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Intellectual Property Rights in Agricultural and Agro-food Biotechnologies to 2030

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Abrasem: Brazilian Association of Plant Breeder’s

AOC: Appellation d’origine controlée -French geographical indication-

CBD: convention on biological diversity

DHS: distinctiveness, homogeneity and stability

EPIPAGRI: European Collective Management of Public Intellectual Property for Agricultural Biotechnologies

Embrapa: Brazilian Agricultural Research Corporation's

EPO: european patent office

EST: express sequence tags

FAO: food and agricultural organisation

GMO: genetically modify organism

INRA: French national institute for agricultural research

IPR: intellectual property right

ISF: International Association of Plant Breeders

MAS: marker molecular assisted selection

MRTPC: Monopolies and Restrictive Trade Practices Commission

MTA: material transfer agreement

NPGI: National Plant Genome Inititiative

OAU: Organization of African Unity

OECD: organisation for economic cooperation and development

PBR: plant breeder’s right

PCT: Patent Cooperation Treaty

PIPRA: Public Intellectual Property Resource for Agriculture

SNP: single nucleotid polymorphism

Trips: trade-related aspects of intellectual property rights

UPOV: Union for the protection of plant varieties

USPTO: US patent and trademark office

WTO: World trade organisation

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1. Introduction

This report presents options for intellectual property rights (IPR) in agricultural biotechnologies by 2030. The reader should keep in mind the suggestion made by France's national planning body, the *Commissariat Général au Plan*, in 2004: "intellectual property rights could not constitute a small island isolated from the rest of the world. Their protection does not constitute an end in itself." An important aspect of intellectual property relates to the connection between protecting particular holders of IPR, and considerations of what is in the general interest.

The report contains two sections. The first analyses the incentive mechanisms in agricultural biotechnologies; it begins with a theoretical and historical analysis. The co-evolution of scientific paradigms and IPR in agricultural biotechnologies is then studied – in particular, the coexistence of various rights to protect the same innovation: a plant variety. The scientific paradigm presented – that of a gene intervening in several functions and a function depending on the interaction of several genes – is shown to modify considerably its link with IPR, so that patent thickets emerge. What is required is to implement at the same time a collective management of IPR and a collective management of research. The section looks at the stakes for farmers, who are the consumers of these innovations. Lastly, it addresses the stakes for the developing countries: the implementation of credible intellectual property rights must be accompanied by the implementation of a credible competition law to avoid situations of abuse of dominant position. These various effects show that research incentives in agricultural biotechnology are increasingly a question of co-ordination of research actors rather than a question of individual incentives.

The second section looks at the future, from the science perspective (what demand will there be for what research tomorrow?) and an IPR perspective under the constraint of environmental change, like climate change. If intellectual property rights in agricultural biotechnologies, as well as the size of the expected market, are necessary conditions to develop innovations, what are the sufficient conditions? Various technologies are presented that could be mobilised in agricultural biotechnologies by 2030, including nanotechnologies.

The report looks at the stakes in terms of intellectual property rights in the case, for example, of a plant allowed to perform multiple functions (food and industrial). It analyses the stakes for the developing countries. Finally, it makes proposals regarded as essential so that intellectual property rights keep up with the evolution of research and demand.

2. The effects of IPR on the organisation of research in agricultural biotechnology

Intellectual property rights have effects on the incentives to create and diffuse innovations. They also have effects on the organisation of research, public as well as private, and the interactions between them. Among those whose behaviour can be modified by IP are farmers, who today are the principal consumers, or "adopters", of the innovations in agricultural biotechnology.

2.1. Some theoretical and operational notes

2.1.1. Inciting firms to innovate

Encouraging firms to innovate means encouraging them to invest in research and development (R&D). In neoclassical theory, if there exists a demand for an innovation that could justify the R&D investment and if that innovation is easily imitated[1] and therefore low in cost, then – all things otherwise being equal – competition on the market of the innovating product is perfect. Thus at

[1] Let us not forget that for most industries, secrecy is preferred over IP as a means of appropriation (Geroski, 1995).

market equilibrium, the price corresponds to the marginal cost of production. This situation does not encourage firms to innovate, since they cannot generate a sufficient return on their R&D investments. Or, whatever the possibility of imitating the innovation, it is necessary to ensure the innovator a return on their investments in R&D. Several options, then, are possible:

* External financing of R&D – either from the state or, for non-profit foundations, private (*e.g.* prizes).

* Positive R&D investment, in which case it is necessary to ensure a financing return for the innovating firm. This return is guaranteed through recognition of an intellectual property right that creates, for the innovator, a temporary monopoly[2] of the innovation's commercialisation[3] and diffusion.

Box 1 – Economic definitions of a patent length, height and breadth

The length of patent protection is characterised by the duration of the monopoly power; the scope of a patent bears on the intensity of the monopoly induced.

The breadth of a patent defines the range of products encompassed by the claims of the patent, and therefore protects the patent holder against potential imitators. In general, the less specific the claims of the patent, the broader the patent is.

The height of a patent confers protection against improvements or applications that are easy or trivial.

The value of a patent to a firm depends on how effective its protection is in the two dimensions of breadth and height, in addition to being related to the patent length.

Source: Langinier and Moschini, 2002.

To implement the second option, the economists Gilbert and Shapiro (1990) propose to seek and implement an optimal intellectual property right, *i.e.* to define the characteristics of the property rights that would lead to a social optimum.[4] It is a question of defining what can be protected – height of the intellectual property; for how long – length;[5] and to what extent (acceptable claims) – breadth.[6] (For a fuller definition see Box 1.) It is a question of supporting the creation and diffusion of innovation. The intellectual property right is primarily a tool whose function is to increase the individual incentives to innovate while preserving a minimal diffusion for the firm.[7] For others, intellectual property rights are also an institutional tool favouring co-ordination.[8]

The three dimensions (height, length and breadth) form a continuum; there is no real intellectual property law if the height is null. Given that context, the monopoly situation arising from the IPR system could be considered socially acceptable, because it can ensure the social optimum.

2.1.2. At the operational level

At the operational level, it is impossible to have an infinite number of types of intellectual property

[2] The monopoly has to be temporary to encourage firms to adopt strategies of sequential innovations: *ex ante* competition, innovative monopoly, *ex post* competition when the innovation falls into the public domain, etc.
[3] Any intellectual property allows the right to exclude rivals from use of an innovation, but does not necessarily grant a use right to that innovation (e.g. development phase during authorisation to commercialise drugs).
[4] For a survey of the stakes of intellectual property, see Langinier and Moschini, 2002.
[5] The duration of intellectual property rights must be long enough to cover the irrecoverable costs of R&D, and short enough to ensure competition in the product market conducive to new R&D expenditures, so that future innovations can be developed.
[6] The scope of the patent must be sufficiently broad to limit risks of imitation, and sufficiently narrow to ensure competition in the search for future innovations.
[7] For more details see Arrow, 1962.
[8] Cohendet *et al.* (2006) quote Winter, 1993 thus: "when a whole of innovators explore a new technological way, the granting of too early patents is likely to block the construction of a base of common knowledge necessary to the blooming of the new paradigm and thus to kill this one in egg, thus leading ultimately to a bad allowance of the resources."

rights – for each innovation and in each country – because of prohibitive transaction costs. To protect an innovation, a state can use a standard right or a right *sui generis*.[9]

Standard tools

There exist today various options regarding intellectual property intended to cover the diversity of types of innovations.[10] These options are: the patent, the copyright and trademarks. The characteristics of these rights are very different, not only in terms of their relationship to the innovation they protect, but also regarding operational characteristics (breadth, length and height).[11] The advantages of these standard tools are their universality (everybody knows what a patent is), and therefore their relative ease of use and recognition throughout the world. Their disadvantages are that they are sometimes employed in sectors, and even in countries, where their effectiveness in terms of social optimum is weak, or even negative. For example, Henry, Trommetter and Tubiana (2003) wrote: "What is to be done when a gene is patented and is not the subject of largely diffused licenses, *i.e.*, in economic terms, when it functions like a monopoly impossible to circumvent (no substitutes) For the economist, it then constitutes an essential infrastructure (here touching [on] health)-, access to which is refused by the one or the ones [who control it]; it is a particularly detrimental form of abuse of a dominant position. The usual reaction with respect to similar abuse is either the judgement of the contravener by an antitrust authority, or the setting under supervision of a regulator, which imposes the access and fixes a maximum [price threshold] ("price cap"). Thus are managed, both in America and in Europe, the infrastructures of public services when they are natural monopolies, like the rails of railroads or the grid system of electricity, [to] which the respectively qualified regulators ensure access at prices that [can] reach a maximum."

To limit the possible perverse effects of standard IPR – and so obtain a second-best social optimum, a number of possibilities exist. These flexible solutions are in general implemented by states: compulsory licences, *e.g.* for essential facilities; introduction of a competition law to limit the situations of abuse of dominant position. More simply, one can reform, by law, the conditions of intellectual protection of an innovation. In the example of the implementation of competition law, the law's relation to IPR appear less problematic in the United States than in Europe, owing to the fact that the relation between innovation policy and competition policy is better in the former than the latter.[12] The interest of these various flexibilities is theoretically proven (Joly and Hermitte, (1993); Scotchmer; Hagedoorn, 2003; etc.). There exist models to explain how these flexibilities can lead to the social optimum – *inter alia*, the joint ownership of patents; costs of litigation in the event of counterfeit or dependence; conditions of compulsory license; and optimal condition for licensing.

Alternative tools

Apart from the traditional tools, protection of innovations is provided by *sui generis* intellectual property rights.

The use of *sui generis* rights is generally limited to well-defined sectors (as recommended by the economic theory optimally defining IPR). It is thus among the new tools designed for adaptation to particular innovations. Two examples: in 63 countries, plant varieties (seeds) are protected by a plant breeder's right from the Union for the Protection of Plant Varieties (UPOV); in Europe, those databases are protected by a *sui generis* right. In the first case UPOV aims at founding a right weaker than the patent in the breadth of protection, whereas in the second case the copyright is regarded as too weak to effectively protect the databases; it is accompanied by a *sui generis* right that increases

[9] The use of a right *sui generis* is usually limited to well-defined sectors. It is thus among the new tools whose objective is to adapt to particular innovations. To implement a new right is expensive, but in these particular sectors the cost associated with implementation is lower than the social costs related to a protection with a standard tool associated with flexibilities.

[10] The choice of rent is directly related to the tradeoff between more innovation and more diffusion of this innovation, which is complex when one refers to a particular innovation. As Tirole (2003) points out: "it will be even more complex when one has to define an intellectual property protection regime that is valid for the entire economy" (authors' translation).

[11] For a survey see Trommetter, 2007.

[12] For more information on this point see Encaoua and Guesnerie, 2006.

breadth compared to a traditional copyright protection.

The advantage of these *sui generis* rights is that they protect the innovation while limiting the perverse effects of the standard right. The disadvantages are mainly related to their effectiveness on the international scene. To be adopted by the innovators, these rights must be implemented in a minimum number of countries, reaching a minimum threshold for the size of the market that will be accessible for the innovator.

Indeed, if the right is implemented on too restricted zones, the only certainty is that the innovator will need to comply with more constraining legislations if they are to reach a perimeter of market sufficient for their innovation, without risk of dependence. The objective is to have a return on investment that justifies the R&D investment in order to create innovations. Thus implementing too weak *sui generis* rights can reduce their effects on research incentives, since the flexibilities they allow will not be mobilised.

These *sui generis* rights can be particularly useful for the countries embarked on a technological process of development. Indeed, the interest in building a *sui generis* right is that it makes it possible for the legislator to take into account the specific characteristics of the system of R&D, of the national demand, and even of the environmental constraints of the country concerned.

2.2. Effects on the organisation of research

2.2.1. IPR and agricultural biotechnologies

Three types of intellectual property laws are mobilised today to protect plant variety innovation:

* Secrecy laws, for example on the parental lines of the hybrid varieties.

* The patent on plant varieties.

* The Plant Breeders' Right, which is a *sui generis* right (Box 2).

A large majority of OECD countries (28 of 30) adhered to the UPOV and, in parallel, accept the patent on plant varieties (Annex 1). This patent is limited to Genetically Modify Organism (GMO) varieties in Europe or Canada; it is extended to the whole of the plant varieties in the United States and Australia:

* Australia and the United States adhere to the UPOV system, and so recognise the Plant Breeders' Right. At the same time, two types of patents are used to protect plant varieties. A patent may be granted for a plant reproduced by asexual propagation (except tubers) and for varieties that have not been protected by a Plant Breeders' Right for more than a year. Or, the utility patent may be granted for plants in countries that allow patenting of plants or higher life forms. The holder of the latter patent has the right to prohibit others from obtaining, using or selling the plant or its seeds.

