold mine, where its announcement will certainly not dissuade others from collecting around the pioneer).

The solution that has received the most attention in the literature consist s of granting an ownership title, covering not only the new idea but also all subsequent "hoped for" developments. This amounts to delimiting "a hunting ground" and avoiding over -investment in the area. Thus, the regime which associates a common resource w ith private rights provides an argument for broad patents. The broad patent not only aims at reinforcing private initiative in the context of the public goods problem; it also concerns the need to avoid the tragedies of common resources. When patents are d elimited "far afield", a vast domain is created in which risks of excessive research no longer exist. This solution has been argued by Kitch (1977) who used it to show the validity of very broad patents. But by creating exclusive rights to a large domain, one is eliminating the advantage, for a specific domain, of research carried out by multiple agents (multiplicity determines a diversity of "talents"), as opposed to research monopolized by a single agent. The knowledge dilemma resurfaces here in a slightl y different form. By granting patents with a wide scope, the problem of an excess of incentives is solved, but at the same time exploration of the field by a diversity of actors with multiple talents is precluded. The same dilemma is found in the utilization of very large scientific facilities (accelerator, synchrotron, giant telescope, space base), a common resource which can lead to a tragedy of commons. To avoid this tragedy, should a mechanism of marginal cost pricing to limit access be adopted, or is i t better to optimize exploitation of the resource by offering free use of the facility to everyone? This decision, which involves a combination of property regimes, is somewhere between setting a price for access – which could result in under -utilization o f the resource – and maximization of the social benefits by allowing free access – which could result in a problem of over -abundant incentives (David, 1997).

- *Collective invention as a solution*

As regards the regime of commons, collective invention ma kes it possible to avoid the tragedy – related to excessive duplication of research – by establishing forms of division of labour that allow for the organized exploration of the domain. The examples in our studies are very clear [WP 02]. Some biotechnology consortia (yeast, Bacillus Subtilis) organize a division of labour based on the similarity of tasks in order to accelerate sequencing; others take advantage of the complementarity

of the participants' knowledge and expertise; others organize the pooling of objects and data so that knowledge of a higher quality can be obtained. In all these cases, the solution to the problem of common resources (here, of the common research domain) is peculiar to collective invention because it lies in the establishment of principles governing the organization and management of research work. It proposes a solution to the dilemma between, on the one hand, the reduction of the problem of excessive incentives and the duplication of research and, on the other, the mobilization of a large number of competencies and capacities in a single domain.

I.1.3-b – Creation of areas of trading and sharing of knowledge

The second main economic rationality of collective invention lies in the possibility of creating localized and temporary spaces for trading and sharing knowledge, in which technological secrecy and the retention of private knowledge are temporarily suspended. In this respect, collective invention will remedy certain adverse effects of the privatization of knowledge.

• Private property regime and collective invention

In the private property regime individuals have private property rights. This regime is at the heart of the knowledge dilemma. Because it allows private incentives to be strengthened, it necessarily hinders the distribution of knowledge. When knowledge is transferred from a regime of shared resources to a private regime, it becomes excludable, thus enabling private agents to benefit from their creative efforts. The private value of the knowledge is thus increased and investment encouraged. However, in the field of scientific and technological knowledge, what is hindered by restrictions on the use of knowledge is not only the individual use by a few "consumers", but also and above all collective accumulation and progress, the thousands of opportunities afforded by new combinations of different elements of knowledge.

Yet this private property regime allows for different ways of reaching compromises between private incentives and knowledge dissemination. First, history shows that intellectual property rights are a precondition for the dissemination of knowledge (without property rights, the owners of knowledge will tend to keep it secret). Secondly, because of unintentional spillovers there is always some diffusion of knowledge (Von Hippel, 1988; Steinmueller, 1996). Finally, license mechanisms allow for market dissemination. The fact remains that, by nature, systems based on the strengthening of private incentives run counter to the distribution of knowledge at certain times.

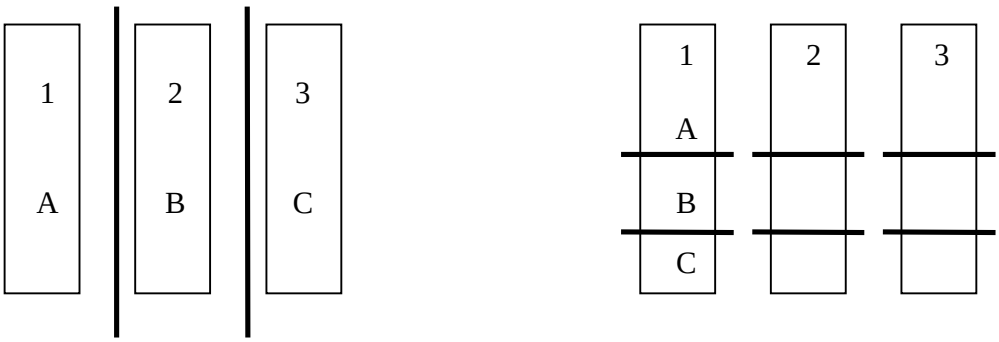
Compared to the private goods regime, which hinders the distribution of knowledge, collective invention creates areas for the sharing of knowledge, in which technological secrecy and the retention of private knowledge are temporarily and locally suspended. The different forms of collective invention organize and formalize modes of sharing research tools and of circulating knowledge between multiple partners. By establishing multilateral rather than bilateral relations,

the most complete forms of collective invention make it necessary to invalidate exclusivity rights and to create areas for collective production. This is a valuable device when the tendency to privatize knowledge is a real obstacle to its diffusion, including in the public resea rch sphere.

Case studies in biotechnology [WP 02] and virtual reality [WP 05], for example, show that the sharing of knowledge and especially the creation of a pool of resources within a consortium is a key point of collective invention. This sharing of d ata may concern not only resources that existed prior to collective invention, but also data produced during its activity.

• Regime and tragedy of anticommons and collective invention

Another regime based on private property can also exist. It is calle d "anticommon" to indicate that its consequences are the exact inverse of the effects of common resources. It is a regime which has produced parcels of private property rights on "indivisible" goods (Olson, 1990) so that each party, being the owner of a po rtion of the indivisible good, has the right to exclude others from its share and no one has the effective privilege of use. The distinction between the private property regime and the anticommon regime can be represented on the following graph where goods 1, 2 and 3 are represented by cells, and the lines in bold type represent the initial property rights of individuals A, B, C.



Private Property Anticommons Property

Table 1: The distinction between Private and Anticommons Property

(source: Heller, 1998)

The private property regime structures the material world vertically because owners A, B and C each own exclusive rights 1, 2 and 3 to an entire good (e.g. a piece of land). In other words, the private property regime does not prohibit exploitation of the resource. By contrast, in the anticommon regime the lines are horizontal, so that private rights fragment the goods. An anticommon is rarely the result of a division of rights based on an initial situation in a private property regime. Agent A may well decide to divide its rights, by renting or mortgaging a part of its good, without this creating an anticommon regime. Indeed, agent A remains an identifi able

owner who continues to exercise control over the new owners of rights, and can therefore coordinate the exploitation of the good. In an anticommon situation, by contrast, there is no hierarchy nor means of coordination among owners. Moreover, private property regimes often include rules aimed at preventing excessive division of the goods.

The tragedy results from the fact that multiple owners of "parcels" or "fragments" of a good each have the right to exclude others from their parcel, meaning that no body can exploit the good in its entirety. This property regime breaks down and fragments objects. If too many owners have these exclusion rights (i.e. if there is too much fragmentation), there is a chance that the good will be under-utilized. The tragedy may then lead to exacerbated forms of non-distribution and under-utilization of the resource, due to the fact that rights on fragments or parcels are solely rights to exclude and can no longer be rights to exploit.

As in the case of common resources, the anticommon regime does not necessarily lead to a tragedy. First, the problem of under-utilization of resources can be solved through the trading of rights. In a world without transaction costs, owners can reorganize initial endowments through ex post exchanges, by gathering anticommon rights into property rights, that is, by recomposing the goods. Of course, the real world is one in which transactions are costly, but some problems of anticommons – particularly those concerning a small number of agents – may nevertheless be reduced by resorting to such transactions with a view to recomposing the goods. Another solution is similar to the one used for the problem of common resources: the adoption of informal norms for managing ownership. Finally, in certain ca ses, far from being a tragedy, the under-utilization of the resource may be socially beneficial (for example, the excessive fragmentation of coastal land which makes extensive property development impossible and helps to preserve the environment).

Finally, to avoid the tragedy it is logical to try to eliminate the regime itself by endowing those concerned with more coherent initial rights.

How can this regime be translated into the knowledge economy? It corresponds to excessive fragmentation of the knowle dge base, due to intellectual property rights on parcels and fragments of knowledge that do not relate to an industrial application. The tragedy of the anticommon appears when these modes of using intellectual property rights lead to a fragmentation of knowledge[2].

Of course, the regime does not necessarily lead to tragedy. In theory, appropriate institutions could be created to help agents coordinate the trading of licenses, and collective learning could lead to real reductions in transaction costs.

With regard to the anticommon regime, collective invention provides solutions on two levels. It does so firstly by making it possible to actually avoid the creation of the regime. With the establishment of collective property rights an initial endowment of pro perty rights can be created,

[2] It is important to grasp this distinction betw een the two regimes in which private rights are applied. In the private rights regime there are obstacles which hinder the dissemination of knowledge but not its exploitation (for instance a broad patent does not fragment knowledge and therefore does not i mpede its exploitation). By contrast, in the anticommon regime there is a chance that knowledge will not be exploited.

which is more coherent in that it respects the indivisibility of goods. The second way in which the consortium provides solutions is by avoiding the tragedy in cases where the regime has been established. By introducing a syste m of mutual concession (in the spirit of the EU guidelines), the consortium favours a process of learning on the trading of rights, which may favour the regulation of the regime. Thus, we observe in our case studies [WP 02] that the manager of collective property, for example the Charity Trust in the case of EUROFAN, is the only agent authorized to acquire rights over the knowledge and material produced by the consortium. This avoids the risk of a multitude of patent applications, and individual claims and problems of payment and conflict are reduced. The manager is, moreover, the only agent authorized to negotiate these rights, which makes it easier for users who wish to negotiate licenses since they will have only one interlocutor. Innovators can therefore build up a set of resources and rights on the yeast genome more easily than if they had to buy multiple fragmented rights. Negotiations on the distribution of income are also facilitated since the principles of distribution were determined at the outset. We can thus see more easily how this type of mechanism affords an unequalled solution to the anticommon problem, by avoiding fragmentation of ownership and reducing transaction costs, for both owners and users.

