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Costs and Risks of Testing and Segregating GM Wheat

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ABSTRACT

Development of genetically modified crops is challenging the functions of the grain marketing system with many participants arguing for Identity Preservation systems prior to release of GM varieties. In this study, a stochastic optimization model was developed to determine optimal testing strategies. The model chooses the optimal testing strategy that maximizes utility (minimizes disutility) of additional system costs due to testing and rejection and allows estimation of the risk premium required for sellers to undertake a dual marketing system with GM/Non-GM segregations over the current Non-GM system. Elements of costs (testing costs, rejection costs, and risk premium) were estimated for a base model representing a grain export chain. The model includes elements of costs and risks for uncertainties within the marketing chain including risk of adventitious commingling at all stages of the marketing chain, grower truth-telling, variety declaration, and accuracy of testing technologies. Sensitivities were evaluated for effects of GM adoption, risk parameters, variety declaration, tolerance levels, and for a domestic market case.

Key Words: Genetically modified organisms, biotechnology, wheat, risk, segregation, identity preservation

HIGHLIGHTS

Development and commercialization of genetically modified (GM) crops has challenged the functions and operations of the grain marketing system. While these have already been confronted and (partially) resolved in other grains and oilseeds, none of these issues have been resolved regarding the anticipated commercialization of GM wheats. While the focus of the GM debate currently in North America is on the *Round-up Ready*® wheat (RRW) trait, there is extensive research suggesting that other traits will be similarly proposed in the coming years. The purpose of this paper is to determine the optimal testing strategy and to quantify the costs and risks of the system.

Virtually all of the major stakeholder groups have taken positions essentially pointing to the desirability of GM wheats, conditional upon developing a system involving Identity Preservation (IP) and testing to satisfy needs of buyers. In addition, in this case the technology developer has indicated not commercializing the trait until such a system is adopted. Beyond these positions, the asynchronous regulations and indigenous differentiated demands resulting in buyer resistance suggest that some type of dual marketing system will need to evolve to facilitate coexistence. Ultimately, this will likely be a system in which buyers specify limits or a tolerance on GM content measured using some type of prescribed test. Then, testing would be adopted at varying points in the marketing system to facilitate segregation and assure contract conformance. Given that testing and segregation entail costs and risks, there is a fundamental tradeoff confronting shippers and buyers. In light of this, there are important operational questions such as the optimal location to test, how intensive to test, sample size represented, the test type, and how numerous factors impact these strategies.

A stochastic optimization model was developed for the export and domestic marketing system. All the elements of the system, including costs and risks, were included in the model. Of particular importance were the costs and risks at each node of the system, as well as the risk imputed upon the shipper. Specifically, we had a focus on the risk premium necessary to induce a shipper to handle Non-GM wheat and to be exposed to the risks and penalties of being out of contract.

The model was posed as the utility for a portfolio representing additional testing and rejection costs of a combined Non-GM/GM system. The results indicated the optimal testing strategies for supplying export and domestic markets and provided an estimate of the risk premium required for decision makers to be indifferent to the Non-GM/GM system and a Non-GM system. A model was developed for the export market and sensitivities conducted to evaluate impacts of risk attitudes, variety declaration, levels of rejection costs, GM adoption rates, grower truth-telling, and tolerances. A second model was developed for the domestic market to evaluate differences between optimal testing strategies and costs for export and domestic markets. Sensitivities of all the critical variables were conducted.

The base case was defined to represent a likely set of situations. Important amongst these were: GM adoption by growers in a region was 20 percent; growers declared GM content at delivery, subject to some uncertainty; and testing was allowed at varying intensities and locations throughout the system. Alternative testing technologies were also included, as well as penalties for being out of contract.

Results indicated the optimal testing strategy was to test every 5th unit (load) at the country elevator when loading and every unit loading at the export elevator. This results in additional costs of testing and rejection for Non-GM bushels of 1.99 cents/bu. Adding the risk premium increased total costs per Non-GM bushel to 3.36 cents/bu. The risk premium in this case was 0.96 cents/bu which is interpreted as the implicit cost accrued by the shipper to be indifferent between a handling system involving Non-GM and GM wheat, versus the current Non-GM system. The testing strategy would result in minimal GM content at the import market, and only 1.75 percent of the shipments would be rejected.

Several factors were examined using sensitivity analysis. Dropping variety declaration at the country elevator increased the intensity of the optimal testing plan, increased costs and premiums, and resulted in a higher proportion of Non-GM flows being diverted to GM within the marketing chain. Increasing the risk aversion of the decision maker increased the risk premium required, but resulted in the same optimal testing strategy. Decreasing the cost of rejection at the importer reduced the intensity of testing, increased rejection rates at the importer, and lowered costs and the risk premium. Additional costs at interior loading points representing additional handling charges increased the intensity of testing, test costs, and the risk premium, while lowering the proportion of flows diverted from Non-GM to GM within the system.

Changes in prospective tolerance levels of tests for adventitious commingling indicated changes in optimal testing strategies as tolerances tightened. More testing was required and tests were shifted from the country elevator when loading to the export elevator when receiving as tolerances were tightened from 1 percent to 0.5 percent. Costs, premiums, rejection rates, and the proportion of flows diverted to GM within the system increased as tolerance levels were lowered. Total costs including the risk premium increased from 1.45 cents/bu with a 5 percent tolerance to 4.25 cents/bu with a 0.5 percent tolerance. While the results for tolerance are illustrative, more research on effects of tolerance tightening on adventitious commingling and rejection rates and their effects would be useful.

The optimal testing strategy for the domestic market had higher rejection rates, costs, and risk premiums than did the export market. Most costs per all bushels, or per Non-GM bushels and risk premiums were about double those for the export market. These were higher for the domestic market largely due to increased testing costs arising from smaller lot sizes for domestic users (railcars) versus importers (ship holds).

There are several implications from these results. First, a system based on testing and segregation can very efficiently assure buyers of GM content at a low cost. While nil tolerance cannot be achieved through a system based strictly on testing, the GM content can reasonably be assured at levels of .5 percent and 1 percent. Second, the cost of a system based on optimal testing and segregation inclusive of a risk premium is much less than most systems that have been proposed on IP and other means to control GM content. Third, there are many factors that will impact the optimal testing system, costs, and risks. Most important amongst these include price discounts/costs for being out of contract, GM declaration at delivery, and others.

Fourth, strict interpretation of the risk premium would indicate that this is the premium required for grain handlers to be indifferent between a dual system of Non-GM and GM or the current Non-GM system. In order for Non-GM to gain a premium, sellers will have to provide proof that it is in fact Non-GM. Buyers must be willing to pay this increased cost and, eventually through competition, price differentials will emerge to approximately reflect these costs. Fifth, an IP system to resolve marketing of GM would be much more elaborate in terms of monitoring, administration, etc., than a system involving tolerances and testing and, as a result, would be much more costly.

Finally, these results are suggestive of some mitigation strategies that could be adopted in the wheat marketing system. Ultimately, these would facilitate conditioning of probabilities which are assumed in this study and would involve contract type mechanisms necessary to control the costs and risks in the system. The most crucial elements of the system would be declaration of GM content at delivery, testing for GM throughout the Non-GM system, buyers aversion to GM, contract specifications for some tolerance level, and the test(s) adopted.

Costs and Risks of Testing and Segregating GM Wheat [1]

William W. Wilson and Bruce L. Dahl [2]

Introduction

Development and commercialization of genetically modified (GM) crops has challenged the functions and operations of the grain marketing system. The adoption of GM corn and soybeans in the United States has resulted in numerous interventions to ease the transition to marketing of these crops. The path taken in the case of GM wheats is more elongated for numerous reasons.[3] In contrast to the other grains and oilseeds, commercialization of GM wheats is evolving concurrent with a fairly extended process of public scrutiny and commercial concerns. One of the more important concerns is that of testing and segregation. Given there will no doubt be market segments adverse to GM content in wheat shipments, adoption, and efficient marketing of GM wheat will require protocols for contractual limits, testing, and segregation.

Implicit in these insinuations are that some buyers, for varying reasons including regulations and product marketing, may choose or have no recourse but to limit the content of GM wheat in Non-GM wheat purchases. Presumably, these buyers would do so by specifying in their purchase contracts some limit on GM content and/or more precise prescriptions regarding production/marketing/handling processes. This is what has evolved in the commercialization of other GM crops. At least initially, or indefinitely, one could envision a marketplace of buyers with differentiated demands for their aversion to GM content. Hence, it is critical to have a prescribed system that conforms to these requirements.

Within the micro-structure and economics of the grain marketing system, some of the important concerns with respect to GM crops marketing center on added costs and risks. Additional testing involves added costs of conducting the tests, of which there are several technologies and varying accuracies. The risk is that of GM wheat varieties being commingled and detected in customers' shipments who place limits on GM content. This is indeed an economic problem as agents seek to determine the optimal strategy for testing and other risk mitigation strategies.

The purpose of this paper is to determine the optimal testing strategy and to quantify the costs and risks to market participants. We analyze factors impacting these costs and risks and assess the distribution of costs amongst participants. In addition to testing costs, other costs

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[1] This project has benefitted from seminars and presentations to the following groups and organizations: North Dakota Wheat Commission, National Association of Wheat Growers, Monsanto Grain Handling Committee, North Dakota Legislative Council, and USDA Economic Research Service.

[2] Professor and Research Scientist, respectively, in the Department of Agribusiness and Applied Economics, North Dakota State University, Fargo.

[3] We use the term GM wheat throughout this paper to be general and recognize that there are several traits prospectively anticipating being adopted. At the forefront of course is *Round-Up Ready*® wheat (RRW), but others including fusarium resistant (Syngenta), drought resistant (DuPont), and varying forms of end-use trait enhancement are being developed. From an analytical perspective, these are all "single-traits" and the testing methodology is that of "single-trait" tests, in contrast to "stacked" traits which would require more costly tests.

include the cost of selling in a discounted market if rejected, and the seller's risk premium for handling GM grain. We capture all of these in our model. The model is a cost function, inclusive of these costs, and is solved using stochastic optimization to determine the optimal location, frequency, and technology for testing.

The primary focus is on testing and tolerance strategies confronting the U.S. marketing system, producers, processors, and foreign processors. The contribution of this research is that it provides a quantitative model that can be used to assess costs and risk of alternative strategies for marketing GM crops. The distribution of costs and risks in the case of GM wheat have come to be an important prerequisite to further commercialization of this trait. Most important, we provide estimates of the risk premium necessary for suppliers to expose themselves to tolerances associated with Non-GM shipments. Though the problem is focused on wheat, the methodologies would be applicable to other crops, characteristics (e.g., vomitoxin), and production processes.

Background

This section provides a background description to the problem and some detail to its various elements.

Experiences of GM Grains/Oilseeds

U.S. agriculture now has several years of experience in the development, adoption, and commercialization of GM grains and oilseeds. For corn, soybean, and other specialty oilseeds (e.g., Canola), GM varieties are an integral part of the current production and marketing systems. Through this process, several experiences have evolved in marketing, which have reinforced the importance of this project. These include:

- Information requirements have become much more intensive. Whereas, prior to adoption of GM varieties, it was common simply to produce and sell on grade and non-grade factors, buyers (domestic or international) are now requiring varying types of information regarding varieties, whether they are GM or not, and other agronomic information on production practices ("process verification" is sometimes used to describe the informational flows associated with these systems).

- Varying types of systems have emerged. In some cases, these rely on Identity Preservation (IP) types of systems, others use channeling, ISO9000 procedures, and more recently, what is referred to as traceability. Adoption of these systems varies regionally and through time as other issues emerge.

- Testing (locations, frequency, and methods) within these systems are evolving as well. In some cases, testing complements the other systems noted above.

Despite the system adoption, risks have become important in marketing GM grains and GM oilseeds. There are two important risks. For a buyer, there is the risk of receiving a shipment that exceeds tolerances and should be rejected. For the seller, it is having a lot rejected that should be accepted because it is within tolerances. These are complicated by adventitious commingling that can occur at all locations within the marketing system.

GM Wheats

Development of GM wheats has lagged other grains and oilseeds for varying reasons. Most important is likely the more complex genetics. Other contributing factors include: 1) wheat is a smaller volume crop within North America; 2) exports are of greater relative importance; 3) import country regulations vary much more for wheat and are less well-defined; and 4) competition amongst exporting countries is likely more intense and compounded by radically different marketing systems regarding quality and trade practices, etc.

These points notwithstanding, there are several initiatives for the development of GM wheats. In North America these have been primarily on the *Round-up Ready*® wheat trait, though there is extensive research elsewhere on a wide range of GM traits in wheat (e.g., fusarium resistance by Syngenta, drought resistence by DuPont, among others). Virtually all development in North America is currently on Hard Red Spring (HRS) wheats. Experimental trials are being planted in South Dakota, North Dakota, Minnesota (and no doubt elsewhere), as well as in selected Canadian prairie provinces.