* In Europe, a plant breeder protects new varieties via a Plant Breeders' Right. The European Union excludes from patents new varieties created during a classical cross-breeding programme or marker-assisted selection, which guarantees free access to genetic resources of a commercial variety. Patents (European Parliament directive 98/44/CE) are reserved for non-agricultural applications and genes that can be introduced into plants by genetic engineering.

  In European law, the scope of patents is still not definitively fixed; there are different interpretations. There is in particular some controversy over what is covered by a patent on a GMO variety.

Box 2 – The Plant Breeders' Right

The Plant Breeders' Right of the International Union for the Protection of New Varieties of Plants (UPOV) is a system to protect varieties of seeds for agricultural and agro-food use. It gives the holder the commercialisation monopoly over a variety, but guarantees automatic and free access to the genetic resources that make up the variety and to the new genetic resource it constitutes, for purposes of research and plant breeding. The objective is to create a common genetic pool, to which each new certificate holder contributes.

In the 1991 version of the UPOV convention, three principal limitations can be found on access to "plant variety" invention:

-The farmers' privilege of reusing harvested seeds is optional and may lead to payment of compensation by farmers to seed suppliers in the case of "custom sorting" (in French, *triage à façon*). This clause of compensation is limited to major farmers as described in the European Union directive 98/44.

-The rights of the certificate holder are limited by the dependence clause of an "essentially derived" variety. That dependence is based on the measurement of genetic distances between varieties. The clause extends protection of the innovation, introducing the notion of "minimal differentiation" of products (Henry, Trommetter and Tubiana, 2003).

-The prohibition of double protection (patent and Plant Breeders' Right) on plant species or genera is lifted.

This system guarantees the protection of the commercialised plant variety, which is the necessary (if not necessarily sufficient) condition to ensure the incentives to innovate, while ensuring access to the genetic resources that compose it.

Source: Teyssendier de la Serve and Trommetter, 2004.

The implementation costs of these various modes of intellectual property rights vary. The cost of the secrecy is practically nothing, but there are major risks of imitation. The total costs of the Plant Breeders' Right amount to less than EUR 5 000. The cost of a patent depends on the country: it varies from less than EUR 20 000 in the United States and Japan to more than EUR 30 000 in Europe because of high translation costs (Table 1).

More precise figures appear in a study from the European Patent Office, published in 2005. The total cost of a patent is EUR 26 630 for a standard European coverage (eight countries) and EUR 41 000 for a Patent Cooperation Treaty (PCT) request. If we take into account the ten-year costs of maintenance, the total costs are EUR 37 500 for a standard European coverage and EUR 57 000 for a PCT request.

It should be noted that in the United States, the mode of protection for plant varieties is a matter of strategic choice from among the various intellectual property rights in plant breeding. In Europe, plant breeder companies must adapt their intellectual property right strategy to the legislation in force.

Table 1 – Patent cost comparison: Europe, the United States and Japan in Euros

	File costs and research costs	Examination cost	Delivery cost	Fees	Translation cost	Wage	Total
EU	810 + 532	1 431	715	16 790	12 600	17 000	49 900
US	690	-	1 210	2 730	n/a	5 700	10 330
Japan	210	1 100	850	5 840	n/a	8 450	16 450

Source : Single Market News, n°22, UE (2000)

2.2.2. An historical analysis

This historical analysis of the joint evolution of scientific paradigm and intellectual property rights is essential to future projections. The links between evolution of the organisation of research and evolution of IPR are particularly strong in the seed sector. This is especially true given that there are different ways to protect seeds.

Evolution of rights and of scientific paradigms

In the 1960s, the organisation of research in traditional cross-breeding innovation was based on free access to both innovations (varieties) and genetic resources (preserved *ex situ* in gene banks or *in situ* in dedicated farms) – seen as mankind's common heritage. Nevertheless, ahead of the market evolution of the seed sector and the necessary incentives to R&D, an intellectual property right on agricultural innovations was created to ensure the safeguarding of the innovation while simultaneously ensuring free access to the genetic resources: the Plant Breeder's Right of the Professional Union of Plant Varieties (UPOV). This right allows the use (open, free, automatic and without contracts) of genetic arrangement (spillovers) in breeding programmes whose lead times to innovation (ten years minimum) are sufficient to ensure a return on investment to the initial innovator.[13] This free access to genetic diversity was claimed by the plant breeders from time immemorial, mainly in Europe. In the United States, the plant breeders generally protect their varieties by the patent (Plant Patent Act[14] and Utility Patent[15]) or by secrecy (trade secret law), although the country also adhered to system UPOV with the Plant Variety Protection Act. The Plant Breeders' Right is thus less used in the United States, which prevents the US plant breeders' protection from working in accordance with the European plant breeding scheme. The organisation of US research rests on a model where the spillovers are weak.

In the 1980s, with the advent of biotechnologies, patents on gene sequences began to be granted. There exist at least two reasons for these patents:

* Chemists' practice of patenting chemical molecules (created and so nonexistent in nature), with claims for all the uses arising from use of this molecule – which, for a molecule created artificially, is economically justified.

* The generation of incentives for private firms to take part in networks of genome sequencing, as research based on technologies for sequencing was long and costly.

At that time this model was all the more "acceptable", economically and legally, because the scientific paradigm was of a gene code for a particular function. However, as the function was not fully known at the time of the sequencing, it was necessary to protect all the functions in the claims to encourage firms taking part in genome sequencing activities. Granting that a patent does not pose problems in itself if it is shown to be the best tool for protecting innovations, its *implementation* can pose problems by producing two effects: that on other research because of wide claims; and that on the varieties protected by the Plant Breeders' Right (the results of standard cross-breeding). For the first effect, it should be noted that, until 2001, the patents granted on a genetic sequence were not systematically associated with proven functions, whereas the extensions granted were for the totality of functions with which the sequence would be associated. Since 2001, the conditions of patentability (height) were more restricted: a patent application must be accompanied by an experimentally proved function, in both the United States and Europe. Unfortunately, the extensions granted remain broad (breadth).

[13] Thus, Lemarié (2000) shows, for example, in research on hybrid seeds, that the time of duplication by the competitors is sufficiently important for sparing incentives.

[14] The *plant patent* is granted for a plant reproduced by asexual multiplication (except plants with tubers), for varieties which were not protected by Plant Breeder's Right since more than one year. Teyssendier de la Serve et Trommetter 2004

[15] The utility patent can be granted for plants in the countries which make it possible to patent higher plants or forms of life, in particular the USA, Europe, Japan… the patentee such has the right to prohibit to obtain, use or sell the plant or its seeds. Teyssendier de la Serve et Trommetter 2004

For the effects on the varieties protected by Plant Breeders' Right, it should be noted that since 1991, the Right was modified to limit the patent's perverse effects on the varieties protected. The legislators re-examined the definition of the breadth of the intellectual property, and basically redefined the concept of imitation to limit the risks of a private appropriation of plant varieties by the producers of GMO seeds (Trommetter, 2005). Plant breeders feared seeing the genetic characteristics integrated in their commercial varieties adapted by the introduction of a patent by an agro-chemist company. An imitation – a counterfeit – becomes a variety essentially derived from a pre-existent variety. Henceforth there exists a minimal genetic distance between two varieties, so that they are regarded as independent. The breadth of the Plant Breeders' Right is thus limited to the commercialised variety plus the essentially derived varieties. This is in contrast to the plant varieties protected by patent, where the breadth relates to any use of the variety; in that case a licence agreement must always be negotiated. From 1991 UPOV allows the double protection of the plant varieties by Plant Breeders' Right and patent.

The step that led to the Plant Breeder's Right corresponds to a research paradigm based on access to biological and genetic diversity. It also corresponds to the ideal models on sequential and cumulative innovations (Scotchmer, 1991, 1999 and 2005), which in turn correspond to the organisation of research in Europe's seed sector.

At the theoretical level, the model of the Plant Breeders' Right falls under the category of non-co-operative research with free access to genetic resources (complete spillovers of innovator's new genetic construction towards its competitors, and vice versa), and there are no contracts of access to the genetic material (and thus no transaction costs). The US model, on the other hand, falls under the category of non-cooperative research without free access to the genetic resources (weak spillovers).

How to manage the coexistence of different rights linked to several international conventions

The existence of different rights to protect innovations must make it possible to limit the perverse effects standard property rights that are either too generic or not sufficiently adaptable. Nevertheless, this coexistence will have impacts on the future capacities of research and the future markets for innovations. Thus, the creators of GMOs assert that a GMO cannot be used in a traditional breeding scheme without prior approval. In parallel, the holders of classical breeding seeds ask for a reinforcement of the Plant Breeders' Right to prevent agrochemical companies using their varieties to manufacture a GMO to which they do not have access. In this debate on the extent of patent protection in the case of GM organisms, some representatives of the seed producing sector (International Seed Federation, 2002; Le Buanec, 2006; Limagrain, 2002) and researchers (Henry, Trommetter and Tubiana, 2003; Feyt, 2000, 2002) are uneasy about blocking access to the genetic diversity of American varieties and the eventual blocking of access to the genetic diversity of GM cultivars. The problem does not arise for a resistance gene introduced into a cultivar already protected by a Plant Breeders' Right. On the contrary: if a company has a patented gene and introduces it into a cultivar that it has itself bred – and if the patent has a broad extent, as desired by certain agrochemical companies – it could license the patent on the commercialised variety (via extension of patent to the plant containing the patented gene), thus blocking access to the genetic resources it comprises.

To solve these potential conflicts, the European directive on biotechnological inventions (98/44) allows implementation of a compulsory cross-licence in the event of dependence in plant biotechnologies.[16] This licence guarantees protection of the innovation with "remunerated open

[16] European directive 98/44, article 12:

1. Where a breeder cannot acquire or exploit a plant variety right without infringing a prior patent, he may apply for a compulsory license for non-exclusive use of the invention protected by the patent inasmuch as the license is necessary for the exploitation of the plant variety to be protected, subject to payment of an appropriate royalty. Member States shall provide that, where such a license is granted, the holder of the patent will be entitled to a cross-license on reasonable terms to use the protected variety.

2. Where the holder of a patent concerning a biotechnological invention cannot exploit it without infringing a prior plant

access" to the genetic resources. Thus, when an innovator cannot proceed without infringing an established IPR, they can ask for a compulsory cross-licence for dependence for a non-exclusive use of the invention protected by the IPR. This licence will be granted with a suitable royalty and/or a cross-licence between the two innovations.[17] At the operational level the directive is complex to implement, and the compulsory cross-licence for dependence can be interpreted as: "an implicit recognition that a patent on a GMO covers the genetic diversity as a whole". This recognition is accepted by the agrochemical groups but disputed by the traditional plant breeders (the International Association of Plant Breeders, ISF). Even if introducing a compulsory cross-licence for dependence, between varieties protected by the Plant Breeders' Right and GMO protected by patent, limits the risks of blocking later research, the plant breeders pass from a system of free open access to a system of remunerated open access. Access to genetic diversity is no longer automatic – or free – but remains a priority in Europe.

Integration of the biotechnology directive into French law in December 2004 produces another type of flexibility that replaces the compulsory cross-licence for dependence. French legislation proposes to limit the breadth of protection by patent. Article L 613 5-3[18] aims to guarantee access to genetic diversity, including GMO varieties that integrate one (several) patented gene(s); the patent covering a gene in a GMO is no longer extended to the plant as a whole. There is thus free access to the genetic diversity of the GMO minus the patented gene(s). Use of this genetic diversity through free access is facilitated by the biotechnological innovations: molecular marker-assisted selection allows a bypassing (non-selection) of any crossing results in which the patented gene is present. Thus in French legislation, as with Germany and Switzerland, access to genetic diversity again becomes automatic, free and open, but there are other constraints – in particular, on access to seed markets and to the characteristics patented in the GMO.[19]

At this level we can note a major difference between the United States and Europe in the development of the legislation. Even if legislative texts exist, the United States has a tradition of common law; Europe's tradition, on the other hand, is one of civil law, based on the Roman system.[20] The compulsory cross-licence of European directive 98/44 is a good example. In the United States, the law court establishes whether there is licence or not in the case of dependence between a variety protected by a Plant Breeders' Right and a variety protected by patent. There thus exists a non-null probability

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variety right, he may apply for a compulsory license for non-exclusive use of the plant variety protected by that right, subject to payment of an appropriate royalty. Member States shall provide that, where such a license is granted, the holder of the variety right will be entitled to a cross-license on reasonable terms to use the protected invention.

