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Abdelhakim Hammoudi, Huong Hue Nguyen, Louis Georges Soler

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GM/non GM Coexistence and Admixture Monitoring in Chains

Huong Hue NGUYEN[1], A. Hammoudi, , L-G. Soler

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Abstract

In this paper we develop a framework of analysis for the main economic issues that arise in the pursuit of system of labelling for GM and non-GM products under the introduction of GM products. This model represents a vertical relationship with three stages in the supply chain: manufacturer, retailer and final consumers. Co-mingling may occur between non-GM and GM products: contaminated non-GM products may be sold on the final market. To avoid this, the retailer induces his supplier to make tests before the sale. The retailer accepts lots if the GM content is under the public labelling threshold. Above the threshold, lots are sold by the manufacturer on a GM market. Public regulation takes the form of the purity threshold or labelling threshold. The impact of the firm's strategies takes the form of the effort (segregation measures) and the sampling size set up by the supplier/manufacturer. The paper aims to determine under what conditions demand for non-GM products can be satisfied, given that upstream coexistence generates admixture risks, thereby resulting in (i) additional segregation and control tests and (ii) a risk of downgrading for non-GM due to this potential mixing. With this model, not only are the prices and quantities of commercialized non-GM products analyzed, but also the level of contamination of non-GM products throughout the supply chain. An analysis is proposed to evaluate impacts of private and public policies on stakeholders' trade-offs and on the GM/non-GM coexistence.

Key-words: Genetically Modified Products, Vertical Relationship, Threshold Labeling, Admixture Risks, Food Chains

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[1] Doctorante à Inra Loria et Université de Paris 2

I. Introduction

A high fraction of consumers[2] in the EU is opposed to the development of GMOs, while producers and manufacturers associations[3] hope to use advances in biotechnology in order to maintain their competitiveness in international markets. To respond to these expectations, the European public authorities have implemented a regulatory plan which aims to guarantee the freedom of choice, for both producers and consumers, whether or not to use GM products. This regulation focuses particularly on:

- A legal framework governing GM cultures and their dissemination on the territory

- A compulsory labelling for products destined for human and animal food if their GM content is above the threshold of 0.9% (178/02/EC).

- Public control rules on the relevance of the information on products sold in the market and GM operators' compliance with documentary traceability requirements, with an obligation to biotechnology firms to provide methods for detection, identification and quantification of GMOs

Despite this regulatory system, conflicts between different stakeholders are important and the conditions for GM products development remain uncertain. Besides environmental issues (impacts on biodiversity, development of resistant varieties…) which are outside the field considered here, an important issue highlighted by GM opponents is contamination question and their impact on the possibility of continuing to serve a demand for non-GM products since GM products may have an important place in the market.

At upstream levels, the contamination risk of conventional or organic crops by spreading pollen from GM crops implemented on neighbouring fields constitute an important preoccupation. If such contaminations occur, they can in fact, lead the decommissioning of conventional or biological products and lead to economic losses for concerned producers and manufacturers. Regarding the contamination risks in the field, the European Regulation (Directive 2001/18/CE) has outlined a framework to make possible coexistence at producer's level, which is responsible for the member nations to implement measures to protect the non-GM, conventional or organic crops, and to define responsibility rules and financial compensation terms in the event of production loss.

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[2] Evenson, R.E. and V. Santaniello, "Consumer Acceptance of Genetically Modified Foods", Wallingford, UK, CABI Publications, 2004

[3] Leprince-Benetrix F., Poeydomenge C., "Study and analysis Coexistence of GM and non-GM sectors : additional costs", Perspectives agricoles n°327, octobre 2006

At downstream levels, faced with the same question, co-mingling may occur because of use of common equipment to conventional and GM products, at the storage, transportation and industrial process levels. These risks are subject to the general provisions and are based on the concept of "fortuitous mixing". The European Commission has proposed thus to consider that a small quantity of GM ingredients in non-GM product (hence not labelled) can be accepted without imposing GM labelling mandatory if its presence is unintentional and technically unavoidable. The firms must take the necessary and set up reasonable efforts to avoid the presence of GM ingredients in not labelled products. The traceability requirement completes this regulatory system and controls in large part documentary, aim to certify the fortuitous nature of possible contaminations found.

However a problem lies in assessing this fortuitous character, to the extent that even unintentional, the risks of mixing GM and non-GM are necessarily influenced by the segregation measures adopted by firms, which are based on arbitrage between the economic costs of this segregation and purity of the product expected by the market. The important question highlighted is[4]: demand for non-GM products can be supplied, and under which conditions if costly segregation measures may affect the price and quality of non-GM products?

Economic research has been conducted for several years to evaluate the impact of GM productions on food chains and evaluate the possible effect of various public and private action[5]. A first block of works focuses on the GM labelling issue and its effects on offer and different actors' gains. For example, Fulton and Giannakas (2004) have proposed a model of vertical relationship between biotechnology firms (which create the GM seeds), producers and consumers. They compare profits and welfares under different labelling regimes, obligatory or voluntary, and show how the effects of introduction of GM products depend on market power of biotechnology firms, consumer aversion to GM product and segregation costs under labelling regime. These authors suggest that the product identity preservation induces costs for GM producers. However, these are always higher for non-GM producers than for GM producers because of non-GM products identity preservation efforts. An increase of these costs reduces producers' profit, but increases the GM seeders' profit.

