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The economics of non-GMO segregation and identity preservation

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Abstract

Rejection of genetically modified organisms (GMOs) by some consumers worldwide has led to the creation of market signals encouraging the segregation and identity preservation (IP) of non genetically modified (GM) grain from GM grain. This article examines the costs of non-GMO segregation and IP for seed producers, farmers and grain handlers in the United States. For soybeans, costs of segregation and IP for farmers appear to come mainly from the production process itself (i.e. from foregoing planting of cost-reducing GM varieties). Additional costs of segregation for farmers, coming from cleaning farm machinery and having to haul grain farther on average, appear to be small. A major cost for handlers appears to come from a flexibility loss due to the necessity of dedicating equipment to one of two handling channels (one for GMOs and one for non-GMOs). For maize, an additional major cost comes from the necessity of preventing pollination of non-GM varieties by GM pollen at the seed and farm production stages. Tolerance levels are a key element of costs of segregation, and zero-tolerance levels may be impossible to obtain without major organisational and economic costs.

keywords: Genetically modified organisms; Consumer preferences; Grain handling system; Market segmentation; Identity preservation.

The Economics of Non-GMO Segregation and Identity Preservation

Introduction

Much controversy surrounds the production and marketing of agricultural genetically modified organisms (GMOs). Many consumers worldwide worry that food derived from GMOs may be unhealthy, or that the production of GMOs may have negative environmental or social consequences. As a result, regulations on GMO authorisation and GMO labelling have increased and markets for non-GM ingredients have developed in many countries very recently. Regulations are variable depending on the country and the market use, and are in rapid evolution (Roberts et al., 2001). Demand for non-GM products by private buyers, who have to comply with government regulations they are facing, is encouraging segregation of non-GM products from GM products and identity preservation of non-GM products throughout the grain production and handling system.

Available empirical evidence suggests that the actual impact of non-GM demand on global trade flows has remained limited so far. However, the potential impact seems huge, if regulations continue to strengthen and if consumer concern remains high (Elberhi, 2001). This impact will crucially depend on the ability of producers and handlers to segregate GM from non-GM crops in countries where production of GMOs is adopted on a large scale. As a result, the feasibility and costs of non-GM segregation and identity preservation (IP) are central to understanding current and future market developments, as well as current and future international negotiations on regulations concerning GMO standards.

In this context, the aim of this article is to explore the costs created by non-GMO segregation and IP, and how these costs depend on standards defining goods as non-GM. Although this question may affect producers and consumers of any food product worldwide, we focus on the specific cases of soybeans and maize in the United States (US), the European Union (EU), and Japan. According to USDA estimates, 63% of US soybean acres and 24% of

US maize acres were planted with genetically modified (GM) varieties in 2001 (USDA NASS, 2001). The US is a major world producer and exporter in both markets, and the EU and Japan are major destinations for US soybean and maize products (Ballenger, 2000). Moreover, a market for segregated and identity-preserved non-GM products has already appeared in the US, so that empirical evidence on segregation feasibility and costs is already available. The purpose of this article is to use the available data to examine the economic effects of GMO regulations and consumer preference shifts on US, EU, and Japanese grain markets.

In the first section we present current GMO regulations in the EU and Japan that define minimum standards for non-GM demand addressed to the US. In the second section we discuss the steps to be taken to maintain purity at each vertical stage of the US grain supply chain, from the seed production to the processing stage. The third section addresses questions of information asymmetry, testing, and contracting costs. In the final section we identify some observable quantitative elements of current premium levels for non-GM products.

EU and Japanese GMO authorisation and GMO labelling standards

Regulations on GMO authorisation define minimum product standards for domestic use. Labelling regulations define minimum standards that a food product must meet to be recognized as “non-GM”. These standards, which are imposed on suppliers, may concern tolerance levels for GM products in non-GM products, markets subject to regulations, products subject to labelling, and government rules to check compliance of private stakeholders. Different standards may lead to different costs of segregation – generally the higher is the standard, the more costly it is to meet.

Authorised and unauthorised GMOs

In the EU and Japan, tolerance levels are zero for unauthorised GMO transformation events.¹ As a consequence, the import of any seed containing GMO transformation events not authorised for domestic planting is illegal, as is the import of any food or feed product containing GMO transformation events not authorised for domestic marketing.

For maize, nineteen events of transformation have been authorised for production in the US, of which only two are accepted for all uses in the EU, and nine in Japan (Agriculture & Biotechnology Strategies Inc., 2001).² Failure to keep traces of unauthorised maize types out of maize exports to Japan or the EU can lead to trade disruption and considerable political turmoil, as evidenced by a recent episode in which US-produced StarLink maize, which is not authorised in Japan, was found commingled with shipments of authorised maize types to Japan (USDA FAS, 2001a). Currently seed companies are postponing sales of maize seed varieties with GMO transformation events that are not approved in export destinations (Pioneer, 2000). Such precaution is being taken to avoid possible commingling in the grain handling system of authorised maize with maize not authorised in the EU and Japan.

In the same way, for soybeans, the American Soybean Association and the National Oilseed Processors Association state that they have “successfully influenced the biotechnology seed companies” to prevent commercial growing of two GM soybeans that have been authorised in the US but not in the EU and Japan (Anderson, 2000). Due to this action, only one type of GM soybeans, Roundup Ready soybeans, is currently available for commercial planting in the US. The corresponding GMO transformation event is approved for all uses in Japan, and for marketing in the EU. Of these destinations, the only market in which US soybeans currently face a zero-tolerance level for the presence of commercialised GM soybeans is the market for soybean planting seeds destined for the EU.