If approved in the United States and/or Canada, there would be no limits on the adoption of these traits, except for the extent that individual companies may impose a limit or tolerance. If the traits are approved in Japan, wheats can be imported, but subject to labeling laws. Since this trait is not (yet) approved in the EU, it would imply a nil tolerance. The EU proposed a policy (July 27, 2001) that is currently under debate, which would allow for a 1 percent tolerance along with some form of yet to be specified system of traceability, and subject to labeling requirements. More recently, a proposal was made for a 0.5 percent tolerance. Developments in these countries are pending and will impact the evolution. Nevertheless, if the trait is approved, these mechanisms will need refining to facilitate and allow trade, albeit subject to a tolerance.

Round-up Ready® wheat (RRW) is an example of 1st stage benefits. Other 1st generation benefits should be commercially available by 2005 (Bloomer). However, 2nd and 3rd generation effects will not be accessible until 2006 and beyond. In the case of wheat, 2nd generation effects would likely include enhanced protein quality, novel starch types (functionality), enhanced nutritional content, reduced allergens, and improved freshness and shelf-life for baked products. These observations were echoed by Biane indicating that consumer benefits in the case of wheat include extending shelf life, improved nutrition, and reduced allergens. The pressures for adopting GM wheat, specifically RRW, come from a combination of cost reduction, reduced dockage, increased profitability of competing crops (being recipients of GM technology), and the prospect of 2nd and 3rd phase benefits associated with GM wheats.

Finally, there is another important and impending problem in the case of GM wheats. The targeted areas for GM wheat development are the same as those regions in which there is a fairly large concentration of organic grain production (Brummond). In fact, North Dakota is the state with the largest acres devoted to organic production, a sector which is growing fairly quickly. Marketing practices in this sector have evolved to use a term called zero-tolerance.

This is despite that USDA standards are on production practices.[4] Hence, as/if GM grains are developed, the issue of tolerances and testing in this sector will undoubtedly escalate.

Positions Taken by Major Industry and Interest Groups. An important element of commercialization of GM wheat is that virtually all of the important stakeholder groups have positions. These include that of the National Association of Wheat Growers and U.S. Wheat Associates (and now complemented by the position of the Farm Bureau), the North Dakota Grain Growers Association (NDGGA), the American Bakers Association, the Canadian Wheat Board, and the Australian Wheat Board, amongst others. In virtually all cases the position reflects that biotech wheats are desirable, mostly looking to 2nd stage benefits; research on biotechnology wheat should continue; but, GM wheats (particularly RRW) should not be commercialized until systems involving IP and testing are developed to satisfy needs of buyers.[5,6,7] In the past year, several major wheat marketing organizations have taken positions that are important to the evolution of GM wheat marketing. Monsanto has indicated they would not release RRW until/unless approval of the trait occurs in the United States, Canada, and Japan and a viable testing and segregation system is developed.

The *U.S. Wheat Associates/National Association of Wheat Growers* position is that they will “work with all segments of the industry to develop and ensure that a viable IP system and testing program is in tact prior to commercialization of biotechnology products.” In addition, they “support an establishment of a reasonable threshold tolerance for adventitious commingling of biotech traits in bulk wheat or products derived from bulk wheat in both U.S. and international markets.”

The *National Grain and Feed Association* also encourages biotechnology crop development. They would want that (among others): 1) as part of the registration process, the protocols for segregation, testing, and IP, etc., be provided to entrust segregation; 2) that analytical tests be defined and approved by USDA for purposes of determining the presence of GM content; and 3) the U.S. government should work toward commercially achievable thresholds for adventitious presence of GM grains in Non-GM grain shipments.

The *American Bakers Association* believes “all biotech crops and ingredients must be accompanied by an efficient, inexpensive trait identification system with accuracy of detection to meet USDA/FDA/EPA, and foreign customers labeling or purity requirements.” The ABA will “work with all segments of the grain and cereal foods processing industry to develop and assure

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[4] There are USDA standards for organic production. However, these do not refer to any tolerance, but instead simply refer to excluded practices. Labeling restrictions apply tolerances based on how the product is sold.

[5] The CWB refined their position as “The preconditions for introducing a GM variety include a credible segregation system, effective testing and sampling methods, and reasonable tolerance levels for GM content” (Wilson).

[6] The position taken by the NDGGA does not make this specification.

[7] Robert Carlson, President of the North Dakota Farmers Union, indicated that prior to commercialization of GM wheat, North Dakota needs to "perfect crop and marketing segregation issues, evaluate market acceptance of GM wheat, and establish standards for liability concerns."

that a viable segregation and testing program is instituted prior to commercialization of biotech products."

The *North American Grain Millers Association* suggests that technology providers and regulators place close consideration to: 1) thresholds–reasonable thresholds must be adopted to allow the movement of grains with adventitious admixture; 2) testing; and 3) identity preservation which they question as being the solution to marketing of biotech-based grains.

The USDA/GIPSA plays a prospectively important role in this evolution. To be responsive, in November 2000, they invited comments related to alternatives for marketing of grains given a market that houses biotech and non-biotech products. That agency is in the process of determining how to facilitate the evolution and commercialization of biotech grains. More recently, the GIPSA proposed a system of *process certification* which could be used to ameliorate some of the problems associated with marketing of GM grains (USDA-GIPSA).

In addition to these, positions have been taken in the primary competitor countries. Noteworthy amongst these include that of the *Canadian Wheat Board* (CWB). Their objective is to ensure that the introduction of GM wheat and barley varieties for production, handling, and marketing will be accomplished in a manner that will satisfy customer requirements and result in net beneficial benefits to western Canadian farmers. However, the CWB believes that GM wheat shouldn't be made available until proven technologies, and associated protocols and procedures are intact to avoid commingling of transgenic and non-transgenic varieties. The CWB believes the segregation system should have the ability to test accurately, quickly, and economically for transgenic presence.

It does not appear the Australian Wheat Board has a formal policy on this issue. However, various organizations in that country are studying the problem (ABARE; Foster). They note that the additional marketing costs of keeping GM grain separate during production and distribution is not inconsequential,[8] even in that country which has extensive controls.[9, 10]

In all cases, there is an insinuation that development of a GM wheat is good and should be pursued. However, it is very clear that GM wheats should not be commercialized, in whatever fashion, until some type of IP and testing system is developed to mitigate risks to buyers.

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[8] For perspective, the results presented in Foster assumed that segregation and testing costs were 10% of the FOB value. This would translate to about $15/mt.

[9] As examples of how private companies are dealing with these issues, in Australia, both Unilever and Goodman Fielder (amongst others) are screening ingredients to ensure they are GM-free, in preparation for the introduction of new national labeling regulations. These require all foods containing more than 1% of GM to be labeled. Consequently, the grains industry is rushing to develop identity preservation (IP) systems to segregate conventional crops from GM varieties to ensure they meet processors' demands (Champness).

[10] The government of Australia currently has a major study ($3.65 million over four years) to assess costs of segregating products. Since then, Australia enacted labeling laws that became effective on December 7, 2001.

The asynchronous regulations, along with selected buyer resistance and indigenous differentiated demands, ultimately suggest that a dual marketing system (or a marketing system to facilitate coexistence) is inevitable. This is likely true in the domestic market even though labeling would be voluntary with different approaches likely adopted by buyers for branded versus non-branded (e.g., private label, food service, etc.) products. This would also occur internationally between countries with and without tolerance limits, and/or other requirements for the traits, and those with approved traits.

The problem in wheat is further compounded due to the fact that most of the effort is focused, at least initially, on HRS wheat which is the primary wheat class grown in northern tier states and Canada. Thus, Canada's position and adoption will have a critical impact of the post-adoption competition. Most important is that the mechanisms to facilitate adoption of GM wheats in Canada are far different than those in the United States (e.g., variety approval process, variety kernel distinguishability, contract calls, the ability to add/create subclasses of wheat with specific characteristics).[11] In a recent comprehensive quantitative analysis of the problem, it was concluded that RRW wheat should not be released in Canada until customers accept the technology and/or unless the cost of IP is less than $C0.01/bu for all growers, or $C0.08/bu for growers adopting the trait (Furtan, Gray, and Holzman).

Finally, inevitably, tolerances will need to be defined and/or those proposed will be needing refinement. There are two forms in which tolerances are applied. One would be those defined by regulatory agencies (e.g., the FDA, and like agencies in other countries). Second, would be as commercial tolerances.[12] Most important in establishing these tolerances are that costs increase as tolerances are tightened, and that risks are mitigated by the use of tolerances. Risks are defined as buyers receiving a product that should be rejected and sellers having a product rejected that should have been accepted. There is a fundamental tradeoff between risks and costs. Tighter tolerances result in increased costs and decreased risks.

Previous Studies on Market Mechanisms, Testing, and Tolerances

The alternatives should be viewed as being on the spectrum of procurement alternatives (Figure 1). Ultimately, it is buyers that determine the approach to their procurement strategy. These can range from spot transactions simply on grade and non-grade factors, to full integration into grain production and/or handling. Intermediate solutions contain varying forms of testing, contracting, and IP.

<u>Identity Preservation and Segregation</u>: Definitions of what constitutes an IP system vary. Dye defined it as a "traceable chain of custody that begins with the farmer's choice of seed and continues through the shipping and handling system." Wilcke refers to IP as separate storage, handling, and documentation of separation; Sonka, Schroeder, and Cunningham define it as a

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[11] All of these would suggest that it would likely be lower cost to adopt mechanisms to control for GM grains in Canada than in the United States.

[12] The experience of vomitoxin in wheat and barley is analogous. Vomitoxin is regulated by the FDA with limits placed on its presence in the semi-processed crops (e.g., flour, malt). However, individual firms can and do adopt different tolerances, subject to the FDA regulations. Similarly, some importing countries adopted tighter tolerances than others and, in fact, tolerances may vary across firms within a single importing country.

coordinated transportation and identification system to transfer product and information that makes product more valuable; and Buckwell et al. and Lin et al. refer to it as a 'closed loop' channel that facilitates the production and delivery of an assured quality by allowing traceability of a commodity from the germ plasm or breeding stock to the processed product on a retail shelf. Finally, the Japanese importers, in communicating to their suppliers, defined Identity Preserved handling as a "management method in which segregation between genetically modified agricultural products and non-GM agricultural products is accomplished, under the care of a good manager at each stage of production, distribution and processing. Further, it must be verified by using documents clearly indicating that segregation has been made" (Bean).

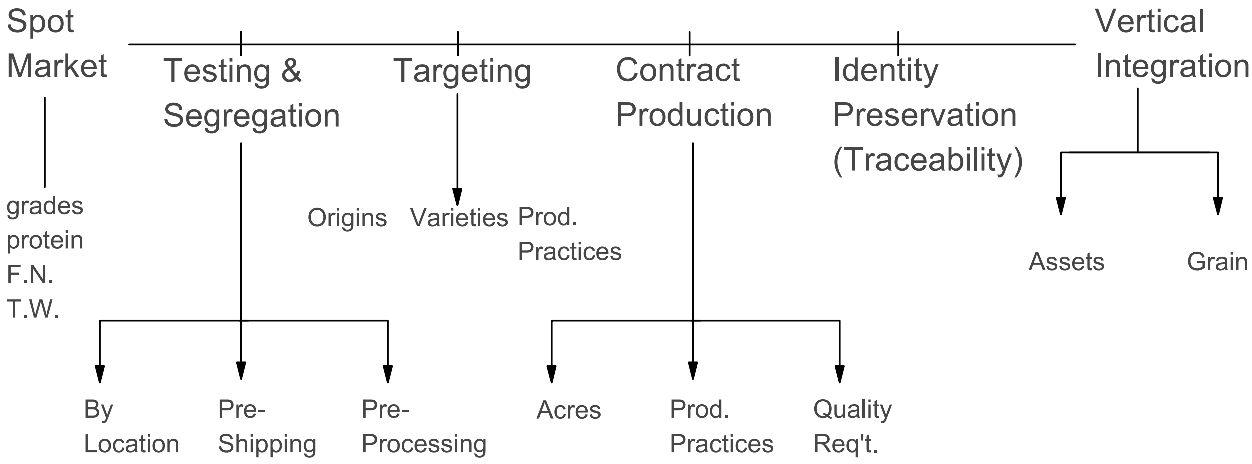

Figure 1. Spectrum of Procurement Strategies.

Several firms have initiated IP programs where sales/segregation are by specific variety/location. The Minnesota Crop Improvement Association (MCIA) operates IP programs for 99.5 percent Non-GMO soybean grain and seed, 99.0 percent Non-GMO corn grain and seed, and an IP grain handler's facility program. The Canadian Soybean Export Association initiated a standard that outlines IP procedures for food grade soybean exports (Strayer). Other examples of IP systems include: CWB-Warburtons, Pro-Mar Select Wheat of Idaho, AWWPA, etc.[13]

Several studies have examined IP/segregation costs for a range of commodities using different methodologies including surveys of elevator managers (Nelson et al.; Jirk; Dahl and Wilson; Wilson and Dahl), cost accounting methods (Askin; McPhee and Bourget; Lentz and Akridge; Dahl and Wilson; Wheeler; Kennet et al.; Hurburgh; Bullock et al.; Shoemaker et al.; Sparks Company; Smyth and Philips), and simulation (Hermann et al.; Maltsbarger and Kalaitzandonakes; Schlect). Costs of segregating IP grains from these studies range from 1 to 72 cents/bu. These are summarized in Table 1. The economics of additional wheat segregations have been studied in the Canadian grain handling system using a number of different methodologies and over different time periods. The most recent of these was undertaken by Agriculture and Agri-Food Canada and summarizes much of the previous work in this area

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[13] A recent study by Janzen and Wilson summarized the activities of numerous of these organizations operating in the U.S. grain marketing system.