Giannakas and Yiannaka (2006) propose a model of vertical relationship with three products: a conventional product, a genetically modified product and a biological product (organic). They analyse the consumers purchasing decisions and their welfare under the introduction of

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[4] Lapan & Moschini, 2004 ; Moschini & Lapan, 2006
[5] Divers travaux ont porté également sur les comportements des consommateurs face aux OGM (see for instance…) ou sur les effets des OGM sur les échanges internationaux ou les pays en développement (voir, par exemple,..). Nous laissons de côté cette partie de la littérature dans la présente recension.

labelling policy. The effects on the market and the welfare depends on segregation costs related to mandatory labelling, consumer's aversion/preferences towards the GM products or organic products and supply chain structure. The lack of mandatory labels on GM products may benefit to biological products when segregation costs are low. If these costs are high, labelling of GM products improves organic sector situation, but can lead to the exclusion of conventional products and reduce the total consumers' welfare.

Second series of works emphasize the obligatory mandatory labelling, but focuses more specifically on the threshold level imposed by the public authorities. For example, Moschini and Lapan (2006) study a supply chain consisting of producers, proccesor and final consumers, taking into account explicitly the accidental mixing of GM and non-GM products at the manufacturer's level. The public regulation takes the form of labelling threshold. In general, it appears that a very low threshold causes the disappearance of non-GM products from the market. Furthermore, these authors underline the existence of optimal threshold for producers and consumers; consumers prefer a more lax threshold than do producers. In another article, Lapan & Moschini (2004) consider another form of public regulation – the penalty paid when the GM ingredients in non-GM product sold in the market is above the threshold imposed. Drawing attention to the impacts of tests frequency and penalty level on GM/non-GM coexistence, the authors show that non-GM production is retained only if testing probability carried out by the public authorities is high. A high penalty may encourage the production of non-GM products, but it is not sufficient measure to maintain it.

Using different methodologies, a third set of papers focuses on segregation measures and on testing strategies that aim to preserve the identity of non-GM products in the supply chain. In Wilson & Dahl BL (2005) and William W. Wilson, Bruce L. Dahl, & Eric Jabs (2007), the authors develop a stochastic optimization model in order to calculate the optimum strategy in terms of tests location, frequency and intensity, taking into account the costs of tests and products displacements. On this base, they calculate the bonus necessary to make possible the GM/non-GM coexistence in the chain. The factors taken into account are risks of fortuitous mixing, tests efficiency, and accuracy of producers' statements on raw material characteristics.

In short, all works that we have today can be divided into two approaches types: on the one hand, papers emphasizing interactions between actors within vertical structure, in which the contamination risks are considered exogenous; on the other hand, works focused on the segregation strategies within supply chain, in which the strategic behaviour are not formally integrated.

This article aims to integrate into vertical relationships study the question of risks of contamination considered, endogenously, as result of strategic interactions within the food chain. In this context, we propose a model of vertical relationship to analyze coexistence between GM and non-GM products in the supply chain consisting of a manufacturer that can produce two types of products and a retailer that focuses solely on the demand for non-GM consumer[6].

The objective is to establish under which conditions the demand for non-GM products is served, as long as the upstream coexistence generates risks of contamination between two types of products, and consequently, on the one hand, segregation extra-costs the risk of disappearance of non-GM products because of potential contamination. The manufacturer must choose the quantities of GM and non-GM products ordered from the farmers, knowing that the higher the purity requirement of non-GM product is, higher the GM and non-GM raw materials prices differential is.

At downstream leval, he sells GM product on the market where he plays simply the role of *price taker* and non-GM product to the retailer specialising on the non-GM market. The retailer induces the manufacturer to make tests on the non-GM products before the sale and the negotiation deals with the intermediate price and tests intensity. The manufacturer defines itself segregation effort level set up in the industrial process[7].

Within this vertical relationship framework, we not only try to analyze the prices and quantities of non-GM commercialized products, but also the level of contamination of GM and non-GM products throughout the supply chain. The GM product quality is defined by the regulatory labelling threshold, but this quality is obtained in an uncertain manner because of the risk of contamination at the manufacturing level (or storage, transport…). The model's originality lies precisely in the endogeneisation of contamination risk where these are considered as the result of the actors' decisions, through the choice of segregation measures levels and testing and analyzing application rules.

Section II in the article was devoted to presentation of the model. Section III highlights the main results. Section IV is devoted to the discussion of these results and specifies the issues that should be investigated in further research

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[6] Majority of European retailers have made thus a commitment not to commercialize GM products, at least as for their own brands.
[7] Industrial process: heat treatment, chemical treatments…

II.   Model

We analyze the GM/non-GM crops coexistence and the impact of the public policies and the private strategies on this one by using a two-sided (upstream and downstream) oligopoly model of imperfect competition. The downstream is formed of only one retailer and his consumers on the non-GM market, and the upstream of a GM/non-GM manufacturer. In this arrangement, there are two products at the manufacturer level (GM and non-GM), and only one product at the retailer level (non-GM) (*figure 1*). We study then only the contractual relation regarding non-GM products between the manufacturer and the retailer: the manufacturer must decide the GM and non-GM quantities to buy from farmers by anticipating the retailer's best choice of quantity sold on the final market and must negotiate the intermediate selling price with this one.

