Who pays the costs of non-GMO segregation and identity preservation?

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Abstract: This paper proposes an analytical framework to examine the market and welfare impacts of GMOs, when some consumers refuse genetically modified organisms (GMOs) and when two supply channels are segregated (one for goods that containing GMOs and one for non-genetically-modified identity-preserved goods). Our analytical framework begins at the level of individual farmers, handlers and consumers, to build up market supply and demand functions. This allows us to circumvent the difficulties of conducting supply and demand analysis in the different horizontally and vertically related markets concerned by GMOs and market segregation. We represent explicitly the costs of non-GMO segregation and identity preservation (IP) for both producers of non-GM IP goods and producers of non-IP goods, and how these costs vary depending on the relative sizes of the two production channels. We then illustrate our model by a simulation of potential adoption of GM rapeseed with non-GMO market segregation in the European Union (EU). We analyze how the costs of IP are distributed among heterogenous producers, handlers and consumers in this simulation.

1. Introduction

Some major world agricultural markets are currently facing a dual situation with regard to genetically modified organisms (GMOs), with many farmers growing GMOs and many consumers reluctant to eat them, or many national regulations slow to accept their use. As a result, some seed producers, farmers, grain handlers and food processors are striving to preserve the identity of non genetically modified goods by keeping them segregated from genetically modified (GM) goods, to meet demand for non-GM goods. A dual stream of supply and marketing is developing, one for goods without GMOs above given tolerance levels, and one for goods that contain GMOs above these tolerance levels. This paper proposes an analytical supply and demand framework to examine the economic effects of this non-GMO segregation and identity preservation (IP). The original features of our model are that we begin at the level of individual agents to build up market supply and demand functions, and that we represent explicitly the costs of non-GMO segregation and IP for both producers of non-GM IP goods and producers of non-IP goods. Our aim is to study how different assumptions on the costs of IP affect measures of the price, quantity and welfare effects of GMOs. In order to do so, we conduct simulations of potential adoption of GM rapeseed with non-GMO IP in the European Union (EU) under different assumptions on how costs of IP are distributed among different agents.

So far, studies on the economic effects of GMO labeling and non-GMO segregation and IP have mainly examined how to account for differentiated consumers' attitudes towards GMOs in an analytical framework, and what are the effects of market segregation on consumers. However, less attention has been given to the way to model costs of segregation and IP and how these costs affect producers.

Nielsen, Thierfelder and Robinson (2001) show how different representations of preferences towards GM and non-GM products affect measures of price, quantity and welfare changes when GMOs are introduced, in a CGE framework. They do not introduce segregation costs, and they only specify that non-GM processed products must be produced using a non-GM bulk ingredient. Mayer and Furtan (1999) analyze graphically the effects of market segregation between GM and non-GM products on the Canadian rapeseed (canola) market. They do not model explicitly how the costs of segregation of GM and non-GM products are shared between producers, but they suggest three possibilities: the costs are borne by all canola production, by only transgenic production, and by only non-GM production. Golan and Kuchler (2001) argue that when GMOs are introduced, externality costs are imposed on producers of the non-GM good to ensure that its non-GM identity is preserved until its final consumption, and that these externality costs are only borne by non-GM producers. Giannakas and Fulton (2001) examine the effects of GMOs and GMO labeling on consumer demand and consumer welfare, using a model of differentiated consumer preferences on GM and non-GM products. They argue that while both non-GM and GM producers may face some segregation costs, these costs will always be higher for producers of the IP good than for producers of the GM good, due to the effort required in preserving the identity of the non-GM good by keeping it separate from the GM good.

These studies account for differential characteristics among consumers, and notably point out that GMOs and non-GMO segregation can cause some consumers to win while others lose. However, they give less attention to the way segregation and IP costs are borne. Moreover, they make different, and sometimes even contradictory *a priori* assumptions about these IP costs. In this context, our aim is to analyze more closely how these IP costs arise, which producers bear these costs, how farmers and handlers are differentiated with respect to these costs, and if the effects of GMOs and non-GMO segregation and IP on their welfare are also variable.

2. Sources of the costs of segregation and identity preservation

It is possible to distinguish two main categories of costs of non-GMO segregation and IP (Bullock and Desquilbet, 2001). The first category is costs to prevent commingling of GMOs and non-GMOs, i.e. to keep non-GMOs intended to IP physically separated from GMOs along the supply chain. In particular, costs are incurred to prevent cross-pollination, to clean farm, handling, transportation and processing equipment, and to dedicate one part of this equipment to GMOs while dedicating the other to non-GMOs. The second category is of costs to correct the information asymmetry about the GMO or non-GMO nature of the goods, i.e. to ensure the buyer that grain that is claimed as non-GM by the seller is actually non-GM. These costs are from chemical testing and drawing up contracts between buyers and sellers and monitoring their abidance. These additional costs have three important characteristics. First, they are likely to arise for both producers of non-GM IP goods (which we will call simply "IP goods") and producers of goods for which no steps are taken to prevent GMO commingling (which we will call "regular goods"). Second, these additional costs are likely to be different from one agent to the other. Third, the additional costs for a given producer are likely to depend on the types of goods, i.e., IP or regular goods, produced by other farmers, handlers or processors. These three characteristics of IP costs are illustrated below, using partly the example of the current IP channel in the United States (US) and in the EU.