I.1.3-c - Summary: economic opportunities f or collective production of knowledge

By creating coordinated research and innovation procedures, and areas for the trading and sharing of knowledge, collective invention provides original solutions to the major coordination problems characterizing the e conomics of knowledge. In this sense, there are numerous economic opportunities for collective action in the field of knowledge production and innovation. But collective action itself can exist in many different forms which we shall now consider.

I.2 – Different forms of collective invention: at what point is our empirical investigation?

Collective invention exists in extremely diverse and varied forms. Our intention is not to exclude any of these forms *a priori*, for we have found that sometimes powerful mechanisms, used to solve one of the problems mentioned above, can be found in relatively informal processes.

I.2.1 – Collusive and spontaneous forms

In our "state of the art" [WP 01], we have distinguished between spontaneous and informal forms of collective invention, on the one hand, and collusive and explicit forms, on the other.
The former are rooted in a professional context (network of knowledge sharing or trading between engineers in rival firms or between producers and users) or in a territorial framework (industrial district). This framework therefore exists prior to the creation of the collective. It reveals cases of convergence or complementarity, opportunities for meeting and transaction which lead to the progressive construction of mechanisms of collective invention.
Collusive and explicit forms have the characteristic of creating the framework or at least of "rigidifying" it (in fact we can consider that a framework always exists) enough to reveal contexts of socialization of knowledge and collective learning, in a concerted and collusive manner. At the same time this helps to control the externalities generated by the innovation (regulating relations between members and non-members, and between privileged users and the "public").

The main differences between these two types of collective invention are as follows [WP 01].
In collective, spontaneous and informal forms of invention, trading or sharing concerns knowledge that is already available. (The participants do not participate in a coordinated research project; they trade or share existing technical data. Some kinds of collective production of knowledge may, however, take place. See our cases [WP 04, 05 and 09]. Collective invention is an incremental process based on the dissemination and reuse of knowledge available within a group of firms. The collective invention process is not co-ordinated by an agreement or central institution; it is relatively spontaneous. Although intentional, the sharing of data is generally not formalized in an agreement. The actors, who may be rivals, engage in strategies of knowledge sharing governed by reciprocity.

In the case of collusive and explicit forms of collective invention, the actors engage in operations of knowledge production, which require explicit coordination mechanisms as well as the formalization of agreements on both the distribution of tasks and the attribution of results. Moreover, collusive forms delimit semi-private areas for the circulation and pooling of knowledge, which may in some cases be less open than informal networks.

The R&D consortium, in the case of multilateral relations and bilateral R&D agreements, characterizes collusive and explicit forms of collective invention.

The trading and sharing of knowledge – especially between producers and users, or among members of a professional community – can be more spontaneous and informal. Trading and sharing must, however, be differentiated. There is trading of knowledge when its free dissemination is hindered by secrecy and confidentia lity. In that case the relationship is engaged and maintained on a basis of reciprocity and compensation [WP 09]. Knowledge trading may be either non-market (reciprocity is guaranteed by a return of knowledge) or market (in the case of buying or exchanging licences). The sharing of knowledge, on the other hand, is based on diffusion and free access to a pool of knowledge, according to extremely loose rules [WP 04 and 05] characteristic of professional communities.

Collective production of standards may fal l either into the category of collusive and explicit forms (a consortium is created, [WP 05 and 10], or into that of spontaneous and informal forms (the standard is created owing to a sharing of knowledge in the framework of a market process, [WP 04 and 05].

The choice of the precise form of collective invention depends on many parameters that Von Hippel (1989) tried to identify. The fact that knowledge exists or not prior to the agreement will govern the choice of either an explicit and coordinated form (in the production of knowledge) or a spontaneous form (in the trading of existing knowledge). In reality, we note that this criterion is rather weak. There is always an existing knowledge base in the context of explicit cooperation, while the process of co llaboration or informal exchange almost always includes some degree of creation. The transaction cost involved in drawing up an explicit collaboration or trading contract may also be taken into account. If it is high (if the value of the knowledge to be tr aded is low compared to the transaction cost), the non -market or sharing option will be preferred.

I.2.2 – Four forms are studied

We have chosen not to exclude any of these forms. From a pragmatic point of view the areas covered have enabled us to iden tify four forms. However, this is not in any way an exhaustive list of the phenomenon.

high tech consortia	knowledge trading in producer – user relations
standards setting consortia	informal knowledge sharing between the members of a community

Basically, the only phenomena that we exclude are those involving unintentional or non -deliberate collective invention, that is, processes of knowledge dissemination. These phenomena are excluded even if institutional mechanisms explicitly support such proc esses. That is typically the case of systems of patents, in which provisions for disclosure are a non -deliberate collective

invention mechanism. It is likewise the case with the mobility of human resources. All these phenomena produce what is often called "unintentional spillovers".

Our empirical research therefore focused on high-tech biotechnology and telecommunications consortia [WP 02 and 08]. The standards-setting consortium was studied in the case of the building of electronic trading networks in the insurance sector [WP 10]. Knowledge trading in a producer-user relationship was studied in the case of the creation of financial software [WP 09] and in that of the virtual reality industry [WP 05]. Finally, informal knowledge sharing was specifically considered in the case of WEB-page design [WP 04] and virtual reality [WP 05]. Some of our cases combine several forms, especially knowledge trading and knowledge sharing for the creation of standards [WP 04 and 05].

We see that these four forms are situated at different points on a continuum between extremely formal and extremely informal processes. The consortium is obviously the finest example of a form of collusion, in which a framework or community is created to implement processes of collective invention. At the other extreme, informal knowledge sharing is a spontaneous form. Between the two, the collective production of standards and producer–user relations are forms that have a degree of explicit coordination, without the same degree of formalization as the consortium. Depending on their modes of organization, which may be vastly different, these two intermediate forms can be situated at varying distances from the two extremes.
While consortia and standards committees may include a "large number" of agents; producer-user relationships are mostly bilateral. When a producer-user relationship is extended to many agents, it tends to evolve towards a consortium form. We consider knowledge-sharing to be a multilateral process which generates a knowledge pool.

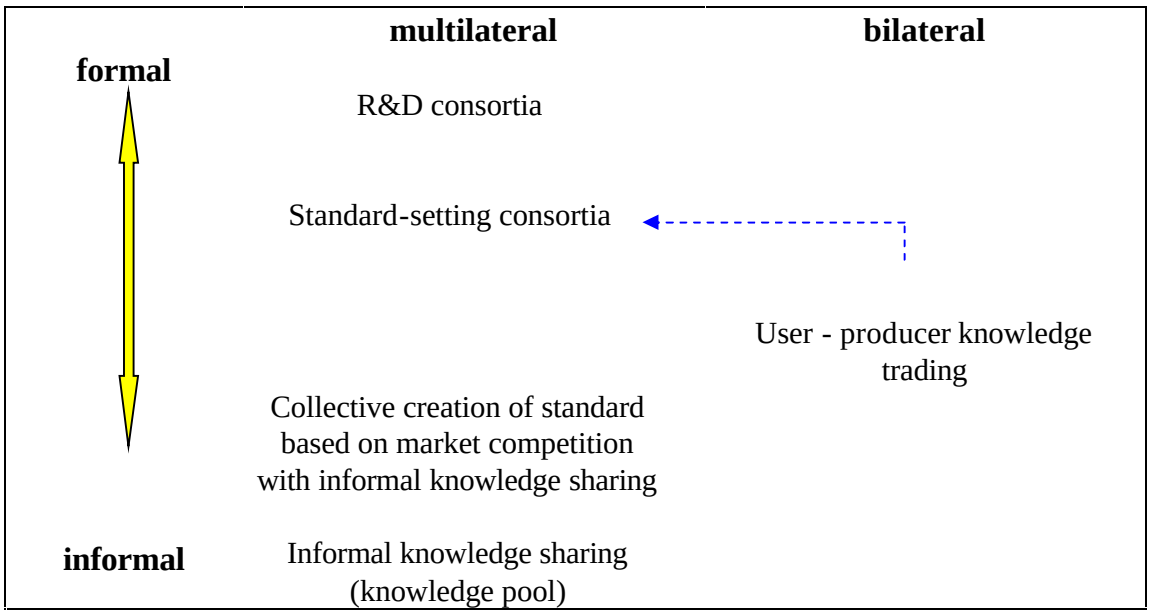


Table 2 – Various cases of collective invention

I.3 – Objects of analysis

Collective invention has been the subject of much research [WP 01]. It nevertheless seems to us that *Colline* has constructed an original object of ana lysis. Although an extensive literature exists on research cooperation, the main aim of such literature is theoretically or empirically to validate the economic rationality of this form of organization. Game theory, the economics of transaction costs or strategic analysis are all mobilized for that purpose. Few analyses attempt to grasp the processes and procedures through which communities are formed, collective goods produced and the social benefits of the activity enhanced. *Colline* has, by contrast, trie d to gain insight into these processes and procedures, i.e. the elements constituting collective invention. Its work is based on three axes.

I.3.1 – The three axes of collective invention

Collective invention has three aspects.

- **Production of knowle dge**
  (division of labour, technical co -ordination, organisation of resources and knowledge access)

- **Appropriation and distribution of results**
  (intellectual property)

- **Composition of the group (internalisation) and dissemination beyond the group (externa lities)**

- First, collective invention is a way of producing knowledge, based on the possibilities afforded by the division of labour when a number of entities or agents come together to pursue a particular goal. This first dimension is that of the "techn ical" organization of the circulation and production of knowledge, which uses collective invention as a solution to problems of dispersion and division of knowledge, and of excessive incentives (cf. above). Technical organization concerns the distribution of roles, and thus the division of labour, and access to a pool of shared resources. While the former aspect is characteristic of explicit forms such as consortiums (although repeated informal trading can spawn primitive forms of division of labour), the l atter characterizes most forms of collective invention, i.e. consortiums [WP 02] but also client -supplier relations and informal exchange between members of the same community [WP 05].

- Secondly, collective invention is a mode of appropriation and distri bution of the results of research and innovation, based on the creation of a community. This involves problems that are neither simple nor easy to solve. A multitude of possible "rules" can be identified, from the establishment of collective property right s to the maintenance of private rights. This dimension is important in a context of galloping privatization which is having the effect, among others, of

fragmenting the knowledge base and producing monopolies on operation that preclude any subsequent development by a third party. In this perspective, collective invention is designed to be an instrument for producing a more coherent logic for the attribution of property rights, or for providing a framework for trading rights at the lowest cost.