Suppose that the regulatory regime applied in our model is the mandatory positive labelling of the GM products in the European Union. The European regulation imposes that all products containing, consisting of or derived from an ingredient with more than **s%** GMO content (*s=0.9%* now) must be labelled as follows: "*This product contains genetically modified organisms X*" or "*This product is produced from genetically modified organisms*". The labelling threshold or level of purity *s* plays an important rule not only for the consumers, but also for the manufacturer and the retailer. For the first, it helps them to distinguish between GM products and non-GM products and to choose the products with full knowledge of the facts. For the lasts, it has an important impact on their commercial activities. Indeed, the more the threshold s is high, the more the non-GM demand is small (decreasing relation),… Suppose in addition that in our model, the raw materials bought by the manufacturer from farmers and the finished products sold on the final market by the retailer face up to the same threshold for the accidental presence of GM material. In other words, the upstream agricultural producers and the manufacturer and the downstream retailer react to the same labelling level *s*.

The possibility of accidental co-mingling between GM and non-GM products, and the segregation measures which can control such a contamination will be raised. In our model the accidental co-mingling can occur at the manufacturer level. In consequence, contaminated non-GM products may be sold on the final market. To avoid this, the retailer induces his supplier to make tests before the sale. The retailer accepts lots if the GM content is under the public labelling threshold. The contaminated lots (their GM content is above the public threshold *s*) are sold by the manufacturer on the GM market. The segregation measures take the form of an effort set up by the manufacturer. The treatment of these assumptions involves different non-contamination probabilities φ corresponding to different non-GM flows in the model: $0 \leq \varphi =$

P $(X<s) \leq 1$ where X is GM characteristic of the product and s is the labelling threshold $s \in [0,1]$.

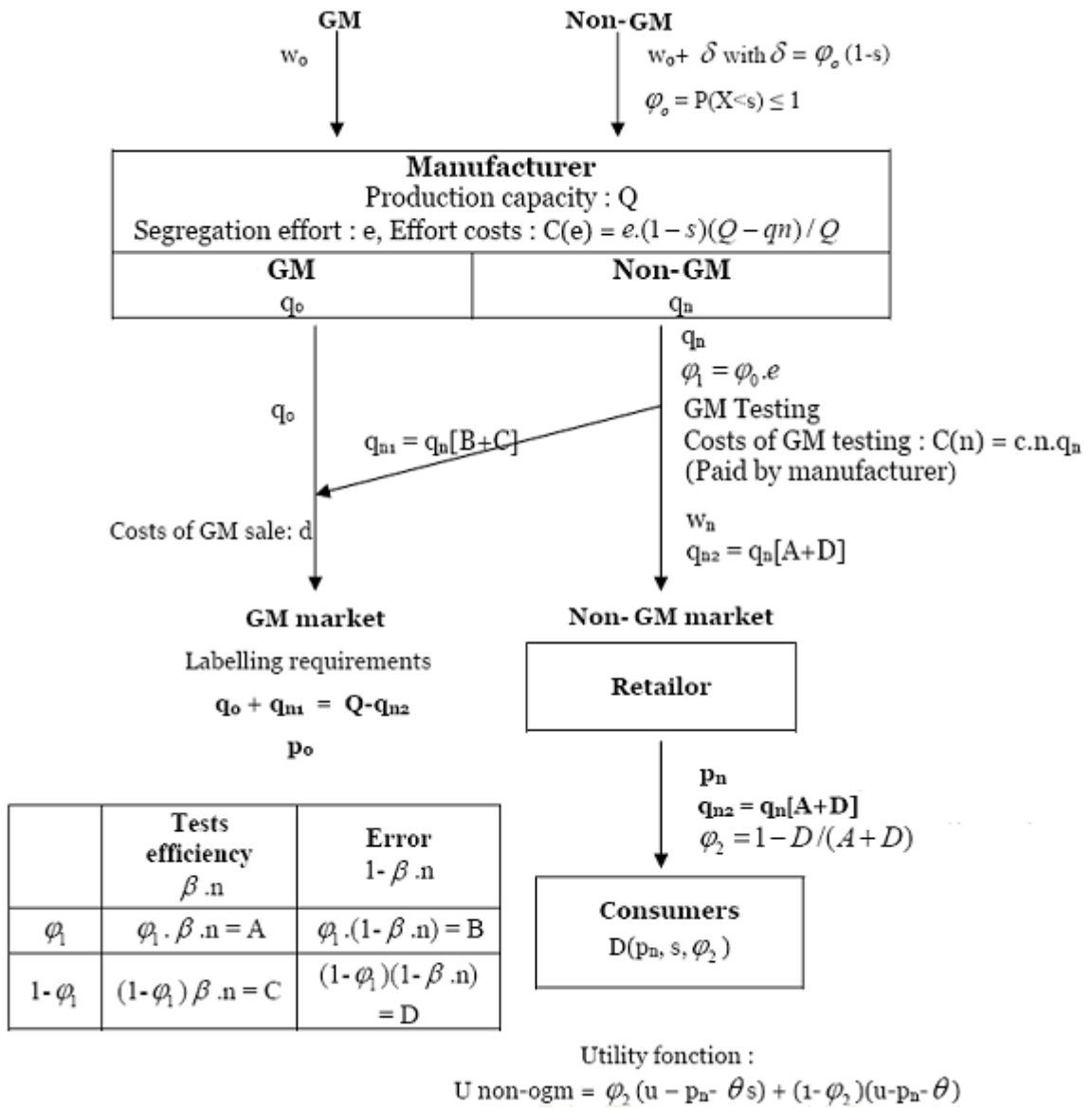Figure 1 : Model

II.1. Manufacturer - M

The manufacturer buys from farmers GM raw materials with a quantity **q_o** at the price **w_o** and non-GM with a quantity **q_n** at the price **w_o** + δ according to his total storage capacity Q such as **Q = q_n + q_o** (condition: q_o < Q). Consider φ_0 the conformity probability ou non-contamination probability of non-GM raw materials: $\varphi_0 \in [0,1]$. Suppose that $\delta = \varphi_0.(1-s)$, the GM and non-GM raw materials prices differential δ is positive, increasing in φ_0 and decreasing in s, which means that non-GM raw materials are sold at a higher price than GM raw materials all the more so as the raw materials non-contamination probability is high and that the labelling threshold is strict.

