

The Economics of Non-GMO Segregation and Identity Preservation

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I. Introduction

Much controversy surrounds the production and marketing of agricultural genetically modified organisms (GMOs). Many consumers worldwide currently worry that food derived from GMOs may be unhealthy, or that the production of GMOs may have negative environmental consequences or other negative social consequences. As a result, recently there have been calls all over the world, but especially in the European Union (EU) and Japan, for increased regulation of the production and marketing of GMOs and of products derived from GMOs. Calls have been made for the banning of GMO imports in the EU and Japan, and laws have been passed mandating the labeling of genetically modified (GM) products in the EU.

According to USDA estimates, 52% of U.S. soybean acres and 25% of U.S. corn acres will be planted with GM varieties in 2000 (USDA NASS, 2000). The U.S. is a major world producer and exporter on both markets, and the EU and Japan are major destinations for U.S. soybean and corn products.¹

If consumers strongly reject products labeled as GMO, then we can expect that market signals will be created that encourage the segregation of non-GM grain from GM grain, and that the identity of non-GM grain be preserved. Indeed, as will be explained, such market signals and non-GM segregation and identity preservation can already be observed in grain markets. In order to understand in any kind of empirical sense the economic effects of labeling laws and/or changes in consumer preferences for non-GM and GM agricultural products, it is first necessary to understand the institutional set-up of world grain markets and marketing channels. Through these channels grain flows from the seed industry all the way up to the processing industry. The effects that GM labeling laws and preference shifts will have on the economic well-being of the industries and people involved is the subject of this paper.

II. Maintaining the purity of non-GM grains

1. Seed and seed purity

1.1. Current purity levels of soybean and corn seeds

Non-GMO segregation and identity preservation must start with the seed industry. For years seed companies have made serious efforts to maintain acceptable levels of purity of their seed. They often have their own quality assurance programs and can also rely on third-party services such as certification by seed certifying agencies to evaluate the quality and purity of their products. Still, no seed company guarantees 100% purity of seed. Because soybeans are self-pollinated, high levels of soybean seed purity are generally obtained. Major seed companies express confidence that a bag of their soybean

¹ In 1998/99, the U.S. accounted for 47% of soybean world production, 57% of soybean world exports, 17% of world soybean meal exports, and 14% of world oil exports. Other major exporters were Brazil (23% of world soybean exports, 26% of world soybean meal exports, 19% of world oil exports) and Argentina (8% of world soybean exports, 34% of world soybean meal exports, 39% of world oil exports). Twenty-nine percent of the U.S. soybean production was exported as whole soybeans. The EU and Japan accounted respectively for 25% and 17% of U.S. exports of whole soybeans. In addition, 8% of U.S. soybean production was crushed and exported as meal and oil, and 3% was crushed with only meal exported and the oil consumed domestically. (These figures are calculated assuming that one ton of soybeans leads to the joint production of 0.79 ton of soybean meal and 0.18 ton of soybean oil). The EU and Japan accounted respectively for 13% and 4% of U.S. soybean meal exports, and for 0.4% and 2% of U.S. soybean oil exports (USDA FAS, 2000a).

In 1998/99, the U.S. accounted for 41% of corn world production, and 76% of corn world exports. Twenty-one percent of the U.S. corn production was exported as bulk corn (USDA FAS, 2000b). Thirty-five percent and 0.7% of 1998 U.S. exports went to Japan and the EU, respectively (Ballenger et al, 2000). The EU is a minor destination for U.S. bulk corn exports; however the EU market is the destination of almost all U.S. exports of corn gluten feed (96% of U.S. exports of corn gluten feed went to the EU in 1998/99 (USDA FAS, 1999)).

seed is, on average, 99.8% to 99.9% pure (Langer, 2000). Obtaining high seed purity levels is more a concern for corn, because cross-pollination of a seed-producing plant by the pollen of a plant of undesirable variety is possible.² This occurs when wind carries pollen from the tassel of an undesirable plant outside the seed-producing corn field to the silks of a plant in the seed-producing corn field. This cross-pollination creates a plant with kernels (to be seeds in the next level of production) that are not of the desired variety, and should be identified and eliminated.³ Major seed companies are confident that under current practices on average their seed corn bags contain at least 99% of the variety on the label (Langer, 2000). Exceptions do occur, however, and some bags of seed reach lower purity levels than others.

These estimates of current seed purity imply that contamination of non-GM commercial seed by GM seed is not so large as to necessarily make infeasible *a priori* GMO segregation and identity preservation. First, the 99+% (for corn) and 99.8% (for soybeans) numbers are not levels of non-GM contamination by GM seed, but rather levels of contamination from any other variety. (For if non-GM grain were mixed with a different variety of non-GM grain, this would cause no problem for non-GMO segregation and identity preservation.) Second, EU labeling laws implemented in April 2000 require that any food product with an ingredient that contains more than 1% GMO must be labeled as “GMO” (European Commission, 2000). At this tolerance level, contamination of non-GM soybean seed by GM seed does not appear to be a major issue. However, too much contamination of non-GM corn seed by GM seed may possibly be a concern under current seed company production and inspection practices. Pertinent questions, then, are what steps would have to be taken by seed companies to obtain higher seed purity levels for corn, and what costs those steps might incur. In order to address these questions, it is necessary first to understand current seed production practices.

1.2. Seed production practices

The production of commercial grain seed occurs in four stages: the breeder seed stage, the foundation seed stage, the parent seed stage, and finally the commercial seed stage. Seed breeders work intensively with a small number of plants, and carefully control the seeds they produce. Therefore, by the nature of plant breeding, little or no additional expenses would be incurred by seed companies to segregate and preserve the identities of breeder seeds. However, for corn at the foundation, parent, and commercial seed stages, cross-pollination of a female corn plant by a male plant of undesirable variety may occur (Langer, 2000).

In the case of corn, seed companies traditionally have taken various precautions to limit contamination by cross-pollination at these three stages. Corn seed fields are isolated by some distance from fields of potentially contaminating corn. Researchers breed corn so that the desirable variety’s pollen is released in abundance at the same time that the desirable variety’s silk, which catches the pollen, is most abundant (Pataky, 2000). The border rows of seed corn fields are planted in all-male corn plants, to act as a barrier between undesirable pollen from other fields and the silks of non-border plants (Langer, 2000). Moreover, inspectors “rogue” seed corn acres. In roguing, a worker visually inspects the phenotypes (primarily flower, leaf, pod, and pubescence appearance) of plants, and removes from the field any undesirable plants identified.⁴

² Corn has both a tassel (male) and silks (female) on the same plant. For a description of the corn male and female reproductive structures and of corn pollination see e.g. Nielsen (1999).

³ Very recently the French government mandated the destruction of 600 hectares of canola plants in France because their seed, of a non-GMO variety, was contaminated in a small proportion (in the order of 1%) by GM herbicide-resistant canola (French Government, 2000). The seed company providing the seeds indicated that they were imported from Canada, where they were contaminated by pollen of GM canola from neighbouring fields during their production (*Le Monde*, May 19, 2000). The French government’s decision was based on the fact that no GMO variety of canola is authorized for cultivation in France or in the EU due to perceived risks of crossing with native plants of the same family.

⁴ For STS soybeans, there is an additional method used to maintain seed purity. STS soybeans are non-GMO, but are tolerant to the herbicides chlorimuron and thifensulfuron (mixtures of which are currently sold by the trade names Synchrony and Reliance (both by DuPont)). STS technology was developed and patented by the DuPont corporation, not by biotechnological “genetic modification,” but by mutation (Gianessi and Carpenter, 2000). By the year 2000, STS soybeans held an important share in international markets for non-GM soybeans, with Fuji Oil company of Japan importing only STS soybeans (Haas, 2000). Glyphosate-resistant (“Roundup Ready®”) soybeans are stunted by chlorimuron and thifensulfuron. Therefore, in the typical plan for producing

Once produced, breeder seeds are used to grow plants that provide foundation seeds. For each variety, a large seed company may at any time have from 5 to 100 acres of plants producing foundation seed. Foundation seed-producing fields are rogued; phenotypes of plants in each row are inspected, at a walking pace. However, different varieties of plant often have similar phenotypes, and to carefully physically inspect each plant producing foundation seed is not economically feasible at current seed prices. Therefore some mixing of different varieties can and often does occur at the foundation seed stage of production (Langer, 2000).

Foundation seed is used to produce plants that produce parent seed. Large seed companies can grow up to 5000 acres of parent seed-producing plants for some varieties of seed. Parent seed-producing fields are rogued, but not as carefully as are foundation seed-producing fields. Generally, an inspector will inspect 6 to 8 crop rows simultaneously, at a walking pace. Again, because every plant is not inspected individually, some mixing of different varieties can and often does occur at the parent seed stage of production (Langer, 2000).

Seed companies generally write contracts with farmers to pay them to use parent seed to grow commercial seed-producing plants. Contracting farmers are instructed about the importance of striving to make planters, combines, and storage bins “kernel clean” (i.e., making sure that every non-desirable kernel is out of the machinery or bin) before planting of the foundation seed or harvest and storage of the commercial seed. Still, planting and harvest times are very busy for farmers, and in reality small amounts of other seed varieties sometimes do end up mixed with the variety that is desired produced and stored.