3. Applicants for the licenses referred to in paragraphs 1 and 2 must demonstrate that:

(a) they have applied unsuccessfully to the holder of the patent or of the plant variety right to obtain a contractual license;

(b) the plant variety or the invention constitutes significant technical progress of considerable economic interest compared with the invention claimed in the patent or the protected plant variety.

4. Each Member State shall designate the authority or authorities responsible for granting the license. Where a license for a plant variety can be granted only by the Community Plant Variety Office, Article 29 of Regulation (EC) No. 2100/94 shall apply.

[17] Theoretically this licence refers to the work of Scotchmer on realising cumulative innovations, and also to the work of Joly and Hermitte on the interest in resorting to compulsory licences for dependence (1993).

[18] "Art. L. 613-2-2. – Subject to the provisions of Articles L. 613-2-1 and L. 611-18, the protection conferred by a patent to a product containing genetic information or consisting of genetic information extends to any way in which the product is incorporated and in which genetic information is contained and has the indicated function."

"Art. L. 613-2-3. – Protection conferred by a patent relative to a biological material which, through an intervention, has determined properties, extends to any biological material obtained from that biological material by reproduction or multiplication and endowed with those same properties."

"Art. L. 613-5-3. – The rights conferred by Articles L. 613-2-2 and L. 613-2-3 do not extend to the acts accomplished with a view to creating or discovering and developing other plant varieties" (authors' translation).

[19] Richard Gold, in a personal comment: "That France and Germany have violated those norms with respect to gene patents is highly contentious within Europe and may, eventually, lead to action by the European Commission against them for a failure to comply with established law."

[20] Richard Gold (personal comment): "For example, while the common law certainly does rely on jurisprudence, common law legislation tends, nevertheless, to be *more* and not *less* detailed than is civil law legislation. Further, even in civil law jurisdictions, judges play as much of a 'legislative' role as in common law jurisdictions although their manner of intervention is admittedly different."

so that there are no licences, but there also exists a non-null probability that there is a licence. In the European case there is a probability of 100% that there is a licence in the event of dependence. But the conditions to prove that the dependence exists are drastic, to avoid abuses. This is the only case to date where there exists a compulsory licence to settle differences between private actors. The two approaches have their advantages and disadvantages. For example, a law based on jurisprudence is more adaptable (flexible) to changes of scientific paradigms; it can also have perverse effects, for example in the case of research exemption. This difference in philosophy can explain a certain lack of understanding between the United States and Europe.

International conventions can also force the use and diffusion of innovations. Thus, to support the protection and diffusion of agricultural genetic resources, the international treaty on Plant Genetic Resources for Food and Agriculture of the FAO takes into account the fact that there exist various types of intellectual property rights that will have various effects on the access to genetic resources integrated in the innovations.

If an innovator protects an innovation by a Plant Breeders' Right or any other *sui generis* system that leaves free access to genetic diversity for competitors, there is a voluntary contribution to an international compensation fund. If an innovator protects an innovation by a patent, with a risk of blocking the access to genetic resources, there is a compulsory payment to a compensation fund. There is thus an incentive to leave free access to the resources according to the amount of the compulsory payment to the international fund. This fund must be used to manage and preserve genetic resources, and to finance plant breeding in favour of the countries of the South. Similarly, access to the collections of genetic resources *in* and *ex situ* are today done in a contractual way, with a material transfer agreement (MTA)[21] homogenised at FAO level. This homogenised MTA is associated with rules of strict traceability, and a certificate of origin to guarantee the legality of the granting of the material and the disclosure of the origin of the genetic resources at the time of deposit of intellectual property.

Nevertheless, with the changes in statutes regarding agricultural genetic resources, only the plants covered by the FAO international treaty remain open accessible, and even that access becomes contractual and paying in the event of privative appropriation. On the other hand, what will happen to plants not covered by the FAO international treaty, which are thus covered by the Convention on Biological Diversity? Their access will depend on the sovereignty of the states to define the use and access rules in a contractual and individual way.

This coexistence of various tools does not facilitate access to the seed markets for the plant breeder's firms. To diffuse European seeds in the United States is at best very risky, owing to the fact that there are no compulsory cross-licences in US law. France and Germany have more flexible legislation than other European countries in their adoption of directive 98/44. They can modify the terms of diffusion of seeds from the rest of the world, which can be dependent on other varieties according to the legislations in force. This legislation is thus mainly favourable to the national plant breeders' firms on niche markets: the multinationals (like Limagrain or Pioneer Hi-Bred) always fashion their IPR strategy to the most restrictive legislation, rather than that of the market in view.

2.2.3. Consequences of a new scientific paradigm confronting intellectual property rights

At the end of the 1990s, in addition to impacts from the coexistence of patents and the Plant Breeders' Right to protect agricultural innovations, scientists – public as well as private – identified a deep change within the scientific paradigm: a gene can code for several functions, and in parallel a function can depend on the interaction between several genes (Joly and Hervieu, 2003). In this context of complex interactions between genes and functions, the economists highlighted situations of patent

[21] An MTA is a contract that defines the conditions of access and uses of genetic resources. It could forbid as well as authorise commercial uses, but with clauses regarding licences and royalties payments.

thickets or situations of hold-ups that are at the origin of research blockages.

Patent thickets and stakes for research

Shapiro (2000) defines "patent thicket" as a situation where a patent depends on a very great number of other patents. Thus to continue to innovate, the innovator must have access to all of the licences of these patents. Economic and social inefficiency can result if too many agents hold rights – the phenomenon of "multiple margin". These inefficiencies can be related to two elements: uncertainty – one of the owners of the patents is able to refuse to concede a licence and so block future research; and the high costs of transaction (tragedy of anti-commons – see Heller and Heisenberg, 1998). Thus, GoldenRice uses technologies that are themselves protected by patents. Golden rice is a rice cultivar enriched with provitamin A, in order to compensate a chronic deficiency found in populations for whom rice is the staple food. Three genes were inserted to complement the β-carotene biosynthesis pathway. This technology also required the use of transformation vectors, promoters, and antibiotic resistance markers, all patented or covered by material transfer agreements (MTA). The whole represents more than 70 items controlled by about a dozen patent holders (Kryder, Kowalski and Krattiger, 2000).

This overlapping can come from rights too easily granted (height), from claims too easily accepted (breadth), or from a combination of both. In agricultural biotechnologies, they are without any doubt a combination of the two effects. There exists an increasingly extensive fragmentation of rights that could lead to patent thickets and limited research exemptions. A widely accepted exemption is the "exemption for research", which in several European countries more or less explicitly grants public research institutes the freedom to use patented products (*e.g.* promoters, genes, proteins) without a licence contract, as tools and not only as objects, for their own non-profit research ends. Teyssendier de la Serve and Trommetter (2004) write that "[r]esearchers must nevertheless know that this broad exemption does not apply in the case of a contract with a private company and that a problem can arise in the case of patent filing or commercial application. Moreover, this broad acceptance of exemption for research does not apply in the USA." The exemption for research in the United States has been limited to its more strict expression[22] since the loss of the lawsuit by Duke University to Madey. That had the potential to lead to multiple situations of hold-up or cross-licensing.[23] As early as the beginning of 1990, M.A. Hermitte and P.B. Joly proposed a system of compulsory licensing of dependence to limit the perverse effects of too many and badly identified patents (let us recall that this system was in part included in European directive 98/44 on biotechnological inventions).

The public and private laboratories in parallel realised that a great number of these patents are under exclusive licences (Box 3) with large private companies that can, as holder of the patent, refuse to yield any other licence, including in sectors where the large company does not intervene. Exclusive licences are presented – *inter alia* by economic theory – as essential for encouraging firms to devote major resources to the development of innovations. Nevertheless, as in the implementation of patents, it is necessary to analyse the conditions of exclusiveness. In particular, Weil *et al.* note (2004): "this position largely evolved/moved since, with the assertion that research, in particular the basic research, must be regarded as a public property which is crucial for long-term economic development. It is thus advisable also to take care to avoid the abusive appropriations, insofar as they can constitute a barrier with the good analysis of the acquired results or the exploration of new ways of research."

[22] In 2003, the Duke vs. Madey showed that claiming non-profit educational establishment status does not exempt a university or its employees from infringement liability, even if the activities were solely for research, academic, or experimental purposes.

[23] At the theoretical level, Bessen (2006) shows that these situations of hold-up can go on, owing to the fact that a company can refuse to grant licences *ex ante* in the case where there would be an asymmetry of information with the cumulative innovator. In the same way, Choi (2003) shows complex links between crossed licences, the probability of dependence, the chances of success of the patents and the stakes of litigation in a context of antitrust rules (competition law). Lastly, Shane *et al.* (2007) propose to harden the rules in the event of litigation (so that they become particularly expensive for the loser), because they showed that there was a negative relation between litigation and valorisation of patents in the American universities.

Box 3 – Examples of policies on exclusive licences

Deroin (2000) emphasises that around 50% of the licences granted on patents by American universities are exclusive.

In 1999, Schissel *et al.* calculated a rate of exclusivity of 68% for licences granted by these universities on patents covering genetic diagnostics.

Currently, the rate of exclusive licences on patents granted by France's national institute for agricultural research (INRA) is about 51%. Exclusive licences are normally limited to three or five years and to restricted domains.

NIH practices a deliberate policy of non-exclusive licences, or licences restricted to a particular technological field or geographic territory. NIH granted only 12 exclusive licences out of 1 000 licences in the year 2000. Moreover, these licences stipulate that the NIH reserves the right to use the invention for research and stipulates that results be made widely available (OECD, 2003).

Source: Teyssendier de la Serve and Trommetter, 2004.

There remain controversies over the effects of this multiplication of rights on research in terms of blockages. First of all, is it convenient to speak about blockages, in light of work published? It appears more convenient to speak about delays, reorientation of research, or skirting existing patents. The controversy stems from certain papers concluding that the blocking of research is not proved, and others claiming that it is. If there is no blocking, that justifies the current system of protecting innovations. If there *is* blocking, that justifies changing some intellectual property rules. However, everyone agrees on the existence of "additional delays". These additional delays can have very negative consequences on research, the timing of the innovation race, and on the costs of research. Multiplication of rights and their broad claims also led to a multiplication of litigation (see Box 4).

Box 4 – Some examples of litigation situations

The patent 6 943 282 on transgene Bt, deposited by Dow Agro in 1988, was disputed by Monsanto; only in 2001 was it granted to Dow Agro. More recently (2004), the US Patent and Trademark Office (USPTO) published its decision on an interference proceeding to determine who had invented methods of designing synthetic *Bt* toxin genes for expression in plants. Monsanto's inventors had been ahead of Mycogen Plant Science's inventors, the USPTO decided. Consequently, the USPTO eliminated 12 of 14 claims in Mycogen's US Patent No. 5 380 831. In a patent infringement case decided several weeks later, the Federal Circuit limited the scope of the remaining two claims to a particular *Bt* toxin gene disclosed in the patent.

In another *Bt* toxin case, Monsanto filed an action in a Missouri district court, seeking a declaratory judgment that its *Bt* toxin-expressing transgenic corn does not infringe four patents owned by Aventis CropScience (actually Bayer BioScience). The patents concern methods for expressing a truncated version of a *Bt* insecticidal protein. Monsanto took the position that the patentee's inequitable conduct bars Bayer from enforcing the patents. The district court granted Monsanto's summary judgement motions, holding the four patents unenforceable because of inequitable conduct during patent prosecution. Bayer appealed. The Federal Circuit reversed the summary judgement and sent the case back to the district court for further proceedings. The Federal Circuit decided, among other things, that the lower court had improperly granted summary judgement on Monsanto's inequitable conduct claim, because there was a factual dispute about whether the patentee's statements on the ease of expressing truncated *Bt* toxin genes in plants were false or misleading, and had been made to deceive the patent examiner.

Source: Wright and Pardey, 2006

Thus today, universities and biotechnology companies carrying out research can depend on many patents (public as private) whose negotiation of licences can lead, according to Henry, Trommetter and Tubiana (2003), to: "the costs of transactions which can become dissuasive because of [the] existence of too [many] agents having rights". This situation is the result of the broad demands for claims on the patents (breadth), often accepted by the patent offices, and broad extensions in the demands for exclusive licences. Barriers to the marketing of products and research exist, including in sectors where the company is not positioned. Universities and biotechnology start-ups can then infringe rights whose existence they were unaware of. It is then effective, economically, to limit the

claims (breadth) of the patents to the functions that are closed (essential derivation as in the Plant Breeders' Right) to the initial function.

Collective management of intellectual property and research

As to the various consequences for research of the change of the scientific paradigm, initiatives have been developed to limit the perverse effects of past patents. These initiatives, often complementary, are co-dependent: on the one hand there is collective management of the intellectual property, to limit today the effects of the patents granted yesterday; on the other there is collective management of the research, which aims at handling the pre-competition phases of research and starting a patent race only in the product development phase.

