WELFARE EFFECTS OF NON-GMO IDENTITY PRESERVATION: THE CASE OF POTENTIAL COEXISTENCE OF GM AND NON-GM RAPESEED IN THE EU

Marion Desquilbet
Institut National de la Recherche Agronomique, France

and

David S. Bullock
University of Illinois, Department of Agricultural and Consumer Economics

paper presented at the

Symposium

"Product Differentiation and Market Segmentation in Grains and Oilseeds: Implications for Industry in Transition"

Sponsored by

Economic Research Service, USDA

and

The Farm Foundation

Washington, DC

January 27-28, 2003

Corresponding author: Marion Desquilbet, INRA ESR, université Pierre Mendes France, BP 47, 38040 Grenoble cedex 9, France. desquilb@grenoble.inra.fr. Phone: (00) 33 4 76 82 54 39. Fax: (33) 2 23 48 53 80.
Co-author: David S. Bullock, Department of Agricultural and Consumer Economics, University of Illinois, 326 Mumford Hall, 1301 W. Gregory Drive, Urbana, IL 61801. Phone: (217) 333-5510. Fax: (217) 333-5538. dsbulloc@uiuc.edu.

WELFARE EFFECTS OF NON-GMO IDENTITY PRESERVATION: THE CASE OF POTENTIAL COEXISTENCE OF GM AND NON-GM RAPESEED IN THE EU

Marion Desquilbet and David S. Bullock

ABSTRACT

The paper presents a theoretical framework to analyze the welfare effects of non-GMO segregation and identity preservation (IP) on different types of consumers and producers. Our framework recognizes that IP may create some costs both producers of IP goods and non-IP goods because of flexibility losses in the production system. We illustrate our results using a simulation model of the rapeseed market in the EU and the rest of the world. The simulations show the effects of GMO adoption in the EU, given various levels of rejection of GMOs by domestic consumers. Our main objective is to examine how the simulation results are affected by the assumption of the presence or absence of flexibility losses in the production system due to the coexistence of regular and IP rapeseed.

INTRODUCTION

In the European Union (EU), the Ministers of Agriculture reached an agreement for a new regulation project on GMO authorization and labeling in November 2002, while the Ministers of Environment found a compromise solution for a project on traceability of GMOs in December 2002. The European Parliament must now give a decision on these two projects before the effective adoption of the regulations. The five EU Member States that originated the EU moratorium on new GMO authorizations in 1999 demanded such a regulatory framework. In this context, the lifting of the EU moratorium is possible in the short run. Still, many EU consumers are still strongly opposed to GMOs, because they feel that the consumption of GMOs is unhealthful, or that the growing of GMOs places the environment at unnecessary risk. The combination of the reluctance of many to consume GMOs with the willingness of others to grow GMOs could bring about the emergence of dual markets in the EU, with some farmers adopting GMOs and some farmers, grain handlers and food processors segregating GMOs from non-GMOs.

In this paper, our purpose is to explore the question of who pays the costs of and who reaps the benefits of maintaining a dual-market system of GMOs and non-GMOs. This paper builds on the analytical supply and demand model developed by Desquilbet and Bullock to examine the economic effects of non-GMO segregation and identity preservation (IP). We use here this theoretical model to conduct simulations on the effects of potential adoption of herbicide-tolerant GM rapeseed and IP in the EU.

More specifically, our aim is to study how different assumptions on the costs of IP affect measures of the price, quantity and welfare effects of GMOs. As a matter of fact, while changes in these assumptions clearly affect the results of the welfare analysis, different and sometimes contradictory assumptions on these IP costs have been made so far in studies of non-GMO segregation and IP. Most authors have assumed that the introduction of segregation results in a constant IP cost, for IP producers only (Mayer and Furtan, Saak and Hennessy, Lapan and Moschini, Lence and Hayes, Pekaric and Meilke, Golan and Kuchler, Sobolevsky et al.). Saak, as well as Nadolnyak and Sheldon, have pointed out that segregation costs for IP producers may vary depending on the size of the IP channel. At least, Giannakas and Fulton, without explicitly modeling it, have suggested that GMO producers may bear some costs of segregation too. So far, not much attention has been given to the consequences of these assumptions on the welfare effects of IP segregation.

Non-GMO segregation and IP incurs costs to physically separate non-GM IP goods (which we will call "IP goods") and goods for which no steps are taken to prevent GMO commingling (which we will call "regular goods") along the supply chain, and costs to ensure buyers that grain that is claimed as IP by sellers is actually IP. Costs of physical separation 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. Costs to ensure that grain that is claimed as IP is actually IP are incurred to perform chemical tests and to draw up contracts between buyers and sellers and monitor their abidance (Bullock and Desquilbet, 2002).

Segregating regular and IP goods along the supply chain results in a loss in the flexibility with which grain can be moved and stored. Because of this flexibility loss, to our view, this segregation creates costs for both regular producers of and IP producers. These costs of less flexibility may consist in costs of capacity underuse, cleaning costs, management costs to organize more complicated grain flows, additional transportation costs to handling or processing units that are dedicated to IP or to non-IP products. In addition, the larger is one production channel and the larger is the cost of IP in the other production channel (i.e., the additional costs for IP producers increase with the relative size of the regular channel, while the additional costs for regular producers increase with the relative size of the IP channel).