Commercial seed produced on a farm is shipped (in a kernel-clean truck, it is hoped) to the seed company, which then runs the seed through a conditioning process. In the conditioning process, the seeds are run over an air screen cleaner and various separating machines in an attempt to remove weed seeds and other foreign matter. Since the same screens and other separating devices may be used to process both GM and non-GM seeds, they too must be cleaned between conditioning process runs to maintain segregation (Pataky, 2000). But some seed companies are avoiding this expense by conditioning GM and non-GM seeds in separate legs of their processing plants, so that there is no potential for contamination (Outtrim, 2000). After undergoing the conditioning process, the seed is bagged and shipped to sales agents and seed dealers.

1.3. How to increase seed purity

To produce purer seed corn, seed companies (or independent farmers under contract with seed companies) would either have to (i) increase isolation distances between seed-producing corn fields and other fields, (ii) increase the difference between the times at which seed-producing corn fields put out silks and neighboring corn fields release pollen, (iii) increase the number of all-male border rows in seed-producing corn fields, or (iv) increase labor to rogue seed-producing corn fields more thoroughly. Obtaining further spatial or temporal isolation of the seed-producing fields would require agreements with neighboring farmers, in which the neighbors acceded to not grow GM corn of varieties that would emit pollen during the time that the non-GM seed-producing field's plants are putting out silks. It is not likely that neighboring farmers would sign such a contract unless they were at least compensated for the economic losses suffered from refraining from growing GM corn of the type they wanted, when they wanted. Clearly, there would be costs to writing up and enforcing any such agreement with many neighboring farmers.

1.4. Conclusions about seed purity

At this early stage, it seems evident that because soybeans do not cross-pollinate, non-GM soybean seed is already being delivered at levels of purity high enough to not preclude, a priori, the final delivery of soybeans that meet the 1% contamination tolerance level of the EU. Cross-pollination makes keeping non-GM corn seed sufficiently pure more difficult. Still, at this early stage it is not clear that any additional steps need to be taken to increase its purity level, either. If purity levels do need to be increased, it is an open question whether it would be less costly to organize and enforce agreements among neighboring farmers to increase the spatial and temporal isolation of seed-producing corn, or

STS soybean foundation, parent, or commercial seed, the maturing plants may be sprayed with chlorimuron and thifensulfuron, thus stunting the growth of any glyphosate-resistant plants that happen to be growing in the STS field, and making it less likely that any seeds coming out of that field will be genetically modified (Outtrim, 2000).

rather to increase the amount of labor used to rogue seed-producing corn fields. One can envision whole geographic areas declaring themselves “non-GMO,” and running spot-checks to monitor compliance among farmers in the area. Such organization and interdependence in production decisions among farmers run very much counter to traditional farming culture and practices, however.

2. Maintaining non-GM purity on the farm

Obviously, to the extent that commercial non-GM seed is contaminated by GM seed, the grain the farmer produces will be contaminated as well. It would be economically infeasible for a farmer to attempt to locate and remove the small number of GM plants that end up growing in his hundreds or thousands of acres of fields. In addition, other possibilities for contamination come about during the planting, growing, and harvesting of grain.

2.1. Maintaining purity while planting

Planting is a busy time of the year for farmers. If a farmer chose to plant both GM and non-GM varieties, it would be necessary for him to clean out the mechanical planter between GMO and non-GMO planting runs. The time needed for a farmer to clean out a planter depends on the type and the size of the planter and the degree of cleanliness desired. Many Midwest farmers use a planter with a finger pick-up mechanism, made by John Deere, which comes in 8-row and 12-row sizes. If farmers are simply cleaning out the planter between runs, but not worrying about GMO/non-GMO segregation, it takes from 8 to 10 minutes to clean out an 8-row planter, and from 12 to 15 minutes to clean out a 12-row planter. For a farmer wishing to segregate GMOs from non-GMOs, the planter must be cleaned out more carefully. If he has just previously planted GM soybean seeds, to clean out his planter well enough to assure a 99% level of average purity (assuming 100% pure bags of non-GM seed), 15 minutes of labor are required for an 8-row planter, and approximately 25 minutes of labor are required for a 12-row planter. To obtain a 99.9% level of average purity would require approximately 40 minutes of labor to clean an 8-row planter and about 55 minutes for a 12-row planter (Hanna, 2000; Hanna and Greenlees, 2000). Thus, assuming that farm labor can be hired during planting season for \$15 per hour, it would cost the farmer no more than \$15.00 to sufficiently clean out the planter between GMO and non-GMO runs.⁵

The numbers calculated in the paragraph above imply that, all taken together, the costs to the farmer of keeping the planter sufficiently clean to assure adequate non-GMO purity do not seem especially high. First of all, a farmer could simply choose to produce all non-GM or all GM grain, in which case the planter would not need to be cleaned any more than under conventional practices. Next, even if the farmer chose to plant some of his fields to non-GM grains and other fields to GM grains, by planting non-GM grains first, he could avoid cleaning the planter until after the busy planting season was over. Or, he could simply hire a custom planter to plant either his GM or non-GM crops. While it would cost money to hire the custom planter, of course he would save in his own time and effort. Even if in the same year the farmer decided to alternate between planting GMOs and non-GMOs himself, cleaning the planter each time to ensure very low levels of contamination would probably cost less than \$15, which is negligible relative to total production costs. If we assume that a farmer grows 500 acres of soybeans, achieves a yield of 40 bushels per acre, and only needs to clean out the planter once per season, then cleaning out the planter would entail a per-bushel cost of less than $\$15/(500 \times 40) = 0.075$ cents per bushel.

2.2. Discouraging cross-pollination

Once seed is planted, during the growing season there would be risk of contamination of a farmer's non-GM corn by cross-pollination from GM corn in distant fields (similar to the problem faced by corn seed companies trying to maintain seed purity). (Again, because soybeans do not cross-pollinate, this risk of contamination is not present.) A non-GM plant pollinated by a GM plant produces a kernel that has genetically modified characteristics. Farmers growing corn for grain are advised to follow some of the steps taken by farmers growing corn for seed to maintain purity, namely spatial and temporal

⁵ An additional complication enters in if bad weather threatens and it is highly desirable for the farmer to plant his crop before bad weather starts. In such a case, having to spend 40 to 55 minutes more to clean out the planter could conceptually delay planting for several days. Such delays most likely would be rare events, however (D.G. Bullock, 2000).

isolation of fields from GM corn fields and planting of all-male border rows (Burris, 2000; Nielsen, 2000). For a farmer to hire labor to carefully rogue hundreds of acres of corn would undoubtedly be too costly to be economically feasible. In the end, perhaps the only “practical” way to meet very high (well over 99.5%, say) non-GMO purity standards for corn would be to create very large isolation zones in which only non-GM corn is grown for miles around. But to set up and administrate such an isolation zone, and to enforce compliance by neighboring farmers who may have economic incentives to grow GM corn, might well prove to be an expensive organizational nightmare.

2.3. Maintaining purity during harvest

The harvest presents additional possibilities for contamination of non-GM grains by GM grains. When a farmer harvests grain, usually some grain remains in the combine and is not successfully thrown by the combine into the truck or trailer that is supposed to receive the grain. Therefore if a farmer chose to harvest both GM and non-GM grain with the same combine, he would have to clean out that combine after harvesting GM grain and before harvesting non-GM grain. Conceptually, he might only have to clean out the combine once per year, before harvesting the non-GM grain. To prevent needing additional combine clean-outs, he would simply harvest all of the GM grain, then all of the non-GM grain (or vice-versa).⁶ A procedure to make a combine completely clean (“kernel clean”) is detailed in a video produced by South Dakota State University (2000), and takes two people approximately four hours to remove virtually every kernel of grain from the combine’s inner workings. Most certified seed producers currently use a less exacting combine clean-out procedure that takes two people approximately two hours (Ingemansen 2000). Alternatively, high levels of seed purity may be obtained by using a less rigorous procedure to manually clean out the combine, but then running the combine through a field of non-GM grain in order to “flush out” the GM grain.⁷ By using such a procedure, two experimenters working together took approximately fifteen minutes of time in the field to clean out a combine, then harvested and unloaded 60-70 bushels of soybeans to “flush” the combine, and obtained at least 99.8% purity (Greenlees, 2000; Greenlees and Shouse, 2000).

Let us compare the per-bushel economic costs of procedure 1: two workers cleaning a combine for four hours, and procedure 2: two workers cleaning a combine for fifteen minutes, then harvesting 70 bushels of non-GM soybeans to “flush” GM soybeans out of the combine. Procedure 1: Assuming that farm labor skilled enough to clean out a combine can be hired for \$15 per hour, two laborers working four hours each would cost $\$15 \times [2 \times 4] = \120 . Procedure 2: Two workers working fifteen minutes each to clean out the combine would cost $\$15 \times [2 \times 0.25] = \7.50 . Then, since the current premium paid to farmers for non-GM soybeans is approximately \$0.15/bu (DuPont, 2000c), the cost of using 70 bushels of non-GM soybeans to “flush” the combine would be $70 \times \$0.15 = \10.35 . So, total costs of cleaning the combine using procedure 2 would be approximately $\$7.50 + \$10.35 = \$18.85$. If we assume that a farmer grows 500 acres of soybeans, achieves a yield of 40 bushels per acre, and only needs to clean out the combine once per harvest, then using procedure 2 to clean the combine would entail a per-bushel cost of $\$18.85 / (500 \times 40) = 0.09$ cents per bushel. Procedure 1 would entail a per bushel cost of $\$120 / (500 \times 40) = 0.6$ cents per bushel. Clearly, procedure 2 seems more economical than procedure 1.⁸ Assuming a higher wage rate would widen the gap in costs between the two procedures. Assuming a higher premium would narrow that gap.⁹

⁶ An additional complication comes about because farmers can plant their fields in less time than they can harvest them. So that all of his grain does not reach its optimal harvesting stage at the same time, a farmer usually plants different varieties that mature at different times, so that he has a wider window of time in which to harvest all of the grain at its peak. In order to first harvest all his GM grain, then next harvest all his non-GM grain, the farmer would have to plant early-maturing GM varieties and late-maturing non-GM varieties (D.G. Bullock, 2000).