(Wheeler). Notable amongst these is that some are estimates in anticipation of what the process would be, some are a result of budget types of analysis of costs, some entail process verification and pure segregations throughout the system, but none quantify risks or the exposure to risk of the agents.

Table 1. Previous Studies on IP and Segregation Costs

Researcher	Methodology/Scope of Analysis	Estimated Cost of Segregation/IP
Askin, 1988	Econometric model of costs for primary elevators	Increase of 2 grades handled increased costs < .5 c/bu
Jirik, 1994	Survey of Elevator Managers and Processors	11 to 15 c/bu
Hurburgh et al., 1994	Cost Accounting Model for High Oil Soybeans	3.7 c/bu
McPhee and Bourget, 1995	Econometric model of costs for terminal elevators	Increasing grades handled increases operating costs 2.6%
Hermann et al., 1999	Stochastic Simulation Model	1.9 to 6.5 c/bu
Maltsbarger & Kalaitzandonakes, 2000	Simulation Model for High Oil Corn	1.6 to 3.7 c/bu
Nelson et al., 1999	Survey of Grain Handlers	6 c/bu corn, 18 c/bu soybeans
Bullock, 2000	Cost Accounting	30 to 40 c/bu soybeans
Dahl and Wilson, 2002	Survey	25 to 50 c/bu
Wilson and Dahl, 2001	Survey of Elevator Managers for Wheat	15 c/bu
USDA-ERS (Lin et al., 2000)	Cost accounting adjustments to survey results for specialty grain handlers	22 c/bu corn, 54 c/bu soybeans
Smyth and Philips, 2001	Analysis of GM IP system for canola in Canada, 1995-96	21-27 c/bu
Gosnell, 2001	Added transportation and segregation costs for dedicated GM elevators	15-42 c/bu High throughput 23-28 c/bu Wooden elevators
Sparks Companies, 2000		Non-GM Canola 38-45 c/bu Non-GM Soybeans 63-72 c/bu

Finally, most of the work on segregations has focused specifically on GMOs. Bullock et al. examined costs of GMO/Non-GMO segregation from seed to market in the United States. The Directorate General for Agriculture, Commission of the European Community, summarized much of the literature to date on costs of segregation, many of which focused on costs within the United States but also included studies from France and Brazil. However, these methods may not resolve problems in GM grain marketing. Specifically, while IP systems may provide process verification and retain segregations, typically, they would be incapable of assuring end-users that tolerances for adventitious materials are met unless, as part of the system, testing protocols were specified. This is a major theme of this research and was highlighted recently in a speech by Mr. Krejci, Executive vice-president of the Grain Elevator Processing Society (*Milling and Baking News*). He indicated that ". . . for GMO's, grain handlers are being asked to assure that end-users are not getting something . . . and IP as it has evolved doesn't function well to exclude something."

Economics of Testing and Tolerances: One of the major areas identified in a recent workshop on *Coexistence of GM, Non-GM and Organic grains* was that of tolerances.[14] Issues related to inconsistency in the value of tolerances, interpretation, and frequency of nil-tolerance were addressed. It is important that establishment of these tolerances frequently ignore risks, costs, and buyer implications associated with violations. The resolution was that there should be future joint efforts to "discover" the appropriate methods for tolerances distinguishing amongst not only GM content, but also organic.[15]

There have been few economic studies on this topic in the case of grains. One exception is that of Hurburgh et al. They developed economic engineering cost functions for testing and segregation costs and applied them in the case of corn.

IP and traceability typically may not contain testing protocols and tolerances. Instead, in these regimes informational flows are critical. Unless tests are an integral component of the system, the risks of not conforming to desired limits would persist. Interestingly, if a testing system were included, and contracts used appropriately, then IP and traceability systems would be unnecessary. In summary, for these reasons, pure IP types of systems without specification and testing would likely not be sustainable in credibly resolving the GM wheat problem.

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[14] The workshop titled *Strategies for Coexistence in Crop Production*, sponsored by a USDA/IFAS project (Minneapolis, November 28, 2001) addressed these issues. Specifically, that conference was by invitation and included government, academics from multiple related disciplines, and industry. Their major objective was to identify strategies for the coexistence of GMO, Non-GMO, and organic crop production. See Fehr for a summary of issues on coexistence.

[15] Though there are USDA standards for organic production, these do not refer to any tolerance, but instead simply refer to excluded practices.

Elements of a Dual Marketing System and Sources of Risks

Ultimately, an alternative to a regulated system is a system with dual market channels. Such a system (as envisioned in the model later) is represented in Figure 2. All the basic elements are included from grower delivery, handling at country and export elevators, and the potential for testing at each of these functions. Thus, the system only involves movement to the point of first processing.[16] An important and non-traditional practice reflected here is that growers declare GM content at point of first delivery. That is, subject to their own uncertainty about the GM content, growers would declare (i.e., as in some type of contract or affidavit) whether the content of the grain includes GM varieties. This is commonly referred as GM declaration and has been an important element of the evolution of the market of GM grains (Harl).

This system could be envisioned as being adopted with several different scopes. It could reflect an elevator that seeks to segregate within their own facilities, or it could be elevators specialized in handling GM versus Non-GM. Or, it could be a vertically integrated firm with some elevators specializing in GM versus Non-GM handling. Each type of adoption has occurred in the marketing of other GM grains.

Sources of Risks: Risks are incurred throughout this system. Each are described here briefly and the actual distributions used in the model are explained in a later section.

There are three sources of grower risk. These include volunteers in subsequent crops, pollen drift, and on-farm adventitious commingling. Experience with volunteers has been limited in these crops for obvious reasons. Current literature suggests the level of risk of volunteers to be in the area of 31 percent of fields infested with an average density of 9 plants/sq. meter in the first year (Thomas and Leeson). The percent of fields infested and densities decline as years since the last wheat crop increase. By year 5, only 9 percent of fields were infested with an average density of less than 1 plant/sq. meter. These results indicate that there is a positive incidence, and this declines through time and is dependent on variety and agronomic practices. Using reasonable assumptions about planting rates etc., these risks translate to a probability of about .009 in year 1 (which would apply if wheat were planted on ground that was planted to wheat in the prior year), and diminishes to virtually nil in the years following.[17]

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[16] In concept, the model could be extended to cover and assess risks and costs within the processing sectors. However, the current state of knowledge, with respect to risks and costs in these functions and testing technology, is not available and would preclude extending the model empirically.

[17] If we assume average infestation rate of 9 plants/sq. meter, this equals 36,434 plants/acre. If we convert this to a seed equivalent at 14,000 seeds/lb., then 2.6 lbs. or 0.04 bu would be required to generate 36,434 plants/acre. Assuming a normal seeding rate of 1.5 bu/acre, the rate of infestation is equivalent to 2.89% of planting rate. If infestations are likely to occur with a probability of .31, then the expected infestation rate is 2.89%*.31+0*.69=0.9% in year 1, and declines thereafter.

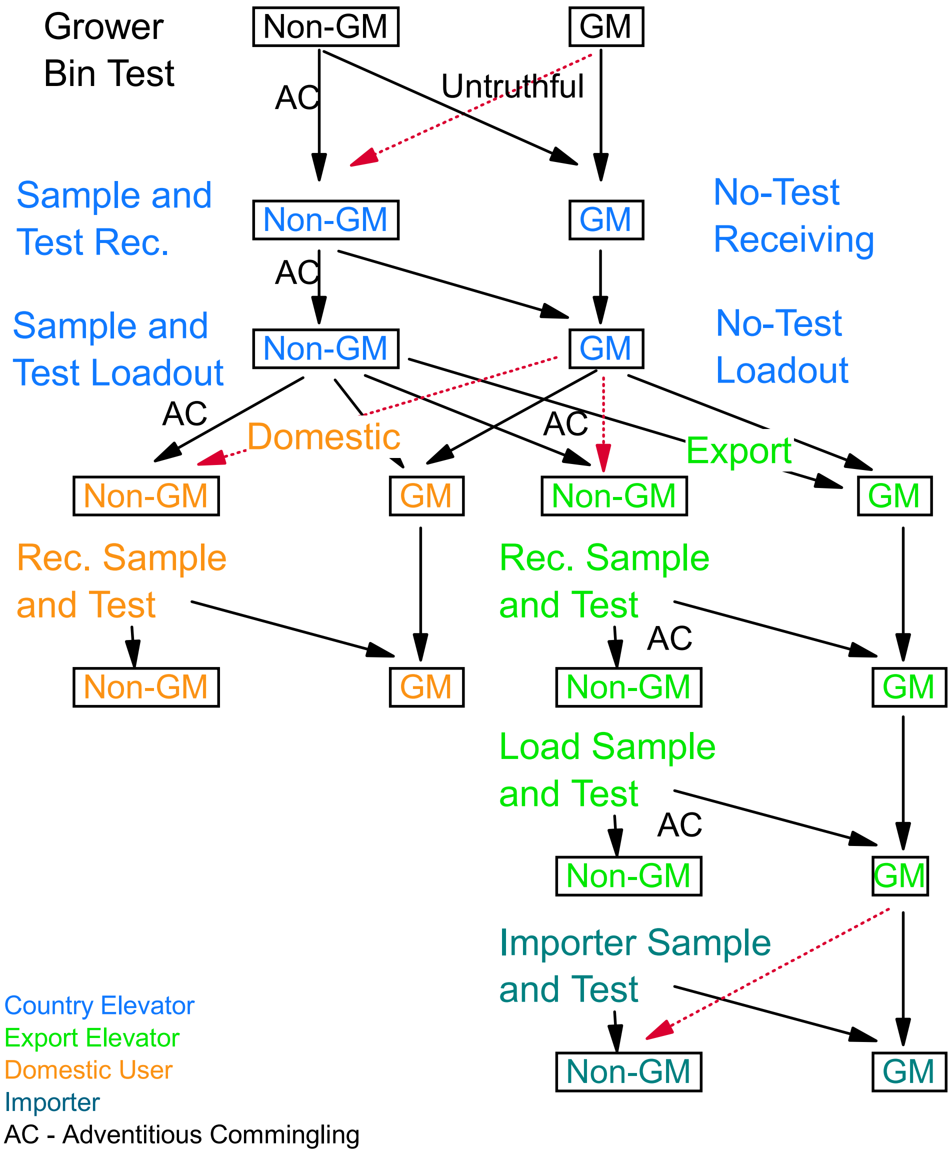

Figure 2. Grain Handling Subject to Adventitious Commingling.

Pollen drift, in the case of self-pollinated GM wheats, is relatively modest compared to cross pollinated crops like corn. Previous studies for wheat have suggested that the rate of outcrossing is generally less than one percent but can range as high as 5 percent with pollen drifting from 5 to 48 meters. Hucl and Matus-Cadiz indicate this may result in higher than acceptable levels of off-types occurring in isolation strips of 3 to 10 meters. They indicated outcrossing varies by variety with Oslo and Roblin having higher outcrossing rates which may require isolation strips larger than for low-outcrossing varieties. Finally, Hurburgh (in the case of corn) indicated on-farm handling risks of adventitious commingling to have a probability of about .016. The most likely sources of mixing errors at the farm level were: planter box .6, combine .6, transport .2, handling-on-farm .3 or .017 excluding pollen drift.

While handlers routinely segregate and blend grains as a primary function of their business, there is added risk of handling GM grains due to the possibility of adventitious commingling. A recent published study by USDA/ARS found that if running elevators non-stop, contamination is 4 percent; after 3 minutes, it declines to .2 percent. (i.e., probability=.002) (Casada, Ingles, and Maghirang). These are corroborated by Hurburgh who suggested the sources of adventitious commingling at the elevator/handling function to be: handling .3 percent, shipping .3 percent, and mixing 1 percent for a total of =1.6 percent or a probability of .016.

Another source of risks is testing. Throughout the system there are risks associated with testing. Tests are not 100 percent accurate. However, the level of risk can be determined and varies with technology and tolerance. These are described below. Finally, inevitably a contract penalty may be imposed by the buyer if GM content is found in a Non-GM shipment. This may be a simple penalty, or a rejection of the shipment by the seller. In either case, costs to the seller would be accrued.

Testing and Tolerance

There are several aspects of testing that are important. Most important is that testing would only apply to Non-GM shipments. It would be unnecessary to conduct tests on those shipments/lots already known to be GM. Thus, testing would only occur for those shipments/lots that are thought to be Non-GM.