- Lastly, collective invention produces a new boundary, an original partition between a set of coordinated agents and the rest of the world. The question of the dissemination of results and thus of the social returns to collective research represent the third aspect of collective invention. This aspect raises the question of the "composition" of the group, that is, the internalization of the knowledge externalities. Is the group composed of all the members of a set (an industry, for example)? – in which case the question of dissemination is less relevant. Or does it consist of a significant part of this set? – in which case collective invention can become a hindrance to the entry of new actors into the industry. Or, lastly, is it limited to a very small number? – in which case the question of the organization of dissemination beyond the circle is raised. One important issue to be considered here is the elaboration of rules about “rights of entry” for newcomers.

Having identified these three axes, an object of analysis emerges: the communities which support collective invention are not all accomplished in the same way, in terms of the following criteria: the production and circulation of knowledge will be distributed and collective to varying degrees, the appropriation of results will be distributed to varying degrees, and the final dissemination will be broad and organized to varying degrees. Moreover, these three criteria are not independent of one another and there may be transfers between the three poles. For example, the integration of new partners (composition of the group) may occur at the expense of a change in the collective nature of the production and distribution of knowledge. A balance between these three requirements will then have to be defined. These balances to define are at the centre of our questioning.

Box 2 - Examples of tension

- in biotechnology consortia, the integration of industrial partners (internalization of externalities) implies stronger intellectual property rights within the consortium (alteration of collective invention?);

- in the standardization of electronic data networks consortium (London insurance market), the integration of US firms (internalization of externalities) leads to a certain loss of control over innovation and a slackening of collective invention;

- in a user-supplier relationship, the rule of non-disclosure agreement (blocking externalities) may condition the quality of the relationship.

Of course, the economics of collective invention, as presented in relation to these three axes, appears differently, depending on the form considered.

I.3.2 – Respective problematics of the different forms

The economic problematics will differ, depending on the precise form of the collective invention, even if the general principles of economic rationality remain the same (see Section 1 above).

The consortium naturally offers an appropriate framework for implementing complex forms of division of labour and circulation of data and materials (production of knowledge), for designing sophisticated mechanisms of attribution of results, and for defining controlled procedures of diffusion towards society. The problem here is the creation of a balance between the composition of the group and the collective production of knowledge. There are purely academic consortia which internalize externalities to a very small extent, but in which the organization of labour and the attribution of results are profoundly collective. The ultimate problem in that case is one of spin-offs and the transferability of results to industry and users. Other consortia, consisting essentially of industrial firms, internalize externalities to a large extent. In that case the question of spin-offs is less relevant. However, the organization of labour and the attribution of results may be less collective because the condition of participation is the protection of intellectual property rights, even within the consortium. The problem is therefore clearly one of a fragile equilibrium that has to be built and maintained between a significant effect of internalization of externalities and a profoundly collective mode of organization of labour and attribution of results.

In the case of knowledge trading in supplier-user relationships, we find all three aspects of collective invention: a mode of collective production of knowledge, for example well formalized by the concept of prototyping [WP 09] (users provide feedback on each stage of the incremental development process; confidentiality clauses consolidate the exchange); a problematic of attribution of property rights that are relatively simple but imply compensation mechanisms of the "favoured-first-user" type; and, lastly, a problematic of externality management based primarily on the differentiation between critical and highly competitive knowledge and "semi-public" knowledge. Thus, the same tensions are found here as those listed above. The strength of the bond and therefore the collective production of knowledge most often depend on a non-disclosure agreement. This implies that the new area of circulation and production of knowledge is relatively impervious to the outside. The quality of the collective is enhanced, to the detriment of the externalities. Without a non-disclosure agreement, the pooled knowledge is likely to be less sensitive or critical. From this point of view, an essential development is the shift from a bilateral relationship to a multilateral one (a supplier and several users, or even several suppliers and users). This shift from bilateral to multilateral forms of production and knowledge trading may, moreover, contain the seeds of a consortium. Is greater internalization of externalities, as in the preceding case, at the expense of the collective nature of knowledge production?

The case of informal knowledge sharing is substantially different. Informal knowledge sharing exploits ex post the virtues of a division of labour that it has not explicitly generated, and produces sharing mechanisms based essentially on trust and reciprocity. The establishment and reinforcement of these informal norms (for example in terms of property rights) are determining factors here [WP 04 and 05]. On the other hand, informal knowledge trading will not determine explicit mechanisms for the wider dissemination of that knowledge. The main point is the pooling of resources, without an organized procedure for the attribution of results. The problem with

informal knowledge sharing is the creation of a community which transcends the borders of the organizations to which the agents belong. Designers are simultaneously members of a WEB - authoring company and a broader design community [WP 04]. This t ranscending is then based on the establishment and strengthening of informal norms, which define acceptable practices, especially in terms of intellectual property rights. The whole problem of collective invention lies in this tension between the functioni ng of the organizations to which the agents formally belong, and the transversal development of a community.

The collective production of standards is an extremely interesting form of collective invention in so far as it can generate a wide variety of mec hanisms and solutions, with respect to both the production of the standard and issues of intellectual property rights and externality. The collective production of standards is a particular case which often concerns a very large number of agents. A "good standard" is essentially a standard that has to concern the largest numbers. But the greater the number of agents, the more the nature of the collective invention is likely to be changed, and the greater the chances of the group breaking up. Communities tha t are not strong enough may disintegrate, leaving the field open to pure forms of technological competition that lead to the selection of a de facto standard. The risk is all the greater when collective invention concerns highly competitive markets where r isks of clashes between cooperation and private interests are particularly great. The management of intellectual property rights, often established before the collective work, will therefore be decisive.

I.3.3 – Tools and mechanisms for reconciling the t hree axes

The aim of our research is therefore to define the tools and mechanisms used to establish an equilibrium and compromise between the three dimensions, respectively defined as the collective production and pooling of resources, the attribution of results and, lastly, the composition of the group and dissemination beyond it. Our results are presented and discussed in the following chapter.

I.4 – Implications of economic policy with regard to collective invention in Europe

The implications of economic policy on collective invention must be considered in relation to the evolution of both private and public sectors of research and invention. Collective invention can be analysed as an instrument of regulation, allowing both sectors to evolve and to cope with some important issues regarding their transformation.

I.4.1 – Collective invention as an instrument of the evolution of the public and private sectors

The accelerated privatization of the knowledge economy is manifested mainly in a proliferation of private property rights on human activity. This tendency can lead to certain abuses, resulting in inefficiency traps. Collective invention, as an institution promoting the definition of the bounds of research and innovation, in which resources are pooled and rights attributed in a concerted way, is then analysed as a possible form of regulation of privatization regimes.

This trend towards the privatization of knowledge bases has various aspects: extension of property rights to new areas of research; adoption of industrial property policies by scientific institutions; and take-over of basic research by the private sector. We know from many empirical analyses that such a tendency can lead to inefficient cases of "excess of private property". Four situations are cause for particular concern:

-The proliferation of broad patents creates monopoly not only on a method to obtain a result but on the result itself, without any limitations on method. Such broad patents have the potential to block subsequent developments and cumulativeness in a given field. (A case in point is an additive to a mineral oil, which has the property of preventing it from crystallizing below a certain temperature. The broad patent does not cover a particular additive but "all mineral oils that do not crystallize below the temperature threshold").

- The jump in patenting (Kortum et Lerner, 1997) – the dramatic increase in the absolute number of patents – may generate many negative effects such as "congestion phenomena" which cause an increase in litigation costs and the exclusion of small companies from certain markets in which large companies with low litigation costs are operating (cf. Lerner, 1994).

- The increase in the number of "exclusive licenses" (i.e. when the new knowledge resulting from publicly-funded R&D projects is yielded exclusively to a private firm) creates a real problem in terms of knowledge distribution. The proliferation of exclusive contracts in bilateral relations between a single academic laboratory and a single private company leads to various forms of quasi-integration, which seriously impair the public research domain (Mowery et al., 1998).

- The jump in patenting on fragments of knowledge which do not correspond to any industrial application can lead to anticommons tragedies. When private rights are created on fragments of knowledge before the corresponding products are identified, the development of the new product is greatly complicated. In the case of biotechnology, two types of blockage appear (Heller and Eisenberg, 1997):

  -The first results from the fact that rights are created on portions of knowledge before the corresponding product is identified (whereas previously it was the genes corresponding to products that were patented: e.g. therapeutic protein, diagnostic tests). The proliferation of patents on fragments of knowledge owned by different agents hugely complicates the coordination required by an agent wanting to develop the product. In particular, if the acquisition of all necessary licenses is too complicated or expensive, the product will never materialize.

  -A second blockage results from procedures known as “reachthrough licence agreements”. These procedures give the patent holder rights over future discoveries. These rights may consist of the payment of royalties on sales, of licenses on future discoveries or of a priority option for obtaining licenses. The system was originally designed to enable researchers with few financial resources to use a patented discovery and to pay only if the research produced results. But it turns out that this kind of system gives the owners of first patents the right to be present at all stages of subsequent developments, even if they did not contribute to them. Once again, there is a risk of under-utilization of certain discoveries because of situations in which the rights of those concerned are entangled.

Many other sectors are the theatre of anticommons regimes. A case in point is the software industry and, more generally, the information and communication technology industry in which anticommons regimes can block any process of setting up technical standards (see I.1.3)

Those various cases are useful for making the point that conflicts between private property and the distribution of knowledge are likely to occur when the tendency toward privatization is not controlled and can lead to some "excess of privatization".

In this context of privatization, collective invention is an important regulation tool for it creates areas for the sharing of knowledge, determines more coherent initial endowments of intellectual property rights and promotes the trading of rights.

The most recent example is the TSC consortium created by ten major pharmaceutical laboratories for producing a human genome map to be placed in the public domain. The consortium is used by firms to produce collective or public data that will be disseminated in the research system, and to work in partnership with academic laboratories (the TSC consortium mobilizes several major university genome centres, including the Cold Spring Harbor laboratory).

Faced with the US model of uncontrolled privatization of knowledge bases, the European experience must be brought to the fore. Incentives to cooperate, "in a certain spirit", set up in the

context of framework programmes, have led to the creation of an original model: a type of third way, between the undivided domination of the market and the blockage of our systems on relatively outdated public research structures.