⁷ Then the mixture of non-GMO and GMO grain must be sold at non-GMO prices.

⁸ Contracts between farmers and grain handlers to assure non-GMO segregation and identity preservation are already being written that stipulate that the farmer will use procedure 2. Contracts between farmers and the handlers Consolidated Grain and Barge company and Protein Technology International, Inc stipulate, “Combine was blown or swept clean and visually verified to be free of all other grain and soybeans...Flush run on STS or other non-GMO beans was used to assure equipment was free of contaminants” (DuPont, 2000b, 2000c). Farmers are signing contracts with Archer-Daniels-Midland that stipulate, “I used reasonable care to clean all harvesting equipment to ensure it was free from any contaminants to the STS grain. ...A flush run was done if

2.4. Calculating the on-farm costs of planter and combine cleaning

In Table 1 we show calculations of per-bushel costs of planter and combine cleaning to maintain non-GM soybean segregation and identity preservation. Note that for a typical farm, one with 500 acres of soybeans yielding 40 bushels per acre, the per-bushel costs of planter and combine cleaning are quite small, less than 0.2 cents per bushel. Since soybeans do not cross-pollinate, there should be few additional costs to the farmer of segregation and identity preservation. It seems reasonable that similar small costs of flushing and cleaning combines and cleaning planters would prevail for non-GM corn segregation and identity preservation. But it may be important that the extra costs of discouraging cross-pollination of corn are not included here.

Table 1. Per-bushel on-farm costs of non-GM soybean segregation and identity preservation (assuming 500 acres of soybeans planted and yields of 40 bushels per acre).

Activity	Labor	Assumed wage	Labor costs	Bushels of GM beans flushed	Premium per bushel of GM beans	Flushing costs	Labor costs + Flushing costs	Total yield on farm	Labor costs + flushing costs per bushel
Clean Planter	1.0 (or fewer) hours	\$15/hour	\$15.00	n.a.	n.a.	n.a.	\$15.00	20,000 bu	0.075 cents/bushel
Clean Combine (procedure 2)	0.5 hours	\$15/hour	\$7.50	70 bu	\$0.15/bu	\$10.35	\$18.85	20,000 bu	0.094 cents/bushel
Total									0.18 cents/bushel

3. Transportation off the farm

After grain is harvested (and possibly stored on-farm after the harvest), it is most often transported by truck to a nearby country elevator, or transported by grain wagon to on-farm storage bins. Both traditional harvesting trucks, which carry approximately 400 bushels of soybeans or corn, and semi-trucks carrying approximately 800 bushels are used to transport grain to country elevators. If the farmer elects to sell his grain directly after harvest and not store it, then it is necessary for him to coordinate the loading and driving of trucks from the farm to the country elevator. For reasons explained in detail in footnote 9, during a window of good harvest weather, any delay in the harvesting process can be quite costly. It seems that keeping trucks sufficiently clean to maintain adequate non-GMO purity would not entail much cost. The types of trucks used to haul grain off farms are designed to easily dump, and easily sweep clean. However, if GMO testing at country elevators causes trucks to remain longer in queue, then unless he bought or rented additional trucks during harvest, the farmer might be forced to shut down his combine in the field while waiting for a truck to return from the country elevator. Farmers owning on-farm storage facilities would not face this same additional cost, since they could elect to deliver their grain to the elevator at less busy times of the year.

the prior harvest field was not of STS grain” (DuPont, 2000a). (STS soybeans are a type of non-GMO soybean, the patent for which is held by DuPont Corporation.)

⁹ Valuing farm labor at \$15 per hour during harvest may be an underestimate of the total costs of cleaning out the combine, since there are non-labor costs of delaying harvest. Taking into account these non-labor costs further widens the cost gap between procedures 1 and 2. Harvest is the busiest time of the year for farmers. Underestimation might be the case because delaying harvest to clean out the combine may cost the farmer far more than merely the price of labor for cleaning out the combine. There are several potential non-labor costs from harvest delays: corn stalks tend to lodge (fall to the ground) over time, making it difficult for the corn to be mechanically harvested. Also, during any good weather after the harvest, many farmers prefer to conduct other fieldwork, such as chopping corn stalks, fertilizing for the next spring’s crop, and tilling. Farmers understand that delaying this work until the next spring might very possibly delay planting, and delaying spring planting can result in lower yields, for corn anywhere from 0.5 to 1.0 bushels per day of delay. Farmers enjoy a much wider time window for planting soybeans, and can usually delay planting soybeans well into the month of May before significant yield losses occur (D.G. Bullock, 2000).

4. Country elevators

4.1. The grain flow in the elevator

When a truck filled with grain arrives at an elevator, a tubular probe is used to take a sample of the truck's grain. Such probes have been used for years, and grain samples need to be taken whether non-GMO segregation is desired or not. Elevator employees then analyze this grain sample for various characteristics, including moisture content and foreign material. When farmers deliver grain and claim that it is non-GM grain, it may be necessary for the elevator employees to also test the grain sample taken to detect the presence of GM grain in the claimed non-GM delivery. Rapid strip tests are already available that allow detection of GM soybeans and certain types of GM corn in the sample.¹⁰ The farmer may have to wait five to ten minutes before the test shows whether his load is accepted as non-GMO or not.

After a truck's grain has been sampled and tested for GMOs, the truck driver then pulls the truck over a dump pit, which is basically a big hole in the ground covered by a metal grate. When grain is dumped into the pit, some inevitably bounces off the steel grate instead of through it, and scatters on the surrounding concrete floor, or gets caught in cracks in the grate. It is possible for employees to use a broom or an air blower to sweep away or back into the pit grain that has bounced off the grate and has not gone into the pit.

At the bottom of a dump pit is an area called the boot, where the grain sits until it is carried up and away by a machine called a leg, which is like a large belt with buckets or shovels attached to it. The leg cannot scoop all the grain out of the boot; a small amount of grain is usually left at the bottom of the boot where the leg's buckets do not reach. To get rid of this grain at the bottom of the boot between dumps, an employee would have to remove the grate, and climb down into the pit with a broom or shovel to clean the boot. It is possible that loose pieces of grain could get caught in the leg. Additionally, grain dust—small particles of grain chipped off from the grain as it is dumped and moved by machine—gathers in the leg. The only way to clean such dust would be to basically disassemble a leg, which would take many hours of worker time, and for practical purposes is rarely if ever done.

When the leg scoops the grain out of the boot, it carries it up (“elevates” it) into a distributor, which directs the grain onto a series of conveyor belts, which then carry the grain to separate storage bins. It is possible that loose grain could fall into nooks and crannies in the distributor and conveyor belts, though these are designed to be relatively self-cleaning.

The bin in which the grain is stored depends on the type of grain and on the results of its sample's test; grains of one type or quality can be stored in one bin, and grains of another type and quality can be stored in another. Clearly, it would be possible to use some storage bins for GM grains, and other storage bins for non-GM grains. Otherwise, before a storage bin could be switched from holding a GM grain to a non-GM grain, it would have to be emptied and cleaned. However, dedicating certain bins to be permanently used for storing non-GM grains would offer the elevator less flexibility in the number and types of grains it could store within its existing storage bins. A simple example would be that of an elevator possessing two bins, which before the creation of GMOs it used to store “high-quality” corn and “low-quality” corn. (For the sake of the example, say that these are the only two types of corn.) After the arrival of GMOs, there would be twice as many types of corn: “high-quality” GM corn, “low-quality” GM corn, “high-quality” non-GM corn, and “low-quality” non-GM corn. The arrival of GMOs doubled the number corn types, and so if the elevator wanted to segregate GMOs from non-GMOs, it would no longer be able to separate by high and low quality—it would lose flexibility.

Country elevators are usually located next to train tracks. Periodically, an elevator will order a train to stop to receive grain, to then be shipped either to a domestic processor or an export elevator. To move grain from the storage bins through a spout and into train cars, generally the grain is released from the storage bin, from where it flows back into the pit by the force of gravity. Then the leg is used to elevate the grain up to the distributor, where it is directed onto a conveyor belt that carries it into a bin that has a spout that hangs out over the train cars. Often elevators mix grain from several bins into one car, in order to just meet the quality standards for the grain set forth in the contract between the elevator and the buyer.

¹⁰ Details about these tests are presented in section III.2.2.a.

4.2. Maintaining non-GMO purity in country elevators

Grain elevator facilities are huge pieces of capital, consisting of one or more “grain paths” of dump pits, boots, legs, storage facilities, conveyors, and spouts. The pieces of equipment that make up the grain paths are generally designed to keep themselves reasonably clean, in order to prevent the build-up of grain dust, which can lead to safety hazards for workers. But they are not designed to be kept “kernel clean,” and it would be prohibitively expensive to achieve this degree of cleanliness in the pits, boots, conveyor belts, storage bins, distributors, and especially the legs of an elevator. The cost-effective procedure, then, is for grain handlers to dedicate separate grain paths to non-GM and GM grains. Which elevators will dedicate their grain paths to GMOs, which will be used solely for non-GMOs, and which will be used for both will depend largely on the physical make-up of the equipment at the elevator. Those elevators with multiple and separated grain paths of dump pits, legs, storage bins, conveyor belts, and spouts will be able to practice segregation and identity preservation with lower costs than those without separated grain paths. Of course, companies or cooperatives that own several different elevators in close geographic proximity may be able to dedicate entire elevators exclusively to non-GM grains, and avoid many of the costs of cleaning the grain storage and moving equipment that way.