There are two basic tests that could be used for analyzing for the presence of RRW. These are commonly referred to as strip tests and PCR tests.[18] Characteristics of these tests and their costs are shown in Table 2. These tests are for "single-trait" events. The PCR test is based on DNA technology and is more commonly used in international contracts. Strip tests are or would be more commonly used domestically. Table 3 shows the cost of these tests as they would typically be applied at different points in the marketing system and converts them to a cents/bu, respectively.

It is important that government and grain industry participants have concluded that zero tolerance is an impractical concept. In addition, the North American Millers Association (NAMA) has embraced testing of inbound grain, opposes testing on intermediate or finished products, and indicates government mandated testing programs need not be adopted. Further, NAMA conducted an analysis in the case of Starlink corn. Results indicated that the domestic industry quickly adopted contract terms and tests to control the adventitious presence of Starlink. They indicated that the samples testing positive for Starlink averaged 1.2 percent from October 2000 to June 2001. By fall 2001, this declined to "as close to zero as you can get" (Sjerven).

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[18] However, the PCR tests may be less appropriate in GM wheat because unlike corn, there is no need at present for a single PCR test to identify several biotech events that use the same marker gene. Further, there is no need to test for event GA21 which in corn currently requires a PCR test because strip tests are not accurate (Tobin).

Table 2. GM Testing Tolerances, Costs, and Accuracies

GMO Tolerance Tested for (%)	% Confidence Level (%)	Seeds	Cost per Test ($)
		PCR Tests	
1	99	600	120
.1%	95	3000	300
.1%	99	4650	400
		Strip Tests	
1	95		7.50

Source: Communications with Danny Giggax. Based on batch testing in 150 seeds/batch.

Table 3. GM Cost per Test by Location

	Testing Cost $/test	Lot Size	Testing Cost c/bu
Farmer Bin Sample	7.50	5,000 bu	.15
Country Elevator Receiving	7.50	800 bu	.94
Country Elevator Loading	7.50	3,300 bu	.23
Domestic User Receiving	120-400*	3,300 bu	3.64-12.12
Export Elevator Receiving	120-400*	3,300 bu	3.64-12.12
Export Elevator Loading	120-400	33,000 bu	.36-1.21
Importer Receiving	120-400	33,000 bu	.36-1.21

* Depending on tolerance required and test applied.

Concurrent with any test is a tolerance which is normally specified in purchase contracts. Technically, a tolerance is defined as the allowable variability from a standard. In the context of the grain trade, a tolerance for Non-GM is referred to as the maximum allowable GM content to still be considered Non-GM. Ultimately, it would be the buyer that would specify the tolerance and testing methodology as part of their purchase contract.

However, the term threshold is often used interchangeably. The American Seed Trade Association defines threshold as “a level below which the adventitious presence of protein or DNA is considered *de minimis* from either a safety or marketing (quality) standpoint”

(Schroeder). In debating this terminology, the NAMA recognized that "With some degree of adventitious mixing bound to occur between biotech-based and conventional grain, whether it be in the field or in the grain marketing and processing system, the NAMA stated that thresholds must be established to allow the movement of grains with adventitious admixture" (Schroeder). The distinction between tolerance and threshold is important. The NAMA found it to be important to change the wording of it in their biotechnology statement to focus on "thresholds" and not on the term "reasonable tolerance". . . the term tolerance often implies that the product being tested for–generically engineered grains, in this case–is bad or unsafe and needs to be tolerated at a certain level.

Trade Practices

The grain marketing system is evolving and beginning to adopt these protocols in GM corn and soybeans. Of importance in each case, as it would be in wheat, are tolerances, testing technologies, frequency at which tests are applied, declaration of GM content at the country elevator, and associated added costs and risks.

Contract Specifications: End-users and buyers express their needs and aversion to GM in contracts with tolerances. This is critical. Ultimately, it is incumbent on those buyers wanting to limit GM content in Non-GM shipments, for whatever reason (commercial or regulatory), to specify limits/restrictions in their purchase contracts. Those not averse to GM would not have to do anything special.

This can be implemented in existing contract forms and in a way similar to other factor limits. Specifically, for non-grade determining factors (e.g., dockage, vomitoxin, etc.) buyers specify limits in their contracts. This could be similarly accomplished for GM content. For example, a buyer may specify a limit simply as: not to exceed X percent GM content and/or a discount may apply if the tolerance is exceeded. In addition, an acceptable test/sampling procedure would have to be concurred. Presumably, that would be standardized in such a way to make the contract language and implementation common across transactions.

Declaration of Known GM Content or Variety: Growers declare varieties (i.e., whether the shipment contains GM varieties) at time of delivery (Harl). It is important that the grower knows the variety being delivered or at least has the capability of knowing. That provides a wealth of information that needs to be conveyed to the marketing system. Not only does this provide the essential information for segregation and testing requirements, it has several other positive benefits.[19]

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[19] Ultimately, this would provide a precursor to marketing by variety or, more likely, restricted varieties. This would be a fundamental paradigm shift in grain marketing and would be similar to that in France and other exporting countries using variety in varying ways for marketing and classification

Empirical Model

A model of grain flows reflecting the structure of a dual system with testing and segregation of GM/Non-GM flows (similar to that depicted in Figure 2) from growers to either importers or domestic end-users was developed. The model assumes adventitious commingling can occur at various stages of the grain marketing chain with given probability distributions. A level of GM/Non-GM adoption by farmers is assumed and farmers may/may not identify grain lots delivered as GM/Non-GM with a probability of "truth-telling." Tests are conducted at various stages to determine if grain indicated as Non-GM contains levels of GM exceeding tolerances. Non-GM flows exceeding the tolerance are diverted to GM flows at the stage of the marketing chain where they are identified and subjected to a penalty.

Risk Premiums and Utility

An important and innovative feature of the analysis relates to the risks the handler/shipper is exposed to and the consequence of violating a tolerance. For example, if a ship is being loaded with Non-GM wheat, and even though the shipper is taking grain from a segregated Non-GM flow, it is possible that the ship may be found to have a detected level of GM content (for example, BT or RRW corn materials in wheat). In practice this would be interpreted as a contract violation and subject to either rejection, penalty, or renegotiation, all at a loss to the shipper. Any of these would be terms of the purchase agreement. In any case, the shipper would be subject to an implicit cost or "risk premium" associated with this type of content. We estimate the value of this risk premium (π) as the expected costs for a Non-GM system (EV_{NGM}) less the certainty equivalent (CE) of the utility of additional costs of a system containing both GM and Non-GM segregations and include it in our cost function.[20]

$$\pi = EV_{NGM} - CE$$

This premium reflects the point at which decision makers would be indifferent to the current Non-GM system or a system handling both GM and Non-GM segregations.

Model Specification

The model is developed as a stochastic optimization model of a grain marketing chain. The model utilizes an objective function presented by Saha and used earlier by Serrao and Coelho. The objective function contains a von-Neuman-Morgenstern type utility function, with decreasing absolute risk aversion and increasing relative risk aversion. The model chooses the optimal testing strategy (where to test and how often to test) that maximizes utility by minimizing additional system costs for a supply chain handling a portfolio of segregations representing two states of nature (GM and Non-GM grains). The portfolio utility is comprised of the weighted disutility of additional system costs for handling both GM and Non-GM segregations. The objective is:

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[20] In this case, we assume the expected costs for the current Non-GM system are unchanged and examine only the marginal costs of testing and rejection. Thus, the expected costs for the Non-GM system are assumed zero.

$$Min(C) = \sum_{i=1}^{2} \delta_i (\lambda - e^{(-\phi - C_i^{\eta})})$$

s.a. $X_j \in K_j$

where:

δ_i	is the proportion of flows devoted to each state of nature (i=1-2),
e	is the natural logarithm,
λ	is a parameter that determines positiveness of the utility function,
ϕ	and η are parameters which affect the absolute and relative risk aversion of the utility function,
C_i	is the additional system costs associated with each state of nature (i=1,2),
X_j	is the decision variable vectors of the model ($j=T_k$, S_k), and
K_j	is the opportunity set of model.

This model is appropriate for this type of problem because it is flexible (it allows for changes in both absolute and relative risk aversion of decision makers). The model has been utilized previously by Serrao and Coelho to determine optimal proportions of cropland devoted to specific crops and to determine the risk premium for crop insurance programs. Parameters of the utility function are λ, ϕ, and η. A value of 2 for λ within the objective function above allows for a positive utility function. The parameters ϕ and η affect absolute and relative risk aversion. Increasing the risk parameter ϕ while holding η constant increases the absolute risk aversion, but does not affect the optimal solution. Increasing η while holding ϕ constant increases relative risk aversion and its effect on the objective function is larger than that for ϕ. Thus, following Serrao and Coelho, fixed values for λ and ϕ were adopted and sensitivities conducted for η.

The additional costs for the system are estimated from the expected value of the system of GM and Non-GM segregations as follows:

$$\pi = E(\sum_{i=1}^{2} \delta_i (\lambda - e^{(-\phi - C_i^{\eta})})$$

where π is the risk premium and the other parameters are as previously defined. The risk premium is interpreted as the additional revenue necessary for decision makers to be indifferent between the system handling both GM and Non-GM segregations and the current Non-GMO system.

The model estimates the additional system costs due to testing and segregation for each of the segregations (states of nature) separately. Additional system costs are defined as:

$$C_{NGM} = \sum_{k=1}^{n} T_k * S_k * V_{NGM\,k} + D_k * V_{DGM_k} \text{, and}$$

$$C_{GM} = 0$$

where:

C_{NGM}	is additional testing and segregation costs added to Non-GM shipments to maintain GM separation,
C_{GM}	is additional costs for GM bushels (assumed zero),
k	is location in the system where tests can be applied (country elevator receiving, local elevator loading, export elevator receiving, export elevator loading, importer receiving, domestic user receiving),
T_k	is cost of individual test applied at location k,
S_k	is sampling intensity at location k,
V_{NGMk}	is volume (number of lots) of Non-GM handled at location k,
D_k	is discount or penalty applied to grain diverted from Non-GM to GM flows at location k, and
V_{DGMk}	is bushels diverted from Non-GM to GM flows at location k.

The model derives additional system costs at each stage of the marketing chain, tracks segregation flows throughout the system, and derives statistical properties on the proportion of shipments with GM exceeding specifications within end-use flows.[21]

Simulation Procedures

The model is solved as a stochastic optimization problem using *RiskOptimizer* (Palisade), a program designed to solve optimization problems with uncertainty. The stochastic optimization program employs a genetic search algorithm to identify optimal solutions. Each combination of choice variables is simulated for 1,000 iterations for which means for objective values and other variables are collected and then the genetic search algorithm identifies the next set of choice values. The model continues choosing sets of choice values until stopping criteria are indicated (no significant improvement in best mean objective values has occurred for a significant period of time).

Testing/sampling is applied at various locations within the grain handling system utilizing a hypogeometric distribution.[22] This distribution is a discrete distribution used to simulate sampling plans where parameters for the distribution represent the number of samples drawn, the number of items not meeting specifications, and the population size. Samples drawn are assumed to be representative, reflecting standardized procedures across various lot sizes which conform to specifications associated with the accuracy level of the tests applied.

The model tracks the volume within the Non-GM flow that are adventitiously commingled at each location in the grain handling system, as well as the proportion of volume in both the Non-GM and GM segregations. These are utilized to determine the proportion of

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[21] System costs excludes other costs for IP verification, segregation, which would be highly autonomous.

[22] At one point in the model, a binomial distribution was substituted for a hypergeometric due to errors generated when the number of samples exceeded 1000. When the population size is larger, a binomial should be used and, if population is infinitely large, then there is no difference between the hypergeometric and binomial distributions (Uitenbroek).

samples adventitiously commingled for sampling at subsequent locations. Factors affecting the volume of adventitious commingled at a location include prior adventitious commingling, grain diverted from Non-GM flows to GM due to positive test results for samples, and effects due to accuracy of tests (false positives–Non-GM samples identified as adventitiously commingled; and false negatives–adventitiously commingled lots identified as Non-GM).

Distributions and Parameters Used in the Model

The model incorporates risk in a number of random variables. These include farmer "truth-telling;" adventitious commingling which occurs at several locations (farm, country elevator, export elevator, and transportation equipment) due to various factors (inadequate cleaning, etc.); sampling and inspection plans; and test accuracy.

Sources of information were from other published research, a survey of market participants, and/or industry judgement. These were supplemented by information contained in recent studies on adventitious commingling. The distribution of grower risks (inclusive of volunteers, pollen drift, and on-farm handling) were derived to reflect the risks depicted in previous studies. Similarly, handling risks were taken to depict those reflective in Hurburgh and Casada, Ingles, and Maghirang. Testing risks were from the test specifications and are contained in Table 2.

To get some judgement of the distributions about grower and handler "truth-telling," we conducted a survey of participants knowledgeable on this topic as it pertains to marketing of GM corn and soybeans. Results from this were used to derive a triangular distribution on truth-telling.