The paper is organized as follows. The analytical framework is presented in section 2. Comparative statics results are presented in section 3. Section 4 gives the results of the simulations.

ANALYTICAL FRAMEWORK

Our theoretical model is presented in more detail in Desquilbet and Bullock. We consider one production sector aggregating farmers, handlers and processors. We assume that three different types of good may be produced. The first one (indexed by n) is produced from a non-GM seed, but no steps are taken to prevent its possible commingling with a GM good. The second one (indexed by g) is produced from a GM seed. The third one (indexed by i) is non-GM and IP (later simply called "IP"): it is grown from a non-GM seed, and efforts are made to avoid it commingling with the GM good. Consumers consider good n and good g to be the same product, that we call the regular good (indexed by r). Therefore, they only distinguish the IP good and the regular good.

EU consumers

We consider two attitudes of consumers towards GMOs: indifference or hatred. Indifferent consumers derive the same utility from the regular good and the IP good, while GMO-haters derive no utility from the regular good. In the absence of hatred, the EU demand function is denoted by

$D(p)$. In the presence of hatred, we let q denote the proportion of GMO-haters. Total demand functions for the regular good and the IP good are then given by:

(1) $D_r(p_r, p_i, q) = (1-q)D(p_r)$ if $p_r < p_i$, $D_r(p_r, p_i, q) = 0$ otherwise ,

(2) $D_i(p_r, p_i, q) = qD(p_i)$ if $p_r < p_i$, $D_i(p_r, p_i, q) = D(p_i)$ otherwise ,

where p_r is the price of the regular good (latter called "regular price") and p_i is the price of the IP good (latter called "IP price").

EU producers

We assume the existence of a continuum of producers, each of which is producing only one good in equilibrium (*n*, *g*, *i* or *a*, where the good indexed by *a* is an alternative crop). Each of the four goods is produced under competitive conditions with a Leontief technology, using a fixed factor owned by the producer in quantity 1, and a set of variable inputs perfectly elastic in supply. Each producer is characterized by two parameters a and b. We denote the unit good-specific restricted profit on good *k* as $p^k(.)$, *k = n, g, i, a*. We assume that unit profits take the form:

(3) $p^n(p_r, x_i; a, b) = p_r - a - b - gx_i$,

(4) $p^g(p_r - v, x_i; b) = p_r - v - b - gx_i$.

(5) $p^i(p_i, x_i; a, b) = p_i - a - b - d - e(1 - x_i)$

(6) $p^a = e$

In these equations, a is the conventional weeding cost per unit of production of crop *n*. We assume that adoption of herbicide-tolerant GMOs only affects the weeding inputs, with conventional herbicides being replaced by the herbicide to which the GM seed is resistant. The unit cost of this herbicide and of the technology fee paid to access to the GMO technology is equal to *v*, that we call the GM weeding cost. Parameter b represents other costs of production.

Parameters *g*, *d* and *e* represent costs of IP for regular and IP producers. They are assumed to be identical for all producers. x_i is the share of the IP good in total domestic production (i.e. in IP plus regular production). The term $g\,x_i$ represents the negative production externality created by the existence of the IP supply channel for regular producers. The term $e(1-x_i)$ represents the negative production externality created by the existence of the regular supply channel for IP producers. In the rest of the paper, we call them simply "externality costs". *d* represents the IP costs that do not result from the existence of a regular supply channel.

Because p_i-p_n is constant, all producers either are indifferent between producing the non-GM non-IP good or the non-GM IP good, or prefer one of these two non-GM goods. In addition, the linear unit profit functions imply that each producer finds it optimal to produce only the good yielding the maximum profit level, i.e. the non-GM good, the GM good or the alternative crop. The aggregate supply functions for the non-GM and the GM good are then obtained as the sum of individual supply functions. The supply function of good *k* is given by $S_k(p_r, p_i, v, x_i)$, *k=n, g, i*.

Equilibrium conditions

We assume that consumers in the rest of the world are indifferent between regular and IP rapeseed. Because the IP price is necessarily higher than the regular price, 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 $M_r(p_r)$.

In equilibrium, the value of x_i is equal to the quantity of the IP good supplied by domestic producers divided by the total quantity supplied by domestic producers. The domestic supply of the regular good is equal to the sum of the domestic demand and the excess demand of the regular good. The domestic supply of the IP good is equal to domestic demand of the IP good.

(7) $x_i = \dfrac{S_i(p_r, p_i, v, x_i)}{S_r(p_r, p_i, v, x_i) + S_i(p_r, p_i, v, x_i)}$;

(8) $S_r(p_r, p_i, v, x_i) = D_r(p_r, p_i, q) + M_r(p_r)$;

(9) $S_i(p_r, p_i, v, x_i) = D_i(p_r, p_i, q)$.

Given the values of the GM weeding cost v and of the proportion q of GMO-haters, equations (7) to (9) may be solved for the two equilibrium prices $p_r(v, q)$ and $p_i(v, q)$ and the equilibrium share of IP crops in the handling system, $x_i(v,q)$.

COMPARATIVE STATICS

Here we summarize comparative statics results formally derived in Desquilbet and Bullock.