Suppose that the contamination risk in the process can occur at the manufacturer level. To avoid and/or control this, the manufacturer has to set up co-existence measures or segregation precautions defined by the parameter e: $e \in [0,1]$. In first approach, e has an increasing influence on the effort cost and thus on the manufacturer's production costs : the higher e is, the higher effort cost and production costs are and conversely. The cost of segregation measures is defined by:

$$C(e) = e.(1-s).q_0 / Q$$

After the transformation of the raw materials into finished products, the manufacturer sells GM products on the GM market where all products must be labelled with a quantity **q_o** at the price **p_o**. Due to this sale, he has to incur an unit cost *d* which is labelling cost. Regarding his **q_n** non-GM finished products, they are subjected to the tests in response to the retailer's request before the sale. These products' conformity probability is φ_1 : $\varphi_1 \in [0,1]$ which depend increasingly on the raw materials' non-contamination probability φ_0 and the segregation effort carried out by the manufacturer *e* : the higher φ_0 and *e* are, the higher φ_1 is. We suppose that φ_1 is expressed as follows :

$$\varphi_1 = f(\varphi_0, e) = \varphi_0.e$$

Indeed, if φ_0 and *e* are high, φ_1 could tend towards 1, i.e. non-GM products avoid contamination. On the contrary, if φ_0 and *e* are low, this flow has a high accidental co-mingling possibility. Moreover, if the effort is null, φ_1 will be himself null too. It means that without effort set up by the manufacturer, non-GM products will be all contaminated; and if the effort is maximal (=1), φ_1 will depend completely on φ_0. In the same manner, if φ_0 is null (=0), the

manufacturer will not be incited to carry out effort and if φ_0 is maximal, φ_1 will depend completely on *e*.

Suppose that the tests carried out by the manufacturer cost as follows: **C (n) = c.n.q$_n$.** We define *c* as the unit cost of the tests; and *n* the sampling size. The retailer buys lots of non-GM products only if their GM content is under the public threshold *s*. The contaminated lots (their GM content is above the public threshold *s*) are sold by the manufacturer on the GM market. We consider that the test has an efficiency β : the size of the rejected lots is given by $q_{n1} = q_n \left[\varphi_1.(1-\beta.n) + (1-\varphi_1)\beta.n \right]$ and the size of the accepted lots is given by $q_{n2} = q_n \left[\varphi_1.\beta n + (1-\varphi_1)(1-\beta.n) \right]$. The non-contamination probability of these non-GM lots is φ_2.

$$\varphi_2 = 1 - (1-\varphi_1)(1-\beta.n) / \left[\varphi_1.\beta n + (1-\varphi_1)(1-\beta.n) \right]$$

Consequently, the manufacturer's profit is given by:

$$\Pi_M = q_{n2}.w_n + (q_o + q_{n1}).p_o - w_o.q_o - (w_o + \delta).q_n - e.(1-s).q_o / Q - c.n.q_n$$

II.2. Retailer - R

The **retailer** (R) is an intermediary between the manufacturer and the final consumers on the non-GM market:

- By anticipating the non-GM demand on the final market, he buys from the manufacturer a quantity of non-GM product **q$_{n2}$** at the price **w$_n$**

- And he sells them to final consumers on the non-GM market at the price **p$_n$**.

In first approach, the non-GM demand D$_{non-ogm}$ decreases with **p$_n$**. In other words, a lower price allows a higher quantity of non-GM products.

Retailer's profit is given by :

$$\Pi_R = p_n.q_{n2} - w_n.q_{n2}$$

II. 3. Consumers - Demand

Note θ the consumers characteristic, the consumers utility function is given by :

$$U_\theta = \varphi_2(u - p_n - \theta s) + (1 - \varphi_2)(u - p_n - \theta)$$

where :

- o U_θ is the unit utility related to the purchase of a non-GM product.

- o φ_2 is the non-contamination probability of non-GM finished products sold on the non-GM market by the retailer.

- o The parameter u is basic unit utility. We suppose that u exceeds the price of non-GM products.

- o θ can represent the aversion for the GMO, or individual propensity to pay for non-GM product for each labelling threshold level: $\theta \in [0,1]$. Indeed, the consumer is ready to pay a higher price for non-GM product all the more so as the threshold fixed by the legislator is strict and that the aversion for the GMO is high.

- o The labelling threshold s plays the role of utility discount factor. The higher s is, the lower non-GM consumption utility is. In other words, s is viewed as an index of quality. The better quality (i.e. s is small) allows a higher non-GM consumption utility. s is equal to 1 if a GM product is consumed. It means that non-GM product has a higher quality than GM product.

$u - p_n - \theta s$ is satisfaction level obtained by a consumer when he buys a non-GM product at the price p_n on the non-GM market. $u - p_n - \theta$ is satisfaction level obtained obtained by this same consumer when he buys a GM but labelled non-GM product at the non-GM product price : p_n on the non-GM market.

Our utility function captures the notion of vertical product differentiation (Musa et Rosen). For these authors, the two products are differentiated vertically when, at the same price, all consumers classify them in the same preference order. The preferred good is this having a higher quality. In our model, if both the GM and non-GM product were sold at the same price, all consumers would choose the non-GM product whose quality is higher.