Farm costs of segregation and IP

In the case of farmers, the cost of transporting IP grain to an elevator willing to accept it varies among farmers, depends on the size of the IP channel and arises for both producers of the regular or the IP good. Currently in the US, IP crops make up a small share of total supply, and only a fraction of all elevators are participating in the IP channel. Moreover, some of these elevators are only receiving IP crops from farmers during specified periods, and not near harvest time. In this situation, the additional cost of delivering IP grain to an accepting elevator varies among farmers. The additional cost is small for a farmer located near an elevator accepting IP grain at harvest time, or for a farmer possessing adequate on-farm storage and located near an elevator accepting IP grain only out of harvest time. On the contrary, the additional cost is dissuasive for a farmer located far away from an elevator accepting IP grain, or for a farmer possessing inadequate on-farm storage capacity, even though he may be located near an elevator accepting IP grain only out of harvest time. In addition, for a given farmer, the cost of delivering IP grain to an elevator accepting it depends on the size of the IP channel. If the share of IP crops in total supply increases, some new elevators will start to accept IP crops, or will accept them during wider periods of time. Then, the cost of participating in an IP channel will decrease for some farmers located near these elevators. Yet simultaneously, as the size of the IP channel grows, a similar cost of participating in the regular channel will arise for producers of the regular good. In the extreme situation where the size of the regular channel is very small, the cost of transporting regular grain to an elevator willing to accept it will become dissuasive for many farmers.

Farmers growing IP crops incur a cost of preventing cross-pollination by GM plants for cross-pollinated species (including corn and rapeseed, but excluding soybeans which are almost exclusively self-pollinated), because pollen from neighboring GM fields can fertilize plants in a non-GM field and lead to the commingling of GM and non-GM grain. To prevent cross pollination, costly measures must be adopted, such as increasing distance between non-GM fields and GM fields, or harvesting border rows separately. This cost varies among farms (for example, depending on the presence of natural barriers or depending on wind direction). It also varies for a given farmer depending on the share of GM crops in total supply (this cost increases for some farmers as the share of GM crops in total supply increases, when some of their neighbors begin to grow GM crops).[1]

At least, the opportunity cost borne from not using GM technology in production varies among farmers. Several studies underline that economic benefits from adopting GMOs vary widely between farmers (Bullock and Nitsi, 2001; McBride and Books, 2000; Desquilbet, Lemarié and Levert, 2001). One main reason is that different farmers face different weed situations, or different insect pressures, so that pesticide cost reductions or yield changes following from GMO adoption vary among them. Then, the potential indirect cost of not using a GM seed in order to grow an IP crop varies among farmers.

[1] Here, no similar cost exists for producers of the regular good, because regular producers do not have to prevent cross-pollination of their crops by non-GM pollen.

Handling and processing costs of segregation and IP

At the handling stage, too, some examples show that IP costs vary among handlers and vary depending on the size of the IP channel in total supply. In the current situation where the IP channel is small in the US, because of the physical design of their facilities, some elevators have smaller costs than others of participating in the IP channel. For example, strict tolerance levels can be attained more easily in storage locations that have multiple paths (as opposed to a single path) of dump pits, legs, conveyors belts, etc, along which grain is moved before being stored. It is also easier to segregate IP crops in a facility with multiple small storage bins rather than few large bins. Moreover, having different elevators in close proximity is an advantage for some handlers that may dedicate some elevator locations to GMOs and others to non-GMOs. This situation will change if the share of IP crops in the handling system increases and new elevators enter the IP channel. In the EU, where only IP crops are supplied, all facilities are used exclusively for IP crops. In this case, this physical design and location of elevators does not create IP cost differences among handlers. Similarly, regular crops may also bear a cost of segregation. For while regular crops need not be kept clean of non-GM crops, segregation still can lead to costs of capacity underuse, cleaning costs, and management costs to organize more complicated grain flows. Similar cost differences and variations of cost with the size of the IP channel apply to food processors.

3. Analytical framework

In order to analyze the aspects of non-GMO segregation and IP described above, we develop a model allowing welfare analysis of GMOs and IP using supply and demand analysis. Our model is of two vertically related markets, a market of agricultural products at the farm stage and a market of agricultural products at the handling stage, and two countries, a domestic country (the EU), and the rest of the world (ROW). We consider three different types of rapeseed that may be produced by farmers. The first one (indexed by n) is rapeseed grown from a non-GM seed, but for which no steps are taken to prevent possible commingling with GM rapeseed, or which is not delivered to handlers accepting IP crops. The second one (indexed by g) is rapeseed from a GM seed. The third one (indexed by i) is non-GM IP rapeseed (later referred to simply as "IP"), grown from a non-GM seed, for which special efforts are made to avoid any commingling with GM rapeseed. Handlers buy rapeseed from farmers, to produce either regular handled rapeseed (indexed by r), or IP handled rapeseed (indexed by i). We assume that IP handled rapeseed can only be produced using IP farm rapeseed. Regular handled rapeseed is rapeseed that cannot be sold as IP and is produced using GM rapeseed or non-GM non-IP rapeseed (handlers view these as the same product). Consumers buy regular rapeseed and IP rapeseed from handlers.