Labelling regulations

For food products containing domestically authorised GMO events of transformation, laws for mandatory labelling have been passed in the EU in April 2000 and in Japan in April 2001. Stated roughly, labelling is required for any food product with presence of these domestically authorised GMOs above a 1% tolerance level in the EU and a 5% tolerance level in Japan.

More precisely, in the EU, a food product is exempt from mandatory labelling if in each of the product's ingredients, the DNA or protein content resulting from an EU-authorised genetic modification makes up less than 1% of the ingredient's total DNA or protein. Also, any presence of GM material in the ingredient must be adventitious (i.e., operators must be able to demonstrate that they have used appropriate steps to avoid the presence of GM material in the ingredient, even though traces of GM material might exist). If these requirements are not met for every ingredient in a food product, the product has to bear a label listing the ingredients not meeting the requirements as being GM (European Commission, 2000).

In Japan, regulations cite twenty-four "basic ingredients" as subject to GM food product labelling laws. A basic ingredient is subject to GMO labelling requirements if three conditions are met: 1) if DNA or protein resulting from a genetic modification is present in the basic ingredient; 2) if the basic ingredient is one of the top three ingredients of the product in terms of weight; and 3) if the weight of the basic ingredient accounts for 5% or more of the total product. A basic ingredient meeting these three conditions in a food product must be listed on the product's label as "genetically modified" if it comes from a GM shipment for which IP procedures were followed. This basic ingredient may be, but is not required to be, listed as "not genetically modified" if it comes from a non-GM shipment for which IP procedures were followed. If the basic ingredient comes from a shipment for which no IP procedures (either GM or non-GM) were followed, it must be listed on the product's label with an indication that

“GM and non-GM elements were not separated.” The regulation does not define an official tolerance level for adventitious commingling of GMOs in non-GM products. However, the Japanese Ministry of Agriculture has set an unofficial 5% maximum threshold for adventitious commingling. (USDA FAS, 1999 and 2001b).

As these labelling regulations do not apply to animal feed, feed companies currently voluntarily labelling their products as “non-GM” do not have to comply with the 1% and 5% tolerance levels. In addition, food products (such as soy sauce) for which all traces of GM or protein DNA have been eliminated during processing are exempt from labelling regulations.

It can be foreseen that more stringent labelling regulations will evolve in the future. The EU is currently working on legislation that would extend mandatory labelling to animal feed, define thresholds for adventitious GM presence in non-GM seeds, and require traceability of GMOs. Enactment of the proposed traceability requirements would mean that even ingredients produced from GMOs but no longer containing GM DNA or proteins would have to be labelled as GM (European Commission, 2001). The Japanese Ministry of Agriculture is also proposing to extend labelling requirements to some processed products produced from GMOs, but in which GM DNA or proteins are no longer present (USDA FAS, 2001b). In addition, regulations aiming at normalising detection methods of GMO content are expected in the future.

Maintaining the purity of non-GM grains

GMO regulations discussed above define current standards on acceptable non-GM purity levels that US grain producers and handlers have to meet if they desire to export non-GM products (or even to export GM products, but without unapproved GMO transformation events) to Japan and the EU. But there are several places in the US grain supply chain in which the purity of non-GM grains may be compromised by inadvertent commingling of GM

grains with non-GM grains. The challenges in the US grain supply chain for segregation of GMOs and non-GMOs to meet Japanese and EU regulations are discussed below. The main topics developed below are summarised in Table 1.

INSERT TABLE 1

Maintaining non-GM seed purity

Non-GMO segregation and IP must start with the seed industry. Efforts to maintain seed purity have always existed in the seed industry, but absolute seed purity has never been obtained. A major potential source of impurities in seeds is pollen drift, which can occur with cross-pollinated crops. Seed purity levels are generally lower for maize than for soybeans, because maize is mostly cross-pollinated, while soybeans are almost exclusively self-pollinated.³ Seed impurity may also come from inadvertent commingling in the seed production, harvesting, and bagging processes. Current seed purity levels obtained by identification of plants according to morphological characteristics are around 99% for maize, and 99.8% for soybeans (Langer, 2000).⁴ These numbers indicate that potential GMO presence in non-GM seed could be a problem under usual practices, for two reasons. First, unapproved GMO transformation events facing a zero-tolerance level could be present in seeds. Second, it is not certain that non-GM food products containing maize products would meet the EU 1% tolerance level.

Different steps may be taken to increase seed purity levels. For maize and soybeans, these measures include eliminating plants showing typical aberrations and segregating varieties in seed manufacturing plants. In addition, for maize, purity levels can be increased by planting all-male border rows and increasing temporal and spatial isolation of seed-producing fields from other fields. However, such measures are imperfect because pollen can travel wide distances. Consequently, these measures can contribute to the attainment of very

high purity levels, but cannot ensure absence of unapproved transformation events in maize seeds.