Some country elevator companies or cooperatives have already begun dedicating some of their elevators solely to GM storage and handling, and other elevators solely to non-GM storage and handling. For example, the Grand Prairie Cooperative elevator in Sadorus, Illinois has been dedicated solely to genetically modified corn (Billman, 2000). Some handlers (for example the Grand Prairie Cooperative elevator in Tolono, Illinois) that have facilities with multiple grain paths are dedicating one of their grain paths to non-GMO segregation and identity preservation of non-GM grains (Billman, 2000). New elevators being built this year are being built with future segregation and identity preservation needs in mind (Flavin, 2000).

5. Transportation from the country elevator

Grain is typically carried by train from the country elevator to a domestic processor, a an export elevator. Hopper cars are used to transport the grain. Each hopper car carries approximately 4000 bushels of soybeans or corn, and fifty-car trains are standard, with trains generally stopping at several elevators to receive enough grain to fill all fifty cars. Hopper cars are built to receive various types of bulk cargo, and are cleaned after each shipment as a matter of standard procedure. When a train is loaded at a country elevator, the elevator usually hires federal grain inspectors to inspect the grain being shipped. The inspectors issue for each train car a certificate stating its grain’s grade at that point in time, called its origin grade (Billman, 2000).

6. The export of bulk corn or soybeans

Roughly 30% of U.S. soybean production and 20% of U.S. corn production is exported in the form of whole grains (USDA FAS, 2000a and 2000b). About 75% of this is exported from export elevators out of Gulf ports (USDA FGIS, 2000), with most of this being transported to New Orleans by barges that receive corn and soybeans at river elevators.

River elevators operate in a manner similar to that of country elevators, except that they tend to receive grain from trucks and move it to barges. Barges do not have holds, therefore it is not possible for one barge to simultaneously carry and segregate GM and non-GM grains. Each barge carries approximately 55,000 bushels of soybeans or corn. After unloading, barge owners pay private companies to clean out their barges, no matter what the barge’s cargo has been. The current cleaning cost is \$300 (Ayers, 2000). The principal site of U.S. soybean and corn export is New Orleans, though smaller amounts of corn and soybeans are exported on ocean-going ships from Great Lakes, Atlantic, and Pacific ports.

Export elevators can receive grain by barge, train, or truck. Different export elevators have different physical set-ups. Some export elevators use shipping bins, in which the grain is conveyed by belt from storage bins, right before being loaded onto a ship. Each shipping bin has a spout out of which grain flows into the ship. Export elevators with shipping bins usually have several of them, which facilitates the loading of different varieties and grades of grain into different holds of the ship (McKinstry, 2000). Other export elevators do not have shipping bins, so that grain travels from all storage facilities to the ship via a common spout. Ocean-going vessels have separate holds, physically

separate compartments within the ship. One hold typically carries 200,000 to 300,000 bushels of corn or soybeans. By law, ship holds must be cleaned between shipments. Vessels sail to ports overseas, where they are unloaded and grain is delivered to processors.

Maintaining the identity of non-GM grains in barges and ocean-going vessel holds, which are already cleaned between each shipment, does not entail much additional cost. As with country elevators, the most economical way to avoid contamination in river elevators and export elevators is to dedicate separate grain paths to non-GM and GM grains. Over the past year, some export elevators have begun segregating GM and non-GM grains.¹¹

7. The export of processed corn or soybean products

Grain that is not exported in bulk form is transported from domestic elevators to domestic processors. The first stage of soybean processing extracts soybean oil from the bean by solvent methods, which results in joint production of a high protein component and crude soybean oil. The high protein component is mainly used to produce soybean meal for feed. Other protein products are soy flour, soybean molasses, soy protein concentrate, and isolated soy proteins. Crude soybean oil is primarily processed in edible products, such as salad and cooking oils, margarine, shortening, salad dressings, and soybean lecithins used as food additives. U.S. exports of processed soybeans originate from roughly 10% of U.S. soybean production (USDA FAS, 2000a). Corn wet millers break down corn into starch and by-products. The by-products are subsequently recombined in various ways to give a range of animal food products (notably corn gluten feed).

Domestic processors already offer price premiums to elevators for certain non-GM soybeans (Archer Daniels Midland, 2000). Avoiding contamination of non-GM grain by GM grain at the processing stage may require either dedication of separate facilities to GM or non-GM grain, or processing of GM and non-GM grains at different times in the same facility, with clean-up before non-GM grains are processed.

III. Information, testing, and vertical coordination of the grain industry

When one firm controls more the one stage of vertically linked production process, we say that the process is vertically integrated. How different levels of a production process are organized (e.g., with one firm controlling an entire vertically linked industry, or with many firms, each controlling one stage of the production process and selling that stage's product to a separate buyer at the next stage) is called the industry's vertical coordination. The arrival of GMO technology may cause changes in the vertical coordination of the grain industry.

Maintaining a very low GMO content while producing, handling and processing grains requires two types of effort at each stage of the vertical supply chain: making sure that the grain product purchased is non-GMO, and preventing GMO contamination before selling the product to the next stage. Simple observation by the buyer does not reveal whether the seller has made these two types of effort or not. As a result, there exists an asymmetry in information about the efforts undertaken by the seller to keep its production free of GMOs. The buyer has then two options by which to increase his information on the efforts made by the seller. He can use a test to estimate the GMO content of the purchased product, or he can attempt to write a contract specifying that the seller adopt the required production practices (i.e. uses a non-GM product and makes sure that little or no contamination arises at his stage), and then to some degree observe the seller's practices.

In the case of an open market spot transaction, the buyer would rely exclusively on a test to determine whether purchased products are accepted as "non-GMO." Using a GMO test creates an extra cost. Moreover, it can delay the usual product flow, because the buyer has to wait for the result of the test to make sure that he can mix the product with other non-GM products. The test's estimate of a shipment's GMO content is imperfect, both because only a small sample from the entire shipment is

¹¹ For example, in Fall 1999 an export elevator owned by the Andersons company near the mouth of the Maumee River at Lake Erie near Toledo, Ohio loaded a one-million bu ocean-going vessel with non-GM soybeans, which had been segregated and identity preserved (McKinstry, 2000). The destination of the shipment was Japan, where the beans were to be processed to make tofu for human consumption. The Andersons had guaranteed that at least 95% of the shipment would be non-GMO. Sample testing of the grain after it was loaded on the ship suggested that 98%-99% of the soybeans were indeed non-GMO.

drawn, and because the physical test itself can be in error. In this context, the rationale for increased vertical coordination is to limit the buyer's uncertainty about product quality. For example, the farmer can commit himself in a contract to use a non-GM seed and to adopt production practices (cleaning out the combine, etc.) limiting GMO contamination of non-GM grain. In the extreme, vertical integration may avoid contract disputes about whether a shipment of non-GM soybeans was sufficiently "pure" to meet contract specifications.

If either testing, contract writing, or observation of the seller's actions is too expensive, it may be economically infeasible for the buyer and the seller to be separate entities. (They can't trust each other, and it is expensive to monitor or test the results of the others' actions.) In this case, often the same firm will be both its own seller and its own buyer. Thus, it is conceptually possible that GMO technology could increase the vertical integration of the grain industry. To assess the likelihood of increased vertical coordination, we must examine GMO testing costs.

1. The GM events in soybeans and corn in the US

At this time, for soybeans, eleven transformation events have been granted environmental, feed, and food release in the US¹². One event confers glyphosate herbicide tolerance (Roundup Ready trait); nine events confer glufosinate herbicide tolerance (Liberty Link trait); and one event confers high oleic acid expression (Agriculture & Biotechnology Strategies Inc., 2000). However, glyphosate-resistant soybeans were the only biotech soybean varieties commercially grown in 1999 and will be the only biotech soybean varieties available for open commercial planting in 2000 (American Soybean Association, 2000). This means that currently only one event has to be recognized by a test in order to assess the GMO content of a US soybean product.

Testing for GMO content in corn is more complicated than in soybeans. For corn, sixteen transformation events have been granted environmental, feed and food release in the US. Two events confer resistance to the European Corn Borer (ECB) insect; seven events confer glufosinate herbicide tolerance; one event confers glyphosate herbicide tolerance; four events confer both glufosinate herbicide tolerance and ECB insect resistance; and two events confer both glyphosate herbicide tolerance and ECB insect resistance.¹³ This means that multiple transformation events have to be recognized by a test in order to assess the GMO content of a US corn product.

2. The available tests

2.1. Herbicide tolerance bioassay

A herbicide tolerance bioassay is a quantitative GMO test. It allows identification of whether viable seeds or grains are tolerant to a given herbicide, by making seeds/grains germinate in the presence of this herbicide. This test works only on seeds or grains that germinate. It does not allow assessment of the GMO content of dead seeds and dockage. This test currently exists for both herbicide tolerance traits commercialized in soybeans and corn, the Roundup Ready trait and the Liberty Link trait. The test requires seven days. The company Mid-West Seed Services, Inc. (MWSS) currently offers this test for the Roundup Ready trait in soybeans at \$18 for 400 seeds or grains tested individually, and \$30 for 1200 seeds or grains tested individually; and for Roundup Ready and Liberty Link traits in corn, tested together, at \$40 for 400 seeds or grains tested individually (Midwest Seed Services Inc., 2000; Brix-Davis, 2000).