This model allows us to take into account three simultaneous shifts in supply and/or demand curves in three different markets. First, the GMO technology lowers costs of production for some subset of all farmers. Second, for many consumers, worry about possible health and environmental effects of GMOs causes their demand for GM versus non-GM products to shift in favor of non-GM products. This shift in preferences begets a third shift, this time in the demand for segregation and identity preservation of non-GMOs. We start from supply and demand at the individual level, and we define aggregate supply and demand functions by summing up individual supplies and demands. Since the model consists in modeling heterogeneous individual agents, it allows to distinguish how GMOs and non-GMO segregation affect the heterogenous members of the same interest groups.

Domestic farmers

We consider a set of F farmers, each of whom may produce the four different farm crops n, g, i or a, where the good indexed by a is an alternative crop. Each of the four crops is produced using land, owned by each farmer in equal area L, and a set of variable inputs. Each of the four goods is produced under competitive conditions using a Leontief technology, with the variable inputs perfectly elastic in supply and land perfectly inelastic in supply. Handlers do not distinguish between the two types of regular rapeseed, i.e., non-GM non-IP rapeseed and GM rapeseed. Therefore, farmers are paid the same price for these two products. The IP supply stream results in a negative production externality for farm producers of regular rapeseed. We assume that production costs of regular rapeseed increase linearly with the share of IP rapeseed in total handled rapeseed. In the same way, we assume that the costs of production of IP rapeseed increase linearly with the share of regular rapeseed in total handled rapeseed.[2] Farmers get the same constant yield y for each of the three types of rapeseed. Let w_r denote the farm price of regular rapeseed (i.e., rapeseed n or rapeseed g), let w_i denote the farm price of IP rapeseed (i.e., rapeseed i). Let s denote a government per-hectare subsidy on rapeseed (this subsidy will be kept constant in our model). We denote the per hectare crop-specific restricted profit on crop k by farmer f as $\pi^{kf}(.)$, $k=n, g, i$. Omitting argument s (that we keep constant), the crop-specific per-hectare profit function for crop n is given by:

(1) $\pi^{nf}(w_r,\tau_i) = Max\left(w_r y + s - c_{nf} - e_{rf}\tau_i ; 0\right)$

where c_{nf} is farmer f's per-hectare variable cost of production for crop n when regular rapeseed is the only good supplied; e_{rf} is a production externality parameter for regular rapeseed for farmer f; τ_i is the share of IP rapeseed to total rapeseed (i.e. to IP plus regular rapeseed) in the handling system.

The crop-specific per-hectare profit functions for crops g and i are defined in an analogous manner as:

(2) $\pi^{gf}(w_r,\tau_i,t) = Max\left(w_r y + s - c_{nf} + r_{gf} - t - e_{rf}\tau_i ; 0\right)$

(3) $\pi^{if}(w_i,v,\tau_r) = Max\left(w_i y + s - c_{nf} - c_{if} - e_{if}\tau_r , 0\right)$

where t is a GMO technology fee; r_{gf} is a per-hectare reduction in costs when GMOs are adopted, non including the technology fee; e_{if} is a production externality

[2] Some causes of these externality costs were presented in section 2: costs of transporting regular or IP rapeseed to an elevator willing to accept it; cost to prevent GM cross-pollination of IP rapeseed. By nature, these costs depend on where other regular and IP farmers and elevators are located. We take them into account in a simple way in our non-spatial framework, by assuming that they depend only on the share of the other good (IP or regular) in total IP and regular rapeseed quantities.

parameter for IP rapeseed; c_{if} is a per-hectare additional cost of IP; τ_r is the share of regular rapeseed to total rapeseed in the handling system, equal to $1-\tau_i$.

For simplicity, we make the partial equilibrium assumption that the profit level obtained from the alternative crop is constant, and we assume that it is equal to π^a for each farmer. The profit functions specified imply that for each crop the farmer has constant returns to scale. Therefore the farmer always finds it optimal to grow only one crop, the one yielding the maximum profit level. Farmer *f*'s maximum per-hectare profit is given by (suppressing argument *s* which will be held constant):

(4) $\pi^{\max f}(w_r, w_i, \tau_i, t) = Max\left(\pi^{nf}(w_r, \tau_i); \pi^{gf}(w_r, \tau_i, t); \pi^{if}(w_i, 1-\tau_i); \pi^a\right)$

Depending on prices, some farmers may then find it optimal in equilibrium to grow GM rapeseed, while others find non-GM seed more profitable, some with and some without identity-preserving their crop. Farmer *f*'s supply function for crop *k=n, g, i* is then defined by:[3]

(5) $q_k^{sf}(w_r, w_i, \tau_i) = \begin{cases} y\,L & if \quad \pi^{\max f}(.) = \pi^{kf}(.) \\ 0 & otherwise \end{cases}$.

The aggregate farm supply function of crop *k=n, g, i* is denoted $Q_k^{sF}(.)$, and is defined as the sum of individual supplies for that crop:

(6) $Q_k^{sF}(w_r, w_i, \tau_i) = \sum_{f=1}^{F} q_k^{sf}(w_r, w_i, \tau_i)$.