Situation 1: GMO adoption in the absence of hatred

We consider here GMO technology introduction in a situation where there exist no GMO-haters ($q = 0$). In such a situation, the IP good is neither supplied nor demanded. We find the usual price and welfare effects resulting from the introduction of an innovation, summarized in proposition 1.

Proposition 1: *in the absence of hatred, GMO technology introduction lowers the equilibrium regular price (* $p_{r0} < p_{r1}$ *, with no GMOs introduced in situation 0). Consumers gain from the GMO technology introduction. Non-adopters of GMOs lose. Adopters with "high conventional weed costs" win. Adopters with " low conventional weed costs" lose.*

Situation 2: GMO adoption in the presence of hatred, with externality costs

In this section we assume that some consumers hate GMOs (i.e., that $q > 0$). We consider the case in which IP cost parameters γ, δ and ε in equations (3) to (5) are positive. In other words, there are some costs of IP for both regular producers and IP producers, with the cost in each channel increasing with the relative share of the other channel in total domestic production.

Before turning to the comparative statics results, we first examine the implications of equation (7) defining the equilibrium share of the IP good in total production. This equation implicitly defines x_i as a function of p_r, p_i and v. All other things equal, an increase in x_i reduces the externality IP cost for IP producers, $e(1-x_i)$, and increases the externality IP cost for regular producers, $g\, x_i$. This tends to increase the supply of the IP good and to decrease the supply of the regular good. From equation (7), these two effects lead to a new increase in x_i. Therefore, the equilibrium is stable only if the supply functions do not react "too" strongly to a change in x_i. If this stability condition is not met, then the IP and GM goods cannot coexist in a stable equilibrium. The results in propositions 2 and 3 below are established assuming that the stability condition is met.

Given the GM weeding cost *v*, two different types of equilibrium situations may occur depending on the exogenous share of GMO-haters. We let $q_{sup}(v)$ be the value of *q* defining the change between the two types of equilibrium situations. Proposition 2 gives the characteristics of these equilibria.

Proposition 2: *We consider a case with externality costs and where supply functions do not react "too" strongly to changes in the share of the IP good in total production. Given v Î (a_L, a_H), there exists a unique number $q_{sup}(v)$ Î (0, 1] such that:*

- *Given a small amount of hatred, i.e. q Î (0, $q_{sup}(v)$), there is a unique equilibrium (call it 2a). In equilibrium 2a, $q_n > 0$, $q_i > 0$, $q_g > 0$, and $p_i - p_r = d + e(1-x_i) - gx_i$.*
- *Given much hatred, i.e. q Î ($q_{sup}(v)$, 1), there is a unique equilibrium (call it 2b). In equilibrium 2b, $q_n = 0$, $q_i > 0$, $q_g > 0$, and $p_i - p_r > d + e(1-x_i) - gx_i$.*

With a small amount of hatred (i.e. with *q* low), in equilibrium the production of the non-GM good exceeds the demand for the IP good by GMO-haters. Some of the non-GM good is then sold as an IP good to GMO-haters. The IP premium covers the IP cost plus the difference in externality costs for the IP good and the regular good ($p_i - p_r = d + e(1-x_i) - g\,x_i$). The rest of the non-GM good is sold as a regular product to indifferent consumers.

With much hatred (i.e. with *q* high), in equilibrium everything that is non-GMO is also identity-preserved, and GMOs and IP goods coexist in equilibrium. The premium for IP is greater than the IP cost plus the difference in externality costs on IP and regular markets ($p_i - p_r > d + e(1-x_i) - g\,x_i$), because some producers with high conventional weed control costs (that is $\alpha > v$) have to be willing to leave the GMO sector (that is, give up the low cost *v* and instead bear α) and go into the IP sector.

Proposition 3 gives the price effects of the introduction of the GMO technology in the presence of hatred and of the introduction of the hatred in the presence of GMOs.

Proposition 3: *Let p_{kx} denote the equilibrium price of good k in situation x.*

- $p_{r2b} - gx_{i2b} < p_{r2a} - gx_{i2a} = p_{i2a} - d - e(1-x_{i2a}) < p_{r1} < p_{i2a}$ *and* $p_{r1} < p_{i2b}$.
- p_{r0} *may be lower or higher than* p_{r2a}, p_{r2b}, p_{i2a} *or* p_{i2b}.
- p_{r1} *may be lower or higher than* p_{r2a} *or* p_{r2b}.
- $p_{i2b} - d - e(1-x_{i2b})$ *may be lower or higher than* p_{r0} *or* p_{r1}.

Given hatred, GMO technology introduction may increase or decrease the regular price depending on the model parameterization (the relative levels of p_{r0} and p_{r2a} or p_{r2b} are indeterminate), as a result of three effects of the introduction of GMOs. First, GMO cost reductions tend to decrease the regular price. Second, some producers and some consumers turn to the IP market, tending to decrease the regular price even more. Third, the externality cost borne by regular producers is partially transmitted to indifferent consumers, tending to increase the price of the regular good.

Given GMO technology, introduction of hatred may increase or decrease the regular price depending on the model parameterization (the relative levels of p_{r1} and p_{r2a} or p_{r2b} are indeterminate), as a result of the last two effects described above.