The penalty for GM contained in a Non-GM shipment was assumed to be uniformly distributed within a range of 40-90 cents/bu in the export market and 2-20 cents/bu in the domestic market. Given the grains in this study are not currently traded, we cannot use observed values. There are several aspects of the cost components. First, it is a result of a contract specification agreed between buyer and sellers. Second, it is important whether the test is evaluated at origin (i.e., export port) or destination (import port). If the former, being out of contract is not as great. Finally, some export elevators (e.g., with shipping bins) may be more capable of testing prior to loading than others.

The logic to the export penalties is based on two components. Discounts for GM in Non-GM corn have been in the area of 10 percent of the value, which in the case of wheat would be about 40 cents/bu. However, in some cases, rejection may entail re-shipping the grain to some other market at a cost to the shipper. In many geographical locations internationally, this would be about the equivalent of 50 cents/bu. For the domestic market, these would reflect handling costs and possible shipment to alternate destinations. Thus, these likely reflect a worst case scenario. The final distributions used in the base case simulations are contained in the Table 4.

The risk aversion parameters for the utility function are λ, ϕ, and η. Following Serrao and Coelho, parameter values for λ and ϕ were assumed to be 2 and .01, respectively. For the risk parameter, η, a base value of .5 was utilized, then sensitivities are conducted for values from .1 to .9 with .9 indicating higher risk aversion and .1 lesser risk aversion.

Table 4. Base Case Distributions

	Distribution	Minimum	Most Likely	Maximum	Corroboration
Grower Risks	Triangular	0.01	0.025	0.05	Hurburgh
Country Elevator	Triangular				
Receiving		0.001	0.01	0.02	Casada et al.
Loadout		0.001	0.01	0.02	
Export Elevator	Triangular				
Receiving		0.001	0.01	0.02	Casada et al.
Loadout		0.001	0.01	0.02	
Truth-telling (retention)					
Farmer	Triangular	0.8	0.95	1.00	
Handlers	Triangular	0.95	0.99	1.00	
Price Penalty	Uniform				
Export		40 c/bu		90 c/bu	
Domestic Users		2 c/bu		20 c/bu	
Testing		Cost	Accuracy		Test Type
Country Elevator		$7.50/Test	0.95		Strip Tests
Export Elevator		$120/Test	0.99		PCR

For all the important and interesting random variables, we conducted and present simulations to illustrate their effect on the solutions.

Results

A base case was defined and simulated. Results from this are described first. Simulations and sensitivities are then evaluated relative to this base case. Sensitivities were conducted to examine affects of risk attitudes, tolerance, variety declaration, level of GM adoption, level of discounts for rejection of Non-GM shipments, and choice of test type by location. A second model is developed to also examine impacts for shipments to domestic users.

Base Case

The base case was defined to reflect the most likely system and protocols. These include:

- Export shipment to importers;
- GM adoption by farmers of 20 percent (based on market distributions of GM aversion of buyers);
- Grower declaration of GM content at the country elevator;

- Testing was allowed at any or all of the following: Country Elevator (CE) at receiving and/or loadout and at the Export Elevator (EE) at receiving and loadout;
- Testing technology at the export/import level was required restricted to the PCR tests;
- The risk aversion parameter $\eta = .5$; and
- Finally, no additional costs of segregation were included.[23]

In addition, a PCR test at the importer is applied at a cost of $120/test on every unit designated as Non-GM and is also used to impose an accept/reject mechanism for deliveries of Non-GM wheat not meeting GM content specifications.

The results identify the optimal testing strategies which maximize utility (minimize disutility) of GM/Non-GM system versus the current Non-GM system (Table 5). The optimal strategy would be to test every 5th railcar at the country elevator when loading and to test every ship sublot when loading at the export elevator. This testing strategy results in average rejection rates at the importer of 1.75 percent with less than .02 percent of lots containing adventitious commingling remaining in importer flows after testing at the importer (due largely to test accuracy). The distribution of the probability of rejection for the optimal strategy suggests three discrete levels of rejection rather than a more continuous distribution for rejection rates (Figure 3). These three distinct levels occur for rejection rates of <.01, <.02, and <.03. For example, there is a 25 percent chance that the probability of rejection at the importer will be less than 0.01 and 85 percent chance that it will be less than 0.02.

The proportion of flows in the Non-GM channel declined from .80 at the farm level to an average of .696 at the importer. The distribution of the proportion of flows at the importer while averaging .696 had a 5 percent probability of being less than .667 and a 95 percent probability of being less than .723 (Figure 4). Thus, on average, over 10 percent of Non-GM shipments are diverted to the GM segregation throughout the handling system. This illustrates the risk of incorrectly rejecting shipments throughout the system. As noted in the lower panel of Table 5, most of this occurs after unloading at the export elevator. Further, we are 95 percent confident that diversions of Non-GM to GM shipments should range from about 8 percent to 17 percent of shipments. This diversion takes place due to large samples containing units with both adventitious commingling and Non-GM which are represented by a single test, adventitious commingling which occurs in the system, and through effects due to test accuracy.

The utility of the base case is 1.0097 which converts to a certainty equivalent of 0.96 cents/bu. This is the premium that would be required for a decision maker to be indifferent to this Non-GM/GM system with its testing scheme (where and how intensive to test) and a system of Non-GM only. Thus, this premium represents the value of the additional risk associated with the Non-GM/GM system and is the added cost suppliers would implicitly accrue by handling GM and selling to a Non-GM contract.

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[23] Additional segregation costs are somewhat elusive, and are certainly autonomous and highly situation specific. To support this, most country elevators in the HRS area already segregate by grade, protein, test weight, dockage, falling numbers, and vomitoxin. Thus, segregating GM wheat should be viewed as an additional segregation. This could be viewed as an additional segregation or alternative segregation to others. Or, in a very practical case, it would be viewed as a dedicated facility handling only GM (or Non-GM) shipments.

Table 5. Base Case Results

	Base Case
Utility	1.0097
Test (1=yes/0=no, Every nth unit)	
Country Elevator Receiving	0-0
Country Elevator Loading	1-5
Export Elevator Receiving	0-0
Export Elevator Loading	1-1
Probabilities	
GM in Importer Flows	.02%
Rejection at Importer	1.75%
Costs	
Additional Costs/All bu	1.39
Additional Costs/Non-GM bu	1.99
Certainty Equivalent (Premium)	0.96
Total (Add + Prem)/All bu	2.35
Total (Add + Prem)/ Non-GM bu	3.36
Percent of Flows Non-GM by Location	
Adoption Rate	80.0%
Farmer in Bin	80.0%
Country Elevator in Store	81.7%
Country Elevator Loaded on Track	76.8%
Export Elevator in Store	77.2%
Export Elevator after Loading	70.8%
Importer after Test	69.6%

Additional system costs for testing and discounts for rejection at the importer in the base case were 1.4 cents/bu. The approximate components of these costs are: testing of every 5th railcar loaded at the country elevator, .037 cents/bu; testing of every ship hold at the export elevator, .282 cents/bu; testing of every ship hold at the importer, .259 cents/bu; and rejection cost at the importer of .808 cents/bu.

If this cost was absorbed solely by the Non-GM bushels, the costs average 2.0 cents/bu. The cost of the system includes both additional system costs and the risk premium. Adding these two cost elements results in total costs of 2.4 cents/bu when measured across all bushels and 3.4 cents/bu when attributed solely to Non-GM bushels. These costs only reflect additional costs of testing and rejection within a system of Non-GM/GM wheat. Other costs could include costs for additional segregation, monitoring, etc., but were not included here.

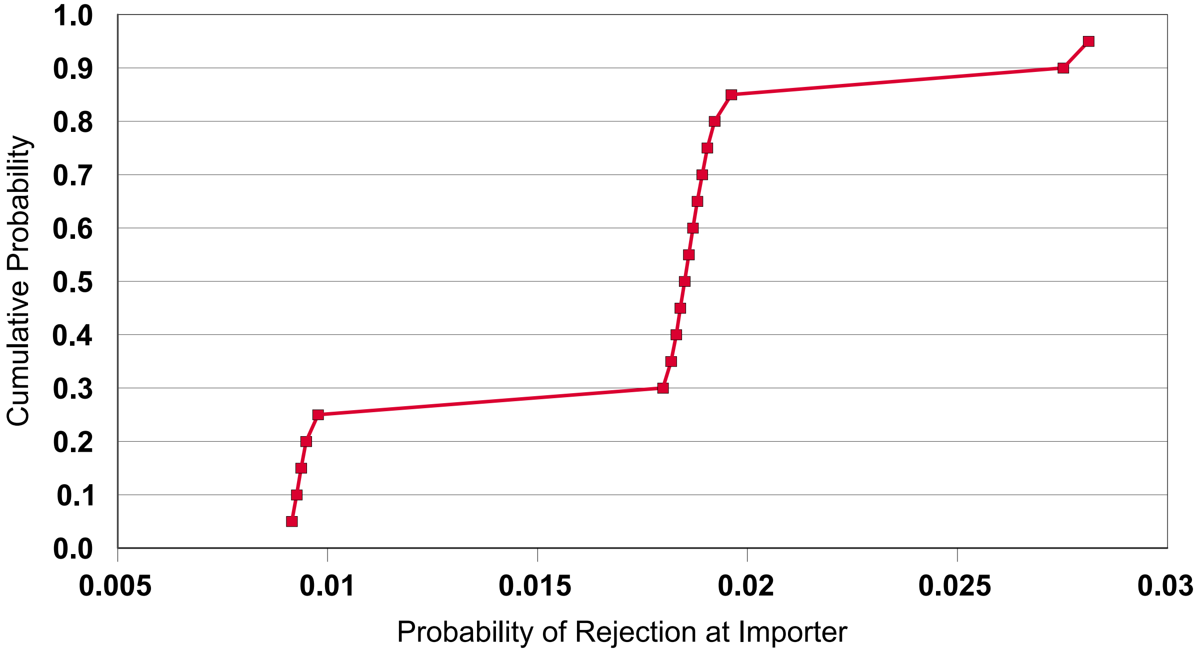

Figure 3. Base Case: Distribution of the Probability of Rejection at the Importer.

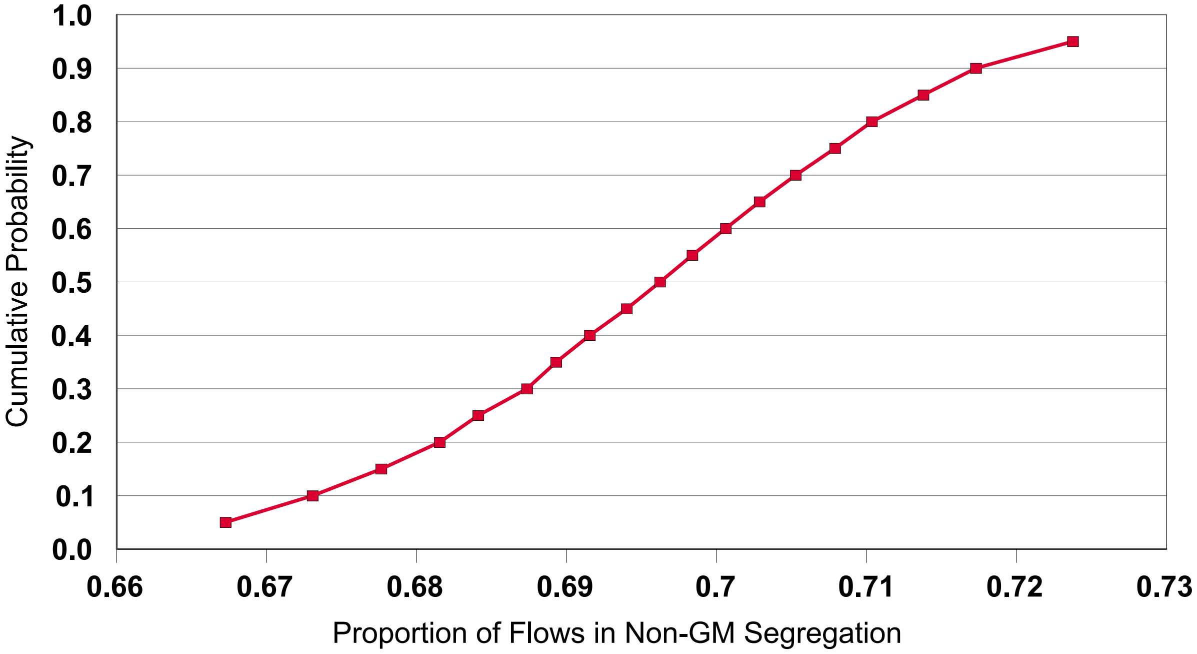

Figure 4. Base Case: Distribution of Proportion of Flows in Non-GM Segregation at the Importer.

Variety Declaration and Testing

In the base case, mechanisms are used to elicit information from growers on the GM content of their grains. In fact, this function would normally be included in "closed loop" marketing plans. This facilitates segregation at the point of first receipt, albeit at an allowed risk of adventitious commingling at the grower level and due to grower truth-telling (below). If such a mechanism were not developed, initial handlers would have greater uncertainty upon receipt, which in turn could impact the level of adventitious commingling due to the inability to segregate GM from Non-GM without testing. To simulate this impact, we developed a model without variety declaration which included a higher rate of adventitious commingling (20 percent, which is equal to the percent of GM adoption) at the point of first receipt.