I.4.2 – A way of transforming and mobilizing the public sector

It has been possible for a long time to analyse the role of collective invention in relation to necessary developments in public research. Take, for example, the constitution in the 1960s, in France, of public laboratory consortia for grouping together collections of research material and producing data together. It was the HLA workshops, initiated by Jean Dausset, in which participant academic laboratories compared their results obtained from a single sample collection. Another more recent example is the research network organized around the Centre d'Etude du Polymorphisme Human (CEPH) in the early 1980s, also based on shared access to a sample collection. The creation of consortia was also aimed at facilitating the diffusion of knowledge in the economic fabric (industrial platforms of European research consortia) and promoting research cooperation between public and industrial laboratories. Here collective invention is an instrument of mobilization and transformation of the public research sector (by facilitating its openness towards industry, promoting the evolution of its framework of action and its diffusion mission, and even by orienting the content of its research more towards techno-science and its commercial applications).

I.4.3 – A political and research tool for transforming systems

These different examples clearly show that the actors, whether public or private, local (a group of academic laboratories or industrial firms) or central (EU R&D programmes), establish consortia for generating an added value on research (by benefiting from the creation of data collections and organizing a division of labour). Collective invention finally seems to be a tool for relatively rich action for public policies, both for supporting knowledge production and limiting the negative effects of excessive privatization. It is also a way of facilitating the transformation of the public research sector (from a mission policy to a diffusion policy) and encouraging the public and private sectors to complement each other more fully.

The *Colline* project is thus at the intersection between two challenges facing European innovation policy. To what extent do collective invention models offer a solution to the "shortcomings" and/or excesses of the market system and public research? Can Europe design its own way in this respect, as the progressive development of an original form of coordination based on the collective production of public goods?

We shall try to answer these questions by successively examining the tools and mechanisms of collective invention, in the framework of our four configurations, in the hope to revealing best practice.

Chapter II :
Observation of best practice and good properties

We shall now focus primarily on three situations, identified on table 2. Two situations correspond to relatively formal processes, in which the division of labour is explicitly organized, problems of intellectual property rights explicitly managed and the management of externalities controlled. These situations concern high-tech consortia and formal processes (consortia) of collective production of technical standards. The third type of situation concerns less formal knowledge trading and knowledge sharing processes. Even if the different aspects of collective invention are less organized in such situations, our framework of analysis remains relevant, especially for observing tensions and contradictions between these three aspects (collective production, attribution of results, management of externalities).

II.1 – The fragile equilibrium of European consortia

The concept of an R-D consortium is an important tool and institutional mechanism for technology policy :

- It creates spaces for sharing knowledge, in which there is a break from technological secrecy and the retention of knowledge by private agents. It generates a new economic category of knowledge called collective or pooled knowledge, which is shared among participants during the period of research.

- It allows agents to develop concerted actions by organizing the division of labour to explore a certain domain and providing an institutional framework to assemble divided and dispersed knowledge.

- It can enable agents to create a more consistent and coherent initial endowment of intellectual property rights, which does not fragment the knowledge base. When the knowledge is initially fragmented (anticommons property), the consortium provides a space in which rights can be exchanged at a low cost, because partners are well identified and some collective learning can occur.

All these good properties of consortia prove to be extremely useful for the regulation of the knowledge-based market economy. They show that consortia have the potential to "regenerate"

the two main mechanisms which traditionally organize research activities: private property and public organization.

The *Colline* project was initially based on the perception of a high rate of creation of R&D consortia in Europe. However, it was also based on the assumption that beyond a sort of generic form of consortium, there are numerous particular constructions and that it might be useful to thoroughly investigate the mechanisms of collective invention and to try to identify some good practices.

The analysis presented here draws on 9 monographs; 8 on biotechnology consortia (6 are European consortia supported by Community programmes and 2 are international consortia, see [WP 02] and 1 on telecommunication, see[WP 08].

To investigate the mechanisms of collective invention, we use the framework which articulates three dimensions: the production of knowledge (division of labour, access to the common pool of resources); the attribution of results (intellectual property rights policy) and the internalization of externalities and management of spillovers.

II.1.1 - Two generic models

We have identified two models in the particular case of the European biotechnology consortia [WP 02].

In a first model, there is little diversity of institutional actors. Consortia are mainly academic. That means that externalities are internalized to a small extent. On the other hand, the process of knowledge production and the attribution of results are highly collective:

- there is a formal and strong process of organization of the division of labour;
- the pool of resources (data, tools) is highly collective and the resources circulate freely among the members of the consortium;
- some consortia have established a regime of collective property. In these consortia, each partner agrees that any patentable result obtained during the project will be the joint property of all partners and that the share of each partner will depend on their participation in the work. Because the system of collective property can pose particular management problems, some consortia create an ad hoc institution for managing its collective property.

These consortia (model A) thus approach the idea of a "perfect community" to a large extent, i.e. a community that is strong enough to resist private incentives generated by patent and publication races.

However, these consortia are relatively weak in the internalization of externalities, for industrial partners remain on the outside. That is certainly why the community is so perfect. We immediately

realize that the main economic issu e will be the transferability of knowledge to society (particular users); that is the social return of the consortium.

In a second model there is a wider diversity of partners. Industrial partners are integrated into the consortia, although at the expense of the collective nature of both the knowledge generation process and the attribution of results. Consortia are characterized by very little sharing of research and small knowledge pools. The results are ultimately appropriated separately by participants. Why this is the case? Industrial companies working within a consortium are reluctant to disclose confidential information. Thus, the circulation of data is strictly limited within confined areas, so that rival firms participating in the same consortium ar e never in contact and work in different sub - parts of the general project. Finally, private partners cannot release their rights to a collective body. These consortia nevertheless fall into the category of collective invention because there is also some po oling of resources, knowledge sharing, and concerted decisions to organize the division of labour.

We can thus differentiate between these two models, in which the main problematic is different in each case.

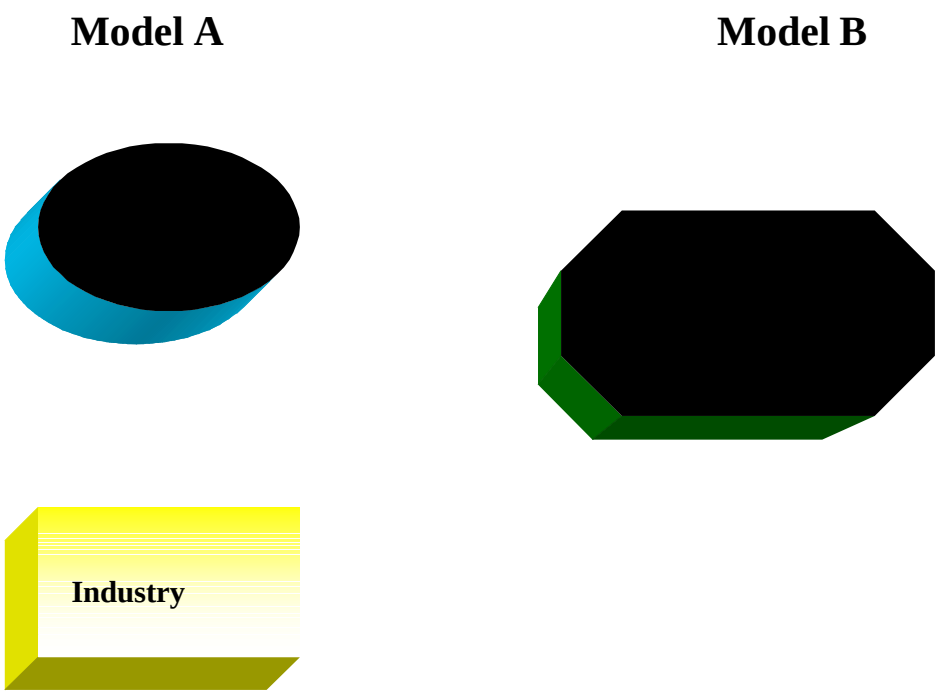


Table 3 – Two models of consortium

We have here a clear illustration of our assumption that the development of three dimensions of collective invention corresponds to conflicting objectives: externalities can be internalized (which means integrating industrial partners) at the expense of the collective nature of the enterprise which will be altered, and the generation of strong communities requires that industry be left out.

For each of model the problematic is different. We shall now consider each one successively.

II.1.1-a - Model A: Issues of the industrial transferability of knowledge

For model A, the main issue is the social exploitation and transferability of knowledge, once produced by the academic consortium. An important practice here is the building of an industrial platform which includes certain privileged users. In this design, however, the industrial partners do not participate in the consortium's agenda (model A1).

Another solution is for the industrial platform to become a contracting party within the consortium. This form of quasi-integration aims at strengthening interactions between laboratories and industrial users, who participate at least in the definition of the programmes and the discussion of results, if not in the research itself (model A2).