Collective management of intellectual property

The collective management of intellectual property must be in conformity with the rules enacted by the jurisdictions charged implementing antitrust rules (for example, the "competition council" in France). This collective management must lead to an improvement in social welfare and, more particularly, in "the consumer's surplus". Therefore, in the absence of a situation of "abuse of dominant position", researchers can consider creating a club for managing their patents, with each one individually remaining the owner of his patents. These clubs manage access and use, and hold a collective portfolio of patents. The aims are:

* To identify the complementarities inside the portfolio so as to build innovations based on technological clusters (identified modular technologies *ex post* with the deposit of the patents concerned);[24]

*To identify the complementarities with other portfolios of public and/or private patents;

* To facilitate access to the complementary licences of patents held by other institutions or firms; taking part in the club increases the power of negotiation of the actors.

These are centres of exchanges of patents, or clearing house mechanisms, in the field of plant biotechnologies. Examples are: the Public Intellectual Property Resource for Agriculture, PIPRA, in the United States; the European Collective Management of Public Intellectual Property for Agricultural Biotechnologies, EPIPAGRI, in Europe; and even the open source genomic network in Australia and the United States. Graf (2001) explains the rationale for implementing a clearing house mechanism, like PIPRA or EPIPAGRI, for management of the public patents:

* To limit the risks related to the patent thickets, to seek and propose attractive licences of patent pools, and/or to carry out innovations in the public sector.

* On the more important level of negotiation, to have access to the licences of patents held by the great multinationals of biotechnologies.

At the theoretical level, the collective management of intellectual property raises the question of its conformity with competition law, *i.e.* how to limit the risks of collusions. Economists have sought and identified situations in which building a patent pool is economically and socially effective. Thus Shapiro (2000) shows which patent pools are beneficial to consumers if the patents are perfectly complementary, or harmful if the patents are perfectly substitutable. In the same way, the competition councils will prefer pools built *ex ante* (creation of standard), rather than pools created *ex post*; the latter always undermine the collusive will of the partners (creation of monopoly) to the detriment of the consumers. Work carried out on patent pools and cross-licences (Lerner and Tirole, 2004; Clark *et al.*, 2000; Verbeure *et al.*, 2006) is particularly useful. A licence on a patent pool seems the most

[24] For innovations identified as "modular technologies standards", research is carried out *ex ante* on patentable and complementary modules.

adequate tool to limit these perverse effects. Patent pools are generally used within the framework of constructing standards or modular innovations (complementarities *ex ante*); their *ex post* use is often compared by competition councils with anti-competitive situations. In this theoretical context, patent pools in agricultural biotechnologies are particularly badly designed, since they are created *ex post* and can integrate more or less substitutable patents (each patent blocks new research). In the past, the use of licences on *ex post* patent pools was reserved for the state when it wished to re-dynamise economic sectors (*e.g.* the aircraft industry in the United States in 1919, the semiconductor industry in the 1950s. For building biotechnology patent pools, the analysis of Lerner and Tirole (2004), which extends that of Shapiro to intermediate situations, is particularly relevant. One of their conclusions is that in the drafting of the contract of the constitution of a patent pool, it is necessary to make compulsory a clause authorising each research participant to propose an individual way to obtain a licence on its own patents. They show that with this clause, the patent pools that are increasing the welfare of consumers remain stable, and agreements on patent pools reducing the welfare of consumers become unstable. Bessen (2006) reinforces this notion of creating a pool to limit the perverse effects of past patents, because he shows that it is hard to distinguish a good patent from a bad one, a difficulty that presents a disincentive. In other cases, extrapolations of common agency models (Sinclair Desgagné, 2001) to questions of collective management of knowledge could be considered.

Collective management of research

To circumvent the risk of being blocked – or delayed – by patents, public and private research organisations propose an alternative to building a collective management of intellectual property: build a novel organisational mode of research based on new collective and co-operative relations in the pre-competition phases. The objective is to define the operating rules of the consortia of research, so that they are economically effective and do not fall under the influence of competition law: privileged access of the network members to certain information; delay in the diffusion of certain information inside the network; little or no joint ownership of patents.[25]

There is another favourable aspect. Research is increasingly complex and expensive, with the development of all the new technologies – genomic, proteomic, transcriptomic, etc. – and entails the creation and mobilisation of databases and software.[26] Biotechnological researches also require the preparation of various biological and genetic resources (collections of mutants; expressed sequence tags, ESTs; bacterial artificial chromosomes, etc.). The high cost of producing these databases encourages a pooling of effort and the creation of national and international consortia. Awareness of this complexity came from the fact that patents fell into the public domain even before they could be economically valorised. That led to a double movement: concentrations in agricultural biotechnologies; and placing in the public domain great masses of genetic data.[27] Thus, the main idea behind creating consortia on genomic structures is to accelerate production of new structures of proteins resulting from the crossings from various partial sequences of genes that one finds in the public databases (Williamson, 2000). Examples are presented in Box 5.

Therefore, inside the consortia and the network research activities, defining the rules is a precondition to each research project. This is because, as Cassier and Foray (1999) show, an absence of rule at the beginning leads automatically to opportunist behaviours and jeopardises the networks of research. The

[25] Hagedoorn (2003) has written about "joint patents", which are increasingly numerous, but work by Cohendet *et al.* (2006) see the patent as an institutional tool for co-ordination in addition to being a simple tool of incentive. Bitter (2004) insists on the need for sharing the intellectual property when each partner makes a real contribution. It is a question of sharing the costs, but also the results.

[26] As pointed out by Teyssendier de la Serve and Trommetter (2004): "The USA protects databases by copyright law. Europe does so as well but on its own has added a right that protects the creator against unauthorized extraction and reuse of all, or a substantial part, of the contents of a database (European Union, 1996). Maurer and Scotchmer (1999) expressed doubts about the actual effect of these new property rights because of the multiplication of databases particularly in biotechnology. In addition there is a growing volume of results derived from the cross utilization of several databases (homology searches), and from new types of organization of bioinformatics research (mainly consortia)."

[27] According to Wright and Pardey, 2006.

introduction of rules is thus necessary to limit moral hazard – an asymmetry of information on the real action of the agents, and the actions of the partners obscured to some degree. There is indeed double uncertainty regarding the real activity of genetic evaluation and the circulation of information among members of the network. Rules on the conditions of participation, and even of exclusion from the consortium, are thus central.[28]

Box 5 – Examples of research consortia

National Plant Genome Inititiaive

Private sector concerns have had varied reactions to the NPGI. Some grower associations, such as the American Soybean Growers Association, the Sugarcane Association and Cotton Incorporated, have contributed funding for the publicly financed genome projects that benefit them directly (NPGIreport 1999). Large agricultural companies are mostly providing modest levels of funding or in-kind support for specific projects on an individual basis. At least one company, Novartis, has participated directly in two corn genome projects and the rice genome research project.

The SNP Consortium, TSC

One model for effective industrial partnerships might be the non-profit Single Nucleotide Polymorphism Consortium, which was provided with USD 46 million by ten international pharmaceutical companies and the Wellcome Trust philanthropy of the United Kingdom. Within the framework of the consortium, more than 300 000 human SNP were put in the public domain (Williamson, 2000). This research is financed by private funds and is carried out by public and private research institutes. The public data allow for quicker discovery of genes useful in the development of drugs (patentable innovations); various databases can be crossed without having to worry about possible holders of IPR on the SNP used (leaving free access to the sequences for all functions).

The "Génoplante" contract

In the case of this French consortium of research between public laboratories and private firms, it is expected that the more fundamental patents (upstream patents) will be deposited by the research institutes, and the downstream patents by the private firms. In addition, it is envisaged to have free compulsory licences for the members of the consortium. Owing to the fact that the patent is deposited by one of the actors of the consortium, the paying licences can be yielded to other companies or laboratories more easily than if one needed the acceptance of all members of the consortium. The royalties drawn from these licences will then be distributed among the various actors of the consortium according to their effective participation within the project. The participation of each actor is measured in a "book of research" held in each laboratory (time spent on the project, source of the biological material used, techniques used, etc.).

The Open Source Model

The open source model is mobilised in biotechnologies where there is a possibility of extending the principles of commerce-friendly, commons-based peer production – exemplified by open source software development – to the development of research tools in biomedical and agricultural biotechnology. This ensures access to the genetic sequences by the means of contracts (of licences). Each laboratory is committed by contract to not blocking access to the sequences in the innovations, without a guarantee of exemption from payment for the access to the innovation. Feldman (2004) notes that "fledgling efforts exist to establish open-source projects in biotechnology…participants agree that advances in the technology must remain as openly available as the original technology".

[28] These organisational modes are in line with works of Combs (1992, 1993), which study the trade-off between multiplying the research projects and sharing the costs of a project. He identifies the role of information sharing in cases of co-operation. It is necessary to establish rules regarding the sharing of research activities and the associated rights of use of new technology, which amount giving up monopoly profits in the event of successful research. If both cost sharing and results sharing are agreed, what follows is a two-step process: choosing whether or not to take part in a common research, then fixing of the rules of sharing and the levels of research effort each partner will undertake. The general conclusion is that the stronger downstream competition is, the more a co-operation agreement can diminish the total effort. That difficulty seems to be solved (at least partly) with models based on partial co-operation agreements (Bhattacharya and Sappington, 1992).

In this system of research co-ordination, there is no patent demand on the pre-competitive phases of research, resulting in a contractual open access to genetic diversity. The Plant Breeders' Right model is a bit different: it proposes that the access to the genetic resources is, for plant breeders, free and non-contractual, therefore without costs of transactions. Patents on living materials, on the other hand, lead to a contractualisation (economically and socially necessary) of open access. That contract, however, is a guarantee against private appropriation of the genetic resources, and so approaches an organisational model resembling the Plant Breeder's Right.

2.2.4. Consequences for farmers

The evolution of property rights in agricultural biotechnologies has had economic consequences for farmers. These relate to access terms and seeds use.

In the majority of countries, farmers have access to seeds that are registered with the catalogue of plant varieties. Varieties not in this catalogue cannot be sold, nor can there be production resulting from their use. In France, to be registered within the catalogue, a variety must meet the same conditions as those to obtain a Plant Breeders' Right. That therefore excluded the old varieties and population variety types. This situation no longer holds today, since a European directive authorises the marketing of the old varieties if the objective is conservation.

For the varieties protected by the Plant Breeders' Right from 1978, there exists an implicit "farmer's privilege", which allows the farmer to keep part of his harvest to resow his field. This privilege was justified by the selection work performed by the farmers over the centuries. Implementation of this privilege can be compared with the concept of "private copy" in the audio-visual sector in France. Indeed, the farmer cannot share the technology to carry out the activity of custom sorting, nor resell the seeds thus produced.

In the Plant Breeders' Right of 1991, the farmer's privilege becomes optional. A certain number of countries abolished it, others partially implemented it (France), and others finally adopted it (mainly in the developing countries). In the case of France, custom sorting remains authorised but is framed to encourage firms to continue their R&D effort. Thus, the exemption from payment of custom sorting is limited today to the small-scale farms; the large farms must pay royalties. This is more in line with economic theory than the former situation. Tirole in 2003 saw little economic justification for farmer's privilege.

As regards the access and use of the varieties protected by patent (GMO varieties for example), their reproduction is prohibited and marketing of the production can itself be regulated. In this context, farmers were already condemned for infringement because of using too high a percentage of varieties protected by patents and not purchased. These judgements depend on whether the act of infringement was voluntary in nature.

The net effect on the farm is discussed in GMO case studies. If the GMO is a substitute for pesticides, it is necessary to compare the cost of the GMO seed with the cost of a non-GMO seed plus the cost of the pesticide. The studies show contrasting results according to the species – rather positive for corn, rather negative for cotton. They do not address the question of taking into account the costs of damage that could arise through uncontrolled genetic dissemination. The costs of these damages could be the farmers' "civil responsibility" or "environmental responsibility". Thus, in certain countries like Germany, the risk of dissemination is not covered by the insurers; it thus remains the onus of the farmers if his responsibility is proven.