Given GMO technology, because IP is costly, the IP price with hatred is necessarily higher than the regular good price without hatred ($p_{r1} < Min(p_{i2a}, p_{i2b})$. Given hatred, the IP price with GMOs may be higher or lower than the regular good price without GMOs (p_{r0} may be higher or lower than p_{i2a} or p_{i2b}), as a result of two opposite effects. First, GMO technology introduction lowers the regular price, causing the least efficient regular producers to turn to the alternative crop. Therefore, more efficient producers are ready to supply the IP crop (which tends to make p_{i2} lower than p_{r0}). Second, the premium for IP has to be high enough to encourage producers to enter the IP market (which tends to make p_{i2} higher than p_{r0}).

In situation 2 the regular price minus the externality cost borne by producers of the regular good is lower than the regular price with GMOs and no hatred, or without GMOs ($p_{r2} - g\, x_{i2} < p_{r1} < p_{r0}$). With a small amount of hatred, the IP price minus the cost of IP and the IP externality cost in situation 2 is lower than the regular price with GMOs and no hatred, or without GMOs ($p_{i2a} - d - e\,(1 - x_{i2a}) < pr1 < pr0$). With much hatred, it may be lower or higher than either of these two prices ($p_{i2b} - d - e\,(1 - x_{i2b})$ may be lower or higher than p_{r0} or p_{r1}) depending on the model parameterization. Indeed, as the amount of hatred increases, encouraging additional producers to turn to the IP market may require an increase in the IP price.

The welfare changes of individual producers and consumers following from the introduction of GMO technology or hatred are given in the corollary below.

Corollary of proposition 3:
<u>Effect of GMO technology introduction, given hatred.</u> GMO technology introduction may hurt or benefit all indifferent consumers, and may hurt or benefit all GMO-haters, depending on the model parameterization. It benefits GMO producers characterized by "high conventional weed costs", while it hurts GMO producers characterized by "low conventional weed costs". Given a small amount hatred, all producers who are not GMO producers in the presence of hatred are hurt by the GMO technology introduction. Given much hatred, all these producers are either hurt or helped by the GMO technology introduction depending on model parameterization.
<u>Effect of the introduction of hatred, given GMO technology.</u> The introduction of hatred may hurt or benefit all indifferent consumers depending on the model parameterization, while it hurts all GMO-haters. It also hurts producers who are GMO producers in the presence of hatred. Producers who are not GMO producers in the presence of hatred are all hurt by the introduction of a small amount of hatred, while they are either all hurt or all helped by the introduction of much hatred, depending on the model parameterization.

Situation 3: GMO adoption in the presence of hatred, no externality costs

We consider here the particular case in which identity preserving a non-GM good entails a cost d for all IP producers, but no externality costs. This assumption is the most commonly used so far in the literature with IP (see introduction). This situation is described by propositions 2 and 3, assuming that the externality parameters γ and ε are equal to zero for all producers.

From proposition 3, with $\gamma = \varepsilon = 0$, the regular price necessarily decreases when GMOs and hatred are introduced (p_{r2a} and $p_{r2b} < p_{r0}$). Accordingly, the welfare effects in the absence of externality costs are now determinate for indifferent consumers, as summarized in the corollary below.

Corollary of proposition 3: *In the absence of externality costs, given GMO technology, the introduction of hatred benefits all indifferent consumers; given hatred, GMO technology introduction benefits all indifferent consumers.*

SIMULATIONS

We now illustrate our comparative statics results using a simulation model of the rapeseed market in the EU and the rest of the world in 1999/2000. The first simulation assumes that GMOs are adopted in the EU in the absence of hatred. We then study the effects of GMO adoption in the presence of various levels of hatred. Our main objective is to examine how the simulation results are affected by the assumption of the presence or absence of externality costs of IP (i.e., the presence or absence of flexibility losses in the production system due to the coexistence of regular and IP rapeseed). For this purpose, we use two alternative sets of assumptions about IP costs, one with no externality costs from IP for any producers, and one with externality costs from IP for both regular producers and IP producers. For both sets of assumptions, we simulate different levels of GMO hatred, by assuming that the proportion of GMO-haters, q, is alternatively equal to 5%, 25%, 50% or 75%.

Our assumptions on the values of IP cost parameters are necessarily to an extent ad-hoc, because data on IP costs are scarce. These assumptions are based on observable data on premiums for IP soybeans imported in Japan from the United States (U.S.) on the Tokyo Grain Exchange, and data on premiums for IP soybeans delivered by Midwestern farmers (Bullock and Desquilbet). Between May 2000 and September 2001, the average of monthly premiums for non-GM soybeans on the Tokyo Grain Exchange was equal to $27.50 per metric ton (ton). A typical premium for a U.S. farmer selling IP soybeans at that period was $7.50. The premium at the farm level partly paid for the cost of not using GMOs on the farm (i.e. for giving up cost savings from GMOs). Therefore, we base our assumptions about IP costs on the difference between observable IP premiums at the import level and observable IP premiums at the farm level, i.e. $20/ton. This procedure is not entirely satisfactory for two reasons. First, our observable premiums are for soybeans and not for rapeseed. Rapeseed producers may face additional complications in attempting to identity preserve their product, because non-GM rapeseed is subject to cross-pollination by GM rapeseed, whereas soybeans are self-pollinated and so basically not subject to cross-pollination. Second, there is a 5% tolerance level for GM content in non-GM products in Japan, while this tolerance level is only 1% in the EU. For these reasons, the results of our simulations should not be considered in absolute terms, but rather in relative terms.