To completely avoid the presence of GM pollen in a field producing non-GM maize seed, it would be necessary to designate whole geographic areas in which no GM maize is grown for miles. But the possibilities that such “non-GMO” areas could be institutionally organised currently seem remote. At present there exists no regulatory framework under which to define such areas. Government attempts to mandate that GM seeds could not be planted in some regions yet allow them to be planted in other regions would surely face stiff political opposition from farmers. To define and administrate such areas on a voluntary basis would require extensive consultations between participants. It would require convincing farmers and handlers who otherwise would have the legal right to adopt or store GMO varieties not to do so. Seed companies, processors, exporters, or third-party certifiers might try to organise agreements among farmers and elevators in a wide area by designing contracts offering economic incentives to not produce or store GM maize. Yet even if all farmers and handlers in a fairly large region could be convinced to sign such contracts, monitoring compliance among them would prove difficult and expensive. Even if an entire region made planting GM maize illegal, smuggling of GM seed into the region might occur.

The difficulties brought about by cross-pollination in maize varieties might be solved in the near future, however. Scientists have used conventional breeding methods to build a genetic barrier in hybrid maize to prevent cross-pollination. They claim that commercial non-GM varieties with this gene could be sold commercially in 2003 (Kermicle and Gerrish 2000). This would enable seed companies to sell non-GM seed maize and farmers to sell IP non-GM maize without having to cope with cross-pollination. However, more time will have to pass before the commercial feasibility of this genetic barrier is known.

Maintaining non-GM grain purity on the farm

In addition to the commingling of commercial non-GM seed by GM seed, other possibilities for commingling come about during the farmer's planting, growing, harvesting, storage, and transportation of grain.

If a farmer chose to plant both GM and non-GM varieties, it would be necessary for him to clean out the planter and the combine between GMO and non-GMO planting and harvesting runs.⁵ For a typical planter used in the Midwestern US, in an average situation, it would take approximately 40 (for an 8-row planter) to 55 minutes (for a 12-row planter) to clean very thoroughly a typical planter (Hanna, 2000; Hanna and Greenlees, 2000). Using a combine previously used to harvest GM grain in an entirely non-GM field, very high purity levels of harvested grain can be expected by cleaning out the combine for approximately half an hour, and then running the combine through a field of non-GM grain in order to harvest and unload 1.60-1.90 tonnes of soybeans (Greenlees, 2000; Greenlees and Shouse, 2000). Then, the mixture of non-GMO and GMO grain obtained when flushing the combine must be sold at the lower GMO prices.⁶

In Table 2 we show calculations of per-tonne costs of planter and combine cleaning, once per season, to maintain non-GM soybean segregation and IP, for a typical farm with 200 hectares of soybeans yielding 2.8 tonnes per hectare. These calculations assume that farm labor can be hired for \$15 per hour and that a typical premium paid to farmers for non-GM soybeans is approximately \$7.5/tonne (DuPont, 2001a). For this typical farm, the costs of planter and combine cleaning are minuscule, approximately \$0.066 per tonne.

INSERT TABLE 2

Since soybeans do not cross-pollinate, there should be few additional costs to the farmer of segregation and IP. It seems reasonable that similar small costs of planter and combine cleaning would prevail for non-GM maize segregation and IP. But the costs of arranging wide buffer zones to prevent cross-pollination by GM maize from outside fields could add

significantly to these costs. Farmers growing maize for grain are advised to follow some steps taken by farmers growing maize for seed to maintain purity, namely spatial and temporal isolation of fields from GM maize fields and separate harvesting of border rows (Burris, 2000; Nielsen, 2000). As for maize seeds, the only way to meet very high non-GMO purity standards for maize (well over 99.5%, say) may be to create very large isolation zones in which only non-GM maize is grown for miles around. But, as stated before in the context of seed production, it could be very expensive to set up and administrate such isolation zones, and to enforce compliance by neighbouring farmers and elevators.

After a US farmer harvests grain, he generally either delivers it by truck to a grain handler, or stores it on his farm to be delivered to a handler later. There are various categories of grain handlers, including country elevators, river elevators, and export (or “terminal”) elevators. In each of these types of elevators, segregation and IP of non-GMOs will imply some extra costs.

Maintaining purity in country elevators

Typically, US country elevators are relatively small grain storage facilities located along railroad tracks, scattered every few kilometres in the countryside. Country elevators provide the service of storage for farmers who do not possess sufficiently large on-farm storage facilities to take in an entire harvest. They also serve to load grain into train cars, which carry the grain either to domestic processors or to an export (or “terminal”) elevator. Commingling of GMOs and non-GMOs can occur at several points along the “paths” in which grain at a country elevator is moved, stored, and loaded.

To prevent commingling of GMOs and non-GMOs at country elevators, it is first necessary to dedicate some storage bins to GMOs and other storage bins to non-GMOs. Typically, a country elevator has just a few grain storage bins, allowing segregation of one

crop from the other, but not necessarily allowing segregation of different qualities of a given crop. Consequently, not all country elevators are able to segregate GMOs and non-GMOs within a facility (at least, without additional investment). Even with storage bins dedicated to GMOs or non-GMOs, several potential sources of commingling appear at various points in the grain path of dump pits, boots, legs, dryers, conveyor belts and spouts that make up a country elevator facility. These pieces of equipment usually remain reasonably clean without human intervention, but they are not designed to remain “kernel clean.” Under traditional grain movement, storage, drying and loading practices, some pieces of grain become caught in the equipment, only later to be jostled free and commingled with other grain shipments. Therefore, extremely strict tolerance levels for commingling of GM grains with non-GM grains would not be met under traditional handling practices at country elevators. The steps to take to prevent excessive commingling of GMOs with non-GMOs then depend greatly on the demanders’ level of commingling tolerance.