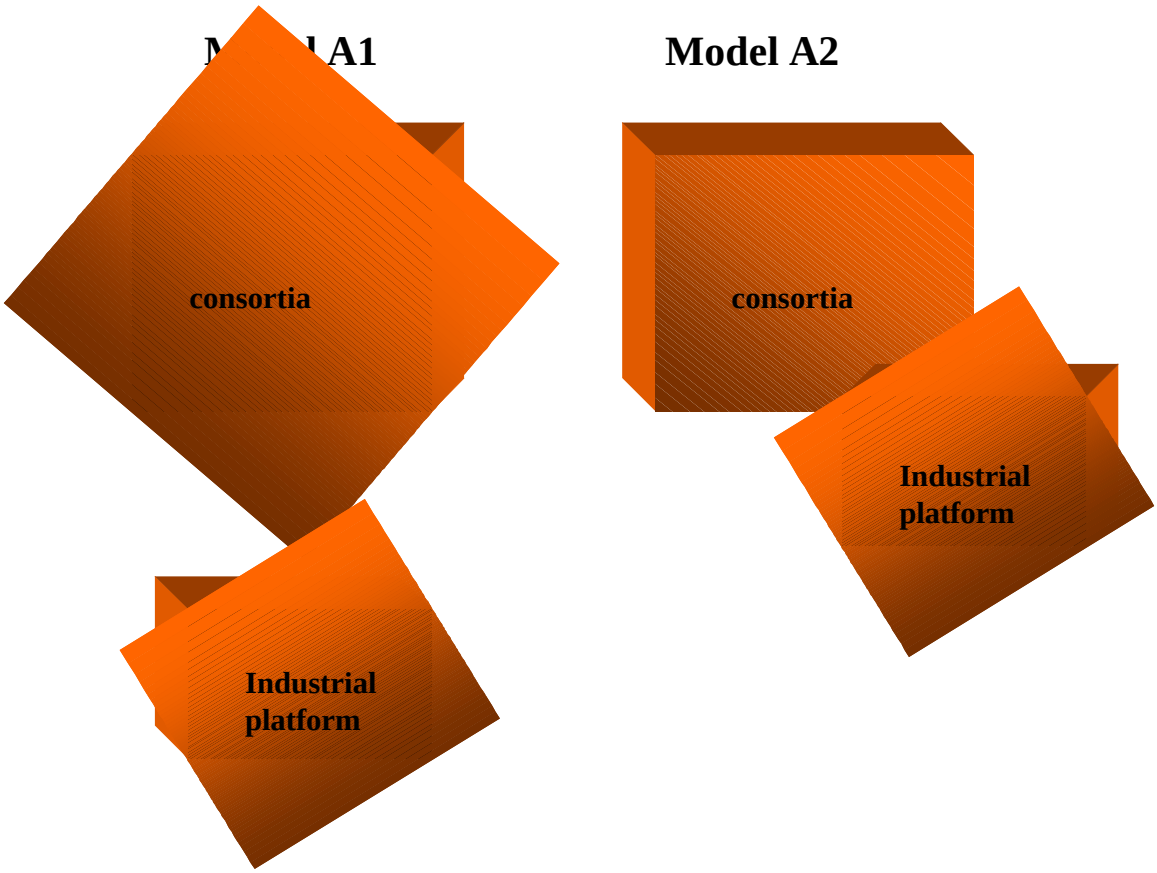


Table 4 – Externalisation or quasi-integration of industrial platforms

We thus have two different schemas. It immediately becomes apparent that model A2 is intended to achieve a fragile equilibrium between keeping the collective nature of the process at a very high level, and integrating industry. This is an interesting type of practice.
Another mechanism is absolutely critical in the production of such an equilibrium: partial dissemination of knowledge. This is a remarkable innovation used both to reserve the results for a certain period (which preserves academic institutions' ability to file for patents) and to inform industry immediately about certain interesting results. It is based on the differentiation between effective diffusion of knowledge and the sending out of signals. Signalling has a twofold advantage: the consortium immediately publicizes information on its results while maintaining access rights and confidentiality; the firms receive early signals on research underway and can undertake direct negotiation to enter into contractual relationships with the laboratories that own the data.

To sum up, it is clear that a "perfect community" with weak performance in terms of the transferability of knowledge would have no impact on society. That is why such a model has to be equipped with specific mechanisms aimed at promoting knowledge transferability. The combined system of (quasi-integrated) industrial platform and partial dissemination of knowledge is in this sense valuable.

II.1.1-b - Model B: How to produce a strong community with heterogeneous actors?

Model B raises quite different issues. In this model the internalization of externalities is the strong aspect of collective invention. Industries are within the consortia, so that the transferability of knowledge is not an issue. But pushing industry into the consortium implies explicit policies and mechanisms to protect the industrial entities within the community of partners. Two possibilities exist. The first is simply to redirect the research agenda towards "non critical" projects (this was the case for instance of SEMATECH; see Grindley et al., 1996). The alternative is to reinforce the protection of intellectual property. This is the case of most of the biotech consortia. However, such an option has the potential to deteriorate the collective and multilateral character of partnerships. The problematic of model B is thus to find an equilibrium between the need for providing better protection to private companies within the consortium, and the need for preserving some kind of collectiveness. Thus, problems here concern the production of knowledge and the attribution of results.

There are various difficulties in pooling data when industry is involved and the partners bring in private materials that they want to exploit with the help of academic partners, without disclosing information on these materials to potential rival companies that are also members of the consortium. Such difficulties are partly overcome through the building of complex systems for circulating data, which are strictly compartmentalized within small teams with only one firm each.

The same kind of system is used for the knowledge and data which are produced during the collective research activity. The basic principle here is the "controlled" dissemination of data which can lead to very complex patterns of concentric circles and gradual processes of dissemination [WP 02].

The attribution of property rights also raises difficult issues. There are different possibilities [WP 02]:

- Disjoint property rights: in some consortia, while participants agree to exchange research results, they set up a system of separate ownership in which each firm retains control over its confidential material, technical know-how and invention. The consortium is divided into five sub-projects, each of which includes one firm. Because firms are spread out among separate contracts, they are not forced to grant licenses to their rival partners, as in a typical EC contract. Each firm controls its territory and files patents on the inventions developed within its own sub-project.

- Temporary property rights: the other alternative is to grant participants temporary ownership, lasting for the duration of the research, on the fragments of chromosomes they receive and decrypt. During that period the participants can publish or patent data concerning their fragments. The right to do so lapses once the research has been completed.

To sum up, although consortia are close to the idea of perfect transferability of knowledge (because industry is involved in their actual activity), there is a need for some institutional innovations in order to establish a balance between the collective nature of the process and the protection of private interests. These innovations have to be developed to create such a balance at two critical points: the circulation of data and knowledge during the process, and the attribution of results. According the mechanisms at work at both levels, a continuum can be drawn from the least to the most collective arrangement. Here again, as in model A, the compromise is difficult to find.

II.1.2 – In search of best practice

Good practices in model A concern the transferability of knowledge (platform, partial dissemination). In model B they concern maintenance of some collectiveness while the entry of industry into the consortium is promoted (organization of the circulation of knowledge and the attribution of property rights).

In the absence of good practice in model A, there is a risk of funding collective research with a very weak impact on the economy. Without good practice in model B, there is a risk of having communities which are not resistant enough to withstand private incentives (patent races). That was the case of the International Breast Cancer Consortium.

This does not mean that the consortium has no impact, as a form of collective invention. For example, in the case of the international breast cancer consortium, participants effectively shared

resources and data to narrow down the gene research field (enabling them to target their own work better so as to remain in the race, and excluding groups not participating in the consortium). But the field of breast cancer genetics was so competitive that once the area to investigate had been defined, strategic knowledge was kept secret as each group negotiated with industrial firms. The analogy with minerals prospection or deep-sea fishing is obvious. With the sharing of "geographic" information between a few agents, a first selection can be made among the groups, before the real competition starts. This process helps to understand a result that is a priori paradoxical. There is not necessarily a contradiction between the sharing of certain resources and the creation of an anticommon regime.

We can roughly draw a continuum along the different criteria set out above: circulation of data and organization of the work; attribution of results and management of externalities. This continuum must not, however, mask a gap between:

- on the one hand, forms of collective invention producing strong communities which propose real alternative solutions – both local and temporary – to the mechanism of market coordination (we mean that they propose clearly different coordination mechanisms to those used in a private market, and which are based on clearly defined and relatively codified forms of self-regulation);

- and, on the other hand, forms of collective invention producing far weaker communities – situations in which collective invention seems to be subjected to market mechanisms (we mean that collective constraints are weakened greatly and that the community does not seem to be strong enough compared to patents race mechanisms).

It is remarkable to note that a consortium does not automatically fall into the category of "weak communities", even though a private property regime precedes its creation (participants initially possess private rights). Admittedly, the solutions of collective property observed are applied by consortia composed essentially of academic laboratories or small private sequencing laboratories, with no direct interests in the industrial exploitation of knowledge. These consortia define collective property regimes to manage indivisible knowledge or facilitate transfers towards industry. Industrial users can benefit from this form owing to lower transaction costs (the yeast industrial platform upholds the principle of a trust and of the collective property of the EUROFAN consortium). These solutions of collective property are therefore perfectly articulated to the market in so far as the trust sells access rights to industrial users who will subsequently develop proprietary innovations or take out application patents. However, these solutions are disputed by those who, within the consortia, have special agreements with industrial firms or strategies for exploiting the results (e.g. the Pasteur Institute is bound by exclusivity agreements to three firms in the field of diagnosis and therapeutics).

II.1.3 - A challenge for European policy

The effectiveness of solutions to the coordination problems mentioned above will therefore be different, depending on whether the consortium belongs to one or the other of the two extremes. In this respect, the European model of collective invention in biotechnology is at a crossroads. The new principles aimed at increasing the industry's participation in consortia by reinforcing the protection of intellectual property within the community of partners, are positive and certainly unavoidable. These new principles concern, firstly, limitations to scientific publication (the scientist has to send a copy to his or her industrial partner, who has a period of 60 days to make a "motivated opposition"). Secondly, the academic laboratory needs the authorization of its initial partner if it wants to continue a research programme with a new partner. These principles should not, however, deteriorate the collective and multilateral character of such partnerships. A fragile equilibrium could thus be found between the need to provide better protection to private companies within the consortia, and the need to promote strong knowledge communities. There is, however, a risk of these new principles pushing consortia into forms of far weaker communities, which have proved too weak to withstand private incentives generated by the patent and publication races.

II.1.4 – Institutional creativity

Now, we should not underestimate the co-evolution of practices and attitudes among academic and industrial partners as a result of better mutual understanding. Evidence of this co-evolution of attitudes and the power of collective learning (about how to cooperate) is provided by the great production of local rules and practices. High-tech consortia are areas of high levels of institutional creativity. The actors have to devise rules for sharing and appropriating knowledge, which are used to manage the multiple tensions between individual priorities and collective invention, members and non members, academic participants and industrial partners. We have documented an abundant production of rules and institutional innovations. The reason for such creativity is the somewhat unusual context of collective invention in biotechnology. This context is characterized by highly specific technical objects and a configuration of actors (either the consortia include rival companies or they are composed of a very large number of partners (about 138 labs in Eurofan). Two specific "European constraints" oblige people to be creative in designing consortium agreements for supplementing European standard contracts:

- the absence of a grace period implying the need for deferred or partial access;
- the thrust towards knowledge sharing (produced by the European standard contract) which implies the need for reinforcing individual protection.

These local arrangements are mainly produced by researchers. Some are merely guidelines; others appear as appendices to the contract. Such work on local arrangements demonstrates the incompleteness of research contracts and of the legal system concerning intellectual property rights. For lawyers, guidelines and local rules are private arrangements between actors, organized under the principles of "self-discipline of a professional partnership".

On the one hand, these rules express a tendency towards the decentralization of economic regulation. In this respect, they serv e as experiments that can be influential in the development of persistent patterns of inter-organizational behaviour. That means that some of these rules are now codified and replicated in various contexts. Some kinds of institutional learning and experimentation can thus be identified. On the other hand, the emergence of these local practices and arrangements are raising questions of their compatibility with the general corpus of contractual law and intellectual property rights. While some of the new rules can be a source of inspiration for lawyers and legislators, it is by no means a simple and immediate process. Most often, the authors of guidelines working in the context of a given project have to solve a local problem and do not raise the broad issue of incorporating guidelines into the general structure of intellectual property laws. Thus, the diffusion of some local rules in several projects, or the recurrence of a pre-existing arrangement in a new project are good indicators for assessing the robustness of some of those rules and the possibility of transforming them into "intermediate entities" that can connect local practice to more general institutions such as ordinary contract provision or other legal arrangements.