Based on these observations, we set d = 20, g = 0 and e = 0 euros/ton in simulations with no externality costs of IP. In simulations with externality costs of IP, we set d = 1.5, g = 15 and e = 20 euros/ton. In this second set of assumptions, parameter d represents the per-unit IP cost for IP producers when domestic supply is almost entirely identity preserved. In this situation, IP costs come mainly from costs of writing and enforcing contracts that certify that products are non-GM, and costs of testing for GM content of these products. The low value of d is consistent with the low testing costs reported in Bullock and Desquilbet. Parameter *e* is set equal to 20 euros/ton so that when the IP production channel is small, (as in our two simulations in which 5% of consumers are GMO-haters), the premium for IP is similar in the absence or in the presence of externality costs. We expect that the externality costs borne by producers of regular rapeseed are lower than the externality costs borne by producers of IP rapeseed. Since consumers of regular rapeseed would not mind if the product they consume were mixed with non-GM rapeseed, but IP rapeseed has to be kept thoroughly separate from regular rapeseed or else face rejection by GMO-haters, then of course segregation procedures have to be stricter for IP products than for regular products. Parameter *g* is therefore set equal to 15 euros/ton, i.e. a lower value than parameter *e*. Assumptions on other parameters of the simulation model are presented in the appendix.

In the baseline situation, EU farmers produce only non-GM non-IP rapeseed (rapeseed *n*), which is either consumed domestically or exported to the rest of the world.[1] Baseline EU rapeseed production is equal to 11.55 million tons, out of which 10.55 million tons are consumed domestically and 1 million tons is exported to the rest of the world. The rapeseed price is 183 euros/t. Simulation *a* is the baseline situation. Simulation *b* assumes GMO adoption with no hatred. Simulations *c* to *f* assume GMO adoption with four different levels of hatred and that there are no externality costs of IP. Simulations *g* to *j* assume GMO adoption with four different levels of hatred and that there are externality costs of IP. Simulation results are summarized in Tables 1 to 3. Table 1 gives prices, quantities, IP costs and changes in domestic welfare compared to the baseline situation. Tables 2 and 3 detail welfare effects for GMO producers, non-GMO producers, producers turning to the alternative crop (which we call "leavers"), indifferent consumers and GMO-haters. Table 2 presents the welfare effects of GMO technology introduction given hatred, i.e. the welfare effects compared to the baseline situation in which GMOs are not introduced (simulation *a*). Table 3 presents the welfare effects from the introduction of hatred in the presence of GMO technology, i.e. the welfare effects compared to the situation in which GMOs are introduced with no hatred present (simulation *b*).

Introduction of GMO technology in the EU in the absence of hatred

Compared with the baseline situation, when GMO technology is introduced in the presence of no hatred, the equilibrium price of regular rapeseed decreases by about 0.4% to 182.2 euros/ton from 183 euros/ton. 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 regular rapeseed produced on the farm is GM rapeseed. A result of interest not reported in Table 1 is that cost savings for producers adopting GMOs range between 0 and 38.5 euros/t, with average cost savings of 8.5 euros/t for GMO adopters. EU domestic consumption increases by about 0.3% to 10.58 million tons from 10.55, and exports to the rest of the world increase by 14% to 1.14 million tons. Domestic consumers' total

[1] In our simulation model, the EU is a net exporter of rapeseed. As a result, in the initial situation, even GMO-haters 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 of not having eaten meat from animals fed with GMOs.

utility increases by 9 million euros and producers' total profits increase by 60 million euros (Table 1, simulation *b*). Those who produce GM rapeseed after the introduction of GMOs gain 63 million euros while those who produce non-GM rapeseed after the introduction of GMOs lose 3 million euros. Total profit losses for leavers (those turning to the alternative crop) are very small (Table 2, simulation *b*). In total, domestic welfare increases by 69 million euros.

Introduction of GMO technology introduction in the EU in the presence of hatred

With 5% or 25% of consumers being GMO-haters, non-GM rapeseed production is higher than IP rapeseed demand in all our simulations. Some non-GM producers then supply IP rapeseed while others supply non-GM rapeseed in equilibrium ($Q_n^s > 0$). These simulations correspond to our equilibrium 2a from Proposition 2 (small amount of hatred). On the contrary, with 50% or 75% of consumers being GMO-haters, all non-GM rapeseed production is IP in all our simulations ($Q_n^s = 0$). These simulations correspond to our equilibrium 2b from Proposition 2 (much hatred). In conformity with our theoretical results, the premium for IP just covers the difference in unit costs of IP for IP producers and regular producers if the amount of hatred is small, while it more than covers this difference if the amount of hatred is high. Given much hatred, the premium for IP has to be high enough to give an incentive to additional producers to turn to the IP good.

In all our simulations, the introduction of GMOs and hatred lowers the regular price, and results in an IP price that is higher than the initial regular price of 183 euros/ton. Variations to the regular price are small, because this good is partly exported towards the rest of the world, where the excess demand for regular rapeseed is very elastic. The IP price is much higher than the initial regular price, because this good is only consumed domestically and domestic demand for IP rapeseed is inelastic. Therefore, the final premium for IP (i.e. the final difference between IP and regular prices) results mostly from a final IP price that is higher than the initial regular price, and to a smaller extent from a final regular price that is lower than the initial one.