To ensure very high purity levels of non-GM grain, it would be necessary to clean the grain path equipment thoroughly, whenever it is used for non-GM grain after having been used for GM grain. This could be done by sweeping clean the pits, boots, conveyor belts, storage bins and distributors, and especially disassembling and cleaning the legs of the elevator, and the dryer (for maize). Another possibility would be to “flush” the equipment by running some non-GM grain through it, and then storing the grain used in the flush with GM grain. Using one of these procedures to clean the grain path between every shipment of grain would be arduous and costly. The practical solution currently observed in the US Midwest is to dedicate entire paths (and not only storage bins) to either GMOs or non-GMOs, at least for a given period of time. This may involve dedicating existing equipment, or investing in new capacities for moving and storing grain.

Dedicating entire grain paths to either GMOs or non-GMOs avoids the direct costs of cleaning the grain paths. Still, there are indirect costs of dedicating grain path equipment in this way. First, there may be an indirect cost because of capacity underuse. This could occur, for example, if grain quantities delivered at a facility dedicated to non-GMOs were not sufficient to fill up the non-GM bins. To adjust flows of grain delivered by farmers and flows of grains delivered to processors or terminal elevators to capacity, the handler would have to incur additional management costs, and possibly the additional costs of setting up contracts with farmers and processors or terminal elevators to organise grain flows. Second, handling facilities with only one grain path would have to dedicate the entire facility to either GMOs or non-GMOs, but never both. Then, farmers would have to drive a bit farther, on average, to deliver their grain to find a buyer who handles it. Fuel and time costs of this extra hauling would typically be very small, because some country elevators would be dedicated to GMOs and some others to non-GMOs in close proximity. However, longer grain hauling at harvest time could be quite costly for farmers, who always prefer to harvest rapidly while weather permits. In addition, nearby elevators may belong to different companies. It may be costly for a given company to accept only one type of grain at a given location, because it may cause some farmers nearby to switch to competitors.

In addition to the indirect cost of dedicating equipment, there would also be a cost of performing tests on GMO content at delivery. When a truck filled with what is claimed to be non-GM grain arrives at a country elevator, an employee typically uses a chemical “rapid strip test” on a sample of the grain, allowing detection of GM soybeans and certain types of GM maize. The direct cost of such testing is estimated later in the article. There is also an indirect cost of testing, because the farmer typically must wait ten to fifteen minutes before the test shows whether his load is accepted as non-GMO. Because testing takes time, it potentially could lead to longer queues of farmers’ trucks at the elevator, which could be quite costly for

farmers during the busy harvesting season. To avoid the development of longer queues, and to be able to dedicate some facilities to non-GMOs at non-harvest time while using them for GMOs at harvest time, grain handling companies have begun signing contracts with farmers before planting time. In signing such contracts, farmers and handlers agree the number of acres harvested that will be delivered to the elevator directly after harvest, and how many acres will be stored on-farm and brought at a date to be named later by the grain handler. Such contracting enables grain handlers to plan out when they will receive deliveries in the months following harvest.

Maintaining purity in river elevators

The principal site of US soybean and maize export is New Orleans, where most grain arrives by barges that have received grain at elevators located on the Mississippi river and its tributaries. River elevators' storage and loading services are similar to those of country elevators, except that they tend to load grain onto barges instead of trains. Barges do not have holds, therefore it is not possible for one barge to simultaneously carry and segregate GM and non-GM grains. After unloading, barge owners always pay private companies to clean out their barges, no matter what the barge's cargo has been. Therefore no extra costs are entailed by cleaning out a barge that has carried GM grain in order that it might next carry non-GM grain without commingling. In general, the costs river elevators face for segregation and IP are similar to those of country elevators discussed above.

Maintaining purity in export ("terminal") elevators

The physical set-up of export elevators is similar to those of country and river elevators, except that generally export elevators are much larger. Export elevators can receive grain by barge, train, or truck, then store it and unload it to holds of ocean-going vessels. Unlike most

country and river elevators, export elevators provide “blending” services in addition to storage and loading. When loading a ship’s hold, export elevators frequently fill the hold with blended grain coming from several different bins, to closely meet the specifications of a contract they have signed with a customer. This “blending” service is a major source of export elevator profits.

If a large export facility decides to handle many more varieties of grain because of the appearance of GMOs in the market, then given its number of storage bins, it cannot store separately as many quality levels as it did when no GMOs were present in the market. This implies a loss in blending flexibility for export elevators, at least in the absence of investment in additional capacity. There is a trade-off here; in order to provide the market with a choice between GMO and non-GMO grain, the grain handling system has to provide the market with less choice among quality levels of that grain. In the short run, given the size and number of current storage bins, the cost of the trade-off between GMO/non-GMO choice and grain quality choice cannot be avoided. In the long-run, handlers may respond to this trade-off by building more and smaller storage bins.

Maintaining purity at the processing stage

Methods used to preserve non-GM identity, and additional costs of segregation and IP will vary among types of processing plants, depending of their physical make-up. But it is possible to make the general statement that processors will face the same kind of cost increases as do grain handlers because of the appearance of GMOs in the market. That is, processors will face additional costs from dedicating some processing equipment to GMOs and other equipment to non-GMOs.

Testing and contracting costs

To maintain a very low GMO content along the vertical supply chain, two actions are necessary at each vertical stage: making sure that the grain purchased is non-GM, and preventing GMO commingling before selling the grain to the next stage. Simple observation by the buyer does not reveal whether the seller has made these two types of effort or not. This information asymmetry may be solved in two ways: using chemical tests at different stages of the vertical supply chain to estimate the GMO content of the purchased grain; and designing and monitoring contracts and quality assurance schemes whereby different stakeholders agree on production and handling practices.