II.2 - The collective production of standards

In the case of knowledge whose structure exhibits properties of complementarity or network externality (see Chapter 1), the existence of standards (those common features of a group of products, services, processes or measurements which bene fit the user and/or producer because the same features are used in all items within the group) is a decisive factor in the improvement of the coordination and organization of activities. This is because standards facilitate the interconnection and interoperability between systems, the re-utilization and recombination of existing knowledge, and so on.

The essential question here relates to the mode of production of the standard. It may be the result of purely private strategies to exploit the effects of ext ernalities, with a view to promoting a proprietary technology that will consequently become the de facto standard. Otherwise, the standard is produced by an official organization with the intention of taking into account the interests of all potential acto rs and proceeding by way of consensus (cf. [WP 07], for a review of the literature).

Lying somewhere roughly equidistant between the unilateral *de facto* standards imposed by Microsoft and the broad, participatory process leading to the development of *de jure* standards by bodies such as the International Standards Organization (ISO), are a plethora of company groupings that have come together to address, most typically, a single discrete technical need. These groupings, variously formal and informal, are us ually referred to as consortia. Their standards are collective, compared to public goods or the quasi-private goods of proprietary standards (see Kindleberger for an historical analysis of collective standards, 1983).

Many arguments exist for explaining t hat the consortium is the relevant form of organization for the production of standards. Such arguments describe economic opportunities for collective action in this field. Most standards are "industry specific public goods". Private firms are not in the b est position to produce a device with the characteristics of a public good. The "industry specific" nature of standards means that they correspond to a level of variety which cannot be controlled by the state. These standards, which should be produced neit her by an individual firm nor by the state, must therefore be "manufactured" in the framework of a process of collective action which groups together the main members of the community (industry) concerned. The famous historical example of this type of proc ess is the "inter-company" technical standardization characteristic of the early automobile industry (Thomson, 1958).

Yet all collective action involves difficult problems of coordination (who should take the initiative, how the work should be organized, how agreement can be reached on objectives when these inevitably diverge) which require the establishment of incentives and mechanisms for managing collective work.

The presence of principles governing the management of collective work through the creati on of an authority to which all parties belong, produces a difference between the standard-setting

consortium and the collective production of standards based on "a process of market competition with informal knowledge sharing" [WP 07]. The latter, analysed in particular in both cases of the WEB development [WP 04] and the virtual reality industry [WP 05], will therefore be treated with other cases of informal knowledge sharing (section 3), even if certain elements are discussed here.

It is moreover necessary to distinguish between two types of consortium: those formed by a group of companies promoting a particular proprietary product set (such as PowerOpen, formed to promote the IBM-Apple-Motorola PowerPC microprocessor architecture and the development of software for that environment); and those consortia that are the result of collective action by a group of companies seeking a common solution. The former type of consortium, referred to as a "strategic" consortium, is in fact a tool to gain competitive advantages in a pure market process of technological competition. The latter is referred to as a "standard setting" consortium.

Compared to high-tech consortia, examined in Section 1, standard-setting consortia have several peculiarities:

- What they have to produce is not only collective work, in which each party is involved, but also work that is unique (there must not be other standards, produced differently, elsewhere). Hence, there is a time constraint, as regards both earliness and speed, and a constraint of generality (a maximum number of actors must be enrolled in the action to achieve a critical mass of participants). Now, these two constraints can produce policies which are often contradictory.

- Except in cases of real earliness of the action (anticipatory consortia), the "invention" work will always be done in the presence of proprietary technologies that can be “essential” for the standard. Cases of standardization processes, when there is an anticommons regime, are also observed more and more frequently. All this involves problems of negotiation on intellectual property rights, with a view to guaranteeing free access to the standard.

- A standard is not only an output; it is also an input, a "factor of coordination" that will require a minimum of stability. How to provide a stable standard in a changing context is a difficult question [WP 05].

The analyses presented here draw on 3 monographs: one on the VRML (Virtual Reality Modelling Language) and the Web3 consortium in the case of the production of formal standards for virtual reality applications [WP 05]; one on the LIMNET (London Insurance Market Network) consortium in the case of the creation of an electronic data interchange standard for the London Insurance Market [WP 10]; and, lastly, one on the creation of standards and norms in Website development [WP 04]. We also are using the specific theoretical literature on standards which is surveyed in [WP 07].

As in the previous section, we shall use our framework in which the three dimensions of collective invention are articulated.

II.2.1 – Initiating collective action with some chance of success

If collective action aimed at producing a standard is to succeed, three conditions must be met:

- a common perception (shared by a majority of the members of the industry) of the importance of standards in the context in question;

- divergent interests which, although inevitable, remain within tolerable limits for the collective action.
These first two conditions have been formalized by Besen and Saloner (1988), who conclude that when they are met, the chances of achieving a cooperative standard are high. We think, however, that an additional, more "institutional" condition is also required (very clearly demonstrated in the case of the insurance market, [WP 10].

- a common view of the importance of collective action in this domain.

The first condition appears clearly in some of our cases [WP 05, WP 10], although to differing degrees. In the case of virtual reality, there is a general perception of the importance of a standard related to the obvious fact that certain opportunities (such as re-usage) are missed. However, discussions suggest that the best programmers can usually design around problems with non-standard interfaces [WP 05]. In the case of the insurance market, the perception is far stronger and derives from the sharing of a common experience related to significant economic changes: "the net effect of all these developments was to increase dramatically the quantity and diversity of information that needed to be exchanged in the conduct of commercial insurance and reinsurance. The question, therefore, was whether the co-ordination costs of handling this information could be reduced..".

The second condition is strongly dependent on the degree to which the work is anticipatory or not. In an "anticipatory consortium", the odds of success can be high. There is a commonly perceived need for a solution, but no single member has invested so heavily in a specific technology that it is unwilling to work with competitors to develop a "public good" standard. Another way of containing the divergence of interests is by limiting the objectives of incomplete standardization; that is to say, reaching agreement on the "lowest common denominator standard" [WP 07], or orienting the work towards the development of standards which are essentially public goods (e.g. languages or measurements (cf. EDI messages, [WP 10]). The last condition is relative to the institutional conditions of the group concerned. If the group is used to solving problems collectively, it will adopt the same approach for the creation of a standard. Thus, traditions of knowledge sharing and the role of industrial partnerships as forums for the exchange and existence of interpersonal networks, are factors contributing substantially to the choice of the collective mode [WP 10].

Even if these conditions are met, there is a risk of free-riding, with each party waiting for the work to be done by others since everybody will benefit from it anyway. There is thus an element of

additional incentives that needs to be highlighted, stemming from the fact that an active presence in the consortium has positive effects on the firm's reputation but also on the final result (for a standard will never be perfectly neutral). "A firm that could persuade other firms to adopt its own procedures reduced the cost of changing those procedures, as well as enjoying public recognition of its expertise" [WP 10]. There are, thus, some incentives for companies to participate and allocate resources to the process.

II.2.2 – Internalizing externalities without slowing down the process or losing control

Internalizing externalities by extending the group raises new and original questions (compared to high-tech consortia analyzed in section 1). It is important for the interests of small firms, producers of goods and complementary services, and final users to be represented [WP 10]. However, this poses two series of problems. How can small players be encouraged to enter when participation is costly in terms of time and human resources, and participation in standard-making is subject to indivisibility effects (the greater the economic advantage a participant has to gain through the standard, the lower the relative cost of the participation) and thus to economies of scale? How can one ensure that, beyond a certain threshold, the group's performance does not drop, the process slow down or the group break up?

Incentives to enter require the rigorous organization of a division of labour which enables each party to choose a level of access and a field of expertise (cf. following point).

When industrial partnerships are at the basis of collective action, a clear partition appears between those who participate and those who remain outside [WP 10]. The group is extended by way of these partnerships. This preserves the coherence of the group and enables it to grow without penalizing or delaying collective invention: "this has not led to fragmentation or the abandonment of the project, nor to powerful players dominating and excluding others. Instead, the various actors have formed new partnerships and found better ways to articulate their concerns, all the while continuing to share their knowledge and pursue their original goal" [WP 10].

By contrast, the contradiction between the dimension of the group and its performance was experienced fully in the case of LIMNET, when the decision was taken to open the consortium to US firms: "not every firm appreciated the value of the positive network externalities. ...firms felt that they were losing control over their invention, and the rate of innovation slowed down in London after the community was enlarged" [WP 10]. It was the internal functioning of the consortium that made it possible to solve the contradiction.

II.2.3 – Organization of work and collective production

As in the case of high-tech consortiums (seen in Section 1), rigorous principles governing the management and division of labour are at the basis of collective invention. The production of

standards is a process including multiple tasks and activities (research, development, tests, fast prototyping, etc.). Thus, in most standard-setting consortia, there are various classes of members, each with a different set of rights. However, these rights do not simply scale with economic contribution. Instead several categories of membership relate primarily to specific activities. For example, members of the testbed member class are entitled to participate in the consortium testbed programme by submitting their own individual testbed implementation proposals, but without the additional rights and higher membership fees of the "principal member class".
From this point of view we can expect some standard-setting consortia to have the same kind of "compartmentalized structure" as some of the biotechnology consortia investigated above. This is the case of the Open GIS consortium (OGIS) which provides for the establishment of more than one "track" of membership, with each track having a specific technical or other mission within the general purpose and goals of OGIS. Each new member of OGIS thus becomes a member, not of OGIS as a whole, but of a single track (or multiple tracks) of membership. Each track has its own executive director, technical committee chairman, technical committee, and work groups (Updegrove, 1995).

This type of modular structure seems to have the same "good properties" as those we have already highlighted. Compartmentalization helps to reduce potential tension between the growth of the group (internalization of externalities) and the demands of collective invention, as regards both the production of the standard and the appropriation of results.
Of course, this compartmentalized structure requires "coordination mechanisms" in order not to lose the global coherence of the project. In OGIS, the management committee of a track is composed of one representative of each principal member (i.e. paying the highest fees) of that track, as well as two other categories of participants: members of the Board of Directors Executive Committee (thus ensuring coherence of action between the various tracks), and representatives of the lowest class of the track (thus ensuring end-user and other non-vendor input). In order to further integrate the layers of governance, the management committee of each track also selects several representatives to the board of directors, and the executive director of each track is automatically a board member.