¹² To make a transgenic crop, one or more genes of interest from another species are inserted in the DNA of the crop along with promoter and marker genetic material. Any such successful genetic transformation is called an «event.» Events vary depending on the components of the genetic package and where the novel DNA is inserted. For a detailed description of traits and techniques of GMOs see e.g. Nelson et al. (1999).

¹³ ECB insect resistance is obtained by expression of a Bt toxin in the plant. This Bt toxin is the Cry1Ab protein for six events, the Cry9c protein for one event, and the Cry1Ac protein for one event (Agriculture & Biotechnology Strategies Inc., 2000). At this time, corn varieties with resistance to ECB only, glufosinate only, glyphosate only, both ECB and glufosinate and both ECB and glyphosate are commercialized. USDA estimated that in 2000, 25% of US corn production would be genetically modified, with 18% of corn with ECB resistance only, 5% with herbicide tolerance only, and 2% with ECB resistance and herbicide tolerance at the same time (USDA, NASS 2000).

2.2. Immuno assay test

The immuno assay test is a method used to detect proteins created or expressed by the modified gene. The test locates the proteins by locating antibodies that attach to them. There are two types of immuno assays : the strip test and the ELISA test.

a. Strip test

The strip test is a “dipstick” test which requires only minimal equipment and skill to conduct, 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-resistant soybeans. The test requires that a worker grind a sample of soybeans in an electric blender with a solution provided by SDI. The employee then places a dipstick provided by SDI into the ground soybean solution, and waits three to five minutes. After this time, there appear either one line or two upon the dipstick: one line signifies that no glyphosate resistant soybean was detected in the sample; two lines signify that at least one of the soybeans was glyphosate resistant (Strategic Diagnostics, Inc. 1999a). This SDI test costs \$5 every time it is used, and takes five to ten minutes of elevator employee time to conduct (Billman, 2000). Assuming that hiring an employee costs approximately \$15 per hour (\$2.50 per ten minutes), the total cost of a test is approximately \$7.50.

The company EnviroLogix sells a strip test for the detection of two of the three Bt toxins currently expressed in GM insect resistant corn, the Cry1Ab and Cry1Ac proteins. For one corn transformation event, the Cry1Ab Bt toxin is expressed only in the plant tissue but not present in detectable quantities in grain. In order to be able to detect the presence of this transformation event, it is necessary to grind some leaf tissue in addition to grains. A positive result confirms that the sample contains one of these two proteins. A negative result indicates that the grain does not contain one of these two proteins, and is either non-GMO or contains one of the other genetically altered traits. The EnviroLogix test costs \$3.50 every time it is used. Using one test and waiting for the strip to develop 10 minutes provides a high probability for detection of 6% contamination in the sample (EnviroLogix, 2000). Assuming that it takes fourteen minutes to conduct the test and that hiring an employee costs approximately \$15 per hour (\$3.50 per fourteen minutes), the total cost of a test is approximately \$7.00. The company SDI has completed the development and is marketing two test kits for the detection of Bt Cry1Ab in corn. Both kits utilize a rapid, easy-to-use test strip that provides a result in under five minutes (Strategic Diagnostics Inc., 2000).

b. ELISA (Enzyme Linked Immunosorbant Assay)

The ELISA test is a laboratory test allowing quantification of the GMO content of the sample for a given transformation event. ELISA testing is applicable to raw agricultural products or slightly processed products. The results of the assay are visualized with a color development proportional to the concentration of the proteins created in conjunction with the genetic event. The color change can be quantified using a plate reader (Strategic Diagnostics, Inc 1999b). The ELISA tests take in minimum six hours to be completed (Vierling, 2000).

Strategic Diagnostics, Inc. has developed an ELISA test for Roundup Ready® soybeans (Strategic Diagnostics, Inc., 1999). The company MidWest Seed Services, Inc. offers this test at \$60 per sample for a 1200 seed sample, if the customer asks to test three or more samples (MidWest Seed Services, Inc. 2000). The company Central Hanse Analytical Laboratories, LLC. offers this test at \$75 for a one-kg sample, and charges an additional \$25 for grinding the sample (Central Hanse Analytical Laboratories, LLC., 2000; Russell, 2000).

Currently there exists no ELISA test to detect herbicide tolerant varieties in corn. For Bt corn, two companies currently provide ELISA tests.¹⁴ In order to have quantitative results with an ELISA Bt test, it is necessary to test separately individual seeds and green tissue. Mid-West Seed Services, Inc., offers

¹⁴ EnviroLogix has developed an ELISA test for Cry1Ab and Cry1Ac Bt proteins (EnviroLogix, 2000). Agdia, Inc. has developed tests on the Cry1Ab, Cry1Ac and Cry9c Bt proteins. Its Cry1Ab test shows some cross-reaction with Cry1Ac, so it allows detection of this event as well (Agdia, Inc. 2000). In order to detect all current Bt resistant GM corn varieties, it is necessary to use one test for protein Cry9c and one test for proteins Cry1Ab and Cry1Ac. For one Cry1Ab event, the Bt toxin is not detectable in grain, so some dried green tissue has to be used also in order to recognize all current Cry1Ab events. An ELISA Bt test on a ground sample is only qualitative.

a Cry1Ab/Cry1Ac test for \$65 for 90 seeds tested individually and \$70 for 360 seeds where 4 seeds are mixed together to make 90 samples. It offers a Cry9c test at \$70 for 90 seeds tested individually and \$75 for 360 seeds where 4 seeds are mixed together to make 90 samples (Mid-West Seed Services, 2000; Gutormson, 2000).

2.3. Polymerase Chain Reaction

The PCR (Polymerase Chain Reaction) test is a laboratory test used to detect modified DNA by selectively multiplying targeted sections of a DNA molecule. This method is applied to raw materials, processed materials and mixed products. The PCR method offers different levels of precision at different costs.

A distinction must be made between a qualitative PCR test and a quantitative PCR test. The qualitative PCR can detect very low levels of contamination but cannot quantify the contamination level. Its results are reported as “detected” or “not detected”. The quantitative PCR test uses a DNA probe producing a fluorescent signal, making it possible to follow the progress of the PCR reaction to accurately measure the quantity of GMO present in the sample. The qualitative PCR is more sensitive than the quantitative one, and therefore capable of detecting traces of target DNA. The company Central Hanse Analytical Laboratories, LLC. advises its clients to use a qualitative test as a confirmation in the case where no GMOs are detected by a quantitative test (Central-Hanse Analytical Laboratory, 2000a; Russell 2000).

What is detected by either a qualitative or a quantitative PCR test depends on which primers are used. Primers are small DNA molecules whose sequence corresponds to the DNA target sequence for which one wishes to search. A first possibility is to use primers corresponding to DNA sequences that are present in many GMOs. This allows the simultaneous detection of multiple GMOs but does not explicitly state the type of modification.¹⁵ A second possibility is to use primers corresponding to artificially introduced sequences of DNA that are typical of a given event. These sequences do not occur naturally in the species being tested and, therefore, are indicative of a genetic modification. Using such primers permits an unequivocal determination of one individual event of transformation. However, the more primers used, the more expensive is the test (Central-Hanse Analytical Laboratory, LLC 2000a; Russell, 2000).

The base prices at Central Hanse Analytical Laboratories, LLC. are \$25 to grind the sample (usually 1 kg samples are used), \$120 for DNA extraction, \$75 for each primer in a qualitative test, and \$150 for each primer in a quantitative test. Some prices are lower for some service packages. All following prices are the lowest of the sum of base prices and the package price and include sample grinding. For soybeans, only the glyphosate-resistant trait has to be recognized. Using only the specific primer for this event, a qualitative test costs \$205 and a quantitative test costs \$295. This is more expensive than the ELISA test, which quantifies the GMO content in glyphosate-resistant soybeans for only \$100. For corn, using the 35S primer and the GA21 primer allows detection of all current events released in the U.S. A qualitative test with 35S and GA21 primers costs \$235. A package including a quantitative test with the 35S primer, a qualitative test with the GA21 primer, then a quantitative test with the GA21 primer in case of a positive qualitative test costs \$370 and allows assessment of the total percentage of GM corn in the sample. Quantifying individually each of the sixteen GM events in corn is cost prohibitive. However, twelve of the sixteen US GM corn events are not approved for import in the EU, while eight of the sixteen US GM corn events are not approved for import in Japan. A qualitative test to prove that these events were not detected in the sample adds a \$75 cost per event, that is, \$900 for the twelve events not approved in the EU, and \$600 for the eight events not approved in Japan. Normally the tests are completed within three days to a week. Each test can be conducted

¹⁵ For example, the 35S promoter is a DNA sequence from the Cauliflower Mosaic Virus often used in gene technology as a regulation site for the newly inserted genes. Using a primer corresponding to the 35S promoter permits detection of the glyphosate-resistant trait in soybeans, and of all but one of the sixteen corn events currently approved for release in the US (the event GA21 corresponding to the glyphosate-resistant trait in corn is not detected by a 35S primer). A positive result with a method using the 35S primer is not a guarantee of the presence of a GMO since the 35S does occur in nature. Its presence in the sample could be from either a natural admixture or a genetic modification of DNA. However, the natural admixture occurs mainly for plants related to Brassica, and is not expected to occur for soybeans and corn. Moreover, it is possible to use a primer specific to the natural virus sequence in order to assess whether a positive result arises because of a natural admixture or because of GMO contamination.

within a twelve-hour period if technicians and lab facilities are available. Higher prices are charged if the customer wants the results of the test in less than one day (CentralHanse Analytical Laboratory, 2000b; Russell, 2000).