We estimate the testing costs necessary to bring grain from a farmer growing non-GM soybeans to a river elevator, and from there to an importer in Japan or the EU. It is typical for a farmer to haul non-GM soybeans by a truck containing approximately either 10 or 20 tonnes, directly from his farm to a river elevator on the Mississippi, Illinois or Ohio rivers. At the river elevator, typically one strip test is used per truck. The strip test is a “dipstick” test, which requires only minimal equipment and skill, and can be conducted practically anywhere. It is a qualitative test, giving a yes/no answer (detection or not of targeted GMOs in the sample). Strategic Diagnostics, Inc. (SDI) sells a strip test for the detection of glyphosate-tolerant (“Roundup Ready”) soybeans (the only GM soybeans available for commercial planting). Each SDI test costs \$3.50 and takes five to ten minutes to conduct. Assuming a \$15 per hour labour cost (\$2.50 per ten minutes), the total cost of a test is approximately \$6.

After being stored in the bins of the river elevator, soybeans are loaded into a barge, containing approximately 1500 tonnes in a single hold. When loading a barge, a sample of the grain is taken with a diverter sampler. The most economical test to quantify glyphosate-resistant soybeans in this sample is an ELISA test, which must be conducted in a laboratory. The shipping cost for sending a two-kg sample to Central-Hanse Analytical Laboratory, LLC in Louisiana, is \$15. This company offers this test at \$100 per one-kg sample. The laboratory

is able to issue a certificate by the time the barge arrives in New Orleans (Central Hanse Analytical Laboratories, LLC, 2000; Russell, 2000).

When loading an ocean vessel, six samples are taken with a diverter sampler for each hold of the ship, with one sample for every 1200 tonnes, and sent to the testing lab. The ocean vessel then leaves for Japan or the EU, where it typically sails to different import elevator locations in order to unload different holds. Another quantitative ELISA test is conducted when unloading the hold of the ship. Table 3 gives an approximation of the testing costs with this example.

INSERT TABLE 3

Table 4 shows what the testing costs would be for maize with the same grain flow described above for soybeans. Testing for GMO content in maize is more complicated than in soybeans because multiple transformation events have to be recognised by a test in order to assess the GMO content of a US maize product. The company EnviroLogix sells two strip tests for detection of the three Bt toxins currently expressed in GM insect resistant maize, the Cry1Ab, Cry1Ac and Cry9c (or StarLink) proteins. Each EnviroLogix test costs \$3.50 every time it is used and takes five-ten minutes to conduct. Assuming a \$15 per hour labour cost (\$2.50 per ten minutes), the total cost of both tests is approximately \$12. However, these strip tests cannot detect herbicide tolerance events in maize. A quantification of the GM content in maize can be attained using a Polymerase Chain Reaction (PCR) test. Central-Hanse Analytical Laboratory, LLC offers a PCR test allowing assessment of the total percentage of GM maize at \$505 per sample, to which shipping costs of \$15 should be added. A qualitative test to prove by PCR the absence of GM events not approved in the EU or Japan would add \$75 for each event to this cost (Central Hanse Analytical Laboratories, LLC., 2000; Russell, 2000). The unit costs of non-GM tests on maize are higher than on soybeans, because tests are

more expensive, and because an additional test is needed to recognise individual events not approved for import in the EU or in Japan.

INSERT TABLE 4

Contracting with sellers is complementary to testing. The chances that a shipment presented as "non GM" will actually prove to be commingled in a test are lower if the seller has committed to segregation and IP practices in a contract. Consequently, the costs of rerouting shipments brought as non-GM to a GM channel are lower. Contracting in advance also enables the buyer to plan volumes and flows of GMOs and non-GMOs. In addition, tests are imperfect by nature, and even more problematic in the case of small tolerance levels, because sampling is imperfect and because detection methods are themselves imperfect. Then, when a test performed at one stage of the vertical supply chain may be contradictory to a test made at another stage, contracts may help resolve the contradictory evidence.

Identifying premiums and cost changes

Figure 2 illustrates some of the currently observable quantitative aspects of segregation and IP of non-GM grains. First, monthly average premiums to Japanese importers of non-GM soybeans on the Tokyo Grain Exchange (calculated as the difference between monthly prices of non-GM and GM soybeans) have varied between \$18 and \$39 per tonne between May 2000 and September 2001, with an average of \$27.50 per tonne (Figure 1) (Tokyo Grain Exchange, 2001).⁷

INSERT FIGURE 1

Next, elevators have recently paid farmers premiums from \$7.3 to \$11 per tonne for non-GM soybeans delivered with a signed contract (DuPont Specialty Grains, 2001a, 2001b). The size of premiums paid to farmers varies by geography, by whether the farmer has signed a contract with a handler to deliver non-GM soybeans, and by the type of soybean being

delivered. Farmers who sign contracts agreeing to follow specific production and delivery practices (to clean out the planter, flush the combine, etc.) to maintain non-GM purity, tend to receive higher premiums than farmers who just “show up” at the elevator with a delivery of non-GM soybeans. Given the variety and the contract status, farms delivering to river elevators generally receive the highest premiums. This occurs because farms located near river elevators tend to ship their soybeans by barge to New Orleans, whence it is exported. Since the highest demand for non-GM grain is from overseas sources, the price differential between GM and non-GM grain is greater nearer rivers than far away from rivers, where farmers tend to supply to domestic processors who have less demand for non-GM soybeans.