With no variety declaration, the optimal testing strategy included testing of every 5th unit at the country elevator, both when receiving grain from growers and when loading railcars; and testing every 5th railcar when received at the export elevator and every hold when loaded at the export elevator (Table 6). Rejection rates at the importer increased from 1.75 percent for the base case to 2.34 percent with no variety declaration. The largest impact was on the proportion of Non-GM in the system. When flows reach the importer, only 30.6 percent of flows were Non-GM. Thus, a system with no variety declaration results in significant diversion of flows from Non-GM to the GM segregation. This occurs throughout the system, but is concentrated at the country elevator level. These are reflected in the costs when attributed to Non-GM bushels. Costs of testing and rejection for Non-GM bushels increased from 1.99 cents/bu for the base case to 4.38 cents/bu with no variety declaration. Total costs for Non-GM bushels similarly increased from 3.36 cents/bu for the base case to 5.70 cents/bu with no variety declaration (Figure 5).

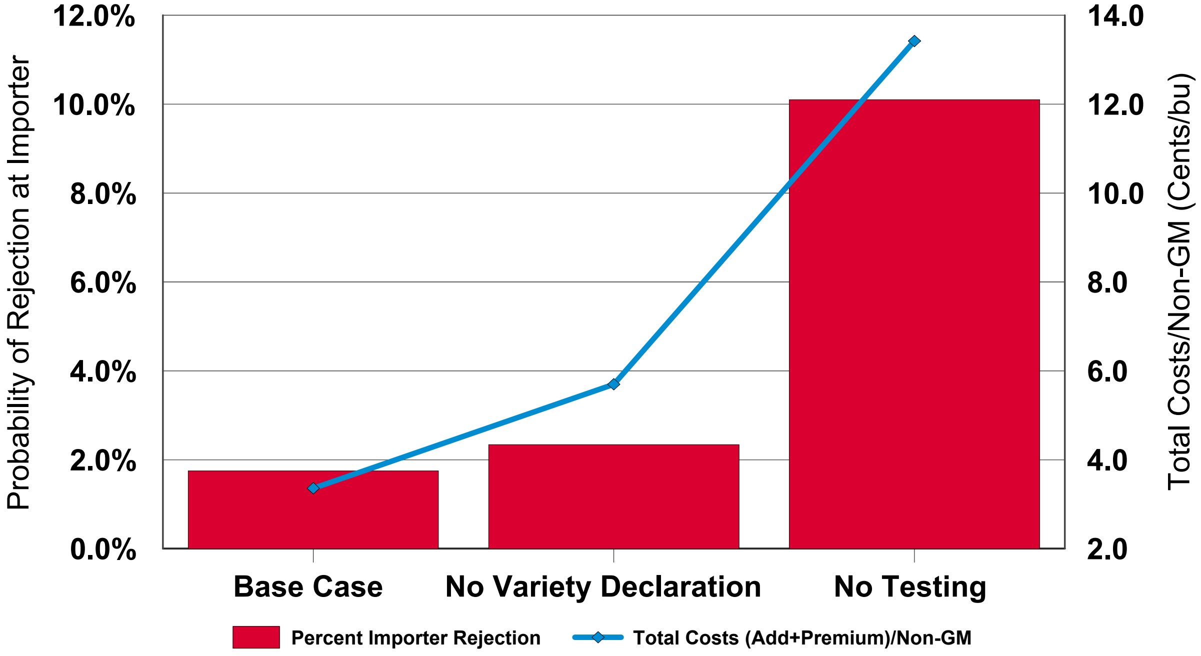

Figure 5. Effect of Variety Declaration and Testing on Rejection Rates at the Importer and Total Costs per Non-GM Bushel.

A case was also developed where no testing and no variety declaration was allowed. This was used to reflect the risks inherent in the system and the value of testing. With no testing allowed, rejection rates at the importer were 10.10 percent (Figure 5 and Table 6). This is significantly higher than either the no variety declaration case or the base case. Total costs per Non-GM bushel were also significantly higher than either of the other cases (13.42 cents/bu).

Table 6. Effect of Variety Declaration and No Testing

Variety Declaration	Base Case Variety Declaration	No Variety Declaration	No Testing & No Variety Declaration
Utility	1.0097	1.0071	1.02
Test (1=yes/0=no, Every nth unit)			
Country Elevator Receiving	0-0	1-5	0-0
Country Elevator Loading	1-5	1-5	0-0
Export Elevator Receiving	0-0	1-5	0-0
Export Elevator Loading	1-1	1-1	0-0
Probabilities			
GM in Importer Flows	.02%	.01%	0.10%
Rejection at Importer	1.75%	2.34%	10.10%
Costs			
Additional Costs/All bu	1.39	1.33	5.70
Additional Costs/Non-GM bu	1.99	4.38	7.75
Certainty Equivalent (Premium)	0.96	0.40	4.17
Total (Add + Prem)/All bu	2.35	1.73	9.87
Total (Add + Prem)/ Non-GM bu	3.36	5.70	13.42
Percent of Flows Non-GM by Location			
Adoption Rate	80.0%	80.0%	80.0%
Farmer in Bin	80.0%	80.0%	80.0%
Country Elevator in Store	81.7%	77.7%	81.7%
Country Elevator Loaded on Track	76.8%	51.1%	81.7%
Export Elevator in Store	77.2%	39.0%	82.0%
Export Elevator after Loading	70.8%	31.3%	82.0%
Importer after Test	69.6%	30.6%	73.7%

Effect of Risk Parameter (η)

The risk parameter, η, would likely vary across handling firms, some more and some less willing to assume risks. In addition, it is important that there is a tradeoff between incurring testing costs and risks. To illustrate these we conducted sensitivities for the base case with more/less risk aversion. Two cases, η = .9 (more risk averse) and η =.1 (less risk averse) were developed and optimal solutions derived and compared to results from the base case (η=.5) (Table 7). Results for optimal testing for both the base case and for the more risk averse case were the same. The less risk averse model tests more intensively than the other cases, testing every 5th unit at the country elevator when receiving and loading and every 5th unit at the export elevator when receiving and every unit when loading.

Rejection rates at the importer were highest for the less risk averse model, 1.78 percent versus 1.75 percent in base case and 1.75 percent in the more risk averse model (Figure 6). Further, the percent of flows at the importer that were Non-GM were 6.9 percent lower (percent diverted to GM was highest) for the less risk averse model than for either the base case or the more risk averse model.

Utility for each of the models declined as the risk parameter, η, declined. This resulted in a decline in the risk premium at which decision makers would be indifferent to a system of Non-GM/GM or a Non-GM system. With η=.9, the risk premium was 1.3 cents/bu, but declined to only 0.04 cents/bu when η=.1. Less risk averse shippers discount additional testing and rejection costs less than the more risk averse shippers and, therefore, require less of a premium to accept additional costs of operating a Non-GM/GM system.

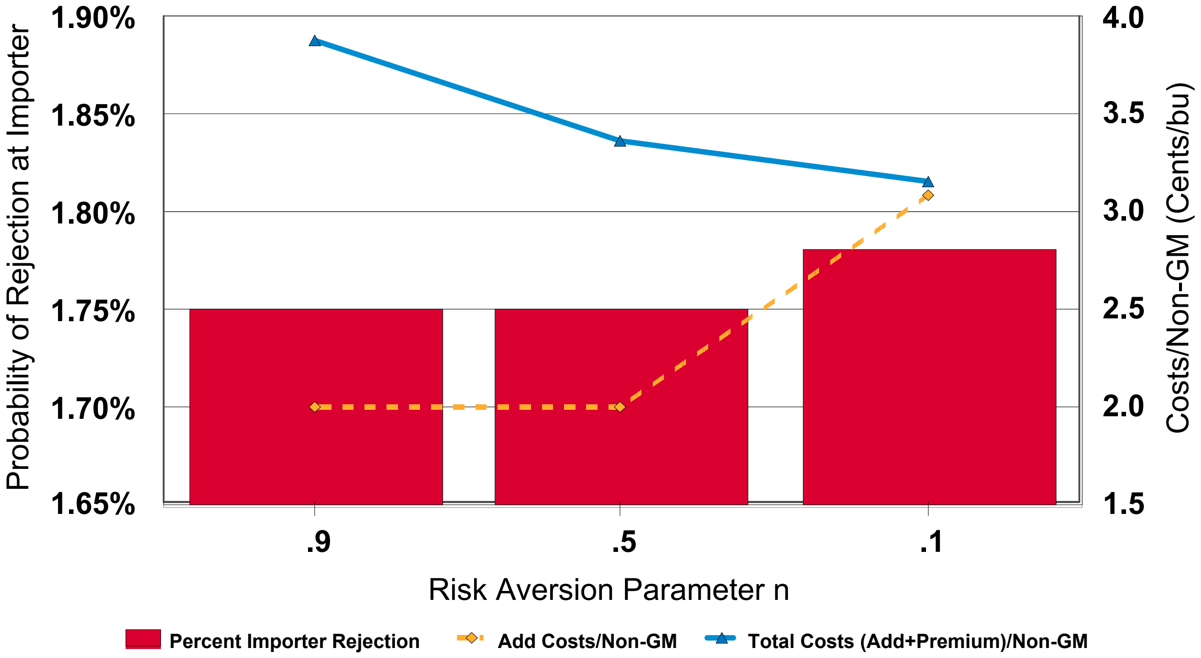

Figure 6. Effect of Risk Aversion Parameter on Importer Rejection Rates, and Additional and Total Costs per Non-GM Bushel.

Additional costs for the more risk averse and base case were the same when applied to either all bushels or Non-GM only bushels. Additional costs for the less risk averse case were higher, 1.97 cents/bu for all bushels and when applied only to Non-GM bushels costs increased to 3.09 cents/bu. Total costs were higher for the more risk averse case. Even though, additional system costs for the more risk averse case were lower than for the less risk averse case, the risk premium was the highest and the difference in risk premiums was larger than the difference in additional system costs. Total costs for all bushels for the more risk averse case were 2.7 cents/bu and 3.9 cents/bu when only applied to Non-GM bushels. Thus, for less risk averse decision makers (lower parameter value), additional system costs increase, the risk premium declines, total costs including the premium decline, rejection rates by the importer increase and the proportion of flows that are Non-GM decline (Figure 6 and Table 7).

Table 7. Base Case Results and Sensitivity to Risk Aversion (η)

Risk Parameter (η)	.9	Base Case .5	.1
Utility	1.0128	1.0097	1.0071
Test (1=yes/0=no, Every nth unit)			
Country Elevator Receiving	0-0	0-0	1-5
Country Elevator Loading	1-5	1-5	1-5
Export Elevator Receiving	0-0	0-0	1-5
Export Elevator Loading	1-1	1-1	1-1
Probabilities			
GM in Importer Flows	.02%	.02%	.01%
Rejection at Importer	1.75%	1.75%	1.78%
Costs			
Additional Costs/All bu	1.39	1.39	1.97
Additional Costs/Non-GM bu	1.99	1.99	3.09
Certainty Equivalent (Premium)	1.32	0.96	0.04
Total (Add + Prem)/All bu	2.71	2.35	2.01
Total (Add + Prem)/ Non-GM bu	3.88	3.36	3.15
Percent of Flows Non-GM by Location			
Adoption Rate	80.0%	80.0%	80.0%
Farmer in Bin	80.0%	80.0%	80.0%
Country Elevator in Store	81.7%	81.7%	77.7%
Country Elevator Loaded on Track	76.8%	76.8%	73.6%
Export Elevator in Store	77.2%	77.2%	69.5%
Export Elevator after Loading	70.8%	70.8%	64.9%
Importer after Test	69.6%	69.6%	63.7%

Effect of Price Differentials (Discounts)

In corn and soybeans discounts have evolved to be about 10 percent of the value of grain. In the base case, discounts were applied which represent 10 percent of the value of wheat and added logistical costs to go to an alternative market. However, these are determined in part by contract specifications of individual buyers and by cumulative interaction of all buyers, sellers, and impacts of technology costs. To illustrate, we varied discounts to determine how these impacted testing strategies and also examined a case where discounts representative of additional handling costs were applied if rejected for country and export elevator loading. Two cases were developed, one with lower penalties (0-10 cents/bu) and a second with higher penalties (100-150 cents/bu). A third case was developed to examine effects of additional discounts applied at loading locations (country and export elevators) when lots are identified as GM and diverted.

Lower penalties resulted in an optimal testing strategy which was less intensive. Optimal testing occurred at the same locations (both country elevator and export elevator loading); however, sampling at the export elevator was less intensive (every 5th unit versus every unit in the base case). This less intensive testing is reflected in a higher rejection rate, which increased from 1.75 percent in the base case to 7.87 percent with lower discounts (Table 8 and Figure 7). Higher penalties resulted in the same optimal testing strategy as the base case.

The third case applied additional penalties at loading and resulted in a more intensive testing strategy. Tests were conducted at the same locations; however, every unit was tested at both the country and export elevator when loading. The effect of this more intensive testing strategy for this case resulted in lower rejection rates at the importer (1.68 percent versus 1.77 percent in the base case).