2.3. Specific IPR stakes for the developing countries

The official aim of TRIPS agreements (trade-related aspects of intellectual property rights), especially Article 27 on patents, is to establish a minimum level of intellectual property rights at international

level, and so ensure the protection of innovations and their diffusion towards those countries that have adequate IPR. The goal is to generalise the patent system worldwide, but at the same time to provide for flexibilities (primarily by limiting the height of patents). That flexibility should make it possible to exclude inventions from patentability (Article 27 2[29] and 27 3[30]) and to apply exceptions to the rights conferred (Article 30 and, to a lesser extent, Article 31). Restrictions also exist on the possibility of excluding inventions from intellectual property; this is the case of plant varieties in Article 27 3/b.[31] This article stipulates that a country is obliged to grant rights on plant varieties, but it also provides for flexibility regarding the tool to implement, since it authorises recourse to *sui generis* rights. *Sui generis* systems other than the Plant Breeders' Right can be implemented, such as the Organization of African Unity (OAU) system described above.[32] Implementation of IPR to attract innovations and direct foreign investments and to instigate R&D at the national level will depend on the characteristics of each country, particularly their capacities of demand and of research. Thus Trommetter (2007) highlighted that there exist today four types of developing countries in agricultural biotechnologies:

* Countries with capacities of research and capacities of demand (*inter alia* India, China, Brazil).

* Countries with capacities of imitation and capacities of demand.

* Countries with capacities of imitation but not capacities of demand.

* Countries without capacities of research or demand.

2.3.1. IPR, technology transfer, direct investment from abroad and royalties – the controversies

Considerations regarding implementation of IPR are undoubtedly useful for the countries that have a demand and/or capacities for research; for others they are perhaps less useful. Thus, Lall (2003) seeks indicators on the effects of implementing homogeneous IPR; he shows that the effects are different owing the differences between countries. Moreover, Aghion, Blundell, Griffith, Howitt and Prantl (2006) note that the impact of market liberalisation reforms will be all the more favourable for innovation and productivity gains for industries in countries considered closed to the technological frontier. That confirms the theory of comparative advantage. Forero Pineda (2006) shows how the scientific communities of the developing countries are particularly sensitive to the limitations of co-operation and of access to information resulting from too-strong IPR. That is all the more frustrating as their efforts to pursue normal research are important. In the same way, Kuanpoth (2006) shows negative impacts of the Trips+ agreements[33] on pharmaceutical research in Thailand.

As pointed out by Trommetter (2007) and Tripp *et al.* (2007), it is necessary to implement rights that are in line with the agricultural development objectives of the country. The same property rights

[29] "Members may exclude from patentability inventions, the prevention within their territory of the commercial exploitation of which is necessary to protect *ordre public* or morality, including to protect human, animal or plant life or health or to avoid serious prejudice to the environment, provided that such exclusion is not made merely because the exploitation is prohibited by their law."

[30] "Members may also exclude from patentability:

(a) diagnostic, therapeutic and surgical methods for the treatment of humans or animals;

(b) plants and animals other than micro-organisms, and essentially biological processes for the production of plants or animals other than non-biological and microbiological processes."

[31] "However, Members shall provide for the protection of plant varieties either by patents or by an effective *sui generis* system or by any combination thereof."

[32] The TRIPS agreements allow for the coexistence of several rights, which should be favourable for the creation, diffusion and commercialisation of traditional seeds.

[33] The bilateral TRIPS+ agreements are free trade agreements signed between a developing country and either the United States or the European Union. These agreements are usually contracts in terms of which the developing country will implement intellectual property rights that go beyond the TRIPS agreement recommendations (primarily by overruling the flexibilities) and often beyond the IP rights of developed countries (*e.g.* by limiting recourse to compulsory licences. In such agreements, developing countries generally accept to renounce…some flexibility tools in intellectual property rights. For example they could renounce the recourse to compulsory licences."

imposed in some countries will have very different consequences on long-term research in other countries. This produces contrasting results. The specific question of Africa is taken up in Ayele *et al.* (2006). They show that relations between the public and private sectors in Kenya are rare, even if Monsanto shared its technology Bt. Lopez Andreu *et al.* (2006) present the case of corn resistant to the panachure, the effects of which would be resolutely positive for small farms in spite of some "overstatement that might arise from the assumption regarding rates of adoption". Gaisford *et al.* (2007) describe the conditions for a developing country to respect imposed IPR: there needs to be a symmetry in the advantages and technology sharing.

Responding to these controversies, the FAO in June 2007 proposed defining priorities in genomic research: the development of plant varieties for the South, using techniques such as molecular marker-assisted selections and with the objective of fulfilling its mission for the developing countries in their right to access food (food safety is defined as a global public good). The FAO thus proposes to work on orphan plants to improve productivity, without entering into competition with the food production of developed countries. In this context, Wright and Pardey (2006) explain: "then there does not need [to be] necessarily strong rights". Moreover, in some of these countries this has more to do with participative breeding, using the most powerful techniques and molecular marker-assisted selection on species considered as marginal.

These thoughts thus relate to implementation of a right that would cover "partially homogeneous" varieties. In the protection of plant varieties, recourse to a tool *sui generis* was often interpreted as implementation of the Plant Breeders' Right in developing countries, but other *sui generis* protective systems can be developed.[34] The Organization of African Unity (OAU) has proposed a system of *sui generis* protection that defines conditions of access to biological resources, as well as community rights, farmers' rights and the Plant Breeders' Right (OAU, 1999). Despite its shortcomings, this document was intended to take into account the particularities of plant breeding in the countries concerned. In most African countries the seed sector often remains empirical, and local varieties, although new and distinct, are generally less stable and homogeneous than seeds in the North. But stability and homogeneity are the conditions needed to employ regular protection tools, the Plant Breeders' Right, or patents. The intellectual property system proposed by the OAU is weaker than the UPOV system in height – that is, what can be protected – and it can be combined with other types of protection. The objective is to favour diffusion of innovations from the North without precluding the development of traditional varieties in the South.[35] To that end, it is necessary for countries to grant authorisation for commercialisation, compatible with their research capacities.

In their search for a social optimum, countries can specify conditions for a variety to be registered in the catalogue of marketable plant varieties. In Europe, commercialised plant varieties must meet the conditions of distinctiveness, homogeneity and stability – the DHS conditions – in order to be protected by the Plant Breeder's Right. In Africa, a country can establish protection of the Plant Breeder's Right or patent type to attract the innovations of North associated with a *sui generis* IPR; this protects the traditional varieties and authorises marketing of the two types of seeds[36] at the same time. A farmer can then freely choose the seeds he will use in his field.

[34] Other tools are envisaged to protect traditional varieties. For example, geographic indication, recognised by the WTO, associates a product, a territory and, in certain cases, specific varieties used to produce that product. In the case of France's AOC Châtaignes d'Ardèche, the chestnuts are from local varieties of the *Castanea sativa Miller*, the list of which is defined in the technical regulations provided for in Article 1 of the 28 June 2006 Decree (Marchenais, 2006, personal paper).

[35] See Note 35.

[36] Article 27/3b of the WTO trade-related aspects of intellectual property rights agreement provides for the combination of rights, since it stipulates that: "Members shall provide for the protection of plant varieties either by patents or by an effective *sui generis* system or by any combination thereof …".

2.3.2. IPR implementation: three case studies

Box 6 – Examples of royalty agreements between Monsanto and several countries

Wright and Pardey (2006) explain that at the end of June 2005, Monsanto announced that it would charge the producers using Roundup Ready soybean BRL 0.88 for each kilo produced. The Brazilian Seed Association (ABRASEM) was expecting a net loss, something around BRL 0.40 per kilo. The amount established by Monsanto means an additional cost to farmers of approximately BRL 56 (or approximately USD 14) per hectare. As many farmers are working at the limit of their resources, some analysts believe they will choose to wait to begin using transgenic seeds. The Batavo Cooperative in the state of Parana, for example, instructed its members not to plant transgenic soybeans this season (US Commercial Services, 2006).

The Brazil agricultural research corporation (Embrapa) negotiated licences with Monsanto following research tasks based on the promoter 35S Bt (Amstaden Sampaio and al., 2004). This agreement was negotiated even while the varieties of Embrapa were in the last phase of tests before marketing. However, the earlier licensing agreements are negotiated, the more favourable they are to the downstream innovator. For soybean, the producers pay 2% of their turnover to be able to use Monsanto technology.

The situation is more surprising in Argentina, where farmers pay to use a technology that is not protected.[37] In fact, the question is then one of access to the US market for Argentina's agricultural produce. In the absence of agreement, there is pressure from the American farmers to limit imports from Argentina.[38] Monsanto has tried to receive royalties from Argentinean exports to Europe, but without success.

Source: Wright and Pardey, 2006.

A country needs to set up an IPR regime that will promote research within the country while simultaneously promoting the importation of foreign innovations (see Table 1 for an inventory of the rights in three countries emerging in terms of biotechnologies). The balance is a delicate one. On the one hand it means setting up sufficiently weak rights to keep open possibilities of research activities independently of the North, but while being deprived of access to the innovations of the North, except those financed by public funds or foundations. On the other hand it means implementing sufficiently strong rights to ensure access innovations, but while being thus deprived of long-term research capacities. What is more, the dependence of innovation diffusion on external innovators can be a source of social under-effectiveness in the long run, depending on how research and imitation capacities evolve, and the distribution of surplus between the innovating country and others. Roffe (2007) explains why today there are "nets transfers of resources of the developing countries towards the most advanced countries". Thus, the United States received royalties of USD 8 billion (including USD 260 million from Latin America) in 1986, whereas the country received royalties USD 48 billion (including USD 2.3 billion from Latin America) in 2003 (Box 6).

Implementing strong rights in developing countries requires that these countries also implement competition law, to limit situations of abuse of dominant position. Thus, the relation between India and Monsanto on the royalties of the varieties containing Bt is very complex: "Monopolies and Restrictive Trade Practices Commission (MRTPC) on Thursday passed an interim order directing Mahyco Monsanto Biotech (MMB) not to charge the high trait value of Rs 900 per pack of 450 gram Bt cotton seeds and to fix a reasonable amount within a month." And, "The MRTPC verdict is related to the application for temporary injunction moved by Andhra Pradesh government. Considering the trait value, otherwise called royalty fee, which is being charged by the parent multinational in neighbouring countries like China, MRTPC felt that the trait value charged in India is very high."

[37] Monsanto did not claim in time the extension of its patent in Argentina. .

[38] Hence in the agricultural sector, if an innovator from country X distributes seeds in other countries and, in parallel, country X's agricultural product market opens up to competition, this will have consequences on competition between farmers in country X and farmers in other countries. Theoretically it can even lead to the disappearance of the agricultural sector in country X if production costs are too high compared to other countries. If farming dies out in country X, the same will apply to the demand for seed in that country. In this case, the innovator has to ensure that the foreign demand is sufficient.

Lastly, "MRTPC opined that the company is charging very high royalty fees from Indian seed producers resulting in higher prices for the poor farmers. Hence, the Commission orders imply that the agreements signed between Monsanto and seed firms are 'restrictive of trade practices' and they are not enforceable."

Table 2 – Intellectual property rights and technologies available in China, India and Brazil

	Biotechnologies	Nanotechnologies
China	Patent in 1993 and "pipeline protection" for innovations that are protected between 1986 and 1993 UPOV for plant varieties GMO for animal foods and GMO for human foods 40 US patents, principally by private Chinese companies	Principally nanomaterials
India	*Sui generis* protection compatible with the UPOV system. Possibility for farmers to resow their production whatever the technology to produce the seed GMO or cross-breeding No patent on plant varieties No GMO for human foods Paid access to Indian genetic resources Globally 84 US patents by Indian Universities	Nanoparticles 11 patents: 4 US
Brazil	Plant variety protection law (UPOV member) Brazil agricultural research corporation (Embrapa) signed some MTA with the private sector 17 US patents but less private valorisation than in India or in China	Good research but no real private valorisation

Source: Based on Niosi and Reid, 2007 and Amstalden Sampaoio *et al.*, 2004.

It is thus a delicate matter to implement IPR in the absence of the institution with the authority to enforce competition law (Box 6). That will be all the more true as the property rights implemented in these countries will be robust. What means of pressure could India have employed on Monsanto? In this context, the Trips+ agreements undoubtedly go too much far in renouncing the developing countries' flexibilities in IPR to ensure a social optimum.

Box 7 – IPR and competition law

Granting IPR to a monopoly makes economists, as well as the competition authorities, ill at ease. It is not enough to presume the legitimacy of the intellectual property law and regard rationing of technological diffusion as the price to be paid to preserve a continuous flow of innovation. It is still important to ensure that the legal monopoly conferred by the intellectual property does not add unnecessary distortions. It is thus advisable to reflect on the contours of IPR-conferred legal monopoly, the possible abuses the patentability, the effects of co-operation between firms, and the risk of "less saying" in the practices of patentability.

What will it cost the developing country to implement intellectual property rights and competition law in term of personal education, infrastructure, etc.… and what will it benefit the developing countries?