Domestic handlers

We consider a set of *H* handlers indexed by *h* = 1, …, *H* who may produce the two different types of handled rapeseed, *r* or *i*.[4] Handled rapeseed is produced with a Leontief technology, combining farm rapeseed, storage capacity and variable inputs, with one unit of farm rapeseed necessary to produce one unit of handled rapeseed. Regular handled rapeseed is produced using rapeseed *n* or *g*, and the amount of regular rapeseed bought from farmers by handler *h* is by definition $q_{rh} = q_{nh} + q_{gh}$. IP handled rapeseed is produced using farm rapeseed *i*. Storage capacity is owned by each handler in a given quantity *Q* and is perfectly inelastic in supply, and variable inputs are perfectly elastic in supply. The IP supply stream creates a negative production externality for regular handlers. We assume that the costs of production of regular rapeseed increase linearly with the share of IP rapeseed in total handled rapeseed. In the same way, we assume that the costs of production of IP rapeseed increase linearly with the share of regular rapeseed in total rapeseed.[5] We denote the

[3] Equation (4) assumes that the profit-maximizing crop is unique. In the case where more than one crop-specific profit levels is equal to the maximum profit level, we arbitrarily decide that the farmer grows only one of the profit-maximizing crops, with crop *i* being the most preferred, then g, then *n*, then *a*.

[4] For simplicity, we do not consider any cross-effects between handling of rapeseed and handling of the alternative farm crop *a*.

[5] This externality cost arises because of the cost of dedicating some equipment to regular rapeseed and some to IP rapeseed (see section 2).

per hectare crop-specific restricted profit of handler *h* on crop *k* as $\pi^{kh}(.)$, *k=r, i*. The crop-specific per-unit-of-capacity profit function for crop *r* is given by:

(7) $\pi^{rh}(p_r - w_r, \tau_i) = Max(p_r - w_r - c_{rh} - e_{rh}\tau_i; 0)$,

(8) $\pi^{ih}(p_i - w_i, \tau_r) = Max(p_i - w_i - c_{rh} - c_{ih} - e_{ih}\tau_r; 0)$.

where p_r is the consumer price of regular rapeseed; p_i is the consumer price of IP rapeseed; c_{rh} is the unit cost of production of regular rapeseed; c_{ih} is an additional handler cost of IP; e_{rh} and e_{ih} are externality parameters for handlers.

Because of the linearity of the profit functions, it is always optimal for a handler to handle only one crop, the one that yields the maximum profit level. Therefore we have:

(9) $\pi^{\max h}(p_i - w_i, p_r - w_r, \tau_i) = Max(\pi^{rh}(p_r - w_r, \tau_i); \pi^{ih}(p_i - w_i, 1-\tau_i))$.

We assume that costs c_{rh} and c_{ih} vary among handlers (some handlers have technological advantages in handling regular or IP rapeseed because different grain elevators are configured differently). In equilibrium, some handlers may find it most profitable to handle regular rapeseed, while others may find it most profitable to handle IP rapeseed. Handler *h*'s supply function for handled crop (for $k \in \{i, r\}$) is then identical to handler *h*'s demand function for farm crop *k* and defined by:

(10) $q_k^{sdh}(p_r - w_r, p_i - w_i, \tau_i) = \begin{cases} Q & if \quad \pi^{\max h}(.) = \pi^{kh}(.) \\ 0 & otherwise \end{cases}$.

The aggregate handler supply function of crop *k*, which is identical to the aggregate handler demand function of crop *k*, $k \in \{i, r\}$, is denoted $Q_k^{sdH}(.)$, and is defined as the sum of individual handler supply functions:

(11) $Q_k^{sdH}(p_r - w_r, p_i - w_i, \tau_i) = \sum_{h=1}^{H} q_k^{sdh}(p_r - w_r, p_i - w_i, \tau_i)$.

Domestic consumers

We consider a set of *C* consumers, and we assume that the utility of consumer $c \in \{1, \ldots, C\}$ takes the form:

(12) $u^c(q_r, q_i, q_z) = \begin{cases} \dfrac{K}{q_r + q_i}(\sigma_{rc}q_r + \sigma_{ic}q_i) + q_z & if \quad q_r + q_i \geq K \\ \sigma_{rc}q_r + \sigma_{ic}q_i + q_z & otherwise \end{cases}$,

where *r* is regular rapeseed, *i* is IP rapeseed, *z* is a numeraire good, q_j denotes the quantity of good *j*, and σ_{rc}, σ_{ic} and *K* are constant positive parameters.

We assume that for $c = 1, ..., C$, $\sigma_{ic} > 0$ and $0 \leq \sigma_{rc} \leq \sigma_{ic}$: each consumer may have some utility from consuming IP rapeseed, but some consumers have no utility from consuming regular rapeseed; and for a consumer consuming only one of the two types of rapeseed, the utility reached from consuming a given quantity of regular rapeseed is necessarily smaller or equal to the utility of consuming the same quantity of IP rapeseed. Consumer c's Marshallian demand functions for goods r and i and indirect utility function are given by:[6]

(13) $q_{rc}^{d}(p_r, p_i) = \begin{cases} K & if \quad \sigma_r - p_r > \sigma_i - p_i \quad and \quad \sigma_r - p_r \geq 0 \\ 0 & otherwise \end{cases}$,

(14) $q_{ic}^{d}(p_r, p_i) = \begin{cases} K & if \quad \sigma_i - p_i \geq \sigma_r - p_r \quad and \quad \sigma_i - p_i \geq 0 \\ 0 & otherwise \end{cases}$,

(15) $V^c(p_r, p_i, M) = M + K\ Max(\sigma_r - p_r, \sigma_i - p_i, 0)$.

The money metric indirect utility function of consumer c is given by:

(16) $\mu^c(p_r^1, p_i^1, p_r^0, p_i^0, M) = K[Max(\sigma_r - p_r^1, \sigma_i - p_i^1, 0) - Max(\sigma_r - p_r^0, \sigma_i - p_i^0, 0)]$,

where p_x^s is the price of good x in situation s.

