

Competition and rules in the seed industry:
Environmental and economic consequences

Les 5^e Journées de Recherches en Sciences Sociales INRA
SFER CIRAD

Adrien Hervouet

21 bis Boulevard Victor Hugo

44200 Nantes

adrien.hervouet@univ-nantes.fr

Competition and rules in the seed industry: Environmental and economic consequences

Adrien Hervouet

Institut d'Economie et de Management de Nantes-IAE,
France

September 6, 2011

Abstract

This study aims to look at the impact of legislation in the seed sector. Two kinds of law exist. The first kind of law is on intellectual property to address a problem of investments of private sector in research and the second is on the commercial rules to correct asymmetric information. The construction of a industrial economic model on product differentiation enable we to take into account the economic consequences of the implementation of intellectual property rights. Then we watch the impact of European legislation with the catalogue. Its implementation has resulted in a decrease in the average welfare of farmers and also a loss of biodiversity.

Key words: Intellectual Property Rights, Plant Breeder's Rights, Catalogue, Seeds, Product differentiation, Asymmetric information, Biodiversity

JEL classifications: D43, D82, K11, L13, Q12

1 Introduction

The aim of this article is to emphasize on the interactions of the seeds market, the intellectual property rights, especially those about plants, and biodiversity. We can say roughly that there are two types of seed or plants in this sector: "free" seeds and "proprietary" seeds. The "free" seeds can be ancient seeds or old proprietary seeds which lost their ownership rights. Proprietary seeds have the characteristic of being proprietary by a natural or legal way of a person or an entity (in most cases they are proprietary of either private seed firms or public research centers).

Different systems of ownership of plants has been much developed during the twentieth century in the worldwide. The reason for this development was a desire to respond to incentive problems in the private sector to innovate in the field of seeds and plants. In the early twentieth century the public sector was very active in this sector because seeds were perceived as a public good (non-rivalry and non-exclusion). However, in order to modernize and increase agricultural yields, the public powers have sought to promote private firms to innovate in the production of new varieties. To do this, it need that living material, is to say seeds or plants, should be in part, the private proprietary of a person or an entity. Beyond the issues of incentives to innovate arising from the establishment of an intellectual property rights system, there is also an information problem. Farmers can't know the quality of the seed before is use it. This problem of asymmetric information can affect the emergence of a market of new seeds, especially seeds from industrial hybridization or others technicals, if there is not a believable signal that demonstrates their good qualities.

Therefore, there are two important legal issues in this sector one hand the rules of commercialization trying to solve informational problems and second hand rules on intellectual property rights with the aim to promote private sector to innovate. Nevertheless, these different legal rules could create problems for the preservation of biological diversity. Some associations bemoan the loss of ancient seeds caused by commercial laws too strict. Moreover, intellectual property rights would push farmers to use only a few varieties of seeds. For breeders, whose views are contrary, intellectual property rights would enhance the biodiversity by creating new varieties.

The second section describes the sector of seed. Firstly, we present the international treaties and conventions which operate on the seed sector. Secondly, in continuation of international treaties, different intellectual property right like patents and plant variety right are described and aslo commercialize rules. And thirdly, we show the market shares of the global market of proprietary seeds.

After that, in the third section we develop a industrial economic model on product differentiation in order to take into account the plant variety right and the commercialize law in the seeds market. Others authors have written about the plant vari-

ety act and its impacts. [Alston and Venner(2002)] and [Carew and Devadoss(2003)] look at PVR (Plant Variety Rights) improve respectively the yield of wheat in USA and the yield of canola in Canada. They don't find a significantly impacts. [Diez(2002)] scrutinize PVR in Spain and its impacts on the incentive to innovate for the private sector. Diez observe a positive and a relevant impact. [Srinivasan(2003)] notes the high concentration of PVR in developed and developing countries. Srinivasan establish that there is a risk for developing countries for the development of the national industries of seeds and a risk of emergence of monopoly prices. In this article we observe the impacts of PVR and commercialize law on the competition. For this, we use an improvement of the Hotelling model realize by [Prescott and Visscher(1977)]. They develop some models where the localisation of products is more or less closed or distant while the main result of [Hotelling(1929)] is a closed localisation of products for two firms. Moreover, the model of [Prescott and Visscher(1977)] can work beyond two firms.

The next section present data which require for the fifth section where we realize an empirical analyze. Under this section, we observe also the impact of the rules and competition on biodiversity. Differents index of biodiversity which are presented by [Polasky and al.(2005)] on the handbook of Environmental Economics enable we to calculate the loss or gain of biodiversity. We find out a loss of biodiversity caused by the catalogue rules and the average welfare of farmers is lower than a situation without presence of asymmetric information. Moreover, the choice of qualities of breeders is around the qualities of local seeds.