We do not detail all of our simulation results here, since our aim is to analyze the implications of our two different assumptions of zero externality costs or positive externality costs on welfare effects. To this purpose, we consider successively the welfare effects of the introduction of GMOs in the presence of hatred (comparison with simulation *a*) and the welfare effects of the introduction of hatred when the GMO technology has already been introduced (comparison with simulation *b*). In both cases, we compare the results obtained with zero externality costs and the results obtained with positive externality costs, for different levels of hatred.

Welfare effects of the introduction of GMOs given hatred

Here we consider the effects of the GMO technology introduction in the presence of hatred. These welfare effects are presented in Table 2.

In all our simulations, introduction of GMO technology helps indifferent consumers while it hurts GMO-haters (we may recall here that both effects are theoretically indeterminate). These simulation results suggest that the complaints of anti-GMO consumers and activists that they have been made worse off by the appearance of GM technology are legitimate. Even though their preferences bring about the appearance of a market for IP goods, segregation and identity preservation are costly procedures, and parts of these costs are passed along to them, so they end up paying more than if GMO technology had never appeared. In a sense, anti-GMO consumers may blame indifferent consumers, because their acceptance of the GMO technology makes them have to pay a higher price for their food**.**

Indifferent consumers win less and GMO-haters lose less from the introduction of GMO technology if there are positive externality costs, rather than no externality costs. Indeed, in this case, GMO-haters bear less costs of IP, while indifferent consumers bear some costs of IP (externality costs for regular producers are partially transmitted to them because the decrease in the regular price is smaller because of the externality costs). In other words, our results imply that costs of less flexibility in the production system may partially offset the effects of GMO technology on the two types of consumers, potentially causing anti-GMO consumers to lose less and indifferent consumers to win less.

Aggregate GMO producer profits rise in all simulations of GMO technology introduction (though in each simulation some GMO producers win and some lose depending on the level of their conventional weeding costs). This results from our calibration, because in our simulations GMO weeding cost reductions are always higher than unit costs of IP at least for a subset of GMO adopters. These GMO producers win less when there are positive externality costs, because they bear some costs of IP in this case.

In conformity with our theoretical results, all non-GMO producers always lose from the introduction of GMO technology if the amount of hatred is small. When there is much hatred, in the simulations, IP producers win if there are no externality costs, while they lose if there are positive externality costs. Indeed, with no externality costs, the premium for IP has to cover more than their unit cost of IP to convince enough producers to turn to the IP good. In contrast, this does not have to be the case if there are positive externality costs. The premium for IP then only has to be high enough so that enough producers prefer IP rapeseed to GM rapeseed, given that they would bear some externality costs if they chose to produce GM rapeseed.

Welfare effects of the introduction of hatred given GMO technology

In this section we consider the effects of the introduction of hatred, if GMOs are already introduced but no consumers hate them in the initial situation. These welfare effects are presented in Table 3. The simulations illustrate our theoretical result that GMO-haters are necessarily hurt by the introduction of the hatred (since these consumers pay a higher price after they become anti-GMO). While indifferent consumers always win when there are no externality costs, they lose if there are positive externality costs if the amount of hatred is at least equal to 25%. In this case, with positive externality costs, indifferent consumers win from the introduction of GMOs given hatred, but they lose from the introduction of hatred given GMO technology. In other words, anti-GMO consumers are not the only group with a basis for complaint. For those whose tastes make no distinction between GMOs and non-GMOs may end up paying a higher price for their food than they otherwise would because anti-GMO consumer's demands for segregation and identity preservation can make the entire supply system less efficient, and part of the cost of this inefficiency is past along to all consumers in the form of higher food prices.

The simulations illustrate our theoretical result that GMO producers are necessarily hurt by the introduction of the hatred. However, these GMO producers lose less if there are positive externality costs. Results for non-GMO producers are similar to the effects described before. These producers all lose from the introduction of a small amount of hatred. The introduction of much hatred helps them all if there are no externality costs, while it hurts them all if there are positive externality costs. In other words, the existence of positive externality costs may rebalance welfare effects between GMO and non-GMO producers.

CONCLUSION

In this paper we present a theoretical model of segregation and IP of non-GM products, acknowledging that IP costs may arise for both IP and non-IP producers and may vary depending on the relative sizes of the two production channels, because of flexibility losses in the production system. Our framework distinguishes two types of consumers (GMO-haters and indifferent consumers), and three types of producers (GM, non-GM non-IP, and non-GM IP producers). We give the price and welfare effects resulting from the GMO technology introduction given hatred, and from the introduction of hatred given GMOs. We illustrate the theoretical results by a simulation model of the rapeseed market in the EU and the rest of the world.

Our simulations show the effects of GMO introduction given various levels of hatred, and the effects of the introduction of various levels of hatred given GMOs. In these simulations, we mainly consider the implications of the assumption of flexibility losses in the production system. More specifically, we compare the results obtained under two alternative sets of assumptions: no externality costs of IP (i.e., no flexibility losses in the production system), or positive externality costs of IP (i.e., positive flexibility losses in the production system). We find that welfare effects are different when we assume positive externality costs of IP. Contrarily to the case where there are no externality costs of IP, we find that indifferent consumers are hurt by the introduction of hatred and that IP producers are hurt by the introduction of GMOs given much hatred and by the introduction of much hatred given GMOs. GMO-haters are less hurt by the introduction of GMOs or hatred, and GMO producers gain less from the GMO introduction, or lose more from the introduction of hatred. So, the existence of externality costs of IP partially rebalances welfare effects between the two types of producers and between the two types of consumers.