Farmers are consistently willing to sign contracts to follow segregation and IP production practices only if premiums cover the increased production costs borne when growing non-GM soybeans instead of GM soybeans. Any difference between the premium and the aforementioned costs on the farm are profits to the farmer. As stated before, costs of segregation and IP (costs of cleaning the planter and combine, and costs of driving further with the grain to the elevator) appear to be rather small and do not seem to explain the premium levels alone. This suggests that the major cost of non-GM segregation and IP to farmers may come from the production process itself. For many farmers, GMOs lower production costs, and a price premium must be available to convince them to give up using cost-reducing GM seeds.⁸

Taking as bases the \$27.50 per tonne premium received for non-GM soybeans by Japanese importers and a \$7.50 per tonne premium received by farmers for contracted soybeans, currently it must not be costing more than $\$27.50 - \$7.50 = \$20$ per tonne for handlers and exporters combined to segregate and preserve the identities of non-GM soybeans to the 5% tolerance level acceptable to Japanese importers. (For otherwise they would be knowingly losing money for segregating and preserving the identity of non-GM grain.) These

numbers are illustrated in figure 2. For grain handlers, in the main the extra costs of segregation and IP do not appear to come from testing costs, which are approximately only \$0.87 per tonne (Table 3). Rather, additional costs appear to come from less flexibility in the grain handling system, because of the necessity of dedicating some equipment to GMOs and other equipment to non-GMOs, and from contracting costs.

INSERT FIGURE 2

In figure 2, we implicitly attach all the segregation costs to the non-GMO channel. Actually, the GMO channel may also bear some segregation costs. It seems *a priori* that these would be mainly costs of less flexibility because of dedicated equipment, and costs of non-GMO IP for shipments first considered as non-GMO then rerouted at some stage to the GM channel because of excessive commingling (although these costs should be diminished by contracting procedures). It is hard to assess the importance of these costs, but it seems that substantial costs of less flexibility for GMOs would arise only in the case of a substantially-sized non-GMO channel.

Costs of GMO/non-GMO segregation and non-GMO IP may vary with the respective volumes of the GMO and non-GMO channels. Whether or not economies of size should be expected is an open question. It is possible that grain paths currently dedicated to non-GMOs have a comparative advantage over others in segregating non-GMO soybeans at a low cost.⁹ In this case, in the short run, marginal costs of segregation and IP may increase if the size of the non-GMO channel increases.

Costs of GMO/non-GMO segregation and non-GMO IP, and premiums for non-GMO grains, may also change over time. Economic incentives exist in grain markets to develop better and less expensive procedures to store, move and process grain while preventing commingling, and to test GMO content. In addition, it can be expected that new grain handling facilities will gradually be built to segregate and preserve the identity of grains at

lower costs. While current demand for segregation and IP are brought about by consumer fear of GMOs, a new type of demand for segregation and IP may come about because consumers will be willing to pay for positive attributes of specialised crops, some of these even possibly being GMOs (Buckwell et al., 1999). If more specialised crops with positive consumer attributes are developed, then even a larger variety of grains will be available in the supply chain, and there will exist demand for more varieties to be segregated and identity-preserved. However, because of the large fixed costs of building grain handling facilities, any adjustment to a new grain handling system with more and smaller handling facilities is likely to be a lengthy one.

Conclusions

Two very different issues on GMO commingling are raised by current regulations on GMOs: how to prevent excessive commingling to comply with labelling laws; and how to prevent any commingling at all to comply with authorisation laws. Segregation and IP procedures presented here aim at preventing commingling above given tolerance levels set in labelling laws. These tolerance levels are probably a key element of costs of segregation and IP, although information to assess how costs vary with tolerance levels is scarce. Quite differently, without the undertaking of huge organisational and economic procedures, it may be simply impossible to prevent all commingling and thus ensure the regular absence of unapproved transformation events. This seems especially to be the case for maize, with the production externality resulting from cross-pollination.

If zero-tolerance is not manageable (at least without drastic organisational and economic measures), regulatory as well as liability issues are raised. There are only two ways to avoid problems following from zero-tolerance to arise: either loosening authorisation regulations, or waiting not only for domestic authorisation but also authorisation in major export destinations

before marketing new GMO varieties. Some steps have been already taken in both directions. On the one hand, the zero-tolerance issue has been brought to the public debate in the EU after several cases of unapproved transformation events being found in imported seeds. The EU Commission has recently proposed to set up “specific conditions under which technically unavoidable presence of unauthorised GMOs could be permitted” (European Commission, 2001). On the other hand, as stated in the article, US seed companies are postponing sales of varieties approved in the US but not in major destination countries. How this issue of zero-tolerance for unapproved events of transformation will be resolved will probably be determinant for the future possibility of a non-GMO IP channel in the US.