2 Institutional Context

2.1 Rules

2.1.1 International treaties

Convention on Biological Diversity (CBD) and International Treaty on Plant Genetic Ressources for Food and Agriculture (ITPGRFA) are two international treaty about respect of biodiversity. For the intellectual property rights on plant there are two main international treaties which are the Trade-Related aspects of Intellectual Property Rights (TRIPS) and the convention of The International Union for the Protection of New Varieties of Plants (UPOV).

CDB was created by the United Nations Environment Programme (UNEP) in Rio de Janeiro in 1992. Its creation enable international community to recognize the threat on the global biological diversity. In order to respond to the decline of biodiversity this convention gives several solutions. Every States have to preserve its own biological diversity by different ways. Firstly the lack of information, about for example species threatened, must be solved by identifying and monitoring the components of biodiversity. Secondly, CBD emphasizes on the conservation of biodi-

versity both in-situ and ex-situ by creation of protected area ecosystem, sustainable use of its components for example. Moreover, States have to promote an increase of public awareness of it.

In comparison of the CDB, the ITPGRFA more specialize in biodiversity of plants and precisely about seeds. This treaty was adopted in 2001 and was promote by the Food and Agriculture Organization. Its aims is to reflect the particular nature of plant genetic resources and to promote conservation of genetic resources. This conservation can be obvious for several reasons. Genetic resources is the raw materials to improve plants and allow breeders, public institutions and farmers to create new varieties to respond the challenges ahead (global warming, severe drought). Then, it take into account farmers' rights (equitable sharing of benefit) as regards the conservation and sharing of their resources (farms seed) and also contribution of farmers in improving resources. The CDB and the ITPGRFA look alike in their aims and in their answers about the conservation of resources.

During the Uruguay Round, it was established a multilateral agreement on intellectual property rights to harmonize international rules and promote the commercialization of protected products by national intellectual property rights. The agreement on Trade-Related aspects of Intellectual Property Rights (TRIPS) has created a comprehensive framework on intellectual property rights.

TRIPS is an agreement grouping the main intellectual protection more particularly of copyright, trade names, geographical indications, industrial designs, patents, patterns of integrated circuits, protection of undisclosed information and anticompetitive practices. It also shows how it should enforce these intellectual property rights.

Regarding the intellectual property of plants and animals that agreement remains hazy. However, one article of the agreement provides a guideline on this point. Thus, Article 27(3)B which is in part restricted to patent, describes how can be implemented protection of intellectual property on life.

Under this article plants and animals which are not micro-organism can be patentable or not. If plants or animals can't patentable in any States then member of WTO must create a *sui generis*¹ system. A combination of two system is also possible.

Therefore, TRIPS allows countries to have the choice on how they will protect the intellectual property on life. This article is in review and there are often conflicts of interest between different countries. Some members want a system completely based on the patent, others an effective *sui generis* system such as UPOV and others countries reject all forms of intellectual protection on life which goes against their traditions.

The UPOV was created in 1961 by the International Convention for the Pro-

¹Sui generis means of its own kind. This term expresses here that members must create a system unique to the living world and to the plants which can be similar to the patent system.

tection of New Varieties of Plants. The last version of this agreement is realized in 1991². It establishes a protection for new varieties of plants which is different of patents.

This agreement clearly defines what are the rights of breeders (person or organization are creating new varieties of seeds or new plants) and also what they must respect to acquire these rights.

In order to acquire Plant Variety Right (PVR), also known as Plant Breeders' Right (PBR), breeders must respect five conditions:

- Novelty,
- distinctness,
- uniformity,
- stability and
- administrative conditions (name of variety, payment of fees)

Novelty is defined by the fact that seeds should not have already been sold or given to somebody before the application of right. Then they must be sufficiently different from other varieties on the date of application (distinction). They must have the same features between them (seeds must be uniform). And finally, after the reproduction or multiplication, their characteristics must stay unchanged (stability). The uniformity is a cross-section criteria while stability is a time criteria.

In order to commercialize a proprietary seed or a seed essentially derived from the protected variety (importation, exportation, donation, sale) we need permission of breeder. This permission is not required for a private use, for different tests, for the research of new varieties, for the output of agriculture except if the aim of output is reproduction of seeds. Is here the main difference with a patent, there is no exception of use for it. Rights last a minimum period of twenty years except for trees and wines where the minimum is twenty five years.