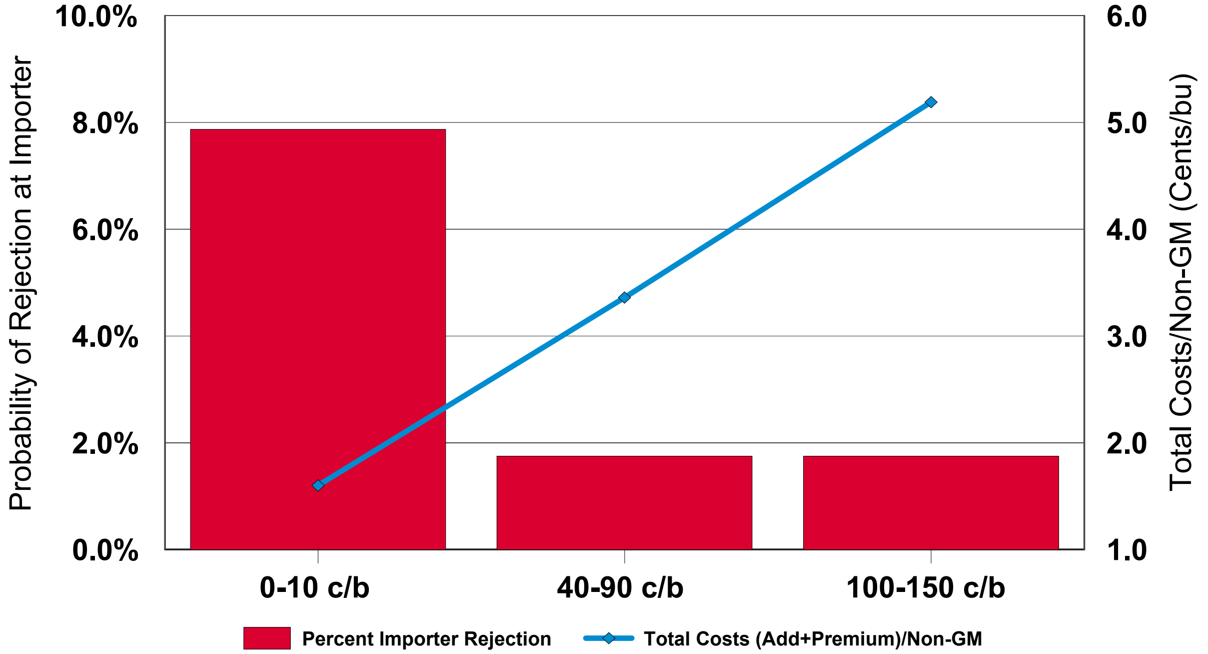

Figure 7. Effects of Penalty for Rejection on Rejection Rates and Total Costs per Non-GM Bushel.

Total costs (Additional + Risk Premium) when attributed to the Non-GM bushels increased as the level of the penalty for rejection increased. With the higher penalty (100 to 150 cents/bu), total costs per Non-GM bushel were 5.19 cents/bu while the low penalty rate had total costs of only 1.6 cents/bu. This indicates that if the penalty for being out of specification for GM is minimal, the optimal response of decision makers is to test less often and accept higher rejection rates. As the penalty increases, decision makers respond with strategies which include greater testing intensities and lower rejection rates. Costs would be higher per Non-GM bushel and require higher risk premiums (Figure 7 and Table 8).

Table 8. Sensitivity to Alternative Rejection Penalties

Penalty	0-10 c/bu	Base Case 40-90 c/bu	100-150 c/bu	Additional Loading Penalty
Utility	1.0063	1.0097	1.012	1.012
Test (1=yes/0=no, Every nth unit)				
Country Elevator Receiving	0-0	0-0	0-0	0-0
Country Elevator Loading	1-5	1-5	1-5	1-1
Export Elevator Receiving	0-0	0-0	0-0	0-0
Export Elevator Loading	1-5	1-1	1-1	1-1
Probabilities				
GM in Importer Flows	.08%	.02%	.02%	.01%
Rejection at Importer	7.87%	1.75%	1.75%	1.68%
Costs				
Additional Costs/All bu	0.63	1.39	2.13	2.00
Additional Costs/Non-GM bu	0.97	1.99	3.07	2.74
Certainty Equivalent (Premium)	0.41	0.96	1.47	1.46
Total (Add + Prem)/All bu	1.04	2.35	3.60	3.46
Total (Add + Prem)/ Non-GM bu	1.60	3.36	5.19	3.74
Percent of Flows Non-GM by Location				
Adoption Rate	80.0%	80.0%	80.0%	80.0%
Farmer in Bin	80.0%	80.0%	80.0%	80.0%
Country Elevator in Store	81.7%	81.7%	81.7%	81.7%
Country Elevator Loaded on Track	76.8%	76.8%	76.8%	76.8%
Export Elevator in Store	77.2%	77.2%	77.2%	77.2%
Export Elevator after Loading	70.7%	70.8%	70.8%	74.4%
Importer after Test	65.2%	69.6%	69.6%	73.1%

GM Adoption Rate

Adoption for GM in the base case was assumed to be 20 percent and was parameterized based on expected buyer aversion. However, this will vary with market forces, and most important, will vary geographically, both of which would impact the optimal testing strategy. Thus, the range of GM adoption was examined for cases with 10 percent and 50 percent GM adoption and compared to the base case.

Optimal testing strategies for 10 percent GM adoption were the same as for the base case (Table 9). However, with GM adoption of 50 percent, the optimal testing strategy included testing at the country elevator and export elevator when loading and added additional testing (every 5th unit) when grain is received at the country elevator. As the level of GM adoption increased, the proportion of samples rejected at the importer also increased from a low of 0.17 percent for the 10 percent GM adoption to 2.12 percent with 50 percent GM adoption (Figure 8).

Costs of testing and rejection, when estimated over all bushels, declined as the level of GM adoption increased. For GM adoption of 10 percent, additional costs attributed to all bushels were 1.53 cents/bu and declined to 0.97 cents/bu with 50 percent GM adoption. When costs are attributed only to Non-GM bushels, the additional testing and rejection costs increased from 1.94 cents/bu for 10 percent GM adoption to 2.56 cents/bu for 50 percent GM adoption. This occurs largely due to the lowering of the proportion of samples that are tested as the rate of GM adoption increases.

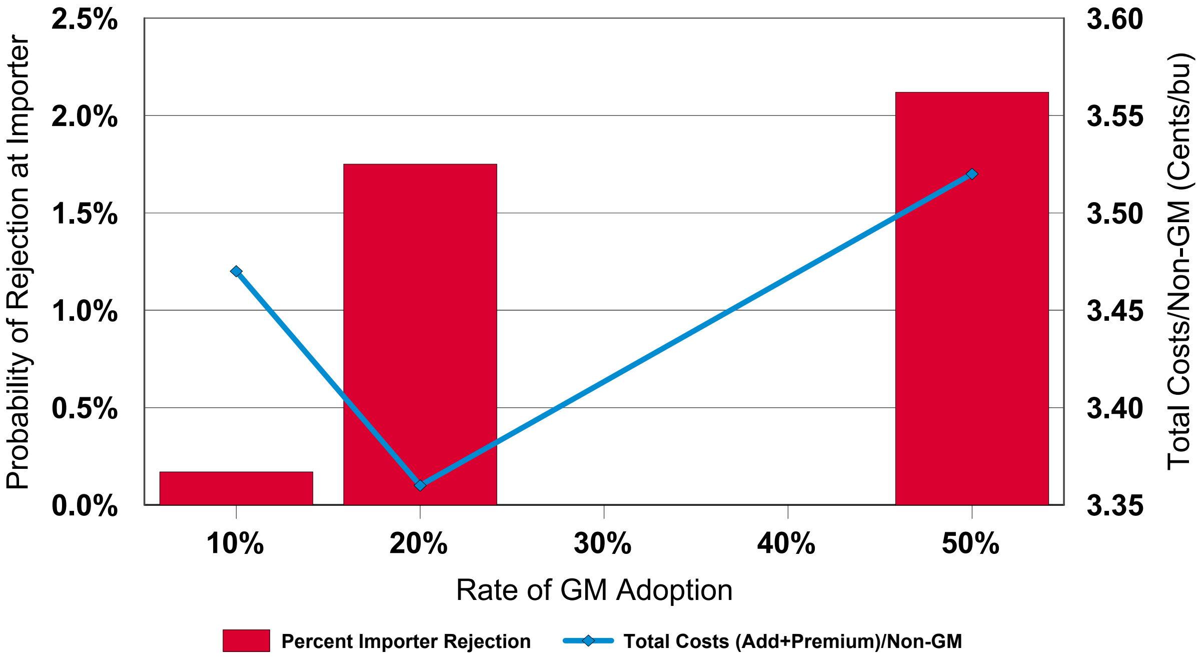

Figure 8. Effect of Level of GM Adoption by Growers on Importer Rejection Rates and Total Costs per Non-GM Bushel.

The risk premium for operating the Non-GM/GM over a Non-GM system declined as the percent of GM adoption increased. For 10 percent GM adoption, the risk premium was 1.21 cents/bu and declined to 0.37 cents/bu with 50 percent GM adoption. Total system costs when applied to all bushels declined as the level of GM adoption increased. Total system costs declined from 2.74 cents/bu with 10 percent GM adoption to 1.34 cents/bu with 50 percent GM adoption. Total system costs when applied to Non-GM bushels were higher than for the base case when GM adoption was either higher or lower than the base case, but was highest when GM adoption was 50 percent (Figure 8). This suggests that with minimal GM adoption, testing costs and the risk premium dominate and are assessed to nearly all bushels. As the amount of GM adoption increases, the proportion of bushels tested declines, lowering total costs and the risk premium required also declines. However, at some point, the effect of higher GM adoption reduces the level of supplies of Non-GM that can be delivered to the importer faster than the declines due to reductions in tests applied and the declines in the risk premium. At this point, total costs per Non-GM bushel increase again.

Table 9. Sensitivity of Rate of GM Adoption

GM Adoption	10%	Base Case 20%	50%
Utility	1.0109	1.0097	1.006
Test (1=yes/0=no, Every nth unit)			
Country Elevator Receiving	0-0	0-0	1-5
Country Elevator Loading	1-5	1-5	1-5
Export Elevator Receiving	0-0	0-0	0-0
Export Elevator Loading	1-1	1-1	1-1
Probabilities			
GM in Importer Flows	.01%	.02%	.01%
Rejection at Importer	0.17%	1.75%	2.12%
Costs			
Additional Costs/All bu	1.53	1.39	0.97
Additional Costs/Non-GM bu	1.94	1.99	2.55
Certainty Equivalent (Premium)	1.21	0.96	0.37
Total (Add + Prem)/All bu	2.74	2.35	1.34
Total (Add + Prem)/ Non-GM bu	3.47	3.36	3.52
Percent of Flows Non-GM by Location			
Adoption Rate	90.0%	80.0%	50.0%
Farmer in Bin	90.0%	80.0%	50.0%
Country Elevator in Store	90.8%	81.7%	48.6%
Country Elevator Loaded on Track	86.4%	76.8%	43.8%
Export Elevator in Store	86.6%	77.2%	45.0%
Export Elevator after Loading	80.5%	70.8%	39.9%
Importer after Test	79.1%	69.6%	38.2%

Grower Truth-telling

Farmers are assumed to declare GM content at the point of delivery. This allows the first handler to segregate and would be typically governed by some type of contractual relations and/or elevator imposed mechanism. In the base case, farmers were truthful in their declaration 95 percent of the time (range from 80 percent to 100 percent). This was represented in the model by a triangular distribution with a minimum value of 80 percent, most likely 95 percent and maximum of 100 percent. Two cases were developed to examine the effect of reductions in farmer truth-telling. One case has truth-telling represented by a triangular distribution with minimum of 40 percent, most likely value of 50 percent and maximum of 60 percent, while the second case has a minimum of 65 percent, most likely value of 75 percent and maximum of 85 percent.

As farmer truth-telling declined, optimal testing strategies resulted in increased testing. Both cases with lower truth-telling included testing of every 5th unit at the country elevator when receiving in addition to testing at the country and export elevators when loading (Table 10). Rejection rates at the importer increased from 1.75 percent in the base case to 1.91 percent for the lower truth-telling case (Figure 9). Also, the proportion of flows at the importer that were Non-GM declined from 69.6 percent in the base case to 58.0 percent with the lower truth-telling case. Thus, there is greater false rejections in the system as grower truth-telling decreases. Total costs for Non-GM bushels also increased as farmer truth-telling declined. Total costs for the lowest farmer truth-telling were 3.81 cents/bu for Non-GM bushels versus 3.36 cents/bu for the base case.