In addition, we express the quality uncertainty through this utility function. In fact, because of the test error, non-GM products accepted by the retailer do not satisfy all the labelling threshold. In other words, a share of GM products which would have being transmitted on the

GM market are labelled non-GM and sold on the non-GM market. We suppose an impossibility for the consumers of checking the non-GM quality for which they are ready to pay more expensive neither before, nor after the purchase, because of the prohibitive costs of the acquisition of this information; they must resort to an expert third (laboratories,…). The probability that the labelled product is non-GM product is defined by φ_2 and GM product by 1-φ_2. The utility balance by the probability in our utility function asserts these assumptions.

The consumer will buy a non-GM product when their utility is positive :

$$U_\theta > 0 \qquad \text{i.e.} \qquad \theta < \frac{u - p_n}{1 - \varphi_2(1-s)}$$

So, the demand on the non-GM market is given by :

$$\theta = \frac{u - p_n}{1 - \varphi_2(1-s)}$$

We note that the consumers' decision depend on *s*, φ_2 *et* p_n.

II.4. The game

The manufacturer and the retailer's access to the market is represented by a sub-jacent game where the players actions are sequenced and the order is specified. In other words, it is a stages-game. In this paper, we study a three-stages game:

- **Stage 1** : The manufacturer chooses q_n and q_o (the quantities of raw materials to buy from the farmers) and *e* effort set up by the manufacturer.

- **Stage 2** : The manufacturer and the retailer negotiate together w_n, the intermediary price and *n* the sampling size.

- **Stage 3** : The retailer chooses q_{n2} and p_n, the quantity and price of non-GM products to sell on the final market.

We aim to find all of the sub-game perfect Nash equilibriums of this game. As it is a sequential game where each player can observe the actions of the others before making his own decisions, the resolution is done classically by *backward induction*. It means that the reasoning is done in opposite direction of the normal game's course and so we starts by the end: first, we determine the optimal strategy of the player who makes the last move of the game (the retailer in our

model). Then, the optimal action of the next-to-last moving player is determined taking the last player's action as given. The process continues in this way backwards in time until all players' actions have been determined.

Stage 3

By anticipating the non-GM demand, retailer chooses the quantity of non-GM products q_{n2} sold on the final market and command this from manufacturer.

As mentioned in the above section, the demand on the non-GM market is:

$$d = \frac{u - p_n}{1 - \varphi_2(1-s)}$$

The quantity that retailer needs to meet demand is thus:

$$q_{n2} = d = \frac{u - p_n}{1 - \varphi_2(1-s)}$$

This quantity has to maximize his profit. So, it is given by :

$$q_{n2}(s, e, \varphi_0, w_n, n) = \arg\max_{q_{n2}} \pi_R$$

where $\pi_R = p_n.q_{n2} - w_n.q_{n2}$

The resolution of first order conditions system lead to the unique sub-game equilibrium:

$$\frac{\partial \pi_R}{\partial q_{n2}} = 0 \rightarrow q_{n2}(s, e, \varphi_0, w_n, n)$$

The equilibrium price is thus: $p_n = u - [1 - \varphi_2(1-s)]q_{n2}$

Stage 2

Manufacturer and retailer negotiate together the intermediate price w_n at which retailer has to pay to buy non-GM products offered by manufacturer and n the sampling size of tests set up by manufacturer. Insofar as it is a contractual relationship (in long term, we suppose), the negotiation of w_n and n is done by joint profit maximisation taking into account the respective negotiation power of each of them. We note k manufacturer negotiation power and (1-k) retailer negotiation power. Accordingly, we have:

$$\pi_J = k\pi_M + (1-k)\pi_R$$

Avec $\Pi_M = q_{n2}.w_n + (q_o + q_{n1}).p_o - w_o.q_o - (w_o + \delta).q_n - e.(1-s).q_o/Q - c.n.q_n$

Et $\pi_R = p_n.q_{n2} - w_n.q_{n2}$

w_n is given by :

$$w_n(s, e, \varphi_0, n) = \arg \max_{w_n} \pi_J = k\pi_I + (1-k)\pi_D$$

And *n* by :

$$n(s, e, \varphi_0) = \arg \max_{n} \pi_J = k\pi_I + (1-k)\pi_D$$

The resolution of first order conditions system lead to the unique sub-game equilibriums:

$$\frac{\partial \pi_J}{\partial w_n} = 0 \rightarrow w_n(s, e, \varphi_0, n)$$

$$\frac{\partial \pi_J}{\partial n} = 0 \rightarrow n(s, e, \varphi_0)$$

Stage 1

Manufacturer chooses quantity of GM raw material q_o and quantity of non-GM raw material q_n to buy from farmers at upstream level and segregation effort set up by himself.

In this stage, n, w_n, q_{n2} are found.

We obtain *e* by maximizing manufacturer's profit :

$$e(s, \varphi_0) = \arg \max_{e} \pi_M$$

The resolution of first order conditions system of manufacturer's profit with respect to *e* lead to the unique sub-game equilibriums:

$$\frac{\partial \pi_M}{\partial e} = 0 \rightarrow e(s, \varphi_0)$$

Regarding quantities of raw materials, we have : $q_{n2} = (A+D)q_n$

Accordingly, q_n is given by :

$$q_n = \frac{q_{n2}}{\left[\varphi_1.\beta n + (1-\varphi_1)(1-\beta.n) \right]}$$

and q_o by :

$$q_0 = Q - q_n$$

III. Results

Proposition 1 : _At equilibrium, segregation effort e*, sampling size n, quantity q_{n2}, price p_n, and conformity rate φ_2 of non-GM products sold on the final market are such as:_

$$\frac{\partial e^*}{\partial s} > 0 \text{ , } \frac{\partial^2 n}{\partial s^2} < 0 \text{ , } \frac{\partial^2 \varphi_2}{\partial s^2} < 0 \text{ , } \frac{\partial^2 q_{n2}}{\partial s^2} < 0 \text{ , } \frac{\partial^2 p_n}{\partial s^2} < 0$$

Proof: _see appendix 1._

When s increases up to a certain threshold, the final price of non-GM product decreases whereas the quantity increases. Then, above that threshold, sense of variations is reversed. They are in fact, affected by several opposing effects.