Thus, the sub-division of the consortium, which can facilitate its growth, must go hand-in-hand with the establishment of powerful integration mechanisms.

II.2.4 – Problem of attribution and appropriation of results

The problem of the appropriation of results of collective invention is above all one of "proprietary influences". Some proprietary vendors invest considerable time and effort in forming and participating in a consortium, with the objective of injecting some proprietary element into the final standard, which they believe will favour them in the market place. There is thus a need for erecting checks and balances and other effective barriers to ensure that proprietary influences do not subvert the search for a "good standard". The question is then how to ensure that the subject under study is in the "general interest".

Although proprietary influences can negatively affect the collective nature of the appropriation of results, we have also noted that the possibility of influencing the process is a considerable incentive for firms. It is therefore advisable to establish a balance between the possibility of having an influence (incentives) and the control of excesses caused by the exclusive pursuit of private interests (collective invention).

The problem of the appropriation of results is then related to the question of the pre-existence of intellectual property rights on technological elements likely to be included in the standard. It arises in situations where the public good (the standard) is produced from partially privatized knowledge bases.
The procedure set up for the GSM standard still seems relevant today. Its purpose is to reduce the risk of a loss of investments in the development of the standard, due to property rights not being identified in time. The consortium records "essential" property rights (the rights granted to protect "unavoidable" technologies) by asking members to reveal the fact that they hold essential rights. It then grants licences (quasi-free licenses, without territorial limits). Of course, when some members have behaviour that is misleading (non-essential rights are announced or truly essential rights are kept secret) this can distort the process. Only with a spirit of cooperation – related to the third condition stated above – is this risk reduced.

When the owner of basic property rights is not a member of the consortium, the situation can become difficult to manage. It may even be inextricable if it leads to an anticommons regime. Clearly, the production of international standards, for example on the DVD, are blocked by the existence of a profusion of property rights which make the establishment of common specifications particularly difficult. The setting of a standard can be obstructed when property rights are too dispersed. The massive arrival of new actors (operators and suppliers) is causing a break with usage that was tacitly established by large corporations in the context of standardization procedures, and in terms of which each party agreed to make its rights available to all under "reasonable conditions". The sudden appearance of a multitude of small operators, each with its own property rights, makes the assemblage of rights far more complicated. Today, close to 200 patents are likely to interfere with MPCG data compression standards (Breese, 1996).

II.2.5 – Best practice and public policy

Our case studies have enabled us to identify a set of good practice and good properties for the collective production of standards.

The existence of an historical tradition of knowledge sharing and cooperation facilitates collective action and the formation of groups for carrying it out. Such traditions of collective action, crystallized primarily in industrial partnerships, help to produce communities that are sufficiently stable to withstand the expansion of the group and to avoid fragmentation of the project or exclusion of certain members.

But the "organizational design" of the consortium is also important. In this perspective, the *mise en module* of the consortium may prove to be beneficial if accompanied by the establishment of powerful coordination mechanisms. Yet the expansion of a consortium can, at certain times, cause the slowing down of the process and problems reaching consensus. Meta-standard devices (or "lowest common denominator standards" or "standardization with respect to base characteristics", [WP 07] can, in some cases, judiciously complete the modularity of the consortium. Thus, meta-standards appear to play an important role. A meta-standard preserves the advantages of variety and thus allows the agents to maintain some specific features as they enter the standardization process. It is a mechanism designed to facilitate the ex post inclusion of the different interests and disparate options of the agents into a unified framework. Of course, meta-standards cannot guarantee direct compatibility between two products which both fit the specifications. The benefits resulting from the implementation of a meta-standard are, however, significant. It is easier, cheaper, and more effective to patch together compatibility through converters than to have competing technologies not constrained by a standard. In this sense a meta-standard provides a framework for setting local standards; it is a means to support the regular development of local standards (Foray, 1994).

Despite the importance of institutional factors, individual incentives should not be underestimated (costs and benefits, possibility of influencing results). As regards costs, the case of information electronic exchange standards shows that the adoption of available protocols (EDIFACT) makes it possible to avoid reinvention, and therefore reduces costs. Hence, the importance of existing public meta-standards.

We note, finally, that the choice of collective invention for producing a standard introduces a general tone of cooperation into highly competitive markets. Risks of clashes with private interests are therefore huge and the stated conditions of success (perception of the importance of the standard, little divergence, tradition of knowledge trading) may be insufficient. Proactive policy on basic property rights is often indispensable.

As regards public policies, we have identified three points of action:

- aid for the creation of meta-standards (such as EDIFACT), the availability of which can have a substantial impact on the cost-benefit ratio;

- aid for the creation of the consortium, through the adoption of policies aimed at providing tools for solving problems posed by collective action;

- formalization of procedures aimed at identifying and controlling essential property rights and allowing for the acquisition of licences at a reasonable cost.

Contrary to the case of high-tech consortia discussed in the preceding section, there is no need for specific rules to attract industry into the standardization field. The need is rather to find the means to soften the impact between this "tone of cooperation" and powerful private interests that industries naturally take with them into the consortium.

II.3 – Knowledge sharing and knowledge trading: cases for less formal processes of collective invention

We are discussing now less formal processes of collective invention – which are essentially based on knowledge sharing and trading.

II.3.1 – User-producer knowledge trading

The collective dimension of user-producer relations has been well documented, especially by Von Hippel (1988) and then Lundvall (1992).

We have identified it mainly in the framework of the case study of "software in finance" [WP 09].

All three aspects of collective invention are clearly at stake.

First of all, as regards knowledge production, the collective nature of invention is captured and formalized with the concept of prototyping, "a method whereby software for other types of application are developed in incremental stages with users providing feedback at each stage". Prototyping (a concept close to the "iterative problem-solving pattern" described by Von Hippel, 1994) signals the decisive and unavoidable nature of the customer as a contributor to the development process, through testing and prototyping[3]. To be sure, prototyping does not lead to the explicit establishment and formalization of a division of labour between software developers and clients (financial houses), but it may impose explicitly collective forms of organization between these two poles. This collective dynamic implies wide access by the developer of the software to the client's confidential data (an element of the particular trading philosophies and derivative pricing models that are used by a particular financial institutions represent highly sensitive information). Formal confidentiality clauses, included in contracts, are therefore provided for. There is, moreover, a sort of natural protection related to the inherent complexity of the systems. Finally, significant elements of reputation are at stake. Developers must be reputed to be infallible if they are to stay in business.

As far as intellectual property rights are concerned, the developer has the commercial property of the software source code, in terms of the Escrow agreement. But users who have actively contributed to the development process are rewarded for their work by gains which are both tangible (lower prices, lower maintenance prices) and intangible (the customer is guaranteed the quality of integration of these systems, that customers buying their software off the shelf will not necessarily have).

[3] For Von Hippel, if the customer is unavoidable, it is because knowledge and information technologies are "sticky".

Finally, as regards the management of externalities, the "non disclosure agreement" clause is a way for the client to ensure that the development work carried out is not reused by the developer elsewhere, with other clients. There is therefore an explicit blockage of externalities which is particularly effective when the relationship is bilateral (because the source of any leakage will be easy to determine). But this clause concerns only the most development-specific elements which afford a competitive advantage (the specific pricing model), without including more standard elements that developers are free to reuse for developing other products. In this case, it is essentially the concept of a "favoured first user" that prevails. For the first customer (the one who contributed to the development) the first movers' benefits are substantial (see above) and the dissemination and reuse of standard elements are not considered to be a serious problem. The opposite may even be true in a market where there is an advantage in appearing to be the best and most experienced user of what is likely to become a market standard.

To conclude, the economic opportunities of collective action in the framework of user-developer relations are obvious and considerable. They stem from the invaluable place of the client as an experimenter and tester of products under development. Thus, little needs to be done to encourage these collective invention processes. Developer-client relations, in the field of financial software, nevertheless reveal certain good properties that it would be well-advised to formalize and diffuse. These properties favour considerable stability of modes of attribution of intellectual property rights (a stability obtained owing to compensation mechanisms) and modes of managing externalities.

II.3.2 – New industries and the formation of a knowledge pool

The constitution and exploitation of a "knowledge pool" – that is, of accessible and lasting knowledge (Steinmueller, 1996) – is a key element in the emergence and development of a new industry. This knowledge pool is the base of collective invention: "The metaphor that consistently emerged was that of a 'value pool'. Agents pull together different elements from this pool in order to create or co-create a product (…) this metaphor highlights the interdependence of innovation and value creation between different contributors. As such it is an important indicator of the sense in which collective invention is present …" [WP 04].

The analysis presented here draws on two monographs on emerging activities (virtual reality and Webpage development) [WP 04 and 05].

Both cases raise the issue of the permeability of the boundary of the firm with regard to the production and reproduction of knowledge. But permeability here is tolerated and even encouraged, with a view to promoting the formation of professional communities.

In the activities that we studied, different factors combine to make this form of collective invention particularly important [WP 04 and 05]:

- First, the knowledge bases consist of modules that can be combined and recombined in countless ways. This property determines a strong relationship between reuse and

production of innovations, which in itself is an incentive to "open" one's own resources in order to use others' resources [WP 05, WP 04].

- Second, the (high) level of reuse of existing knowledge does not allow for forms of market exchange, since the cost of drafting formal agreement would be too high (the value of a particular shared module is too small to justify an explicit and negotiated agreement to sell, license or exchange).

- Third, these are network industries in which it is important to agree on standards but which are not yet endowed with institutions (industrial partnership) likely to launch formal processes (as in the case of the insurance market, [WP 10]. In this context [WP 05], the collective production of standards is based on a process of market competition with informal knowledge sharing. The emergence of design conventions in Website development activity is a typical case in point.

- Fourth, in the industries concerned there is a certain culture of openness and a common perception that shared knowledge generates increasing returns beneficial to all: "The more accessible the pool, the more creative this combinatorial innovation can be, and hence the greater the rate of diffusion" [WP 05] (see also [WP 04]).

This context, favourable to the creation and exploitation of a knowledge pool [4], is nevertheless insufficient as a base for collective invention. The community, which is defined by everyone's contribution and access to the pool of resources, has to "hold". This means that certain rules have to be complied with: non-aggressiveness as regards intellectual property and production of innovation by recombination rather than pure and simple imitation. In fact, these communities are by essence fragile. People who share knowledge are simultaneously members of a company and a broader professional community. They are influenced in their daily work by the norms and values of both cultures. There is thus a risk of these two cultures clashing and a need for some kinds of informal rules to resolve the tensions.