Table 3 – Synthesis

	Breeding technologies	Intellectual property right	Economic and social consequences
Traditional breeding	Cross-breeding	No right Plant Breeders' Right (78) or patent on plant variety PBR has lesser breadth than patent	Free open access to genetic resources if PBR No free open access to genetic resources if patent
Biotech (1980)	Cross-breeding Biotech paradigm: one gene can code for one function	No right Plant Breeders' Right (78) or patent on plant variety Patent on gene sequences with large height and large breadth	Classical breeders anticipate that with the genetic engineering there are some risks of private appropriation of genetic resources, and so a risk of generalisation of the patent system to protect plant varieties
Biotech (1990)	Cross-breeding GMO Biotech paradigm: One gene can code for several functions. A function can depend on the interaction of several genes	No right Plant breeders right (91) with larger breadth or patent on plant variety Patent on gene sequences with lesser height and large breadth	Co-existence of several organisations of research in Europe and United States: GMO/cross breeding In genetic breeding, there are risks of blocking research because of patent thickets situations
Biotech (2000)	Cross-breeding Cross-breeding associated with biotech tools GMO No change in the biotech paradigm	No right Plant Breeders' Right (91) or patent on plant variety Patent on gene sequences with lesser height and large breadth European directive and the concept of compulsory cross-licence between patent and Plant Breeders' Right Trips and Trips+ agreements to impose implementation of IPR in developing countries	There exist some disincentives to using PBR because of the possibility to easily copy (by MAS) specific characteristics. More and more collective initiatives to limit the potential perverse effects of past patent More and more mutualisation of material and technologies For developing countries the access to innovation is linked to the implementation of IPR and also the implementation of a competition law.

3. What about the future?

What will be the demand for the agricultural productions tomorrow in terms of quantity and quality? What will be the "final destination" of the agricultural production – more precisely, what share of agricultural production will remain in the food sector (human and animal), as opposed to the industrial sector? What requirements will there be in terms of the environmental quality of agricultural practices? What will be the consequences of Climate Change on agricultural productions?

The answers to these questions are complex but indicate the options towards which must move research in agricultural biotechnologies. For example, one of the results of the Le Grenelle environment project in France[39] (October 2007) is a proposal to reduce the use of the chemical

[39] The Grenelle of the environment is a great public debate on the environment wished by the President of France Nicolas Sarkozy, its goal is to lead on "a contract between the State, the territorial collectivities, the trade unions, the companies and association". This "contract" would last five years and its results would be evaluated annually.

pesticides; this entails developing biopesticides using existing biotechnologies or other technologies – nanotechnologies by example.

Research needs to evolve to better integrate environmental constraints in the strategy of firms and farms. Agriculture practices and the environment are in dynamic interaction, *e.g.* the positive and negative externalities of biodiversity on agricultural production. There is a new paradigm for plant breeding, with several objectives (Joly *et al.*, 2007). Each one of these objectives involves diverse research organisations, and therefore different requirements in terms of IPR. Which are the major outputs and organisational constraints for agricultural biotechnologies?

* Evolution of the Demand
  - Development of the world population and needs for food as a global public good.
  - Development of the biofuel and biomass.
  - Other industrial outputs for agricultural biotechnologies (fast wood plantations, Cifor, 2003).
* Evolution of environmental constraint
  - Climate Change and its consequence on agricultural productions.
  - Biodiversity and its consequence on agricultural productions.

In this first stage, it is a question of analyzing how agriculture can respond and adapt to these new stakes and these new constraints. That is more important, knowing that the speed and the width of these changes can be variable as well on the level of the demand as of the environmental questions.

Another objective for agriculture is to take into account new constraints and opportunities relating to the environment and biodiversity (to limit deforestation, better mobilise ecological functions and other services in the process of agricultural production, to limit the use of chemical inputs, etc.). In this second stage, it act to study if a better use of the natural resources in the agricultural production can have positive effects on the environment? For example, a new agricultural production process can lead to a reduction of the CO2 emissions or an increase in the CO2 sequestration, therefore potentially could have an impact on the climate change as well in its speed as in its width.

There are thus not one but several stakes for intellectual property rights in agricultural biotechnologies. In the market context, intellectual property is a necessary but insufficient condition for creating incentive to develop innovation in agricultural biotechnologies. So, the definition of optimal IPR is linked to other necessary but insufficient conditions, such as the size of market demand for the innovation. This last necessary condition is a function of the expected demand for the innovation. How to take into account the perceptions and demands of society? How to implement two necessary conditions so they become sufficient? It is a question of making so that the speed of innovation is compatible with the speed and the width of the changes. The effects of the climate change are not necessarily linear with the average evolution of the temperature, it can have some shocks there. How to anticipate them to limit their effects? There is thus a double objective: to slow down the speed and the width of the changes; to answer and adapt to the changes when they emerge.

3.1. Technologies that can be mobilised and the evolution of IPR

To answer these questions, several options exist for the development of agricultural biotechnologies, *inter alia* GMO or genomic tools in traditional breeding and nanotechnologies. None of these developments is by nature exclusive.

3.1.1. Cross-breeding and innovation

As cross-breeding continues as a practice, several questions emerge. What genetic diversity is available? How can the Plant Breeders' Right and patents coexist on a world level? All in all, what do the innovators have access to, and how can research be organised?

Mobilisation of biotechnologies in traditional cross-breeding

To accelerate the plant breeding, the plant breeders increasingly have recourse to the most modern biotechnologies. Genetic breeding makes it possible to shorten breeding times and so reduce the time of return on investment. Technologies that can be mobilised to improve plant breeding conditions are, *inter alia*: genome sequencing initiatives, RNA interference, mutagenesis, the transcriptomic and the proteomic (Fears, 2007).

Thus, the molecular marker-assisted selections (MAS) make it possible to sort the results of the crossings and to choose those that integrate (or not) the characteristic concerned.

This technology can be mobilised on several options of development:

* The will to reach the genetic diversity of the GMO.

* The will to quickly copy a specific characteristic developed by traditional breeding techniques.

The first option remains rooted in a vision of access to the genetic variability of the cultivated species, whereas in the second there is appropriation by the competitors of the work of the upstream plant breeders.

Implementation of the first option will depend on the dependence or non-dependence between a patented gene and a GMO variety in which the patented gene is contained. In the event of nondependence (the situation in France, Germany and Switzerland), MAS would allow use of the genetic variability of GMO varieties without infringing patent law. As implemented in the European directive, if the dependence is real, a compulsory cross-licence exists – but is less effective for the consumer surplus because of a high production cost for farmers (plant breeders have to pay for access to the genetic diversity of GMO varieties).

The second option reveals "the weakness" of the Plant Breeders' Right, including in its version of 1991, insofar as new technologies make it possible to copy more easily expensive innovations. [Varshney *et al.* (2005) show the trend of costs of the MAS.] The degree of protection provided by the Plant Breeders' Right and by the patent is a subject raised by Moschini and Yerokhin; this situation appears to favour the patent. In that sense it is important to reform the Plant Breeders' Right if the objective is not to have it disappear with the profit of the patent. An option suggested by ISF (2005) and Le Buanec (2006) is to set up one period during which the plant breeders would be committed to not using a plant protected by the Plant Breeders' Right. It would thus be a question of transforming the Plant Breeders' Right into a mini-patent, which was not UPOV'S philosophy at the beginning. Another option, one that we propose, would be to dissociate access to the genetic diversity from access to the specific characteristics of the varieties. It would be a question of, for example, extending the concept of essential derivation to "essential derivation of specific characteristics" of the plant varieties protected by Plant Breeders' Right. Protection would thus be on two levels: free open access to the genetic diversity of plant varieties, and limited access to the specific characteristics that compose a plant variety. This essential derivation on specific characteristics of plant varieties protected by Plant Breeders' Right is necessary, because there is no longer any free open access without contracts to genetic diversity, except in the case of plant varieties protected by Plant Breeders' Right. We are moving toward a world in which access is guaranteed but in a contractual way, to limit the risks of privative appropriation. As recalled by Henry *et al.* (2007): "The contract avoids the abusive and [confiscatory] appropriation by a third person." The objective is always to allow

sufficient time of return on investment for the innovator. Access to genetic diversity that is as rapidly available as possible for the competitors is all the more necessary if a company is working to introduce several characters into the same variety; the time required to create new varieties is again long, over ten years.

Parallel to reform of the Plant Breeders' Right, let us note that the evolution of traditional plant breeding by mobilising genetic selection will depend on the conditions of access to the molecular markers. Two questions arise: on which plants will the markers be used? Which are the conditions of access to the markers? Australia and Europe have the will to establish contractual open access to the markers ("open" here does not necessarily mean free), with the implementation of "national genotype centres" that could be created out of public/private partnerships. The United States also has some university initiatives to establish national genomic centres, but the participation of private companies seems less likely. The owner of the property rights on the markers has the possibility to grant licences or not. Thus, if the turnover of the varieties is accelerated, absence of recourse to property rights will likely be the most effective situation, provided that the turnover of the innovations always makes it possible the firms to innovate, *i.e.* to have a sufficient return on investment. This is, for example, already the case with market gardening in France. Nevertheless, such situations are actually rare; could they become more common in the future?

Mobilisation of biotechnologies in traditional plant breeding looks set to replace GMO, with the latter being developed only when the desired characteristic is expressed in too weak a way inside the species. This substitution is justified because of the cost of the R&D activities. Cross-breeding associated with a marker-assisted selection is less expensive than traditional cross-breeding; less time is needed for research and the technology mobilised is well known. It is also less expensive than GMO technologies; the costs of creating a GMO will total at least USD 20 million because of the long and costly "authorisation for commercialisation".[40] This relationship could be modified according to the condition of access to the markers, and could be less efficient for the consumers if the conditions of access are too restrictive.

This point on the introduction or not of delays to have access to genetic diversity, whose molecular markers, is all the more fundamental as one anticipates needs to answer and to adapt to changes which will be able to appear rapidly.

Participative breeding

The participative breeding is a mode of organising research based on a partnership between farmers, researchers and financial institutions. The objective is to improve local varieties that are better adapted to the pedoclimatic constraints of the countries or regions. Initiatives already exist in developing countries. For example, work has been launched by French Agricultural Research Centre for International Development (CIRAD) and France's National Institute for Agricultural Research (INRA) on wheat. The goal is to improve the outputs of the local plant varieties while resorting to chemical inputs as little as possible, for environmental reasons (organic farming) and/or economic reasons (cost of the seed inputs).

For the developing countries, Fears 2007, in a report for the FAO, suggests promoting improvement of local plant varieties to solve the problems of food and poverty. She proposes mobilising the most powerful tools in molecular biology in order to make this research most effective. She indicates that the priority here must be to support research focused on the developing countries. What interest is there in mobilising these technologies to improve local varieties? Access for these countries does not depend on implementation of IPR on the seeds or pesticides. Agricultural production for purely local or regional use would not be in competition with production on the worldwide market. The poorest countries could thus enjoy technological advance without seeing themselves imposing implementation of unsuited property rights. In this context, the developing countries are not obliged to set up IPR to

[40] Bernard Teyssendier de la Serve, personal paper.

cover technologies they do not have the capacity to implement.

In the case of France, it is a question of consolidating access to genetic diversity and the possibility of protecting these local plant varieties, either by specific rights or by geographical indication; in the latter case the guidelines would indicate the names of the specific varieties to be used to profit from the certification. As mentioned in the first section, the conditions of intellectual protection of the plant varieties are drastic, and necessarily do not correspond to certain types of varieties. In this context, the recourse to a *sui generis* right other than the Plant Breeder's Right or geographical indication would make it possible to continue the activity. The interest of the geographical indication is that it would be associated with a mode of production or a product. The disadvantage would be that it does not protect the plant variety as such. If these schemes are carried out with a wider societal view, it is not certain that these products will be more expensive at the end than the others. Some are clearly in niche markets (*i.e.* spatially localised) and related to final demands (bio, quality). Differentiation from other products is by means of certifications or geographical indication. This picture undoubtedly corresponds more to the demand of European consumers, but let us not underestimate the interest for the United States, where there are initiatives to implement agro-ecological practices (in California).

3.1.2. Transgenic technologies and GMO

With GMO, the technological options have different costs. Today the cost of developing and marketing a GMO is at least USD 20 million: USD 5 million for the development of a GM plant and USD 15 million for the "authorisation for commercialisation".[41] Further information on the research costs is given by Monsanto, which estimates that: "it costs some between 50 and 100 million dollars to develop a 'new character'. In fact, between the discovery of a gene of 'interest' and the possible marketing of a GMO, [there passes] on average more than ten years." The technology adopted will thus depend on the size of the anticipated markets. But this cost varies according to the number of genetic traits from which a firm wants to innovate. The higher this number, the longer and more expensive the research will be (up to USD 300 million). It is thus very difficult to advance a cost for research in transgenic research.