On the one hand, when labelling threshold _s_ increases, quality of non-GM products decreases. Accordingly non-GM demand and non-GM price on the final market decrease. On the other hand, when the demand declines because of relaxation of threshold, the suppliers will increase sampling size _n_ in order to improve tests performance. As sampling size increases, analyzing costs increase too. Finally, when s increases, conformity probability of non-GM product increases too for two reasons: on the one hand, the threshold _s_ is easier to reach; on the other hand, sampling size growth increases tests performance which becomes more discriminating. By becoming more discriminating, the tests induce an increase of quantity of non-GM products rejected to GM market, and also an increase of non contamination rate of non-GM products. Consequently, demand for non-GM products and non-GM final price increase.

On account of interactions highlighted in our analysis, it appears several interesting points to emphasize:

- A high quantity of non-GM products commercialized in the final market is obtained neither with a very low labelling threshold, nor with a very slacked threshold

- A very low labelling threshold is opposed to a high conformity probability of non-GM product. The relaxation of labelling threshold improves, and then above a certain value, degrades this conformity rate

- The tests requirement level depends obviously on labelling threshold. Neither a very low, nor a very high labelling threshold induces a high tests requirement level.

-   The optimal segregation effort carried out by Manufacturer increases when the labelling threshold increases. First, the effort aiming to preserve identity of non-GM products is cheaper when regulatory threshold is higher. In addition, from a certain threshold value, part of non-GM product decreases. Accordingly, GM contamination risks increase. Segregation levels must increase thus.

Proposition 2 : *At equilibrium, Manufacturer and retailer's profit and consumer's welfare are concave in s :*

$$\frac{\partial^2 \Pi_M}{\partial s^2} < 0 \,, \; \frac{\partial^2 \Pi_R}{\partial s^2} < 0 \,, \; \frac{\partial^2 Wc}{\partial s^2} < 0$$

Proof: *see appendix 2.*

Consumer's welfare, firstly, is concave in *s* for following reasons. As a first step, the threshold slackness effect on demand is more than compensated by a decline of price of non-GM product, and by growth of conformity probability of this product. Above a certain threshold, the price and the threshold s increase and conformity probability of non-GM product decreases. Consumer's welfare decreases thus.

Second, regarding the retailer, when *s* is slacked, in the first time, his profit increases. In fact, higher demand due to higher conformity rate of non-GM product, as well as higher quantities of non-GM product sold on the market dominate effects related to lower non-GM final price, higher segregation costs and higher intermediate price w_n. Above a certain value of *s*, lower quantities sold, lower final price and lower conformity rate of non-GM product dominate effects related to the lower costs of testing and intermediate price.

Last, the manufacturer's profit increase too when s is slacked in the first time because intermediate price and quantities of non-GM product sold on the market growth dominate the rising of segregation costs and testing costs. Above a certain level, his profit decreases despite a lower costs of tests because of lower quantities of non-GM product sold (which increases the risk of mixing at manufacturer's) and higher segregation efforts.

15

Proposition 3 : *At equilibrium, segregation effort decreases in φ_0. Manufacturer and retailer's profit and consumer's welfare are concave en φ_0 :*

$$\frac{\partial \ e^*}{\partial \varphi_0} < 0 \ , \ \frac{\partial^2 \Pi_M}{\partial \varphi_0^2} < 0 \ , \ \frac{\partial^2 \Pi_R}{\partial \varphi_0^2} < 0 \ , \ \frac{\partial^2 Wc}{\partial \varphi_0^2} < 0$$

Proof: *see appendix 3.*

It is interesting to note that improving conformity level of non-GM raw material induces a decline in segregation efforts set up by manufacturer. In these circumstances, when φ_0 increases, not only the raw material costs increase, but also its purity does, which reduces GM/non-GM segregation demand, and improves output product quality.

When φ_0 increases, segregation efforts increase, at the first time, manufacturer's profit increases thus. Above a certain value of φ_0, when φ_0 increases, quantities of GM product increase because of non-GM raw material costs growth. Consequently, contamination probability and testing requirements level and then non-GM products rejected proportion increase too. So, above a certain value of φ_0 manufacturer's profit decreases despite a lower segregation efforts set up by himself.

Regarding consumers (and retailer), welfare related to a higher φ_0 (which give a higher conformity rate of non-GM final product) is offset by a higher final price (lower quantities sold) above a certain threshold

Corollaire 1 : *At equilibrium, for given φ_0, manufacturer maximizes his profit for a labelling threshold s_M* associated with a segregation effort e_M*; retailer maximizes his profit for a labelling threshold s_R** associated with an effort e_R** such that:*

$$s_M* < s_R** \ and \ e_R** > e_M*$$

Proof: *see appendix 3.*

The choice of labelling threshold induces segregation effort level carried out by the manufacturer. So is it better to impose a lax labelling threshold and require high segregation efforts aiming to control contamination risks or conversely is it better to impose a stricter

threshold associated with lower segregation efforts? The answer to this question depends on the players in question.