The main factor is a relatively relaxed attitude to intellectual property, which limits aggressive protective behaviour. It is based on the common identification and adoption of norms that make it possible to clearly distinguish between acceptable practices of reuse and infringement of intellectual property rights (a distinction between creative emulation and blatant copying [WP 04,]. A sort of ethos is thus emerging and being enforced through mutual understanding.

Furthermore, a minimum of technical organization and access to the pool of resources is necessary if recombination is to be effective. The existence of standards of reference (numerical, symbolic, pictorial, taxonomies of any kind) and performance, and a vocabulary of precisely defined and commonly understood terms all contribute greatly to reducing the time and effort required to produce recombinant innovations (David and Foray, 1996; Steinmueller, 1999).

[4] A criterion often formulated (Appleyard, 1996) is that of the speed of change. Only mature industries, in which change is relatively slow and stable, afford a favourable environment for informal sharing of knowledge. The reason is that, in a context of rapid change, it is difficult to predict the economic value of a particular piece of knowledge. This is, however, an assumption that our case studies contradict to a large degree.

On this relatively small basis collective invention develops as a loose market -driven process in which companies seek to exploit mutual externalities. The consequence of this mode of generating of innovation is often accelerated technological evolution: "the speed with which a succession of design fashion has radically transformed w eb design within such a short space of time … this is a direct consequence of the design community's openness with respect to creative emulation [WP 04].

With regard to public policy, the maintenance of relatively relaxed attitudes towards intellectual property seem to be a point of possible action, especially when there are risks of the system tipping towards more aggressive intellectual property rights (as is currently the case in certain segments of the software industry). The protection of common prope rty – that is to say, the public character of the pool of resources – is an important issue [WP 04, WP 05]. In particular, it involves a certain codification of the distinction between creative emulation and plagiarism.

Public political actions may also b e envisaged with regard to technologies providing access to the knowledge pool and allowing for the search for relevant information.

Finally, we see that in the emergent industries many economic opportunities for collective action remain under-exploited as regards the production of "industry specific public goods, for example codes of conduct for salespeople [WP 05], technical standards and generic R&D. Public action may thus aim at providing agents with tools, enabling them to solve coordination problems posed by the collective action required in the production of these goods (Romer, 1993; and [WP 11].

Chapter III : Policy implications

In order to close this project, a one-day workshop has been organized to present the results of this research and to discuss the policy implications. Economists, science managers and policy makers have been involved in a rather rich discussion. The main developments of this policy forum are presented in [WP 12].

From our research we can draw the five following results (which have been presented and discussed during the policy forum) :

™ First, one important postulate of *Colline* **is that the process of collective invention cannot be reduced to a few formal structures** , and that it is important to recognise that collective invention can in fact be implemented in very informal structures. Hence, an important result is the provision of a framework to capture any form of collective invention and highlight the key tensions and potential conflicts which can occur between the three aspects of collective invention: organization of collective work, attribution of results and property rights, and internalisation of externalities and management of the dissemination of knowledge beyond the boundaries of the community. *Colline* thus provides a new perspective on collective invention. It highlights the fact that, beyond a variety of forms, policy makers have to deal with similar issues: how to widen a community while allowing it to keep control on innovation; how to integrate rival agents in the same projects without undermining the collective nature of those projects; and how to promote the dissemination of the new knowledge beyond the boundaries of the community? This new perspective extends the scope for exchange, communication and institutional learning among policies with various purposes.

™ Secondly, collective action in the domain of innovation and technology is a key issue. Our case studies provide many arguments to show that **there is a large number of economic opportunities for collective invention** – not only in some pre-competitive arenas of scientific research but also in many highly competitive markets. Economists know, however, that collective action can be difficult to initiate. The EU framework programme is a good example of policy instruments which are devoted to this kind of purpose. But such instruments have proved to be inappropriate in certain contexts. When this is the case, and if collective action does not spontaneously emerge, there is clearly a need for other policy instruments. This is for example the case of "virtual reality", in which the generation of

interfaces, standards and norms is impeded by the difficulty to initiate collective actions. New instruments are therefore necessary to allow firms to create institutions for solving collective action problems raised by the production of some kinds of goods, resources and knowledge, usually grouped together in the category "industry specific public goods". There is here a class of instruments which have not yet received the attention of policy makers – for example the so called self-organised investment committee – and a domain of valuable interactions between economists and policy makers (see [WP 11]).

™ A third implication concerns **the tension between the uniformity of intellectual property regimes at the level of the European RTD consortia, and the variety of knowledge creation tasks** – as described in our case studies. A "single rule" may be inconsistent with the diversity of situations. It is however clear from our case studies that the uniformity of intellectual property regimes mainly characterises the general conditions of intellectual property and confidentiality – that is to say, the legal infrastructure for cooperation and networks – while there is ample leeway for devising specific practices and rules under those general conditions. The general framework includes the definition of various classes of knowledge and legal status of participants; the attribution of property rights to those who have produced the knowledge; the sharing of knowledge under reciprocity rules among the participants; and the granting of non-exclusive access rights to non participants. Those conditions express a certain policy orientation in favour of knowledge dissemination and exploitation. But this general framework also includes the possibility of devising specific contractual agreements (the so called "consortium agreement") in order to allow participants collectively to generate ad hoc modes of circulation of data and knowledge and of intellectual property rights attribution. It is, moreover, in the "spirit" of the actions of the DG XII scientific officers to leave networks with extensive leeway for finding original modes of regulation, and this principle of a complementary design of institutional practices and norms is now formally recognised in the rules of the 5th Framework Programme. Thus, there is most often more than one solution to deal with problems of data circulation, attribution of property rights or dissemination of knowledge beyond the boundaries of the network. The important policy question now is what kind of practices – as elaborated within one particular context – could fit into a large class of activities? This leads us to another fundamental implication.

™ ***Colline*** **has identified and documented practices and rules dealing with the issues of attributing property rights, organising access to a pool of resources and knowledge, and managing the dissemination of knowledge beyond the boundaries of the community**. Thus, high-tech consortia are areas of high levels of institutional creativity where the actors have to devise rules for sharing and appropriating knowledge. These rules are used to manage the multiple tensions between individual priorities and collective invention, members and non members, academic participants and industrial partners.
But most of them, while performing very well, remain local, largely uncodified and therefore very difficult to transfer and generalise to other contexts. There is, thus, a risk of under-performance in institutional learning. This first point therefore suggests a need for more in-

depth institutional experiments. "Institutional experiments" does not necessarily mean search for and diffusion of "best practices". It can mean, inst ead, processes of institutional learning through which actors and participants in various contexts are informed about original practices developed in other contexts, and are encouraged to test them, at least intellectually.

™ A fifth implication deals wi th the fact that **the collective invention model** – under its particular organisational form, the consortium – **has been chosen by Europe as a crucial coordination mechanism** to reinforce competitive advantages in some fields of high technology (and in particu lar in biotechnology). Now, an important policy question is to know whether the consortium remains the appropriate and efficient schema as research advances towards the discovery of new knowledge (a new molecule), when patents races are likely to occur. Wh ile the value of collective invention seems to be indisputable during the first phases of basic research (when the pay offs are essentially informational, the question remains open for the latter phase of the process.

The case of the international breast cancer consortium is interesting: participants have effectively shared resources and data to narrow down the gene research field (enabling them to target their own work better so as to remain in the race, and excluding groups not participating in the conso rtium). But the field of breast cancer genetics was so competitive that once the area to investigate had been defined, strategic knowledge was kept secret while each group negotiated with industrial firms and a patents race started within the consortium it self. The analogy with minerals prospection or deep -sea fishing is obvious. With the sharing of "geographic" information between a few agents, a first selection can be made among the groups, before the real competition starts.

Should we conclude here that the constraints of collective invention and assignment of collective property rights can slow down the process while racing has the potential to accelerate it? This cannot be taken for granted, for gene hunting has the potential to impede the cumulative pr oduction of knowledge. Genes would have been discovered earlier if all non-disclosed information had been diffused and shared among the participants.

It is, however, obvious that there is no constant best form of coordination during the whole process of re search, development and innovation. We might think, instead, in terms of finding a best policy flux, an optimised path and rate of movement between promoting forms of organisation that support the collective production of public goods at some stages, and forms of market coordination that can support the acceleration of research at some further stages.

These consortium-related issues immediately lead us to a last issue which is the need for evaluating the impact of the evolution of EU policy in terms of i ntellectual property, as described in section 6 of this summary. The extent to which the number of industrial partners is increasing as a result of the establishment of new rules (aimed at providing a better protection of intellectual property within the consortium); and the way in which these changes affect the "quality" of collective invention, are some of the issues that warrant further research in a second *Colline*.

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ANNEXE 1

Collection of *Colline* Working Papers

Colline WP 01:
" The sharing of knowledge in collective, spontaneous or collusive forms of invention ",
authors: Maurice Cassier and Dominique Foray, April 1999

Colline WP 02:
" The Economics of high tech consortia : case studies in biomedical research ",
authors: Maurice Cassier and Dominique Foray, April 1999

Colline WP 03:
" Public knowledge, private property and the economics of high tech consortia ",
authors: Maurice Cassier and Dominique Foray, May 1999

Colline WP 04:
" The collective invention of the World Wide Web ",
author : Paul Windrum, December 1998

Colline WP 05:
" Collective invention in virtual reality ",
author : Peter Swann, April 1999

Colline WP 06:
" Network, noise and navigation ",
authors : Paul Windrum and Peter Swann, January 1999

Colline WP 07:
" The role of standards for collective invention in network technologies ",
authors: Peter Swann and Paul Windrum, April 1999

Colline WP 08:
" Collective invention activities in the telecommunication sector ",
authors : Alessandra Lanza and Cristiano Antonelli, November 1998

Colline WP 09:
" Software in Finance ",
authors : Andreas Crede and Edward Steinmueller, April 1999

Colline WP10:

“ Software in Insurance“,
author: Gordon Rae, June 1999

Colline WP 11:
“ The creation of industry -specific public goods”
authors: Dominique Foray and Morris Teubal, September 1999

Colline WP 12:
”The Policy Implications of Collective Invention : the Minutes of the Panel discussion concluding Colline ”
author: Serge Petit, December 1999

Colline WP 13:
”Collective Invention and European Policies – Executive Summary”
authors: Dominique Foray and Edward Steinmueller, December 1999

ANNEXE 2

Other Outputs from the project

a) Publications

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b) Conference Presentations

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