In link with this zero-tolerance issue, another type of cost that we did not discuss here is the cost of being held liable for commingling of GMOs in non-GM products. Liability costs for loss of export markets due to the presence of events not approved in these markets could be huge. The possibility of being made liable for such losses could significantly influence decisions of companies along the supply chain. This liability problem has been brought to evidence by the recent Starlink episode in the US. The Starlink case is not completely generalisable, however, because it initially came about only because of a lack of domestic approval. (That is, Starlink maize was authorised for use in animal feed but not for direct human consumption in the US). Absence of efforts to keep StarLink maize out of the general maize supply as well as to prevent cross-pollination of non-StarLink maize by StarLink maize in neighboring fields led to large amounts of commingling of StarLink maize in the general US maize supply in the years 1999 and 2000. A huge row ensued in year 2000 after traces of StarLink maize were discovered in processed food products in the United States. Costs of removing Starlink maize from the general supply channel were partly subsidised by Aventis, the biotech company having licensed the Starlink event to seed companies. It is unclear,

however, that a biotech company could be made liable in courts of law for releasing a variety that is domestically approved, but not approved in export markets.

In this article we report the start of what should be further empirical investigations into the effects of segregation and identity preservation on grain production and handling costs. To understand the effects of non-GMO segregation and identity preservation on the prices at various stages of the vertically linked grain markets, it is important to separate out conceptually the effects of three related phenomena. First, the introduction of GMO technology reduces farm costs of production, which tends to lower grain prices as the lower costs are passed through different stages of the vertically linked grain sector. Second, information about possible risks of GMOs lowers the demand for both GMOs and non-GMOs, if consumers have no way of distinguishing between them. Third, segregation and identity preservation lower the demand for GM grain further (since now consumers can identify the good they perceive as risky), and raise the demand for non-GMOs (since they are now identifiable and perceived as safe). Segregation and identity preservation raise costs of handling both non-GM and GM grain, however, creating forces that help keep prices of both high. Taken all together, the effect of segregation and identity preservation on prices is theoretically ambiguous. Whether their introduction raises or lowers prices is an empirical question, in need of more empirical research. The numbers reported in this article on the costs of segregation and identity preservation are meant to be a contribution to such research.

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Notes

¹ An “event” is a successful transgenic transformation whereby gene(s) of interest from another species and genetic material are inserted in the DNA of the crop. Events vary depending on the components of the genetic package and on where the novel DNA is inserted.

² Three additional events are authorised only for marketing in the EU, and one in Japan.

³ Many experiments report maize cross-pollination from several hundred meters away (Treu and Emberlin, 2000).

⁴ These numbers do not mean that average non-GM purity levels for non-GM seed varieties would be 99% for maize and 99.8% for soybeans. On the one hand, lower non-GM purity levels could be obtained, because molecular tests on GMO content may detect more impurities than identification according to morphological characteristics. On the other hand, higher non-GM purity levels could also be obtained, because impurities are not necessarily GM.

⁵ These cleaning costs were not included at the seed production stage, because planter and combine cleaning are standard procedures for seed-producing farmers.

⁶ This method is more economical than removing every kernel from the combine's inner workings, which would take 2 people 4 hours each.

⁷ It is important that these figures are for soybeans imported in Japan, where the tolerance level for GMO commingling is 5%. Premiums to meet the 1% EU tolerance level could possibly be higher. No systematic information similar to the Japanese Tokyo Grain Exchange transactions is currently available for the EU.

⁸ Production cost savings from glyphosate-resistant soybeans vary widely by farm, depending on the farm's weed situation. Savings as high as \$18/tonne are possible (Nelson et al., 1999).

Only farmers with much lower savings are likely to find a \$7.50 per tonne premium a sufficient incentive to grow, segregate, and identity preserve non-GM soybeans.

⁹ An example of comparative advantage of some grain paths is elevators with multiple grain paths, or handlers with multiple country elevators nearby.

Table 1. Segregation and IP in the Food Supply Chain

Possible Causes of Commingling	Level of Vertical Supply Chain at which this type of Commingling May Occur	Methods Used to Preserve Identity and Prevent this Type of Commingling	Additional Costs of Segregation and IP
Cross-pollination (maize)	<ul style="list-style-type: none"> • Seed production, • Farm production 	<ul style="list-style-type: none"> • Plant all-male border rows • Increase spatial and temporal isolation of non-GM seed fields 	<ul style="list-style-type: none"> • Costs of reduced land used for actual grain production • Costs of giving an incentive to others not to grow GM crops near non-GM zones
Equipment not clean	<ul style="list-style-type: none"> • seed production (bagging equipment) • farm production (planter, combine and on-farm storage, truck to elevator) • handling system (elevator grain paths) • processing system (machinery) 	<ul style="list-style-type: none"> • Clean equipment • Dedicate equipment to GMOs or non-GMOs 	<ul style="list-style-type: none"> • Costs of capacity under-use • Costs of managing new grain flows • Costs of moving grain farther • Costs of reduced blending ability
Commingling of a GM lot thought to be non-GM with a non-GM lot.	All levels	<ul style="list-style-type: none"> • Tests on GMO content • Contracts 	<ul style="list-style-type: none"> • Testing costs • Contracting costs • Indirect costs of waiting for test results the result of the test

Table 2. Per-tonne on-farm costs of non-GM soybean segregation and IP

Activity	Labour	Labour costs	GM beans flushed	Premium on non-GM beans	Flushing costs	Total costs	Total costs per tonne
Clean Planter	1.0 (or fewer) hour	\$15	n.a.	n.a.	n.a.	\$15	\$0.027 / tonne
Clean Combine	0.5 hour	\$7.5	1.9 tonnes	\$7.5 / tonne	\$14.25	\$21.75	\$0.039 / tonne
Total							\$0.066 / tonne

Note: Assumed wage : \$15 / hour. Assumed total yield on farm: 560 tonnes.