As we know, the optimal effort set up by manufacturer increases in s. In addition, the regulatory threshold that maximizes retailer surplus is always higher than the one that maximizes manufacturer surplus (see proposition 2). Accordingly, retailer prefers combine more slacked threshold with higher segregation efforts than manufacturer (see figure 2).
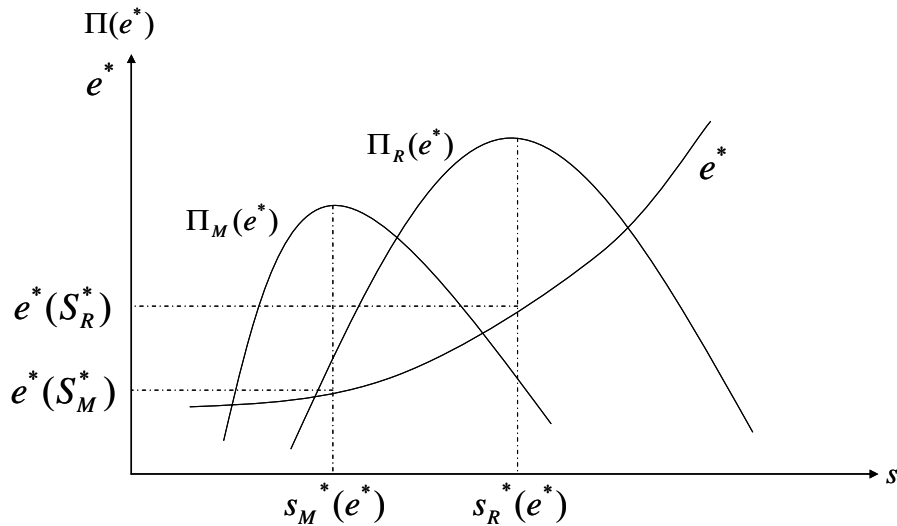

Figure 2 : Manufacturer and retailer's profit-maximizing optimal threshold and effort

Corollaire 2 *: At equilibrium, for given s, manufacturer maximizes his profit by buying non-GM raw material with a conformity probability φ_{0M}^{*} in carrying out a segregation effort $e_{M}^{'*}$; retailer maximizes his profit for φ_{0R}^{*} associated with an effort $e_{R}^{''*}$ such that:*

$$\varphi_{0M}^{*} > \varphi_{0R}^{*} \text{ and } e_{R}^{''*} > e_{M}^{'*}$$

Proof: *see appendix 3.*

In the same way, we may highlight the game combined between two variables φ_{0} and e. Is it better to acquire a non-GM raw material with a high conformity rate (and thus costly) and limit at the same time, segregation efforts set up by the manufacturer, or, conversely, is it better to buy less expensive non-GM raw material (but with lower conformity rate), and carry out high segregation efforts in order to control contamination risk within the industrial process? Again, the answer depends on the players in question

The optimal effort e* set up by the manufacturer decreases in φ_0. In addition, the value of φ_0 that maximizes retailer's profit is always lower than the one that maximizes manufacturer's profit. Accordingly, retailer prefers combine a lower φ_0 with higher segregation efforts than manufacturer (see figure 3)

Thereby, it appears that the optimal effort carried out by manufacturer is always lower than the one expected by retailer. Assuming that this effort level is a private decision made by manufacturer in which retailer can not intervene, it appears that the best way for the retailer to lead manufacturer to choose the good effort level, in his view, is to impose a constraint on φ_0 in the contract with this one.
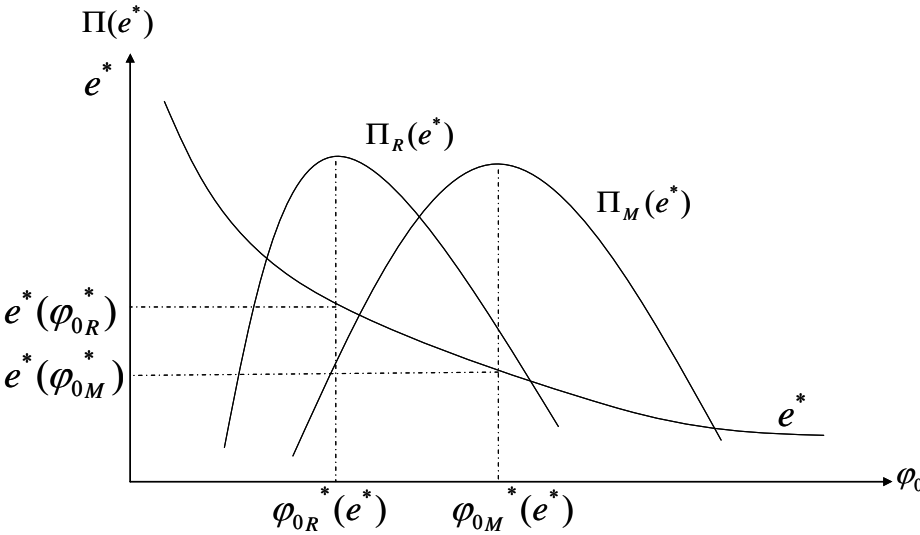

Figure 3 : Manufacturer and retailer's profit-maximizing optimal threshold and conformity rate

Proposition 4 *: GM/non-GM coexistence is maintained if and only if:*

$$\bar{k} > \overline{\overline{k}}_{(s)}$$

$$\underline{s} < s < \bar{s}$$

If these conditions are not satisfied, manufacturer will not offer non-GM product to the market and consumer opposed to GM demand is not served thus.