Each application of the same seed is independent from one country to another. The applicant also acquires rights of a "temporary protection". If the seed produced is used between the time of application from the time of obtaining a plant variety right, then the user must comply with the rights that the seed will come from get.

2.1.2 Commercial rules and Catalogue

Two kind of seeds exist in European Union (EU), in one hand regulated seed and in second hand non-regulated seeds. In order to commercialize regulated seeds in EU where we find six groups of varieties (with fodders, cereals, beets, vegetables, potatoes and oleaginous plants)³, a new seed needs a Marketing Authorization Application (MAA). Breeders obtain a MAA when their seeds are registered in the common catalogue. Before that, breeders must register a seed in a national catalogue where the seed pass two tests which are DHS like in the UPOV convention and

²Available on <http://www.upov.int/export/sites/upov/en/publications/conventions/1991/pdf/act1991.pdf>

³Directives 66/401, 66/402, 2002/54, 2002/55, 2002/56, 2002/57

Value for Cultivation and Use (VCU) if it is a crop seed else it passes only DHS test. The VCU criteria watches if there is a improvement in seed quality in relation to those already registered in the catalogue. The improvement of quality is often observe by an increase of yield. Each country of EU can spread this regulation for others seeds that the six groups. For example, in France, non-regulated varieties are only 18⁴. These varieties have to respond to the consumption code. For others, they must be register in the official catalogue.

For several persons, the catalogue is controversial because it stops the commercialization of traditional seeds which can't respond to the DHS criteria whereas, for others persons, provides an "assurance" of quality of commercialized seeds. In, European Countries others catalogues exist for traditional varieties and for varieties of conservation but it is only commercialisable for gardener⁵.

In others countries a registration in a catalogue is not necessary. For the commercialization of seeds in the USA, the Federal Seed Act requieres different standards like a germination rate, a weed rate, etc. In India, with The Seed Act, several varieties are regulated with different standards like in USA except for the farm seeds which don't have standards.

2.1.3 Intellectual Property Rights on plant

Both patent and PVR are intellectual property rights on plant. PVR comes usually from UPOV convention and is more developed in European countries than in Anglo-Saxon countries.

Plant Variety Rights or Plant Breeders' Right

EU has adopted UPOV convention of 1991 in 1994. A european PVR works in all countries of EU and is valid twenty five years or thirty years if the new plant is wine or tree. An exemption for the reproduction of seeds exist for farmers in addition of the research exemption but it's only for some plants (twenty species)⁶.

In the USA, the Plant Variety Act of 1970 has been created for the sexual plants in order to respond to UPOV convention. Farm seeds was authorized without agreement of the breeders before 1994 and it has already been possible for seeds have obtained a PBR before this date.

France is a major protagonist in the UPOV because this is one of its initiators. Therefore, France has adopted the first convention dating from 1961 and revised in 1978. As a result, applicants for PVR either can use national legislation with the

⁴Decree 81-605

⁵Directives 98/95, 2008/62

⁶Directives 2100/94 and 2100/44

convention of 1978 or can use European legislation which responds to the Convention of 1991 (if the breeder wants to export its seeds through the EU will logically use European law). For the national protection, the PVR last a period of twenty five years or thirty years if the new plant is a wine, a tree or a hybrid variety⁷. Currently, there isn't exception for farm seeds in France.

India, unlike the United States and France, is not a signatory to the UPOV. Yet in 2001, it has established an intellectual property rights for seeds similar to those of UPOV⁸. In addition to property rights on new varieties, this law has created 3 others types of intellectual property rights on plants, farmers' varieties, varieties that have already existed and essentially derivative varieties.

As regards the intellectual property rights on new varieties, they has been largely borrowed from those of UPOV. Thus, seeds must respect the DHS criteria for acquiring a PBR and must respect the test of novelty. However, exceptions are larger. The exception of research for new varieties exist and the exception for the production of farm seeds too, farmers can sell their farm seeds except those which are ownership of a breeder. These rights have a term of nine years renewable once for the wines and trees, 6 years renewable up to 15 years for others seeds.

There are also property rights on essentially derivative seeds. These provide better protection for plant breeders' rights because it will take an agreement between the breeder of the new essentially derived variety and the breeder of the variety by which it was derived. The conferred rights is the same as for a new variety. These rights were adopted primarily to protect the public research that has created a lot of varieties.

The rights for the existing varieties have been developed to provide a "reward" for past research. The seed must respect the DHS criteria but not that of novelty. The conferred rights is the same as for a new variety for a maximum of 15 years.

Finally, varieties which are developed by farmers can also be under an intellectual property rights on plants. However, the law is unclear on the conditions to acquire this intellectual property right (the standard DHS does not seem applicable to farm seed because of their extreme heterogeneity) and on the rights that farmers obtain.