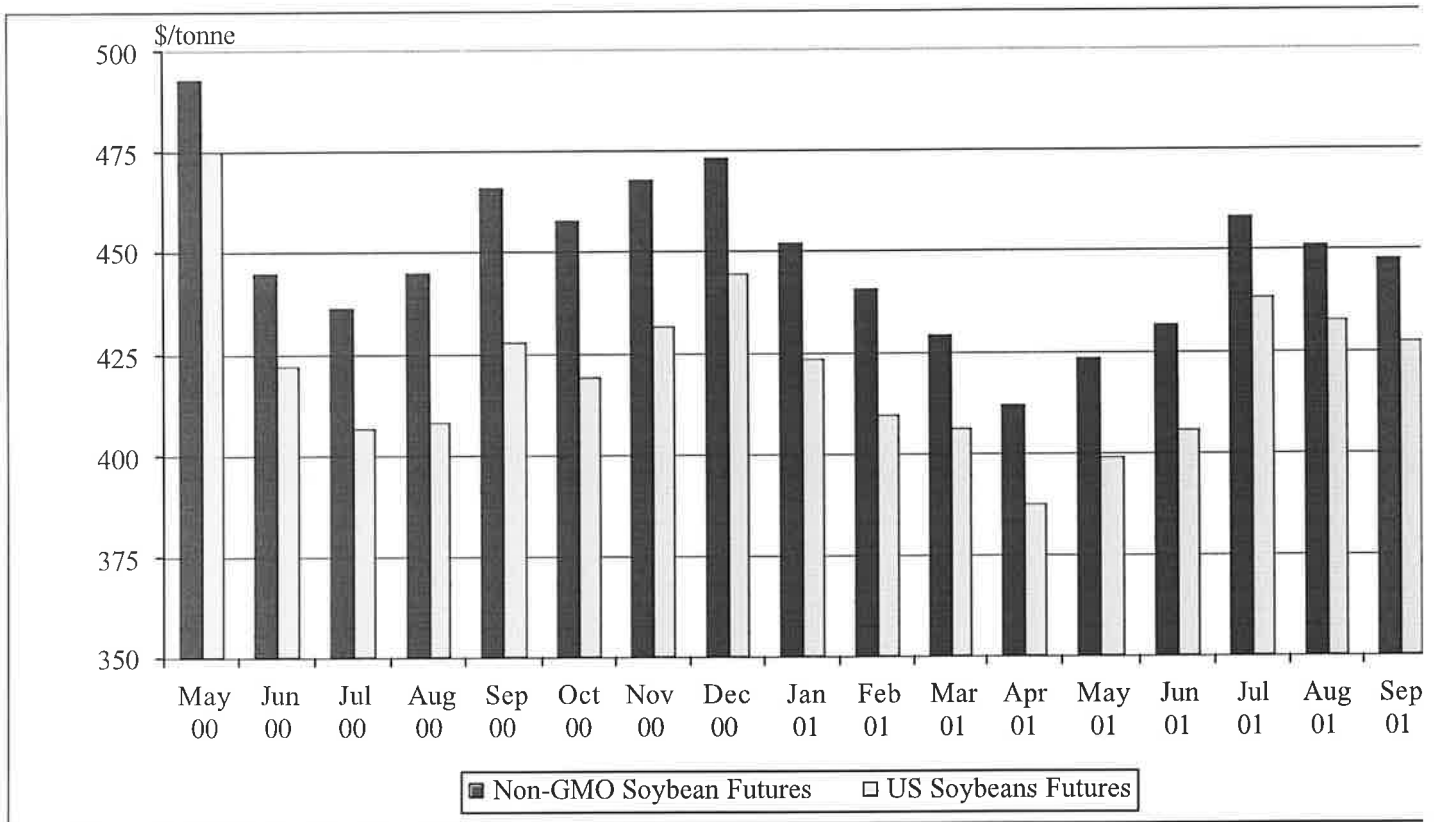
Table 3. Unit costs of non-GM tests on soybeans

carrier	content (tonne)	unit cost (\$)	\$ per tonne
farm truck: 1 strip test	10	6	0.6
barge: ELISA test	1,500	115	0.077
1200 tonnes in an ocean vessel hold at the export location: ELISA test	1,200	115	0.096
1200 tonnes in an ocean vessel hold at the import location: ELISA test	1,200	115	0.096
total			0.87

Table 4. Unit costs of non-GM tests on corn

corn	content (tonne)	unit cost (\$)	\$ per ton
farm truck: 1 strip test	10	12	1.2
barge: quantitative PCR test	1,400	520	0.37
1200 tonnes in an ocean vessel hold at the export location: quantitative PCR test	1,200	520	0.43
1200 tonnes in an ocean vessel hold at the export location: additional qualitative test for 14 events not approved for marketing in the EU	1,200	1050	0.88
1200 tonnes in an ocean vessel hold at the import location: quantitative PCR test	1,200	520	0.43
total			3.31

Figure 1. Premiums for non-GMO Soybeans (\$ / tonne)



Source: Tokyo Grain Exchange (2001), On-line monthly market reports, May 2000 to September 2001, Monthly Volumes and Total Contract Prices of Futures Contracts Traded. Yen to dollar monthly exchange rates calculated from currency converter from www.oanda.com, unit contract volume is 30 tonnes for US soybeans, and 10 tonnes for non-GMO soybeans.

Figure 2. Premiums for selling and costs of producing non-GM soybeans (dollar per tonne)