Each consumer consumes at most one of goods r or i. We consider a set of C consumers with different values for parameters σ_{rc} and σ_{ic}, and, so that in equilibrium some may consume regular handled rapeseed, some may consume non-GM, IP handled rapeseed and some may consume no rapeseed. Consumers' aggregate demand function for good $k \in \{r, i\}$ is denoted $Q_k^{dC}(.)$ and is defined as the sum of individual demands for that good:

(17) $Q_k^{dC}(p_r, p_i) = \sum_{c=1}^{C} q_k^{dc}(p_r, p_i), \quad k \in \{r, i\}$.

Excess demand from the rest of the world and equilibrium conditions

We assume that consumers in the rest of the world are indifferent between regular and IP rapeseed. Because the consumer price of IP rapeseed, p_i, is necessarily higher than the consumer price of regular rapeseed, p_r, in our model, consumers in the rest of the world consume only regular rapeseed. The excess demand of regular rapeseed in the rest of the world is denoted by $Q_r^{dM}(p_r)$. In equilibrium, the quantity of regular rapeseed supplied and demanded by domestic handlers is equal to the quantity of GM and non-GM non-IP rapeseed supplied by domestic farmers, and to the quantity of regular rapeseed demanded by domestic consumers and the rest of the world:

(18) $Q_g^{sF}(w_r, w_i, \tau_i) + Q_n^{sF}(w_r, w_i, \tau_i) = Q_r^{sdH}(p_r - w_r, p_i - w_i, \tau_i)$

(19) $Q_r^{sdH}(p_r - w_r, p_i - w_i, \tau_i) = Q_r^{dC}(p_r, p_i) + Q_r^{dM}(p_r)$

In equilibrium, the quantity of IP rapeseed supplied and demanded by domestic handlers is equal to the quantity of IP rapeseed supplied by domestic farmers, and to the quantity of IP rapeseed demanded by domestic consumers:

(20) $Q_i^{sF}(w_r, w_i, \tau_i) = Q_i^{sdH}(p_r - w_r, p_i - w_i, \tau_i)$

[6] We arbitrarily decide that each consumer consumes only good i when he is indifferent between goods r and i, and that he always consumes rapeseed when he is indifferent between consuming or not consuming rapeseed.

$$(21)\ Q_i^{sdH}(p_r - w_r, p_i - w_i, \tau_i) = Q_i^{dC}(p_r, p_i)$$

In equilibrium, the value of τ_i is equal to the quantity of IP rapeseed supplied by domestic handlers divided by the total quantity of rapeseed handled by domestic handlers:

$$(22)\ \tau_i = \frac{Q_i^{sdH}(p_r - w_r, p_i - w_i, \tau_i)}{Q_r^{sdH}(p_r - w_r, p_i - w_i, \tau_i) + Q_i^{sdH}(p_r - w_r, p_i - w_i, \tau_i)}$$

The five equations (18) – (22) may be solved for four equilibrium prices, (w_r, w_i, p_r, p_i) and the equilibrium share of IP crops in the handling system, τ_i.

4. Simulations

We develop a simulation model to illustrate empirically our modeling framework in the case of rapeseed in the EU and the rest of the world. This model is developed using realistic assumptions on parameter values, presented in the appendix. The simulation model represents the rapeseed market in the EU and the rest of the world in 1999/2000. In the baseline situation, only non-GM non-IP rapeseed, i.e., rapeseed *n*, is produced by EU farmers, and due to regulations GM rapeseed cannot be produced or imported in the EU. Farm rapeseed *n* is processed by handlers into regular handled rapeseed, i.e., rapeseed *r*, which is either consumed domestically or exported to the rest of the world. Consumers in the EU are indifferent between regular and IP rapeseed.[7] Baseline EU farm and handled rapeseed production ($q_{n0}^{sAF} = q_{r0}^{sdAH}$) is equal to 11.55 million metric tons (tons), out of which 10.55 million tons are consumed domestically and 1 million ton is exported to the rest of the world. The farm rapeseed price is 152 euros per ton (euros/t), and the handled rapeseed price is 183 euros/t.

Simulation 1: GMO adoption in the EU when consumers are indifferent between IP and regular rapeseed

In simulation 1, GMOs are introduced in the EU and all consumers are indifferent between regular and IP rapeseed. Compared with the baseline situation, the equilibrium price of farm regular rapeseed decreases by about 1.2% to 150.2 euros/t from 152 euros/t. The equilibrium price of handled regular rapeseed decreases by about 0.7% to 181.7 euros/t from 183 euros/t. EU farm and handled supply of regular rapeseed increases by about 1.5% to 11.72 million tons from 11.55 million tons. 71% of farm regular rapeseed is GM rapeseed. EU domestic consumption increases by about 0.2% to 10.57 million tons from 10.55, and exports to the rest of the world increase by 23% to 1.23 million tons. Total profits of farmers increase by 58 million euros, total profits of handlers increase by 11 million euros and total utility of

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[7] In our simulation model, the EU is a net exporter of rapeseed. As a result, in the initial situation, even consumers who refuse to consume GMOs are not worse off from consuming non IP rapeseed, given that all rapeseed they consume is produced in the EU, and is non-GM in the initial situation. In reality, we can think of two reasons why some consumers would want to consume only IP rapeseed even if no GMOs were produced in the EU: 1) Consumers could be uninformed about the origin of the rapeseed they consume, or worried about consuming rapeseed that could have been cross-pollinated by GM rapeseed from a trial field. 2) The EU is a net exporter of rapeseed and rape oil, but is a net importer of rape meal. Imported rape meal is mainly used for livestock feed. Therefore, some consumers may prefer IP to assure themselves about not having eaten meat from an animal fed with GMOs.

domestic consumers increases by 9 million euros (Table 1). In total, domestic welfare increases by 78 million euros.