Patent

Three global view of patenting of life exist in the world. In many developing countries it's entirely prohibited whereas in some developed countries is entirely authorized. For exemple, in India the patenting of life doesn't exist⁹.

The European Patent Convention prohibits the patenting of plant varieties. However, the EU gives the possibility to patent processes that affect the biological mate-

⁷Articles L623 of "Code de la propriété intellectuelle"

⁸The Protection of Plant Varieties of Farmers Rights Act

⁹However, according to international agreements if the country is an exporter of farm goods, it must comply with some regulations of the importing country [Varella(2006)]

rial. Directive 98/44 recalls that plant varieties are not patentable, but it also gives indications on that which is patentable. Thus, an invention that has a connection with biological material or a process for producing the biological material may be patentable. However, The new process must work on several varieties, it must be independent of the new variety. On top of that, biological material already existing is patentable if it is created by a technical process. For example, the BT gene, which confers resistance to some insects, can be inserted into different varieties of plants, thus BT gene is patenting. A patent is usually a way to protect its discovery without any exceptions. However, regarding as the patenting of life in the EU, researchers have access to varieties which have a patented technical process. Thus, the protection afforded by patents is comparable to the protection of a plant variety right. Finally, the exception provided for in PVR as regards the reproduction of some plants species is also contained in the directive on the patenting of living in Directive 98/44.

The concept of patenting of life has been introduced in U.S. law since 1930 with the Plant Patent Act which is a part of the Patent Act. However, in 1930, only the asexual species could be patentable. Unlike the European Union law there are no exceptions of reproduction for researchers like for farmers. Thus, seed companies have a total monopoly on commercialization and reproduction of their seeds either for profit-making or not. However, seeds must respect several conditions as an elaborate description of the variety. In 1980, the Supreme Court has allowed all forms of patenting of living because, for it, all creations or inventions made by man can be patented¹⁰. The use of utility patent for a plant variety has been approved by the Supreme Court in 2001 with a case between Pioneer and JEM Ag Supply where Pioneer complain against JEM Ag Supply because JEM Ag Supply sold proprietary seed of Pioneer where these seeds are ownership of Pioneer by an utility patent. The defense of JEM Ag Supply was a seed can be "proprietary" only under the PVPA or the PPA. The Supreme Court ruled that the PPA and the PVPA were not the only way to get the federal monopoly on the comercialization, reproduction or use of a plant variety.

2.2 Market shares

In 2007, the seed market worths 26 billion of US dollars according to the ETC group. The market share of the top ten of firms is 55% in the global market and 67.2% in the market of proprietary seeds (Table 1). Monsanto is the company with the highest market share (22,6%) although in the mid-90s Monsanto was not in the top ten of the global firms and these represented 37% of commercialize seeds. Thus, there is a raise of concentration in this market. The Herfindhal and Hirschmann

¹⁰Following the Chakrabarty case, on patenting of micro-organism

Index (HHI) assesses if there is a risk of presence of market power.

$$I = \sum_{i=1}^n s_i^2 * 10000,$$

where s_i is the market share of firm i . If the index is below 1000 there is no risk of market power. If the index is between 1000 and 2000 there is a risk of presence of market power but it is quite weak. Beyond 2000 the market is highly concentrated and the risk is very high.

Table 1: Market share in 2007 of breeders

Breeders	Sales \$ millions	Market share
Monsanto (US)	4,964	22,56%
DuPont (US)	3,300	15,00%
Syngenta (CH)	2,018	9,17%
Groupe Limagrain (FR)	1,226	5,57%
Land O' Lakes (US)	917	4,17%
KWS AG (DE)	702	3,19%
Bayer Crop Science (DE)	524	2,38%
Sakata (JAP)	396	1,80%
DLF-Trifolium (DK)	391	1,78%
Takii (JAP)	347	1,58%
Top 10 Total	14,785	67,20%
Others	7,215	32,80%

Source : ETC Group

To calculate the concentration of the sector it is assumed that 32.8% representing other seed companies are divided into units, each units worth 1% of the market share. Here $I = 922.73$, therefore in the global market of proprietary seeds there is no risk of market power. However, in the market of soybean in Brasil, in 2002, $I = 1814,26$ ¹¹ without take into account agreement between Monsanto and the others firms about the round up ready soybean. Therefore, in market segment we should find a risk of market power.