Before launching research, it is necessary to identify the characteristics of the demand for seeds. There exists a new paradigm of the demand, requiring a standard for the use of genes patented on behalf of the farmers. There is a marked evolution of standard demand for seeds in the United States: the majority of the US farmers want seeds adapted to the round-up-ready herbicide and resistant to the corn borer. Thus to enter the US market, it is necessary to negotiate licences with the holders of patents on these resistances – the case for example with Limagrain, which markets transgenic plant varieties via AgReliant under Monsanto licences. There is then a risk of concentration running counter to various objectives of plant breeding. What will be the consequences on social welfare? The response depends on the capacity of research of the different countries and the institutional options. In plant varieties, the demand for a standard does not depend on GMO technologies. For example, there are cross-breeding plant varieties that are resistant to the corn borer. So there exists some technological competition to respond to a modification in the demand of standard. In the same way, the implementation of IPR associated with a competition law could give some degree of incentive to firms to grant licences to competitors. At this time, one cannot draw conclusions regarding the net effect on social welfare, but it is possible to present some conditions that have to be realised if the objective is to have a positive effect.

This concept of demand is important to the success or failure of the marketing of innovations. For example, many are conscious of the little interest European consumers, particularly the French, pay to GMO, but there are other examples elsewhere: Wright and Pardey (2006) explain why the Flavr Savr tomato is a failure: on the one hand because of low productivity, and so a price higher than consumers are ready to pay; and on the other, because of the "Jeremy Riffkin effect" of managing to persuade the Campbell Soup Company not to use biotech tomatoes in its product.

[41] Bernard Teyssendier de la Serve, personal paper.

Creation and the implementation of a standard would modify the paradigm of research in the sector of plant breeding, bringing it closer to the model one finds in other industries – electronics, data processing, etc. – where there is a standard race in which the runners know that the winner will grant licences to its competitors. It is the quality of the final product that makes the market share of these firms. In such a situation a seed company will may find it beneficial to always be on top of the agronomic quality of its varieties and so certain to reach the standard. It can even question its interest in taking part in the standard race if the number of competing firms is sufficiently large. If so, the seed company would be a simple user of standards that were developed elsewhere.

European directive 98/44 is better prepared for this modification in the paradigm of demand than the transposed versions adopted by French or German law. Indeed the concept of compulsory cross-licences in the event of dependence would today make it possible to ensure the standard would be reached if it becomes the one essential criterion for entering the seed market. The French transposition is satisfied to allow free access to the genetic diversity of the GMO, but does not guarantee a compulsory cross-licensing between the Plant Breeders' Right and the patent. This compulsory dependence will perhaps prove major stakes for the future of R&D in agricultural biotechnology. In terms of the time it takes to implement intellectual property, the EU anticipated the potential evolution of demand better than did France. The European farmers could align their behaviour on their American counterpart. Indeed, with the French transposition one is sure to reach the genetic diversity of GMO varieties, but not necessarily the standard demanded by the farmers in the event of the standard-owner's refusal to grant licences. This evolution of demand requires establishing the conditions under which the model can be exported to the developing countries, and in particular the level of royalties that would be required of them. We saw that without property rights there is no diffusion of innovations in these countries. Diffusion is possible if the innovation is technologically protected by, for example, Genetic Use Restriction Technology. This type of protection has its inconveniences: infinite protection is socially under-optimal. We also saw that the countries that set up property rights must on the one hand implement the means of enforcement and on the other implement a competition law that limits the risks of abuse of dominant position.

3.1.3. Recourse to nanotechnologies

Today in nanotechnologies, the majority of the research projects in the agricultural sector and agro-food relate to the agribusiness industry (packaging, conservation of food, etc.), but applications for the agricultural sector also exist. According to Kuzma *et al.* (2006), "some makers of pesticides, fertilisers and other farms inputs and technologies are betting on nanotechnology to bring unprecedented precision to crop and livestock production".

Therefore, in nanotechnologies, two types of research linked to agriculture were identified:

* Substitution for chemical inputs (same functions as for the GMO currently developed): an environmentally friendly pesticide is in development that uses nanomaterials to release its pest killing properties only when it is inside the targeting insect.

* The development of nano-innovations, so that plant varieties are made technologically multi-functional. For example, it would be a question of transforming the production of corn or wheat: the seeds would be used in food, and the stem – thanks to the use, for example, of nanomaterial – could be used to manufacture biofuels.

In the second type of development there would thus not be more competition between food production and industrial production, but multi-production at the farm level. The development of these technologies will have positive effects on social welfare. The word "will" is used because we do not have information on all the possible consequences (for sanitation, the environment) of using nanotech to produce biofuel.

At the level of plant breeding, that would require growing plant varieties with this double agro-food and industrialist objective in mind. However, these two objectives concern neither the same intellectual property right nor the same international convention. How to reconcile UPOV and patents? How to reconcile, in the same plant, the Convention on Biological Diversity and the International Treaty on Phytogenetic Resources for Food and Agriculture of the FAO?

There exist various options: The FAO treaty covers genetic diversity of agriculture and food use according to a multilateral system of exchange with homogenised material transfer agreement and strict rules of traceability (certificates of origin and obligations of disclosure of the origin). The Convention on Biological Diversity (CDB) covers the other uses of biodiversity, with a national sovereignty of the countries over their genetic resources. In the genome of the commercialised varieties, one will have an intricate set of rights, indeed guaranteeing that a gene sequence from a genetic resource selected for food production does not intervene in functions supporting the industrial production of the plant, and vice versa. In this context, questions about access to the genetic resources will be complex: are the genetic resources managed under the FAO treaty or under the CDB? Are there patents on the gene sequences or not? Is development for agricultural uses or industrial uses? – and so on. Access to the resources will constrain the conditions of advantage sharing resulting from the use of the genetic resources. Royalties could thus be paid to the plant breeders, who would then transfer the royalties to the initial holder of the genetic resource. The farmers will not have to pay according to a good (plant seed), but rather according to the various uses of a good: plant seed for food production, plant seed for industrial production, plant seed for multi-production. The farmers will have to pay "user's rights" for food and other, industrial goals.

Indeed, the difference with the GMO marketing is due to the fact that the GMO could have several functions: food and pesticide for example, but with production at the level of the farmer that was purely food. In the same way, the second generation GMO can lead to non-food production and thus be covered by the CBD. With nanotechnology one can consider multiple productions – food and non-food – within the same farm and in the same plant variety.

There is thus the potential for conflicts of rights during the breeding phase of plant varieties at the level of seed companies. To limit the risks of blocking, it will be imperative to reinforce the conditions for granting patents (Henry, Trommetter and Tubiana already proposed this in 2003) or prohibiting patents on the sequences, or limiting their claims to the functions experimentally proved to avoid having the intellectual property rights overlap. It is thus even more necessary than ever to reinforce the restrictions on the breadth of the patents, knowing that yesterday they were already justified by economic theory.

3.1.4. Biotechnologies intervening in livestock sectors

If agricultural biotechnologies intervene in animal fields, there are no tools of intellectual property protection of animal breeding apart from those in countries that have recourse to patent. Laws were proposed in France beginning in the 1990s (including a fascinating model based on the Plant Breeders' Right) but never went forward. Given the possible consequences on animal breeding, it is important today that such rights be implemented. If agricultural biotechnologies intervene in sectors other than food, they will continue to depend on the CBD; access rules and the benefit sharing will need to be negotiated with each resource holder, as is the case today.

The discussion above applies to property rights in animal breeding: it is more precisely a question of studying the access terms to the molecular markers and the genetic diversity of the genetically modified animals. However, as there are no specific property rights apart from the patent, or a specific international convention at FAO level, these resources are therefore covered by the CBD, which gives countries national sovereignty over their genetic resources. It is thus up to each state to define access and use rules – thus it is on this level that one will implement contracts that will lead to risks of privative appropriation of these resources.

As regards cloning rules, the stakes in terms of intellectual property rights are the same ones as the access rules in other animal biotechnology research.

3.2. At the organisational level

These biotechnologies in agricultural research are often mobilised in parallel. That makes research particularly complex, and the stakes for the developing countries in terms of access are particularly vague.

3.2.1. Increasingly complex research

Whatever the technology in question, research will require that public/public and public/private partnerships be developed – as much in the search for the creation of common resources (collection of mutants, of single nucleotid polymorphism, etc.) as in the creation of standards (technological platforms based on technological complementarities) to support research, including with developing countries. The growth in inter-firms partnerships already observed today (Roijakkers and Hagedoorn, 2006; Gay and Dousset, 2006) is in fact increasing. This renders the picture all the more complex; Rosenkranz and Schmitz (2003) show the difficulties of diffusing knowledge in alliance agreements.

That requires consideration of property rights sharing when they are the result of a collective work (the *génoplante* experiment in France, PIPRA in the United States linked to developing countries) and of the external financing of research (foundations). These various initiatives can be used as a basis for future thoughts on collective research initiatives. One notes that there is more and more joint ownership of patents, whereas economically this is the least favourable situation (Hagedoorn, 2004). In the *génoplante* project, the patent is deposited by one of the actors of the consortium; the paying licences can be yielded to other companies or laboratories more easily than if one needed the acceptance of the whole of the members of the consortium. The royalties drawn from these licences will then be distributed among the various actors of the consortium according to their effective participation within the project. The participation of each actor, as mentioned in Box 5, is measured in a "book of research" held in each laboratory (time spent on the project, source of the biological material used, techniques used, etc.). Here one has a co-operative model, but that is not necessarily the case with an "open source" model, except if the use of a variety becomes contractual (evolution of the Plant Breeders' Right towards a mini patent). (An example is the Material Transfer Agreement –MTA- of FAO: the costs of transactions are introduced but limited by the fact of having a homogeneous tool.) There exist public goods, club goods and, in the case of the development of particular technologies, open source goods. The implementation of an open source model in biotechnology research is more complex than in software, because this can be done only in the upstream phase of research. These upstream results are patented or not, but the objective is to limit by contract the risk of private appropriation of upstream results. In the case of a patented upstream result, thus with annual costs of maintenance, that can lead to paying licence access at a marginal cost near zero if the number of licensors is sufficiently high. In the standard patent, *e.g.* Cohen Boyer, one can diffuse technology with the greatest number of licensors and authorise development if it is dependent on the former patent. On the other hand, co-operative research and joint ventures can be more effective (Gil Molto *et al.*, 2006) in terms of social well-being than patent pools or non-cooperative research.

The philosophy of the open source model is linked to a modular and cumulative good. It is very different in biotechnologies, except for certain technologies or certain characteristics. Today, one finds this model in the open source software, where the access is open but contractual, to avoid the risks of appropriation made possible by the actual legislation.[42] The logic of the copyleft licences for the use

[42] With open source software, a variety of licenses are proposed to the users, and these can appear antagonistic compared to certain uses. In the same way, the Plant Breeder's Right facilitates diffusion of the varieties in the countries having adhered to the UPOV, but limit the diffusion in the United States, where the protection is double and the risks of dependences therefore more frequent.

of open source software (Dequiedt, Ménière and Trommetter, 2006) is, indeed, very near to the logic of the basic Plant Breeders' Right. In 1990 Pioneer Hi-Bred had proposed to yield licences on its GMO to competitors; the counterpart of the licence was that the developer downstream was committed to keeping Pioneer informed about its developments, but Pioneer rather quickly ceased. Similarly, Monsanto offers free access to its rice genome database but on condition of signing a typical contract. In this contract, the condition for access to the database is relatively strict for the signatory. The accessing party agrees to grant Monsanto a non-exclusive licence for any patent that it may file on the basis of data from the base, the royalties being negotiable. This guarantees that Monsanto will always be up to date on the research. The result is a balance between doing the research (or at least guiding the research) and externalising the research (Ambec and Poitevin, 2001); in the latter case Monsanto is sure of being informed about the innovations and has access to them, through licence agreements that closely resemble compulsory licences (Henry, Trommetter and Tubiana, 2003).

This increasingly public/private collective research poses serious limits on the conditions of exemption of research (Noll, 2004). There is thus a risk of seeing the conditions of exemption, hardened in Europe, approaching those for exemption of American research, which are very weak.

3.2.2. The stakes for developing countries

We again will consider that there are two types of country: those that master genetic technologies, whose three leaders are Brazil, China and India; and those that do not master these technologies and which are thus completely dependent on outside research.

For the countries which master technologies, one can anticipate a specialisation of the same order as that which one could see in pharmacy with for example the specialisation of India in the human diagnostic tests. We can anticipate that there will be also a specialisation in agricultural biotechnology. For example China is actually very dynamic in the implementation of animal cloning. This specialisation requires at the level of developed countries to be always in advance in research or to be simple users of the innovations while specialising in other fields.