Simulation 2: GMO adoption in the EU with a shift in consumers' preferences and introduction of IP

Simulation 2 analyzes the consequences of the simultaneous introduction of GM rapeseed technology, a shift in half of the consumers' preferences in favor of non-GM IP rapeseed (good *i*), and the introduction of segregation and identity preservation in the EU. Compared with the baseline situation, the equilibrium price of farm regular rapeseed decreases by about 2.7% to 147.9 euros/t from 152 euros/t. The equilibrium price of handled regular rapeseed decreases by about 0.5% to 182.1 euros/t from 183 euros/t. The equilibrium price of farm IP rapeseed is 7.6% higher than the price of farm rapeseed at the baseline, at 159.1 euros/t. The equilibrium price of handled IP rapeseed is 11% higher than the price of handled regular rapeseed, at 202.2 euros/t. There is a 43.1 euros/t wedge between the price of farm IP rapeseed and handled IP rapeseed, and 34.2 euros/t wedge between the price of farm regular rapeseed and handled regular rapeseed. These wedges are higher than the 31 euros/t wedge between farm-gate and handler prices in the baseline scenario, and reflect higher costs due to identity preservation. In the regular rapeseed market, EU farm and handled supply is equal to 6.44 million tons. About 95% of farm regular rapeseed is GM rapeseed. EU domestic consumption is equal to 5.28 million tons, and exports to the rest of the world are equal to 1.16 million tons. In the IP rapeseed market, EU farm and handlers' production and EU domestic consumption are equal to 5.02 million tons.

Total profits of farmers increase by 2.7 million euros, total profits of handlers decrease by 0.2 million euros and total utility of domestic consumers decreases by 94.1 million euros (Table 1). In total, domestic welfare decreases by 91.6 million euros. Tables 2 to 4 show the change in profits and utilities for different groups of domestic farmers, handlers and final consumers. Consumers who refuse to consume GMOs lose from the introduction of GM technology, even though IP products are available, because the price they have to pay for IP rapeseed is higher than the price they paid for regular rapeseed (that was all non-GMO) in the baseline situation. These consumers, however, do not bear alone all the costs of IP. Profits of farmers who keep producing non-GM non-IP rapeseed decrease. Profits of farmers who turn from non-GM non-IP rapeseed to IP rapeseed or to the alternative crop decrease as well. Profits of handlers who keep handling regular rapeseed or who stop handling rapeseed decrease too.

Even though identity preservation creates externality costs for regular rapeseed, farmers with a high cost advantage in GM rapeseed relative to non-GM rapeseed win from the introduction of GM technology. And consumers who sense no difference between GMOs and non-GMOs win, because they face a lower price than in the baseline situation (although this price may have been even lower in the absence of externality costs due to the existence of the IP rapeseed supply channel).[8] Finally, handlers efficient at handling IP rapeseed win.

[8] Our analysis strictly considers economic effects. We do not consider the possibility that GMOs might actually have harmful health effects on consumers or harmful environmental effects.

5. **Conclusions**

The situation of GMO and non-GMO market segregation raises a range of positive as well as normative questions: who pays the costs in the absence of intervention; who should pay the costs; what kind of government intervention can increase global welfare. In this paper, we propose a framework specifying supply and demand functions at the individual level to study the first question. This framework allows us to circumvent the difficulties of conducting supply and demand analysis in the different horizontally and vertically related markets concerned by GMOs and market segregation. In addition, because our framework is built on individual heterogenous agents, it allows us to quantify welfare effects for farmers, handlers or consumers in general, but also welfare effects depending on various characteristics that describe the various agents.

Our simulation results are still preliminary given the lack of data on costs of GMO segregation and identity preservation. But they point in several interesting directions and suggest further research. First, it would be important to conduct sensitivity analysis on some key parameters of the model, notably parameters describing the costs of IP, and parameters describing the preferences of consumers towards GMO and non-GMO products. Second, this framework could be extended to analyze the welfare effects of public policy instruments, such as a taxation of GMO producers or a subsidy to non-GMO producers.

References

Agreste (2001), Chiffres et Données, Agriculture, n° 131, February 2001, Rica France: Tableaux Standard 1999, Ministère de l'Agriculture et de la Pêche, France.

Alston J.M., Norton G.W., Pardey P.G. (1998). Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting. CAB International, Oxon, UK, New York, USA.

Bullock, D.S., Desquilbet, M. (2001). The economics of non-GMO segregation and identity preservation. Working document, October 23.

Bullock, D. S., Nitsi., E. I. Roundup Ready Soybean Technology and Farm Production Costs: Measuring the Incentive to Adopt. *American Behavioral Scientist* 44(April 2001), 1283-1301.