3 Theoretical Model

3.1 Farmers behaviour

We follow the model of example 3 of [Prescott and Visscher(1977)] but we replace consumers by farmers, hence the demand system of seed is given by the behaviour

¹¹Data provides of [Varella(2006)]

of farmers. They have a complementary production function with two inputs which is as follows :

$$Y = \phi \text{Min}[\alpha S.\epsilon; \beta L.\epsilon], \quad (1)$$

where S is the amount of seed, L is the area of Land, α and β are parameters of productivity, ϕ is also parameter of productivity but is equal to the Simpson index of diversity and ϵ is a random process with a mean μ and a variance σ^2 . For seeds μ shows the germination rate (ex. 90%) and σ^2 the variation of this germination rate (ex. 0,0025), moreover σ_2 insert uncertainty for farmers. The Simpson index of diversity is chosen in order to take into account the biodiversity as a variable which have an impact on the productivity of farmers.¹²

It is assumed that the area of land used by farmers is heterogeneous and distributed uniformly on the range $[Lmin; Lmax]$. Given the perfect complementarity between seeds and lands, the seed demand of each farmers is itself heterogeneous and distributed uniformly on the range $[Smin; Smax]$. Furthermore it is assumed that :

$$Y = \phi \alpha S.\epsilon \quad (2)$$

Depending on the random process, farmers maximise their expected profit with the following equation :

$$E[S] = (P\phi\alpha E[\epsilon] - w)S, \quad (3)$$

where P is the purchase price of consumers for the farmers output, $E[\epsilon] = \mu$ and w is the purchase price of seeds.

To take into account the risk aversion of farmers we take the mean-variance criterion also known as the Markowitz criterion and their welfare become:

$$F = (P\phi\alpha E[\epsilon] - w)S - \theta P^2 \phi^2 \alpha^2 S^2 V[\epsilon]$$

$$F = S((P\phi\alpha E[\epsilon] - w) - \theta P^2 \phi^2 \alpha^2 S V[\epsilon]), \quad (4)$$

where θ is the ratio to take into account the risk aversion and $V[\epsilon] = \sigma^2$. Indeed, for a given variance, the stronger θ become, the lower welfare it is.

Farmers are indifferent between two kind of seeds (i and j) if and only if welfare are equal :

$$V_i - AS\sigma_i^2 = V_j - AS\sigma_j^2, \quad (5)$$

where $V_n = P\phi\alpha\mu_n - w_n$ and $A = \theta P^2 \phi^2 \alpha^2$.

After rearranging (5) the amount of seed is function of prices (on the inside of V_i) and qualities (μ_i) such as the modelisation of [Bresnahan(1987)] :

$$S = \frac{V_i - V_j}{A(\sigma_i^2 - \sigma_j^2)} \quad (6)$$

¹²Simpson Index is outlined in Annex A

The product i is strictly preferred when $F_i > F_j$, using (4) we obtain that i is chosen if :

$$\begin{cases} S < \frac{V_i - V_j}{A(\sigma_i^2 - \sigma_j^2)} & \text{if } \sigma_i^2 > \sigma_j^2 \\ S > \frac{V_i - V_j}{A(\sigma_i^2 - \sigma_j^2)} & \text{if } \sigma_i^2 < \sigma_j^2 \end{cases}$$

Farmers who choose i are thus farmers with seed quantity :

$$\frac{V_{i-1} - V_i}{A(\sigma_{i-1}^2 - \sigma_i^2)} < S_i < \frac{V_i - V_{i+1}}{A(\sigma_i^2 - \sigma_{i+1}^2)}, \quad (7)$$

when $\sigma_{i+1}^2 < \sigma_i^2 < \sigma_{i-1}^2$.

Therefore, given the uniform distribution of S , the total demand for seed i is :

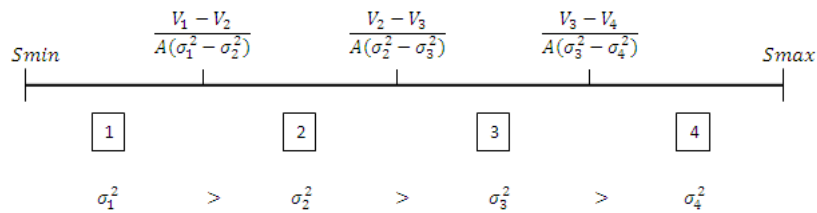
$$S_i = M \begin{cases} \left(\frac{V_i - V_{i+1}}{A(\sigma_i^2 - \sigma_{i+1}^2)} - S_{min} \right) & \text{if } i = 1 \\ \left(\frac{V_i - V_{i+1}}{A(\sigma_i^2 - \sigma_{i+1}^2)} - \frac{V_{i-1} - V_i}{A(\sigma_{i-1}^2 - \sigma_i^2)} \right) & \text{if } i = n \\ \left(S_{max} - \frac{V_{i-1} - V_i}{A(\sigma_{i-1}^2 - \sigma_i^2)} \right) & \text{if } i = N, \end{cases}$$

where M is a parameter of market size.