In this paper, we assume that costs of IP are identical for all producers of the IP good, and that they are identical for all producers of the non-IP good. A potential extension of our simulation model would consist in allowing costs of IP to be heterogeneous between producers. In Desquilbet and Bullock, we show that the existence of such heterogeneity has two implications. First, all producers are not affected in the same way by GMO introduction or hatred introduction. Notably some IP producers may win even when there is not much hatred. Second, some producers may produce non-GM non-IP goods even when there is much hatred (while in this paper all non-GM producers are necessarily IP producers in the presence of much hatred). Such producers would not benefit from cost reductions if they adopted GMOs, and their costs of IP are too high to allow them to produce efficiently the IP good.

APPENDIX: CALBRATION OF THE MODEL

Domestic consumers

We assume that the EU demand function for regular rapeseed takes the constant elasticity form $D(p_r) = b\, p_r^{-0.5}$ in the baseline situation with no hatred. We then find b = 1.43 10^8 (total domestic demand is then equal to 10.55 10^6 t in the baseline situation).

Domestic producers

We calibrate the distribution of the conventional herbicide unit cost, a, from a database on herbicide costs for 1238 French farmers growing rapeseed in 1999 (CETIOM, 1999). This database is divided into two subsamples. In subsample 1 (subsample 2) we assume that adoption of GM glyphosate-resistant rapeseed would result in one application (two applications) of glyphosate (details on assumptions are available in Desquilbet et al.). We fit each subsample to a Logistic distribution. In subsample 1, conventional herbicide costs are distributed between 5 and 60 euros/t with a cumulative distribution function $F_{a1}(a) = 0.5144 / Exp[5.3307 - 0.2088\, a]$. In subsample 2, conventional herbicide costs are distributed between 10 and 63 euros/t with a cumulative distribution function $F_{a2}(a) = 0.50148 / Exp[6.1723 - 0.18811\, a]$.

The EU subsidy on rapeseed is 171 euros per ton.[2] We arbitrarily assume that the unit profit on the alternative crop is equal to one quarter of the initial unit revenue from rapeseed (i.e. $e = (p_{r0}+s) / 4 = 88.5$). We assume that the cumulative distribution function of b is given by $F_b(b) = a\, b^m$, with $b_{min} = 5$. Given this supply function, we calibrate m = 0.575 (the price elasticity of supply is then 0.5 in the initial situation). We also calibrate a = 553,135 (the aggregate rapeseed supply is then equal to 11.55 10^6 t in the initial situation). The cost of one application of glyphosate is equal to 6.7 euros/t. In simulations with GMOs, we set t to 14.8 euros/t. (This value results in a 71% adoption rate of GMOs in the absence of hatred, which is consistent with the estimation of Lemarié et al.). Therefore, the GM weeding cost is equal to 6.7+14.8=21.5 in subsample 1 and 2×6.7+14.8 in subsample 2 of producers.

Rest of the world

We assume constant elasticity supply and demand curves for regular rapeseed in the rest of the world, with supply elasticity equal to 0.5 and demand elasticity equal to -0.5. We take production and consumption levels in the rest of the world to equal 31 million t and 32 million t in the baseline situation. We obtain ROW domestic supply and demand curves defined by $q^{sROW} = 183^{-0.5} \times 31 \times 10^6\, p_r^{0.5}$ and $q^{dROW} = 183^{0.5} \times 32 \times 10^6\, p_r^{-0.5}$. The import demand curve is then defined by $q_M^d = q^{dROW} - q^{sROW}$.

---

[2] EU rapeseed 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 net imports of rape meal. Rapeseed direct aid from *les cahiers de l'ONIC, modèle MONIC: marchés céréaliers: perspectives européennes à l'horizon 2005, October 2000, ONIC, France*. EU price from *CETIOM, Colza d'hiver: les techniques culturales, le contexte économique, May 2000, France*.

REFERENCES

Bullock D.S., Desquilbet M. (2002). The Economics of Non-GMO Segregation and Identity Preservation. *Food Policy* 27, 81-99.

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

Desquilbet M., Bullock D.S. (2003). Who Pays the Costs of non-GMO Segregation and Identity Preservation and Who is to Blame? Working Document.

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. (2002). Consumption Effects of Genetic Modification: What if Consumers Are Right?. *Agricultural Economics*, 27, 97-109.

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.

Lapan H., Moschini G. (2002). Innovation and trade with Endogeneous Market Failure: the Case of Genetically Modified Products. Working Paper 02-WP 302, Center for Agricultural and Rural Development, Ames, Iowa.

Lence S., Hayes D. (2001). Response to an Asymmetric Demand for Attributes: an Application to the Market for Genetically Modified Crops. *NCR-134 Conference on Applied Commodity Price Analysis, Forecasting and Market Risk Management*, St Louis, Missouri, USA.

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., 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.