Desquilbet, M., Lemarié, S., Levert, F. (2001). Potential adoption of GM crops in France, effects on revenues of farmers and upstream companies: an ex ante evaluation, *5th ICABR conference "Biotechnology, science and modern agriculture: a new industry at the dawn of the century", Ravello, Italy, June 15-18, 2001*.

Giannakas, K., Fulton, M. (2001). Consumption effects of genetic modification: what if consumers are right?. Forthcoming in *Agricultural Economics*.

Golan, E., Kuchler, F. (2000). Labeling biotech foods: implications for consumer welfare and trade. Presented at International Agricultural Trade Research Consortium Symposium, Montreal, Canada, June 26-27.

Mayer, H., Furtan, W.H. (1999). Economics of transgenic herbicide-tolerant canola: The case of Western Canada. *Food Policy* 24: 431-442.

McBride, W.D. and Books, N. (2000). Survey Evidence on Producer Use and Costs of Genetically Modified Seed. In Transitions in Agbiotech: Economics of Strategy and Policy. Lesser, W.E. (ed). Proceedings of the NE-165 Conference, June 24-

25 1999, Washington, D.C., 2000, University of Connecticut and University of Massachussetts, pp 22-40.

Nielsen, C. P., Thierfelder, K., Robinson, S. (2001). Consumer Attitudes Towards Genetically Modified Foods: The Modelling of Preference Changes. Paper prepared for the 5th International Conference on "Biotechnology, Science and Modern Agriculture: a New Industry at the Dawn of the Century", Ravello, Italy, June 2001.

Appendix: calibration of the model

The EU subsidy on rapeseed is 564 euros per hectare (euros/ha).[9] In our model we assume the numbers of types of domestic farmers, handlers and consumers to be *F*=2000; *H*=1500; *C*=2000.[10] In the baseline situation, 1000 farmers grow rapeseed while 1000 farmers grow the alternative crop *a*; 1000 handlers handle rapeseed and 500 handlers do not handle rapeseed; 1000 consumers consume rapeseed while 1000 consumers do not consume rapeseed. Land on each farm is *L*=3,500 ha; storage capacity per handler is *Q*=11,550 t; parameter of the utility function is *K*=10,550 t. EU rapeseed yield is 3.3 t/ha.

Parameters for farmers

To calibrate values $c_{n1},...,c_{n2000}$ and π_a, we consider the case where only non-GM non-IP rapeseed and the alternative crop are grown ($\tau_i = 0$). We then rely on two assumptions. First, we assume that the aggregate farm supply function for crop *n* takes on the constant elasticity form $Q_n^{sF} = \alpha\, w_r^{0.5}$, when the marginal farm is indifferent between producing crop *n* or crop *a*. Second, we assume that the average revenue of the 1000 farmers who grow rapeseed *n* in the baseline situation, including the subsidy, is equal to twice their average cost c_{nf}.

Values $r_{g1},...,r_{g2000}$ are calibrated using results of Desquilbet, Lemarié and Levert (2001), who estimate potential adoption of GM rapeseed using data on non-GMO herbicide costs from French rapeseed farmers. In a simulation where the GMO supplier sets the GM seed price at its profit-maximizing level, with other input prices kept constant, they estimate a mean farm herbicide cost reduction of 64.6 euros/ha. They estimate an empirical standard deviation of 30.2, with 71% of farmers adopting GMOs. In our model, we implicitly define per-hectare GMO cost reductions by the equation $\Phi(r_f) = f/2000$, for $f = 1,...,2000$, where $\Phi(r)$ is the normal cumulative distribution function of a random variable *r* of mean 64.6 and standard deviation 30.2. To avoid correlation between GMO cost reductions and production costs for rapeseed

[9] EU rapeseed area, yield, production and exports from Oil World Statistics Update, year 1999/2000, March 30, 2001. A rapeseed net export equivalent was calculated using a price-weighted average of EU net exports of rapeseed, net exports of rape oil and a net imports of rape meal. Per hectare rapeseed subsidy from les cahiers de l'ONIC, modèle MONIC: marchés céréaliers: perspectives européennes à l'horizon 2005, October 2000, ONIC, France. Farm production price from Agreste, Agreste conjoncture, le bulletin, n°5, May 2001, Ministère de l'Agriculture et de la Pêche, France. Handled export price from CETIOM, Colza d'hiver: les techniques culturales, le contexte économique, May 2000, France.

[10] We refer to them later simply as "farmers", "handlers" and "consumers", but they are rather types of farmers, handlers and consumers.

n, we take a random permutation of this list. In the baseline situation, we set t to 1000 euros/ha, which is high enough to cause no farmer to grow GMOs. In the simulations in which GMOs are adopted in the EU, we set t to 48 euros/ha.

Parameters for handlers

Parameters c_{rh} (the cost of handling regular rapeseed, excluding the cost of farm rapeseed and the handler's externality cost) are calibrated in an analogous manner to parameters c_{nf}: in the case where no IP rapeseed is supplied ($\tau_i = 0$), we assume that the relation $Q_r^{sdH} = \beta\,(p_r - w_r)^{0.5}$ is verified when the handler with the highest cost c_{rh} among handlers handling regular rapeseed is indifferent between handling regular rapeseed or handling nothing. We then find: $c_{rh} = 31 \times 10^{-6} \times h^2$.