For example, we make a representation in figure 1 where there are 4 different seeds. Depending on the scale of each seed demand, 3 thresholds appear which mark the boundaries of each seed demand. Here, the demand of the seed type 2 is :

$$Q_2 = M \left(\frac{V_2 - V_3}{A(\sigma_2^2 - \sigma_3^2)} - \frac{V_1 - V_2}{A(\sigma_1^2 - \sigma_2^2)} \right) \quad (8)$$

Figure 1: the boundaries of each seed demand



3.2 Breeders behaviour

The resolution of this model is done in two steps. Firstly, the subgame in prices is the maximisation of profits in order to find the prices of seeds. Secondly, we find

the quality of seeds, μ_i , with the equalization of the profit rates.

Firstly, we describe the subgame in prices. There is two kind of seed industries in this model. The first kind of industry produce local seeds which is not the property at anyone. Therefore, in this market segment, the pure and perfect competition perform here. Indeed, the profit is :

$$\pi_i = (w_i - c_i)S_i \quad (9)$$

where w_i is the sale price per unit of seed, c_i is the marginal cost per unit of seed and S_i is the amount of seed which is produce by the firm. Hence, for these firms $w_i = c_i$. We assume that seeds of this company are the lowest uniformity, therefore the highest variance (σ_i^2).

The second kind of industries are the owners of their varieties of seeds. The solution of this model is found thanks to the Bertrand-Nash equilibrium where prices w_i are strategic variables. Assuming characteristics μ_i and σ_i^2 of each variety of seeds is given and fixed to each owner, the profit function of the owner of variety i for each period (harvest periodically) is :

$$\pi_i = \text{Max}_{\{w_i\}} \{(w_i - c_i)S_i\}, \quad (10)$$

where S_i is function of w_i and we have $N - 1$ equations for $N - 1$ unknowns. Therefore, the first order condition is :

$$\frac{\partial \pi_i}{\partial w_i} = S_i + (w_i - c_i) \frac{\partial S_i}{\partial w_i}, \quad (11)$$

and we obtain reaction functions $w_i^*(P, \theta, \alpha, c_i, \mu_{i-1}, \mu_i, \mu_{i+1}, \sigma_{i-1}^2, \sigma_i^2, \sigma_{i+1}^2)$.

In the second step the assumption of a fixed μ_i is suppressed. It is rather assumed that variety owners have to incur a fixed cost CF_i in order to be able to offer a new variety. This fixed cost has three components. The first and second component, $B * \mu_i$ and $C * (\sigma_i^2)^{-1}$, is the R&D cost of obtaining a new variety with characteristics μ_i and σ_i^2 . The third component, D , is the cost to obtain a PBR. The profit function (10) is the return from the fixed cost CF_i . The rate of return of this investment is given by the ratio on the left hand side of equation (12):

$$\frac{(w_i^* - c_i)S_i}{CF_i} = \eta, \quad (12)$$

if capital is perfectly mobile, the absence of arbitrage possibility that prevails at market equilibrium for assets implies that this rate of return must equal the rate of return η obtained for any other investment in the economy. Equation (12) corresponds to this condition for variety i. Solving the system of equation (12) for all varieties with respect to their μ_i yields the characteristics of seeds varieties at market equilibrium. The other characteristic of seeds, σ_i , has already been fixed in respect of DHS criteria.

4 Data

Parameters numerical values are shown in Table 1. They were worked out thanks to data from GNIS, RICA, *la banque de France* and www.bnains.org or chosen. Price, P , productivity, α , marginal cost, c_1, c_2 and S_{max}, S_{min} are values only usable for the wheat.

Table 2: Variables used

		Parameters	
	worked out	chosen	
P	0.19€/kg	μ_1	0.95
α	59.29	σ_1^2	0.002
θ	0.0036	σ_i^2	$\sigma_{i-1}^2 - pas$
c_1	0.209€/kg	pas	0.0003
c_i	0.52€/kg	CF	$1B. * \mu_i + 1M. * (\sigma_i^2)^{-1} + 5000^*$
S_{min}	140kg	A	$P^2 * \alpha^2 * \theta$
S_{max}	16800kg		0.4568

*B. means billion, M. means million

For one hectare farmers need 140kg of seeds and need 16800kg for 120 hectares (the cereal average area of specialist farms in cereals, oilseed and protein crops in France is 67 hectares). c_1 is the marginal cost of farm seeds and c_i for proprietary seeds. Parameters μ_1, σ_1 which are known because local seeds are ancient and CF is assumed. The variance, σ_i^2 , is function of σ_{i-1}^2 and the difference between σ_i^2 and σ_{i-1}^2 is a step which depends on distinction rule (here it is called “pas”). There are 69770 farmers specialist in cereals, oilseed and protein crops production in France, thus the market size is assumed to 70000¹³.