The countries that do not master the techniques should initially be ensured that there will be an equitable benefit sharing arising from their genetic resources. That requires formalising the co-operation and the assistance with the countries: by supporting on the one hand implementation of the certificate of origin (a tool with more than one objective) and on the other implementation of the disclosure of the origin.

It is necessary to reconsider the priorities of research according to the objectives of food safety for the developing countries (Johns *et al.*, 2006; Fears, 2007). Reece and al. propose to study the use of MAS for the developing countries, the installation of consortia, and mobilisation of approaches to multi-agencies to reduce fragmentation. It is thus necessary to reinforce the contractual approach of the MTA to limit the risks of private appropriation. The question of property rights influences the size of the accessible market, especially as the World Trade Organisation wants to impose a minimum level of intellectual property rights. Unfortunately, on the level of WTO there is no maximum level of the IPR. This is not true in the countries that have implemented a competition law that can "break" situations of abuse of dominant position.

But at a world level, what can be the role of WTO within the framework of undue intellectual property rights implemented in the developing countries, or in the case of technical protection (Genetic Use Restriction Technology) of the biological functions, which should see their impact limited by the anti-monopoly acts (Kesan, 2007)? That requires facilitating implementation of IPR in the countries of the South by respecting their own constraints: in particular facilitating their capacity set up and enforce competition law to limit the risks of abuse of dominant position, which could arise from the implementation of badly adapted intellectual property rights.

3.3. Tools for protecting innovations: some general recommendations

Compared to these general stakes, a certain number of points will have to be analysed regarding implementation of intellectual property rights, whatever the country. We propose seven points:

1. Reinforce patent offices and competition institutions, and reinforce *sui generis* rights in the plant varieties so that they continue to fulfil their functions, first and foremost "to share genetic diversity" without risk of privative appropriation of specific characteristics.

2. Reinforce conditions of granting patents, particularly on gene sequences, by limiting the claims to functions experimentally proved, to avoid the intellectual property right overlapping.

3. Facilitate the dispute of patents and, in the event of dispute, make pay whoever loses the lawsuit – on the one hand to encourage the deposit of good patents only, and on the other to discourage dispute of a patent in unfounded ways.

4. Impose on the holders of patents a fee if they refuse to grant licences on essential facilities.

5. Facilitate access to the intellectual property rights for small and medium-sized enterprises. For example, one can create an insurance patent to help Small and Medium Enterprises.

6. Implement flexibilities to facilitate circulation of innovations and to facilitate the exemption of research. Compulsory licences and compulsory cross-licences have to be generalised in the countries, as minimal flexibility tools.

7. Define a non-costly statute for the results of a collective management of research, to limit the risk of private appropriation and to limit transaction costs.

Some of these actions must be realised simultaneously to be effective. For example, if (1) and (2) are not realised, *i.e.* if patent breadth remains large, (3) must not be realised because, as Shapiro (2000) proves, in the case of a patent with large breadth, it is ineffective to make pay whoever loses the lawsuit.

Point (5) and (6) are important whatever other implementation of intellectual property rights and competition law.

Points (1), (4) and (6) are linked. It is difficult to have point (4) be credible if the points (1) and (7) are not well implemented.

A situation in which the seven points are realised simultaneously could have positive effects on research in biotechnology by the horizon 2030. There are perhaps also negative effects to be identified.

3.4. Future directions

The preceding pages present various options for the development of agricultural biotechnologies and in particular technologies that can be mobilised and the conditions of this mobilisation, both for the developed and the developing countries. They show that even if the property rights are necessary for the development of the innovations, they are not sufficient. Other characteristics are also necessary, one of which is the expected market size for the innovation. According to the options of IPR selected and their implementation in the various countries, there could be favourable or unfavourable consequences for the researchers, public as well as private, for the farmers and (thus) for the final consumers. As Bonneuil *et al.* note (2007), "a new paradigm for plant breeding does emerge where there are several objectives". One of the objectives which is less studied actually, but which cannot be been unaware of in a 2030 prospective is the creation and diffusion of innovations to limit the effects

of the climate change by innovation of practices and / or by biotechnological innovations. With each of these objectives, there can be different modes of organisation of research, and therefore different requirements in terms of intellectual property rights. How to build a system of intellectual property rights that allows the coexistence of various objectives and different modes of organising research? It is indeed the combination of an intellectual property right regime and a function of expected demand that will define the budget of R&D a company will be ready to spend to carry out an innovation. It is the combination of these two necessary conditions that could be sufficient to attain a social optimum for innovation.

The traditional cross plant breeding and the participative breeding associated with genetic breeding require reaching technologies and molecular markers. To accelerate the speed of innovation, it is necessary to facilitate the use of genetic breeding, it is necessary to facilitate access to the markers to facilitate the R&D in agricultural biotechnologies. That can bypass implementation of co-operative or collective research like consortia to create accessible collections of markers – which does not at all mean that there must be a purely free and open access basis. Facilitate the use of genetic engineering is favourable to traditional breeding activities, but as explained previously, that can have also negative effects since it limits the interest of recourse to the Plant Breeders' Right to protect plant varieties. There is a risk that this *sui generis* tool of protection will disappear if it is not revised. It is thus necessary to revise the Plant Breeders' Right, which must remain the tool of access to agricultural genetic resources. This potential reduction of the role of the Plant Breeders' Right in the protection of plant varieties will have strong consequences on future research. Thus, as Bellivier and Noiville (2006) note: "The variety of corn 'Inra 258' created from two American lines, a Spanish line and a French line, could probably have been developed only after years of negotiations with the countries of origin if the system of the CDB had been applied." That means that the Plant Breeders' Right must limit the possibility of copying specific characteristics without paying royalties and facilitate the access to genetic diversity in itself. Lastly, the result of plant breeding that is protected neither by Plant Breeders' Right nor by patent – not so much in the developed as in the developing countries – should be protected by a *sui generis* mechanism or by a geographical indication that could appear adequate as a tool.

On the level of the link between GMO and non-GMO, we see that there exists a change of paradigm of demand that can be favourable to the creation of standards. This exists in other industries but is new in the seed industry world, and in this case the compulsory cross-licence for dependence of directive 98/44 of the EU is undoubtedly good insurance to limit the risks of appropriation of the seed market in Europe. Even if in theory, the creators of standards are incited to diffuse them so as not to be in a situation of abuse of dominant position. This is really interesting, because the demand of a standard is in reality a demand of specific characteristics. So the difference from other industries (where there is a standard supply) is that in agricultural demand of standard, the standard can be reached by different technologies. Dependence on a proprietary technology is not necessary to create the standard if there exist alternative technologies. In that situation the question is: is it costless to negotiate a licence or to perform research to reach the standard by an alternative way?

On the level of the mobilisation of the nanotechnologies within the framework of an agriculture multi-production – food and industrial production – it is shown that to avoid intellectual property rights and international conventions overlapping, it is essential to limit the claims of the property rights on gene sequences to experimentally proved function(s). At the agriculture level, it is also important to note that it will be necessary to pay licence fees not according to the good "seed" but according to the different types of production (annual authorisation to produce in diverse sectors: food and/or biofuel).

Finally, what are the future goals for the developing countries? WTO wants to impose a minimum threshold of intellectual property right, but there is no maximum threshold of the intellectual property right. The countries that have a competition law can make or "break" situations of abuse of dominant position. But what will happen in countries that do not have credible competition law? It can be the role of WTO to help of these countries.

It is necessary to find a balance between the various tools of intellectual property, with a reinforcement of the conditions of granting patents, a reconsideration of the Plant Breeders' Right, and recognition (status) of the plant varieties that are not necessarily homogeneous.

In the absence of this balance between the countries that are the major actors in agricultural biotechnologies – Brazil, China and India – the question will be to know how the international rules will allow for the development of certain biotechnological innovations and their diffusion – in other words, how to build rights that are economically and socially effective on a world level.

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Annexe A - UPOV - Members

International Convention for the plant variety protection
Convention UPOV (1961), revised in Genève (1972, 1978 et 1991)

Situation le 18 octobre 2007

State/Organisation	Date à laquelle l'État/Organisation est devenu(e) membre	Nombre d'unités de contribution	Acte le plus récent' de la Convention auquel l'État/Organisation est partie et date à laquelle il/elle est devenu(e) partie à cet Acte
Afrique du Sud	6 novembre 1977	1,0	8 novembre 1981
Albanie	15 octobre 2005	0,2	15 octobre 2005
Allemagne	10 août 1968	5,0	25 juillet 1998
Argentine	25 décembre 1994	0,5	25 décembre 1994
Australie	1" mars 1989	1,0	20 janvier 2000
Autriche	14 juillet 1994	1,5	1" juillet 2004
Azerbaïdjan	9 décembre 2004	0,2	9 décembre 2004
Bélarus	5 janvier 2003	0,2	5 janvier 2003
Belgique[2]	5 décembre 1976	1,5	5 décembre 1976
Bolivie	21 mai 1999	0,2	21 mai 1999
Brésil	23 mai 1999	0,25	23 mai 1999
Bulgarie	24 avril 1998	0,2	24 avril 1998
Canada	4 mars 1991	1,0	4 mars 1991
Chili	5 janvier 1996	0,2	5 janvier 1996
Chine	23 avril 1999	0,5	23 avril 1999
Colombie	13 septembre 1996	0,2	13 septembre 1996
Communauté européenne	29 juillet 2005	5,0	29 juillet 2005
Croatie	1" septembre 2001	0,2	1" septembre 2001
Danemark[4]	6 octobre 1968	1,5	24 avril 1998
Équateur	8 août 1997	0,2	8 août 1997
Espagne	18 mai 1980	2.0	18 juillet 2007
Estonie	24 septembre 2000	0,2	24 septembre 2000
États-Unis d'Amérique	8 novembre 1981	5,0	22 février 1999
Fédération de Russie	24 avril 1998	0,5	24 avril 1998
Finlande	16 avril 1993	1,0	20 juillet 2001
France[6]	3 octobre 1971	5,0	17 mars 1983
Hongrie	16 avril 1983	0,5	1" janvier 2003
Irlande	8 novembre 1981	1,0	8 novembre 1981
Islande	3 mai 2006	0,2	3 mai 2006
Israël	12 décembre 1979	0,5	24 avril 1998
Italie	1" juillet 1977	2,0	28 mai 1986
Japon	3 septembre 1982	5,0	24 décembre 1998
Jordanie	24 octobre 2004	0,2	24 octobre 2004
Kenya	13 mai 1999	0,2	13 mai 1999
Kirghizistan	26 juin 2000	0,2	26 juin 2000
Lettonie	30 août 2002	0,2	30 août 2002
Lituanie	10 décembre 2003	0,2	10 décembre 2003
Maroc	8 octobre 2006	0,2	8 octobre 2006
Mexique	9 août 1997	0,75	9 août 1997
Moldova	28 octobre 1998	0,2	28 octobre 1998

Nicaragua	6 septembre 2001	0,2	6 septembre 2001
Norvège	13 septembre 1993	1,0	13 septembre 1993
Nouvelle-Zélande	8 novembre 1981	1,0	8 novembre 1981
Ouzbékistan	14 novembre 2004	0,2	14 novembre 2004
Panama	23 mai 1999	0,2	23 mai 1999
Paraguay	8 février 1997	0,2	8 février 1997
Pays-Bas	10 août 1968	3,0	4 avril 1998
Pologne	11 novembre 1989	0,5	15 août 2003
Portugal	14 octobre 1995	0,5	14 octobre 1995
République de Corée	7 janvier 2002	0,75	7 janvier 2002
République dominicaine	16 juin 2007	0.2	16 juin 2007
République tchèque	1" janvier 1993	0,5	24 novembre 2002
Roumanie	16 mars 2001	0,2	16 mars 2001
Royaume-Uni	10 août 1968	2,0	3 janvier 1999
Singapour	30 juillet 2004	0,2	30 juillet 2004
Slovaquie	1" janvier 1993	0,5	1" janvier 1993
Slovénie	29 juillet 1999	0,2	29 juillet 1999
Suisse	10 juillet 1977	1,5	8 novembre 1981
Trinité-et-Tobago	30 janvier 1998	0,2	30 janvier 1998
Tunisie	31 août 2003	0,2	31 août 2003
Turquie	18 novembre 2007	0,5	18 novembre 2007
Ukraine	3 novembre 1995	0,2	19 janvier 2007
Uruguay	13 novembre 1994	0,2	13 novembre 1994
Vietnam	24 décembre 2006	0,2	24 décembre 2006

(Total : 65)

Source: http://www.upov.int