Parameters for domestic consumers

In the baseline simulation, all parameters σ_{ic} are equal to σ_{rc}. To calibrate values $\sigma_{r1}, ..., \sigma_{r2000}$, we assume that the constant elasticity form $Q_r^{dC} = \gamma\, p_r^{-0.5}$ is verified when the consumer with the lowest preference for good r among those consuming good r is exactly indifferent between consuming or not good r. In the simulation, we assume that one consumer out of two refuses non IP rapeseed. In this case, σ_{rc} is set equal to zero for even values of c, and to σ_{ic} for odd values of c.

Rest of the world

We take constant elasticity supply and demand curves for handled regular rapeseed in the rest of the world. The supply elasticity is 0.5 and the demand elasticity is - 0.5 in the baseline situation. We take production and consumption levels in the rest of the world respectively equal to 31 million t and 32 million t in the baseline situation.

IP cost parameters

We expect the cost c_{if} to be positive, but very small. We arbitrarily set: $c_{if} = 0.1$ euros/ha, $f = 1, ..., 2000$. We expect the cost c_{ih} to be positive for each handler and to vary depending on handlers. We generate a set of parameters c_{ih} by a random permutation of 1500 equidistant points between 2 and 4 euros/t. We expect the externality parameter for IP rapeseed to be higher than the farm externality parameter for non-GM non-IP or GM rapeseed at both the farm and handling stages. Moreover, these externality costs are expected to vary between farmers and handlers. We arbitrarily define farm parameters e_{rf} by a random permutation of the list composed of 2000 ordered equidistant points between 0 and 66 euros/ha, and we arbitrarily define $e_{if} = e_{rf} + \varepsilon_{rf}$, where ε_{rf} is drawn from the uniform distribution with support the closed interval between 0 and 66 euros/ha. In the same way, we arbitrarily define handling externality parameters e_{rh} by a random permutation of the list composed of 1500 ordered equidistant points between 0 and 20 euros/t, and we arbitrarily define $e_{ih} = e_{ih} + \varepsilon_{ih}$, where ε_{ih} is drawn from the uniform distribution with support the closed interval between 0 and 20 euros/t.[11]

[11] Since the rapeseed yield is equal to 3.3 t/ha, the per ton values of the ranges of parameters for farmers and handlers are identical.

Table 1. Prices, quantities, profits and utilities in the baseline situation and in the simulations

	base situation	simulation 1	simulation 2
prices (euros/t)			
w_r	152	150.2	147.9
p_r	183	181.2	182.1
w_i	n.a.	n.a.	159.1
p_i	n.a.	n.a.	202.2
quantities (million t)			
Q_n^{sF}	11.55	3.41	0.32
Q_g^{sF}	0	8.31	6.12
Q_r^{sdH}	11.55	11.72	6.44
Q_r^{dH}	10.55	10.57	5.28
Q_r^{dM}	1.0	1.15	1.16
$Q_i^{sF} = Q_i^{sdH} = Q_i^{dH}$	0	0	5.02
variation in profits and utilities compared to the base situation (million euros):			
domestic farmers' profit		+ 58	+ 2.7
domestic handlers' profit		+ 11	- 0.2
domestic consumers' utility		+ 9	- 94.1
domestic total welfare		+ 78	- 91.6

Table 2. Change in profits of farmers' groups (baseline situation to simulation)

Domestic farmers' group	percentage of farmers	average change in profit per ton (euros)
rapeseed *n* → rapeseed *n*	2.7 %	- 9.67
rapeseed *n* → crop *a*	1.6 %	- 3.03
rapeseed *n* → rapeseed *i*	43.1 %	- 2.62
rapeseed *n* → rapeseed *g*	51.8 %	+ 3.12
crop *a* → rapeseed *g*	0.8 %	+ 6.68

Table 3. Change in profits of handlers' groups (baseline situation to simulation)

Domestic handlers	percentage of handlers	average change in profit per ton (euros)
rapeseed *r* → no rapeseed	2.4 %	- 1.59
rapeseed *r* → rapeseed *r*	54.5 %	- 1.56
no rapeseed → rapeseed *r*	0.3 %	+ 1.00
rapeseed *r* → rapeseed *i*	41.5 %	+ 2.03
no rapeseed → rapeseed *i*	1.3 %	+ 2.47

Note: we exclude

Table 4. Change in money metric utility of domestic final consumers' groups (baseline situation to simulation)

Domestic final consumers	number of consumers	average change in money metric utility (in equivalent per ton of rapeseed *i*) (euros)
rapeseed *r* → rapeseed *i*	47.6 %	- 19.2
rapeseed *r* → no rapeseed	2.4 %	- 9.23
no rapeseed → rapeseed *r*	0.1 %	+ 0.78
rapeseed *r* → rapeseed *r*	49.9 %	+ 0.90

Note: Table 1 assumes that the yield on the alternative crop is equal to the yield on rapeseed. Column 1 defines the farmers belonging to the group. For example, "rapeseed *n* → rapeseed *g*" is the farmers growing crop *n* in the baseline situation and crop *g* in the simulation. Column 2 indicates the number of farmers to whom the change described in column 1 applies. Column 3 indicates the average change in profit for this group from the baseline situation to the simulation. In Table 3, the average change in money metric utility in equivalent per ton of rapeseed i is obtained by dividing the average change in money metric utility per consumer by the parameter K of the utility function (this parameter gives the quantity of rapeseed *i* that each consumer would consume if he chose to consume rapeseed *i*).We exclude farmers growing crop *a*, handlers handling no rapeseed and consumers consuming no rapeseed in both simulations in the percentages.