The calculation of the prime-risk enable we to find θ :

$$prime = V[CAC40] * \theta$$

and

$$r = E[CAC40] - prime$$

Hence

$$\theta = \frac{E[CAC40] - r}{V[CAC40]},$$

where $E[CAC40]$ is the yearly average growth of CAC40 index on the last twenty years, $V[CAC40]$ its variance, r is average of legal interest rate on the last twenty years.

¹³RICA take into account only professional farmers, for more information visit <http://ec.europa.eu/agriculture/rica/>

5 Empirical Results

Three situations has been studied. The first situation consider three industrial plant breeders and one firm which produce "local" seeds. Local seeds have the properties of farm seeds. Therefore, this firm is in pure and perfect competition such as explain in section 3 and does not have a choice of prices and qualities for its seeds. The three others breeders are in Bertrand competition.

The second situation is in presence of informational asymmetries. The lack of information about characteristics of seeds causes a mean of prices between local and proprietary seeds. As a consequence breeders don't commercialize their seeds and there are only local seeds.

In a last case, the catalogue which gives informations about characteristics of seeds prevent the local firm from commercializing its seeds because local seeds can't respect the DHS criteria. The DHS criteria and the VAT criteria must be respect for the wheat or other plants to register in the catalogue and if the seed does not register in the catalogue, the breeder can't commercialize it.

Subsequently of the choice of the fixed cost (linear form), the best level of quality is its maximum, $\mu = 1$ (100% of germination) because the profit is a polynom and the fixed cost have a linear form. Thus, we search the number of firm in order to obtain a logical profit rate. With the data of section 4 we obtain 4 firms where the three industrial breeders have a profit rate to 4.26% for the situation 1 and 5.33% for the situation 3. This increase is due to removal of local seeds.

Table 4: Economic results

Table 3: Choice of qualities and prices

	Breeders		Breeders	
	Sit.1	Sit3	Sit.1	Sit3
μ_1	0.95	.	q_1	$1.02 * 10^8$
μ_2	1	1	q_2	$3.85 * 10^8$
μ_3	0.94	0.95	q_3	$3.93 * 10^8$
μ_4	0.85	0.86	q_4	$2.86 * 10^8$
w_1	0.209	.	pi_1	0
w_2	0.696	0.775	pi_2	$6.77 * 10^7$
w_3	0.7	0.705	pi_3	$7.05 * 10^7$
w_4	0.781	0.79	pi_4	$7.48 * 10^7$
			CF_2	$1.59 * 10^9$
			CF_3	$1.66 * 10^9$
			CF_4	$1.76 * 10^9$

The table 3 show the choice of quality for the two breeders where the second breeder chooses the maximum quality and the third and the fourth breeders choose a weaker quality of germination (0.94 and 0.85) than local seeds for the first situation. It is similar in the third situation. The decrease is the consequence of the assumption

of equality profit rates. The price, w_3 , of the third breeder is higher than w_2 because of a better uniformity which means a smaller variability ($\sigma_3^2 < \sigma_2^2$). The profit and the fixed cost is also higher for the third breeder than the second breeder because of a higher prices and a smaller variability (Table 4) for the first situation. The third situation enables the second breeder to increase its selling price w_2

Table 5: Welfare and Biodiversity

	Farmers		Biodiversity	
	Sit. 1	Sit. 3	Sit. 1	Sit. 3
<i>global welfare</i>	27847.9	27834.8	Number of species	4 3
<i>welfare₁</i>	5785.62		Simpson Index	0.683 0.626
<i>welfare₂</i>	22678.3	13275.9	Shannon-Wiener Index	1.303 1.087
<i>welfare₃</i>	34764.4	31701.4		
<i>welfare₄</i>	33193.5	36284.4		

The average welfare of farmers is presented in table 5, the global average welfare is higher in the situation 1 than the situation 3 because of the exclusion of the local seeds. The average welfare of farmers using seeds of the third breeder is weaker than those using seeds of the second breeders because of a weaker germination rate ($\mu_3 < \mu_2$).