3. The costs of testing at the different levels of the grain industry

Strip tests cost approximately \$7.50 for soybeans and \$7.00 for corn (including the employee wage), and can be conducted rapidly. They are useful to verify the GM content at different levels of the supply chain. They are inexpensive compared with the other tests, so they can be conducted to verify the GM content of small carriers, like farm trucks. For corn, only the Cry1Ab and Cry1Ac Bt proteins are detected.

For soybeans, quantitative testing is easier because only one transformation event has been introduced in commercial seeds. Three quantitative tests are available. The herbicide tolerance bioassay, which costs \$30 for 1200 beans, is the cheapest test, but works only on seeds or grain that germinate. A one-kg sample contains approximately 4300 beans, and seems more adequate for export certification (even if at this time no formal laws or standards have been passed on necessary sample sizes). On a one-kg sample, an ELISA test costs \$100 and a quantitative PCR test costs \$295. The ELISA test is the more economical solution for large sample sizes.

For corn, testing is more complicated, because sixteen events are approved for release in the US, and because in addition only four or them are accepted for import in the EU and eight of them are accepted for import in Japan. A quantification of the GM content of a corn sample can be attained by combining a herbicide tolerance bioassay, at \$40 for 400 kernels, and two Bt ELISA tests, at \$70 and \$75 for 360 kernels, for a total of \$185. A quantification of the GMO content in corn can be attained by PCR at \$370 for a one-kg sample (containing approximately 3000 kernels). The PCR test seems more appropriate for export certification because of the large sample size. To prove by PCR the absence of all GM events not approved for import in the EU would add \$900 to the PCR cost, and to prove the absence of all GM events not approved for import in Japan would add \$600 to the PCR cost¹⁶.

Next we calculate an estimate of testing costs at the handling stage, using as an example exports of bulk non-GM soybeans to Japan by Consolidated Grain and Barge company. Consolidated Grain and Barge has river elevators on the Mississippi, Illinois and Ohio rivers. The farmer typically brings non-GM soybeans by truck, directly from his farm to a river elevator. At the river elevator, typically two strip tests are used per truck. The beans are stored in the bins of the river elevator. Then, they are loaded in a barge, containing approximately 55,000 bushels in a single hold. When loading a barge, a two-kg sample is taken with a diverter sampler. The two-kg sample is sent by mail to CentralHanse Analytical Laboratory, LLC in Louisiana, with a posting cost of \$15. The laboratory does a quantitative ELISA test on the GMO content of the sample and issues a certificate by the time the barge arrives in New Orleans. 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 metric tons, and sent to the testing lab. The ocean vessel then leaves for Japan, where it typically sails to different import elevator locations in order to unload different holds (Haas 2000).

Table 2 gives an approximation of the testing costs with this example.

¹⁶ The current understanding is that only twelve of the sixteen corn events approved for release in the US have been commercialized, and that eight of these events are not approved in the EU and four of these events are not approved in Japan (Russell, 2000). Testing for the absence of eight events (for the EU) would drop the additional cost to \$600, while testing for the absence of twelve events (for Japan) would drop the additional cost to \$300.

Table 2. Unit costs of non-GM tests on soybeans

carrier	content (bu)	content (mt)	unit cost (\$)	cents per bu	cents per mt
semi truck: 2 strip tests	800	22	15	1.88	68.8
barge: postage costs to send sample to lab	55000	1499	15	0.03	1.0
barge: ELISA test	55000	1499	100	0.18	6.7
1200 mt in an ocean vessel hold: ELISA test	44040	1200	100	0.23	8.3
total				2.31	84.8

bu=bushel; mt=metric ton; 36.7 bushels per metric ton of soybeans

The following Table gives an example of what the costs would be in the case of corn with the same grain flow, and with PCR testing.

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

corn	content (bu)	content (mt)	unit cost (\$)	cents per bu	cents per mt
farm truck: 2 strip tests	800	20	14	1.75	69.0
barge: postage costs to send sample to lab	55000	1396	15	0.03	1.1
barge: quantitative PCR test	55000	1396	370	0.67	26.5
barge: additional qualitative test for 12 events non approved for import in the EU	55000	1396	900	1.64	64.5
1200 mt in an ocean vessel hold: quantitative PCR test	47280	1200	370	0.78	30.8
total				4.87	191.8

bu=bushel; mt=metric ton; 39.4 bushels per metric ton of corn

The unit costs of non-GM tests on corn are higher than on soybeans, partly because the quantitative tests are more expensive, and partly because there is an additional test to recognize individual events that are not approved for import in the EU or in Japan. Whether samples are currently tested for these individual events for all corn exports towards the EU or Japan is not certain. However, if such testing is not done, the exporter takes the risk that his shipment may be refused at the importer's facility if a test there shows that they are contaminated, even in small proportions, by unapproved varieties.

4. Contracts and certification

4.1. Seed

No seed purity level is required by law in the US, but Federal and State laws require truthful seed labeling information that allows seed buyers to make informed choices. Notably these laws set standards for mandatory labeling of varietal purity on seed bags and for verification of the labeled purity level. Under the Federal Seed Act Regulations (Government Printing Office, 2000), it is mandatory that each soybean or corn seed container that is transported between U.S. states or imported into the U.S. bear a label showing the variety name and the percentage of the seed of the variety named. Moreover, Federal employees and qualified State officials may be asked to draw samples and analyze their purity. Each state has its own seed law that regulates the sale of seeds within the state. For example, the Illinois Seed Law (Illinois General Assembly, 2000) has requirements for labeling of varietal purity similar to the Federal Seed Act Regulations, and mandates the Illinois Department of Agriculture to examine seed samples for purity. This means that the seed label gives the buyer some information about the average purity of the seed, and indicates at least the maximum amount of foreign material present on average in the containers of a given brand, even if the GMO content itself is not known by the buyer.

Large private seed companies already do extensive testing of their seed to assure themselves that they are maintaining high levels of seed purity. Specific labeling about GMO content may not be needed on soybean seed, because its average purity is already high. For corn, it might be expected that if seed companies make special efforts and incur extra costs to limit cross-pollination for some seed varieties, that they will convey this information in their labeling. Some crop improvement associations

have begun to offer non-GM corn seed and soybean seed certification. For example, the Minnesota Crop Improvement Association has 99.5% non-GM seed programs for corn and soybeans (Minnesota Crop Improvement Association, 2000). The program requirements are identical to usual seed certification requirements, and the only additional cost compared with conventional certification is the non-GM test cost (Beil, 2000). The crop improvement associations are official seed certifying agencies, with a long and trusted experience in third-party seed certification. Their non-GM seed programs provide a means to certify credibly non-GM seed purity.

4.2. Farmers and handlers

Contracts between farmers and handlers are a means to increase the amounts of information held by both parties. Contracts can specify farm production practices that limit contamination, and grant the right to the handler to check that the farmer follows these practices. Such contracts limit ahead of time the risk handlers run of receiving contaminated grain after harvest, and provide information to the about proper segregation and identity preservation practices. Contracts can specify the premiums that will be received when delivering the grains. In this case, they eliminate the farmer's risk of getting no compensation for having maintained the identity of non-GM grains. Contracts can also define in advance time windows for delivering grains, and thus help assure the handler a reliable supply flow.

This year, Consolidated Grain and Barge (CGB), Archer Daniels Midland Company (ADM) and Protein Technologies International (PTI) are offering grower contracts using the OSCAR® Internet-based contracting system of DuPont Specialty Grains (DuPont Specialty Grains, 2000e). Approximately 800,000 acres in non-GM STS soybeans and 700,000 acres in other types of non-GM soybeans are expected to be contracted this year through DuPont Specialty Grains (Young, 2000). This represents 2% of U.S. expected plantings in soybeans in 2000 (NASS, 2000). CGB, ADM, and PTI sign contracts with elevators and with farmers. Sample grower contracts are available on the OSCAR® website. These contracts specify certain production practices (the farmer must retain sales receipts of the seed planted, and he must clean the planter, combine, storage bins, and trucks used to transport non-GM grains). These contracts also specify farmers' premiums. Per-bushel farm premiums vary between \$0.10 and \$0.30. Premiums are higher for STS soybeans than for other non-GM soybeans, and higher for soybeans stored on-farm and delivered on a buyer's call than for soybeans delivered at harvest time (DuPont Specialty Grains 2000e). A sample contract between ADM and an elevator for STS soybeans specifies the elevator's handling practices (the elevator has to inform its employees of the nature of handling non-GM soybeans, must make a diagram of the facility to show the location and flow of all grain, and must clean all grain handling equipment). The contract specifies that ADM will pay the elevator a premium of \$0.25 per bushel over ADM's cash soybean bid (Archer Daniels Midland Company, 2000). The ADM grower contracts specify that the elevator will pay the farmer a premium of \$0.20 per bushel over the elevator's STS cash soybean price. In other words, by this contract the elevator receives a premium of $\$0.25 - \$0.20 = \$0.05$ per bushel for segregation and identity preservation STS soybeans. The sample contract also specifies that the elevator has to deliver the STS soybeans on a buyer's call in one of four delivery periods set forth by ADM. This allows the processor to forecast in which period he will be processing the non-GM soybeans.