Nadolnyak D.A., Sheldon I.M. (2002). A Model of Diffusion of Genetically Modified Crop Technology in Concentrated Agricultural Processing Markets - the Case of Soybeans. *6th ICABR conference "Biotechnology, science and modern agriculture: a new industry at the dawn of the century"*, Ravello, Italy.

Pekaric-Falak I., Meilke K.D., Huff K. (2001). The Trade Effects of Bt Corn. Canadian Agri-Food Trade Research Network.

Saak A.E. (2002). Identity Preservation and False Labeling in the Food Supply Chain. Working Paper 02-WP 295. Ames, Iowa, Center for Agricultural and Rural Development.

Saak A.E., Hennessy D.A. (2002). Planting Decisions and Uncertain Consumer Acceptance of Genetically Modified Crop Varieties. *American Journal of Agricultural Economics* 84(2).

Sobolevsky, A., Moschini G., Lapan H. (2002). Genetically Modified Crop Innovations and Product Differentiation: Trade and Welfare Effects. Working Paper 02-WP 319, Center for Agricultural and Rural Development, Ames, Iowa.

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

Situation	0	1	2 (*d* = 20, *g* = 0, *e* = 0)				2 (*d* = 1.5, *g* = 8, *e* = 12)			
q	-	0%	5%	25%	50%	75%	5%	25%	50%	75%
Simulation	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*
Prices (euros/ton)										
p_r	183	182.2	182.0	181.6	180.7	179.4	182.1	182.2	182.4	182.5
p_i	-	-	202.0	201.6	203.6	206.5	202.1	196.0	191.5	188.3
premium for IP ($p_i - p_r$)	-	-	20.0	20.0	22.9	27.1	20.0	13.8	9.1	5.8
unit cost of IP (euros/ton)										
regular producers: $g\,x_i$	0	0	0	0	0	0	0.7	3.3	6.7	10.1
IP producers: $d+e(1-x_i)$	0	0	20	20	20	20	20.7	17.1	12.7	8.0
Quantities (million tons)										
Q_n^s	11.55	3.43	2.92	0.90	0	0	2.92	0.85	0	0
Q_g^s	0	8.29	8.29	8.28	6.70	4.28	8.28	8.22	6.40	3.73
Q_r^s	11.55	11.72	11.21	9.18	6.70	4.28	11.20	9.07	6.40	3.73
Q_r^d	10.55	10.58	10.00	7.94	5.31	2.66	10.05	7.93	5.28	2.64
Q_r^{dM}	1.0	1.14	1.16	1.24	1.39	1.62	1.15	1.14	1.11	1.09
$Q_i^s = Q_i^d$	0	0	0.50	2.51	5.00	7.45	0.50	2.55	5.16	7.80
total cost of IP (million euros)	0	0	10.0	50.3	100	149	17.0	73	108	100
Welfare (million euros)										
Domestic Utility	0	+8.8	-0.3	-36.7	-93.7	-170.9	-1.2	-27.4	-41.0	-40.3
Domestic Profit	0	+60.5	+59.2	+53.8	+55.7	+66.7	+52.6	+22.5	-1.1	-8.8
Domestic Welfare	0	+69.3	+58.9	+17.1	-38.0	-104.2	+51.4	-4.9	-42.1	-49.0

Equilibrium production is denoted by superscript *s* and equilibrium consumption is denoted by superscript *d*.

Table 2. GMO technology introduction given hatred: effects on domestic welfare (million euros)

Situation	0	1	2 (*d* = 20, *g* = 0, *e* = 0)				2 (*d* = 1.5, *g* = 8, *e* = 12)			
q	-	0%	5%	25%	50%	75%	5%	25%	50%	75%
Simulation	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*
Indifferent consumers	0	+60.5	+9.5	+11.2	+12.1	+9.5	+8.7	+6.3	+3.4	+1.3
GMO-haters	0	0	-9.8	-47.9	-105.8	-180.4	-9.9	-33.7	-44.4	-41.6
GMO producers	0	+63.4	+62.4	+58.6	+52.6	+40.7	+57.6	+36.5	+19.9	+12.1
Non-GMO producers	0	-2.9	-3.3	-4.8	+3.0	+26.0	-5.2	-13.9	-21.0	-20.8
Leavers	0	-0.003	-0.004	-0.01	-0.002	-0.1	-0.01	-0.09	-0.1	-0.08

Table 3. Hatred introduction given GMO technology: effects on domestic welfare (million euros)

Situation	1	2 (*d* = 20, *g* = 0, *e* = 0)				2 (*d* = 1.5, *g* = 8, *e* = 12)			
q	0%	5%	25%	50%	75%	5%	25%	50%	75%
Simulation	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*
Indifferent consumers	0	+1.1	+4.5	+7.7	+7.3	+0.3	-0.3	-1.0	-0.9
GMO-haters	0	-10.2	-50.0	-110.2	-187.0	-10.3	-35.9	-48.8	-48.2
GMO producers	0	-0.9	-4.7	-9.7	-11.7	-5.6	-26.8	-41.6	-36.7
Non-GMO producers	0	-0.4	-2.0	+4.9	+17.9	-2.3	-11.1	-19.6	-31.7
Leavers	0	-0.000	-0.005	-0.02	-0.07	-0.07	-0.1	-0.4	-0.9