With this modest example we show that the catalogue have an impact on the loss of biodiversity. Indeed the assement of three index of biodiversity (table 5) present a loss of biodiversity when the catalogue prevent the local industry from commercializing the local seeds (situation 3).

The second situation is not presented in the tables. Only local seeds which are pure and perfect competition are in the market. Here, there would be a decline in biodiversity because one type of seeds is present and also a very sharp drop in the global welfare of farmers that would be 19700.2.

6 Conclusion

After presenting various laws about seed sector has been tested a model that directly takes into account one problem of this sector. The development of new varieties of seeds requires an improvement in the property rules due to the cost of innovation. This creates a competitive problem which is taken into account by the industrial economic model on product differentiation. We look at also the asymmetric information. This is corrected, in the European countries, by the catalog. In the last section we seek impacts on our model of the catalog firstly by an economic point of view with the welfare of farmers and the benefit of breeders and secondly by looking at biodiversity impacts

We observe that the choice of qualities of the industrial breeders is around the quality of local seeds. One of industrial breeders have its seed with a better germination rate than the local seed while the others industrial seeds have a lower germination rate in the first situation. Moreover, there is a loss of welfare of farmers with the implementation of catalogue rules but the worst case is the situation of asymmetric information non-corrected (situation 2). Finally, the catalog have a negative impact on the biodiversity. Hence, according to this model, it would be better to build a credible signal other than the catalog (or reform it) because it prevents ancient seeds to continue to exist. There is a dual negative impact, both on the welfare of farmers and biodiversity.

A result of this model has not yet been discussed. According to this, farm seeds are chosen by very small farm (a farm with a small land area), while industrial seeds are chosen by all other farmers. We can see a large difference in terms of intellectual property rights on plant between developing countries and developed countries may be because the average farm size is very different between the two kind of countries. The developing countries having still a lot of small farms have a large production of farm seeds while farmers in developed countries are much pushed to buy industrial seeds. The modeling also gives this result because the risk aversion of farmers involves that the variability of the seed has a greater impact for large farms than small farms. Futhermore, it would be interesting to try this model with others crops than the wheat in order to look if the consequences of the catalog on this model would be similar.

A Some index of biodiversity

A.1 The Simpson Index

$$D = \sum_{i=1}^n p_i^2,$$

where $p_i = n_i/N$, n_i is the total number of units for one species and N is the total number of units for all species. D is called the Simpson Index. The meaning of this index is the probability that two species randomly chosen are the same. Therefore, when $D = 1$ there is only one species and the diversity is maximum when $D = 0$.

$$E = 1 - \sum_{i=1}^n p_i^2,$$

where E is called the index of diversity. It is the probability that two species randomly chosen are different.

In this article, in order to realize the modelisation, the chosen index is the index of diversity because it is easier to make sense than the Shannon-Wiener index.

A.2 The Shannon-Wiener Index

$$H = - \sum_{i=1}^n p_i * \log p_i,$$

where H measure the difficulty to identify the next species. This index derive from information theory.

References

- [Alston and Venner(2002)] J.M. Alston and R.J. Venner. The effects of the us plant variety protection act on wheat genetic improvement. *Research Policy*, 31(4): 527–542, 2002.
- [Carew and Devadoss(2003)] R. Carew and S. Devadoss. Quantifying the contribution of plant breeders' rights and transgenic varieties to canola yields: Evidence from manitoba. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 51(3):371–395, 2003.
- [Diez(2002)] MCF Diez. The impact of plant varieties rights on research: the case of spain. *Food Policy*, 27(2):171–183, 2002.
- [Srinivasan(2003)] C.S. Srinivasan. Concentration in the ownership of plant variety rights: Some implications for developing countries. *Food Policy*, 28:519–546, 2003.
- [Prescott and Visscher(1977)] Edward C. Prescott and Michael Visscher. Sequential location among firms with foresight. *Bell Journal of Economics*, 8(2):378–393, 1977.
- [Hotelling(1929)] H. Hotelling. Stability in competition. *The economic journal*, 39 (153):41–57, 1929. ISSN 0013-0133.
- [Polasky and al.(2005)] S. Polasky and al. The economics of biodiversity. *Handbook of environmental economics*, 3:1517–1560, 2005.
- [Varella(2006)] M.D. Varella. Point de vue propriété intellectuelle et semences: les moyens du contrôle des exportations agricoles par les entreprises multinationales. *Revue internationale de droit économique*, 20(2):211–228, 2006.
- [Bresnahan(1987)] Timothy F. Bresnahan. Competition and collusive in the american automobile industry : The 1955 price war. *The Journal of Industrial Economics*, Vol. 35(4):457–482, jun 1987.