Crop improvement associations are proposing third-party certification for corn and soybean acres contracted between farmers and grain handlers. It is projected that at least 60,000 acres of non-GM corn and 60,000 acres of non-GM soybeans will be certified by crop improvement associations this year in the U.S. (Beil, 2000; Lawson, 2000; Miller, 2000; Svarjgr, 2000). This certification follows general standards and minimum program requirements for 99.5% non-GM soybean grain and for 99% non-GM corn grain, as defined by the Association of Official Seed Certifying Agencies (AOSCA). The AOSCA programs require explicitly certain farm production practices.¹⁷ In addition, they define third-party verification.¹⁸ The general standards of AOSCA IP program also include requirements to certify grain at an handling stage (notably, facilities must be available to perform handling without introducing mixtures; records of all operations related to the program must be kept and may be subject to inspection). A product meeting the program requirements can be labeled with an AOSCA trademarked

¹⁷ The kind and variety of the previous crop must be specified by the farmers applying for these programs; the farmer must have grown a non-GM crop the year before in order to be eligible for the program; invoices of seed used must be provided; and minimum isolation distances for fields are required.

¹⁸ The fields must be inspected at least once; an authorized agency representative must take samples; agency-approved non-GM tests must be used

IP logo (AOSCA 1999, p 118-122). Using as guidelines the minimum requirements defined by the AOSCA standards, each seed certifying agency writes specific non-GMO programs for each customer, depending on the idiosyncratic needs of the customer. Typically, the handler bears the cost of finding and contacting participating farmers, while the crop improvement association is responsible for monitoring the fields (i.e. checking seed source, inspecting fields, taking samples and testing them). Current charges for monitoring farm soybeans are about \$0.05 to \$0.08 per bushel. Programs for corn involving only one field inspection cost around \$0.02 to \$0.03 per bushel and programs involving three field inspections cost around \$0.08 to \$0.10 per bushel¹⁹. In addition to verification of the seed source, field inspection, and lab testing of non-GMO content, programs may monitor the transport of the grain to a processing plant or barge, or audit the practices of the processing plant (Beil, 2000; Lawson, 2000; Miller, 2000; Svarjgr, 2000).

IV. Will there be a radical overhaul of the grain handling infrastructure any time soon?

Lately statements have been made suggesting that to segregate and preserve the identities of non-GM grains might require radical changes, indeed a complete and rapid overhaul, of the infrastructure of the grain handling system.²⁰ In considering the validity of this speculation, it is necessary to realize some important facts.

The arrival of GM technology does not overturn the basic nature of what grain handlers do, and does not overturn the basic economics of the grain handling industry. Grain handlers make their profits not simply from storing and moving grain. Rather, they make their profits from understanding grain markets, and knowing when market signals are calling for what type of grains to be blended and moved from one location to another. Country, river and export elevators have long had sampling probes, statistically-based tests, and employees with experience in testing grain samples to determine grain quality. Grain handlers store and then mix grain of various quality and grades to efficiently meet market demand when, where, and for what it occurs, and they are paid for this service. In a sense, the grain handling infrastructure has long been used to segregate and preserve the identity of all grain (with the degree of effort placed in segregation and IP depending on the type of grain).

Though it does not change the basics of grain handling, the arrival of GMOs does further complicate grain handling, both because it roughly doubles the number of varieties of grains, and because it raises the required level of purity. The number, size, and location of grain elevators, along with the design determining the ease with which they may be “cleaned” between shipments, has been brought about over the years by an economic equilibrium. This economic equilibrium was determined by the number of types of grains that had to be kept segregated and identity preserved (on the most basic level, corn had to be kept separate from soybeans), and the tolerance levels for impurities in a shipment. Roughly doubling the number of types of grains means that each type then faces a lower demand. Lower demand per type may imply that the economy now finds itself with elevator and export facilities that are inefficiently located, and which have too few and too large storage bins, too few

¹⁹ The per bushels costs may be lower for corn than for soybeans because corn yields are approximately 3.5 times soybean yields.

²⁰ A webpage advertising a conference titled “The New Value-Added Agriculture: Developing the Infrastructure,” to be held in Rosemont, Illinois, in September 2000, sponsored by the Association of Official Seed Certifying Agencies, Freiberg Publishing Company, and Agra Europe, has made the following statements on a web page linked to the on-line magazine *Seed and Crops Digest* (2000):

“Don't miss this first-of-a-kind chance to get in on the multi-billion-dollar development of the new value-added agriculture production system! Because of many recent profound changes in the world trade of agriculture and food products, a value-added, identity-preserved production system is going to become a reality...and billions will be spent in developing this whole new method of ag production! ...The ongoing GMO vs. non-GMO controversy requires segmentation of these crops for certain areas of world trade. ... And none of this can be accomplished without an Identity-Preserved production system! This new infrastructure will require an enormous amount of new services and equipment: new IP storage facilities, an IP transportation system, new certification/lab procedures, a whole new legal and insurance structure, new high-tech equipment of all kinds, new computer software systems, imaginative financial programs, and much, much more! Total price tag: In the billions, bringing more new cash flow, much quicker, into agriculture than ever before in its history! The Developing the Infrastructure conference is specifically designed to show you how to get your share of this huge new cash flow! You'll be able to learn from, and network with, the movers and shakers who are at the ground floor in developing this new infrastructure.”

separate grain paths per facility, and inefficient types of equipment which are harder to clean than would now be economically optimal. As a result, in the current grain handling system built for half as many varieties, grain handlers have lost flexibility in their ability to mix and blend grains to meet market demands over space and time. Grain handling in the new environment of non-GMO segregation and identity preservation is costlier, both for GM and non-GM grains, than it was for in the old environment, for which the system was built. This in itself will lead to higher prices paid by processors to buy non-GM grain. Handling costs will also rise for GM grains, but this cost is likely to be dominated by reduced on-farm production costs provided by GMO technology.

How will grain handlers respond to this lower demand for each variety, and the “inefficient” location and number of grain handling facilities? Will any of them try to do much to change the number of elevators and where they are located? Are there not economic incentives to change the system to meet the new demand? Our answer to this question is that while new economic incentives are now present, we do not predict that the incentives will be strong enough to lead to any sort of rapid overhaul of the grain handling system any time soon. We predict this result because grain elevators are perhaps the best example of what economists call “fixed factors of production”. They are large, expensive pieces of physical capital which do not move, cannot be easily disassembled, and cannot practically be used for any other purpose other than handling grain. Of course, as grain elevators wear out, it might make sense for handlers to build new elevators of a different size and design, in new places. But grain elevators don’t wear out very quickly—many in operation today are over fifty years old. These older elevators are often thought of as outdated and of low technology. Yet their fixed nature tends to keep them in operation. After all, they are too expensive to tear down or move, and there is not much else practical to do with them except handle grain or abandon them. So, the adjustment process from the old economic equilibrium to some new equilibrium is likely to be a lengthy one. Plainly said, it makes more sense for grain handlers to continue to use existing elevators, dedicating some entirely to non-GM grain to attain segregation and identity preservation and having farmers on average drive a little further with their grain, than to build many new elevators or add additional grain-flow paths to existing elevators. This is the same plan that has been used for several years now to segregate and preserve the identities of specialty crops like high-oil corn.

But without a radical overhaul, can the U.S. grain handling system, with its current storage and transportation facilities, maintain segregation and identity preservation of non-GM grains to the degree necessary to satisfy the current EU required non-GMO purity level of 99%? Recent observations suggest that the answer to this question is yes. The increased handling of specialty grains has led to changes in U.S. grain handling infrastructure, but these changes have been relatively small. Exporters have been sending specialty soybeans to Japan for years, and for a premium²¹ have been willing and able to maintain segregation and preserve identity. For specialty corn, even with the difficulties brought on by cross-pollination, the grain handling infrastructure has indeed been able to meet high levels of purity, without taking radical measures such as organizing and enforcing “isolation zones” among large numbers of farmers of high-oil corn. A representative of Consolidated Grain and Barge company has stated that his company’s identity preservation program for high-oil corn regularly exports it at 99.2% to 99.3% levels of purity. Soybean purity numbers are even more impressive; that same representative has stated that his company exports STS (non-GM) soybeans to Japan at the 99.97% level of purity (Haas, 2000).

In any sort of near term, we should not expect to see an overhaul of the grain handling infrastructure, but rather a reshuffling of it. Rather than incur the expense of frequently cleaning out dump pits, boots, legs, conveyor belts, and storage bins, grain handlers are instead dedicating already-separated grain handling paths to either GMOs or non-GMOs. Some elevators that are equipped with two separate paths for moving and storing grain have dedicated one path to GM grain, and the other to non-GM grain. Some companies that own several elevators in close proximity to each other are dedicating some elevators to only receive non-GM grain, and other elevators to receive GM grain. These changes imply that farmers might have to transport their grain a few more miles to find an elevator that receives the particular type of grain the farmer is selling. This reshuffling of elevator uses does have a cost to the farmer and the system. But evidently this cost is much lower than would be the cost of building a whole new infrastructure.

²¹ The size of the premium on specialty soybeans depends on just how “special” the beans are. For certified organic soybeans for tofu, U.S. grain handlers can receive premiums of up to 100% of the standard soybean price (McKinstry, 2000).

V. Some numbers: changes in costs and prices for farmers, handlers, and processors

1. Identifying premiums and cost changes

And how great have non-GMO premiums had to be to bring about this segregation and identity preservation—the cleaning of farm equipment, the testing, and the reshuffling of the grain handling system that has already begun? Figure 1 illustrates some of the currently observable quantitative aspects of segregation and identity preservation of non-GM grains. First, we know that exporters are receiving about \$8.00/mt (roughly \$0.22/bushel) from foreign processors for non-GM soybeans. This \$0.22/bu is the premium that was received by Brazilian exporters of non-GM soybeans to Europe and Japan last year (1999), and it is the number which U.S. exporters are striving to attain in order to compete with the Brazilians this year (Haas, 2000).