Proof*: see appendix 4.*

If the manufacturer offers only GM product, he obtain a profit as follow :

$$\Pi_{M-GM} = (p_o - d - w_o)Q$$

Whereas if he offers both GM and non-GM product, his profit is given by:

$$\Pi_{M-GM/nonGM} = q_{n2}.w_n + (q_o + q_{n1}).p_o - w_o.q_o - (w_o + \delta).q_n - e.(1-s).q_o/Q - c.n.q_n$$

By comparing these two expressions, we can identify under which conditions manufacturer accepts supply non-GM product to retailer and therefore to non-GM market.

In a context where the upstream operator has the choice of coexistence, but downstream one can buy only from this manufacturer in order to meet an unique non-GM demand, the non-GM market coverage depends mostly on negotiation power dispersion between actors in the supply chain.

Moreover, the choice of labelling threshold by the public authorities maintains the coexistence. A too low threshold induces this effect by the extracosts incurred. However, a too high threshold gives the same effect because of higher risk of mixing due to higher part of GMOs at manufacturer's level.

IV. Discussion and conclusion

Through the model proposed in this article, we aim to clarify the GM/non-GM coexistence in a context in which:

- Final demand is mainly composed of reluctant (to buy GM products) consumers;

- Final demand is sensitive not only to quality of non-GM product (statutorily defined by the labelling threshold), but also to firms' ability to ensure the compliance with this threshold;

- Producers want to produce GMOs in order to supply external markets;

- Contamination risk can induce disappearance of non-GM products;

- These risks are all the more high that non-GM product share is high and depend on actors' segregation decisions;

- These decisions result, in part, from strategic interactions between stakeholders in the vertical relationship.

The originality of this model consists mainly in taking into account in an endogenous manner of the contamination between GM and non-GM and its consequences in terms of conformity of the

product sold in the market. Conformity probability involves in the consumers' arbitration and affects final demand. Accordingly, it introduces an arbitration possibility at each level of the chain between price / costs, quality and conformity of the product, which permits to enrich vertical relationship analysis. It appears the following elements:

1. Previous papers focused on the optimal labelling threshold level from the point of view of global welfare. They emphasized very strict labelling threshold effect by putting forward the segregation costs in the case of GM and non-GM coexistence. We can meet again this effect in our model, but we highlight moreover the negative impacts of too slacked labelling threshold which can lead to a reduction in the quantity and the conformity level of non-GM product. That's why it appears that a threshold can be identified for manufacturer on the one hand, consumers and retailer on the other hand. As Lapan and Moschini (2006), we identify an interests divergence between manufacturer and retailer or consumers, but we shows moreover that this divergence on the threshold is due to a difference on the segregation efforts levels: retailer and consumers prefer a more slacked labelling threshold associated with a higher segregation effort set up by the manufacturer.

2. In the same way, it is interesting to reason simultaneously on the choice of segregation level and on the non-GM raw material characteristics requirements. In fact, the choice of non-GM raw material conformity affects the effort level carried out by manufacturer: the higher the conformity is the lower the optimal segregation effort set up by manufacturer is. The interest divergence appears in the following manner: in the light of retailer and consumers' expectations, manufacturer prefers a higher raw material conformity for a lower segregation effort.

Consequently, from the retailer's point of view, it is important to be able to control characteristics of the raw materials bought by manufacturer. This result permit to understand some observations in practice:

- First, the retailers (distributors) who, like Carrefour, are committed not to commercialize GM products have tried to develop contracts with manufacturers incorporating in the specifications constraints on the raw materials characteristics bought by manufacturer. In the case of soybeans, for example, Carrefour requires from animal food manufacturers until 2005 traceability of all products coming from Brazil

- Moreover, we have witnessed during the past few years, a progressive reduction in raw material requirement level imposed by the same retailers. Taking again as an example of Carrefour, we note that traceability and non-GM raw materials purity requirements imposed on the manufacturers in the specifications have been scaled down, which can be interpreted on the basis of our model, as a desire to reduce the raw materials costs at upstream level and incite segregation efforts at manufacturer's level.

3. We have not included in this model the penalty paid when a non-compliant product is marketed. Suppose that consumers react to uncertainty about the conformity of the product (and suppose thus that external actors such as NGOs make this information publicly available), nevertheless we can highlight how non-GM product conformity affects each actor's decisions and welfare.

In this context, we emphasize that GM and non-GM coexistence is possible but not systematic. First, it depends on negotiation power dispersion between actors in the supply chain. In this case, it depends on manufacturer's power in negotiating the optimal testing level and intermediate price. Otherwise, he privileges only the GM market. Second, the coexistence depends also on labelling threshold. Other papers have underlined difficulty in maintaining non-GM product if the threshold is too low. Our model confirms this result too, but we show in addition that a very slacked threshold may also make impossible the supply to non-GM market. In this case, in fact quality decrease due to a high threshold, a high conformity rate and a high price resulting a low intermediate price diverts manufacturer from non-GM market

In these circumstances, it appears that (i) if the labelling threshold is too low, non-GM industry disappears because of the direct costs of production and segregation, (ii) if the threshold is too high, the fall of demand on non-GM market induces industrial capacities reallocation in favour of GM product, which increase contamination risk and imposes additional investment levels that can result in withdrawal of some non-GM operators. In this context, the situation in which the market share of non-GM product is the highest is not necessarily the one that maximizes non-contamination probability of non-GM product sold in the final market.

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