Next, we know that many U.S. grain handlers are currently paying U.S. farmers premiums for non-GM soybeans. The size of the premium 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. Given the variety and the contract status, those 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 of a demand preference for non-GM soybeans (Haas, 2000). 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 segregation and identity preservation, tend to receive higher premiums than farmers who just “show up” at the elevator with a delivery of non-GM soybeans. Producers of soybeans specifically suited for foreign markets²² tend to receive higher premiums for delivering non-GM soybeans than do producers of soybeans less suited for foreign markets.

Elevators are currently paying farmers for non-GM soybeans delivered with no-prearranged contract about \$0.10/bu near the Illinois River (Haas, 2000).²³ This \$0.10/bu must cover not only the costs of segregation and identity preservation, but also any increased production costs a farmer bears when growing non-GM soybeans instead of GM soybeans, such as costs of cleaning the planter and combine, and the cost of driving further with the grain to the elevator.²⁴ Any difference between the \$0.10/bu premium and the aforementioned costs on the farm are profits to the farmer. What these numbers and figure 1 imply are that, at least for some farmers, it must cost much less than \$0.10/bu to segregate and preserve the identities of non-GM soybeans. U.S. farmers growing non-GM/non-STS soybeans under contract are currently receiving a premium from handlers of approximately \$0.10/bu to \$0.30/bu. (DuPont Specialty Grains, 2000a, 2000b, 2000c, 2000d).

Taking as bases the \$0.22/bu premium received for non-GM/non-STS soybeans by U.S. exporters and the \$0.10/bu premium Central Illinois farmers receive for non-contract soybeans at a river elevator implies that, even with the reshuffling of their grain handling facilities, currently it must not be costing more than $\$0.22 - \$0.10 = \$0.12$ per bushel for handlers and exporters combined to segregate and preserve the identities of non-GM soybeans.²⁵ These numbers are illustrated in figure 1. Testing costs at handling stages are approximately \$0.025 per bushel (Table 2). This suggests that less than \$0.10 per bushel are left to compensate handlers for the reshuffling, and that therefore the inefficiencies in the

²² An example is provided by Indiana-Michigan-Ohio soybeans preferred by Japanese tofu manufacturers.

²³ Central Illinois elevators further away from a river were paying farmers non-contracted non-GM soybeans a premium of \$0.08/bu for soybeans destined for domestic processors in May 2000 (Billman, 2000).

²⁴ Production cost savings from using glyphosate-resistant soybean technology instead of conventional technology can vary widely by farm, depending on the farm's weed situation. Savings as high as \$0.50/bu (\$20.00/acre) are certainly possible (Nelson et al., 2000). Of course, no farmer saving \$0.50/bu by using glyphosate-resistant system would accept a \$0.10/bu premium to grow non-GM soybeans. Only farmers whose weed situations provide them much lower savings from a glyphosate-resistant system are likely to find a \$0.10/bu premium a sufficient economic incentive to grow, segregate, and identity preserve non-GM soybeans.

²⁵ Lin et al. (2000) estimated that current segregation costs could be equal to \$0.54/bu for some handlers currently exporting non-GM soybeans. Current premium levels contracted between farmers and elevators for non-GM soybeans (generally between \$0.15 and \$0.20 per bushel) suggest that \$0.54/bu is an extensive overestimate of segregation and identity preservation costs. It is unlikely that farmers would sign a contract to receive \$0.20/bu for activities that cost them \$0.54/bu to carry out.

system from grain handlers now having less flexibility in meeting market demand, are not costing more than about \$0.10 per bushel.

The facts outlined above and illustrated in figure 1 suggest an interesting conclusion: the major cost in segregation and identity preservation of non-GM soybeans comes not from testing, nor from the need to have farmers clean out their equipment, nor even from the need for grain handlers to clean out their equipment. It seems that the major cost of non-GM segregation and identity preservation may come from less flexibility in grain handling. The fact is that with an infrastructure designed to store and move roughly half the number of varieties of corn and soybeans that exist now that GMO technology is here, grain handlers are less flexible in how they distribute grain around the world to meet market demand.

2. Changes in market prices

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 first important to separate out conceptually the effects of three related phenomena. First, the introduction of GMO technology reduces farm costs of production, which in itself tends to lower grain prices as the lower costs are passed through different stages of the vertically linked grain sector.²⁶ Second, in the absence of segregation and identity preservation, news and information about possible health and other risks of GMOs lowers the demand for both GMOs and non-GMOs, since consumers have no way of distinguishing between them, and so perceive possible risk in each.²⁷ Third, once GMO technology has been introduced and consumers grow to perceive risk from GMOs, segregation and identity preservation then 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 create inefficiencies that 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 paper on the on-farm costs of segregation and identity preservation, and on the costs of GMOs are meant to be a beginning for such research.

²⁶ Introduction of a cost-saving technology is usually portrayed in economic models as a downward shift in the supply curve of the basic industry (here farming). This downward shift in supply lowers the equilibrium price.

²⁷ Perception of increased risks from a product can be modeled as a downward shift in demand, which further lowers prices in every stage of the vertically linked grain industry.

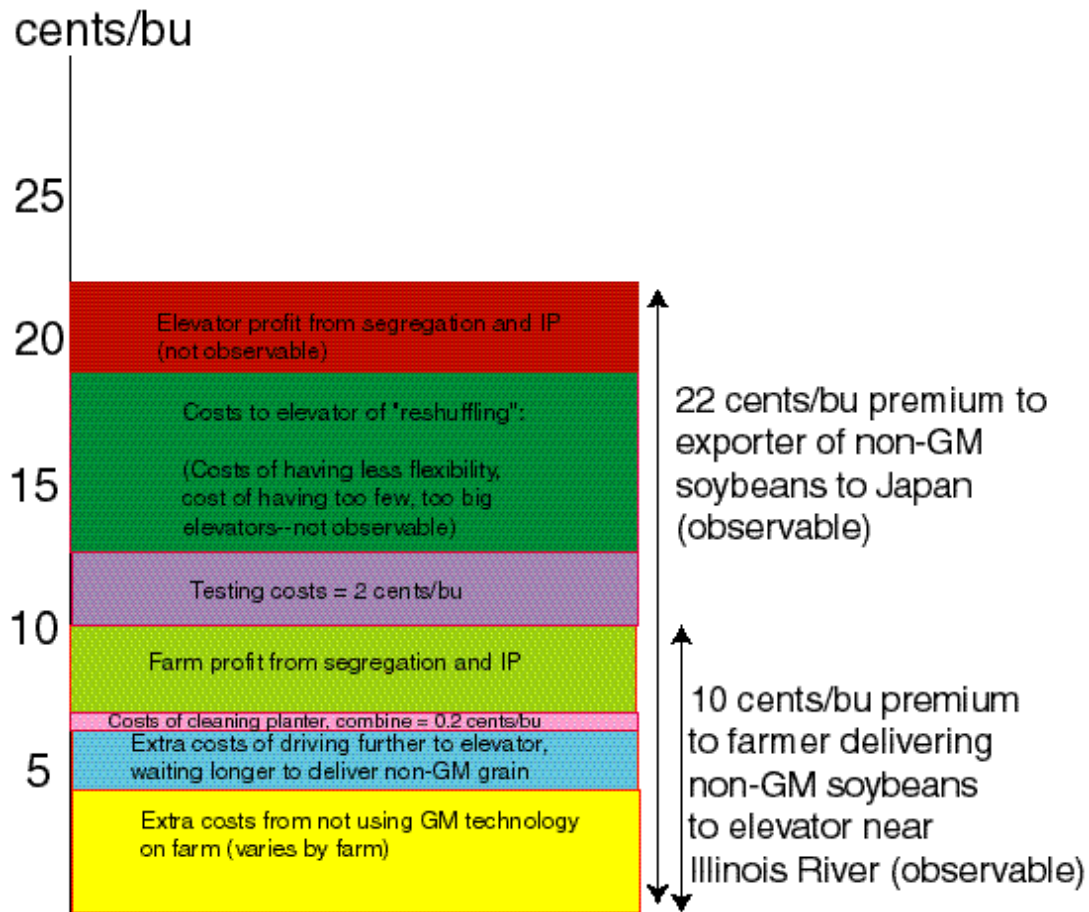


Figure 1. Premiums for selling and costs of producing non-GM soybeans.

V. Conclusions

The major costs of non-GMO segregation and identity preservation will depend crucially on the tolerance levels that governments set with their laws or consumers set with their preferences. Currently, it seems that a major cost in non-GMO segregation and identity preservation does not come from cleaning machinery or testing, but rather from the “reshuffling” of the grain handling system. This cost of reshuffling invites change in the infrastructure of grain handling. But because of the large fixed costs of building grain handling facilities, the adjustment to a new economic equilibrium in which there are more and smaller handling facilities located in the economically efficient places is likely to be a very lengthy one. It seems most likely that in anything but the very long run, a higher level of segregation and identity preservation will be managed at a lower cost within the current grain handling infrastructure, rather than by building a whole new infrastructure and trashing the existing one. The effect of labeling, segregation, and identity preservation on grain prices at various stages of the grain production and handling industry is theoretically ambiguous. In this paper 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.

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