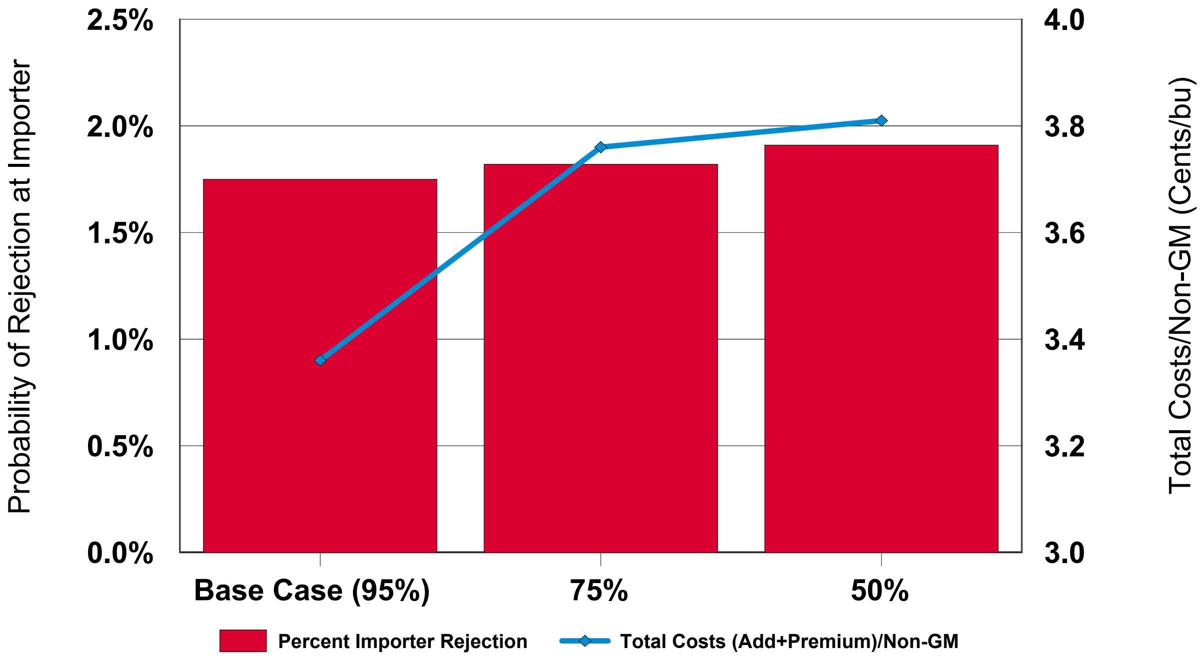

Figure 9. Effect of Grower Truth-telling on Rejection Rates at Importer and Total Costs per Non-GM Bushel.

Table 10. Effect of Farmer Truth-telling

Mean Farmer Truth-telling	Base Case 95%	75%	50%
Utility	1.0097	1.0094	1.0089
Test (1=yes/0=no, Every nth unit)			
Country Elevator Receiving	0-0	1-5	1-5
Country Elevator Loading	1-5	1-5	1-5
Export Elevator Receiving	0-0	0-0	0-0
Export Elevator Loading	1-1	1-1	1-1
Probabilities			
GM in Importer Flows	.02%	.01%	0.01%
Rejection at Importer	1.75%	1.82%	1.91%
Costs			
Additional Costs/All bu	1.39	1.45	1.40
Additional Costs/Non-GM bu	1.99	2.31	2.42
Certainty Equivalent (Premium)	0.96	0.91	0.81
Total (Add + Prem)/All bu	2.35	2.36	2.21
Total (Add + Prem)/ Non-GM bu	3.36	3.76	3.81
Percent of Flows Non-GM by Location			
Adoption Rate	80.0%	80.0%	80.0%
Farmer in Bin	80.0%	80.0%	80.0%
Country Elevator in Store	81.7%	77.7%	77.7%
Country Elevator Loaded on Track	76.8%	71.2%	68.7%
Export Elevator in Store	77.2%	71.8%	68.6%
Export Elevator after Loading	70.8%	64.3%	59.1%
Importer after Test	69.6%	63.1%	58.7%

Choice of Testing Technology

In the base case the type of test was assumed to be a strip test at the country elevator and PCR tests at the export elevator and for importers. This assumption was relaxed and a case developed which in addition to choosing where and how often to test, the model also chooses what test to apply based essentially on the cost and risk. In this case, the choice of test was limited to choice at the country and export elevators. A PCR test was still required by the importer.

The optimal testing strategy when there was a choice of test included testing every 5th unit at the country elevator when loading, every 5th unit at the export elevator when receiving, and every unit at the export elevator when loading (Table 11). At all locations the strip test was chosen, which has a lower cost and test accuracy than the PCR test. This is reflected in a lower proportion of flows in the Non-GM segregation at the importer (65.4 percent) than in the base case (69.6 percent) and a higher rejection rate at the importer (2.08 percent versus 1.75 percent in the base case).

Costs on all measures declined when the choice of test type was allowed. Testing and rejection costs across all bushels declined from 1.39 cents/bu in the base case to 1.23 cents/bu when choice of test was allowed. The risk premium required for decision makers to be indifferent between a dual handling system and a Non-GM system declined from 0.96 cents/bu in the base case to 0.80 cents/bu when the choice of test is allowed. Total costs for Non-GM bushels declined from 3.36 cents/bu in the base case to 3.12 cents/bu when choice of test is allowed.

Table 11. Effect of Choice of Test

	Base Case	Choice of Test
Utility	1.0097	1.0088
Test (1=yes/0=no, Every nth unit)		
Country Elevator Receiving	0-0	0-0
Country Elevator Loading	1-5	1-5
Export Elevator Receiving	0-0	1-5
Export Elevator Loading	1-1	1-1
Probabilities		
GM in Importer Flows	.02%	.01%
Rejection at Importer	1.75%	2.08%
Costs		
Additional Costs/All bu	1.39	1.23
Additional Costs/Non-GM bu	1.99	1.89
Certainty Equivalent (Premium)	0.96	0.80
Total (Add + Prem)/All bu	2.35	2.03
Total (Add + Prem)/ Non-GM bu	3.36	3.12
Percent of Flows Non-GM by Location		
Adoption Rate	80.0%	80.0%
Farmer in Bin	80.0%	80.0%
Country Elevator in Store	81.7%	81.7%
Country Elevator Loaded on Track	76.8%	76.8%
Export Elevator in Store	77.2%	72.0%
Export Elevator after Loading	70.8%	66.7%
Importer after Test	69.6%	65.4%

Effect of Testing Tolerance

Buyers choose the tolerance which in turn defines testing protocols. In the base case a 1 percent tolerance was assumed. It is well recognized that tolerance tightening has the impact of raising costs and prospectively raising risks of not conforming. There are three elements of costs that are critical in evaluating effects of differing tolerance limits. These include testing costs, risk of not conforming, and adventitious commingling in the system. The first two are clear. As tolerance is tightened, testing costs increase and risk of rejections increase.

However, it is not known how adventitious commingling in handling (either through residual grains remaining in handling equipment or through cross-contamination of lots) would be impacted by increasing/decreasing tolerance levels. To approximate for this, we developed two cases. One has a tolerance level of 0.5 percent (50 percent of the base case value) in which we increased the levels of adventitious commingling that would be identified at this tighter specification so parameters of the distribution were twice that in the base case. A second case was developed in which the tolerance level was assumed to be 5 percent. In this case, the parameters for the distributions for adventitious commingling were assumed to be 50 percent of base case levels. These cases illustrate the potential effect of increasing tolerances. However, further empirical research on the effect of tolerances on the level of adventitious commingling is indicated and, as such, results are illustrative but should be viewed with caution. In both cases, alternative tests which achieve these desired tolerance levels and their associated accuracies and costs were utilized rather than the parameters for the base case test accuracies and costs. For the 0.5 percent tolerance level, a strip type test was assumed having a cost of $40/test and accuracy of 99 percent. For the 5 percent tolerance level model, choice of tests was between two strip type tests costing $20/test with one having accuracy of 95 percent and the other 99 percent. Costs and accuracies of these prospective tests were obtained from Giggax.

Results (Table 12) indicate increased testing as tolerance levels tighten from 5 percent to 1 percent (base case). Increasing the tolerance further (0.5 percent) results in testing of every 5th unit, but changes from the country elevator when loading to the export elevator when receiving. The rejection rate at the importer increased as the tolerance became tighter. Rejection for a 5 percent tolerance was 1.07 percent, while at a 0.5 percent tolerance was 3.00 percent (Figure 10).

Costs and risk premiums also increased as tolerances tightened. Tightening the tolerance from 5 percent to 0.5 percent increased testing and rejection costs from 0.63 cents/bu to 1.67 cents/bu for all bushels and from 0.83 cents/bu to 2.60 cents/bu for Non-GM bushels. The risk premium increased from 0.47 cents/bu with a 5 percent tolerance to 1.06 cents/bu with a 0.5 percent tolerance. Total costs for Non-GM bushels increased from 1.45 cents/bu with the 5 percent tolerance to 4.25 cents/bu with a 0.5 percent tolerance (Figure 10).

Table 12. Effect of Tolerances

Tolerance Level	5.0%	Base Case 1.0%	0.5%
Utility	1.0067	1.0097	1.0101
Test (1=yes/0=no, Every nth unit)			
Country Elevator Receiving	0-0	0-0	0-0
Country Elevator Loading	0-0	1-5	0-0
Export Elevator Receiving	0-0	0-0	1-5
Export Elevator Loading	1-1	1-1	1-1
Probabilities			
GM in Importer Flows	.01%	.02%	0.03%
Rejection at Importer	1.07%	1.75%	3.00%
Costs			
Additional Costs/All bu	0.63	1.39	1.67
Additional Costs/Non-GM bu	0.83	1.99	2.60
Certainty Equivalent (Premium)	0.47	0.96	1.06
Total (Add + Prem)/All bu	1.10	2.35	2.73
Total (Add + Prem)/ Non-GM bu	1.45	3.36	4.25
Percent of Flows Non-GM by Location			
Adoption Rate	80.0%	80.0%	80.0%
Farmer in Bin	80.0%	80.0%	80.0%
Country Elevator in Store	81.7%	81.7%	81.7%
Country Elevator Loaded on Track	81.7%	76.8%	81.7%
Export Elevator in Store	82.0%	77.2%	74.0%
Export Elevator after Loading	76.0%	70.8%	66.3%
Importer after Test	75.2%	69.6%	64.3%

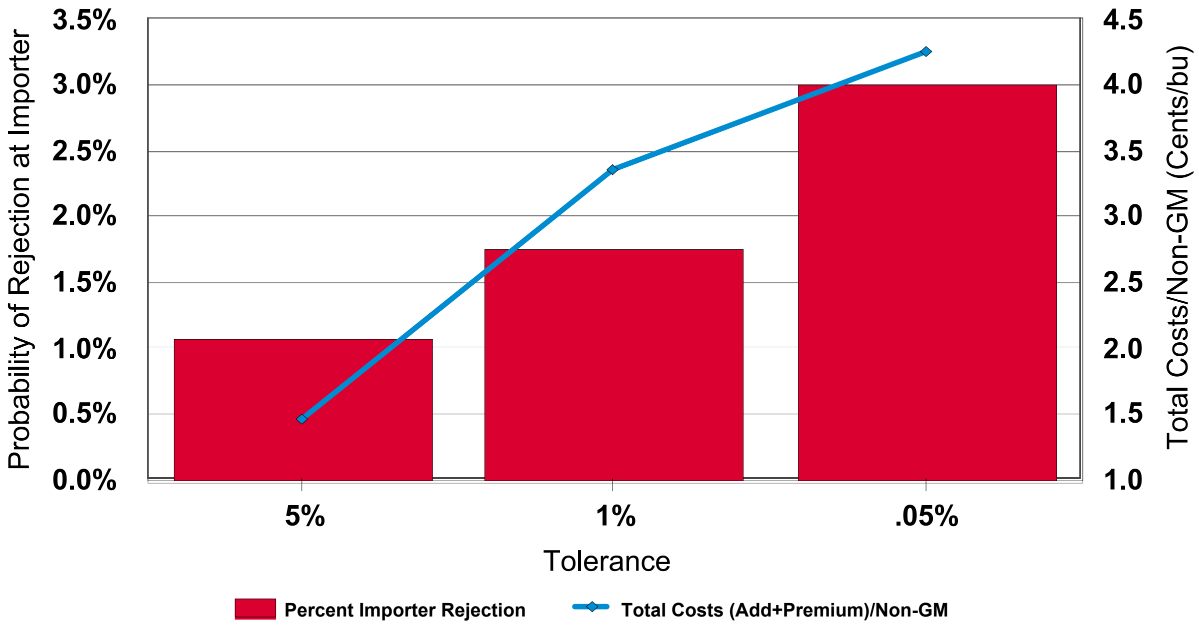

Figure 10. Effect of Tolerance Level on Rejection Rates at Importer and Total Costs per Non-GM Bushel.

Effects on Domestic Versus Import System

The base case examines impacts of testing strategies on a Non-GM/GM system for importers. This type of system involves additional handling, transportation, and subsequent adventitious commingling than that occurring in a system delivering to a domestic market. A model was developed to examine the effects on the domestic market.

Testing plans (whether to test or not and intensity of testing) were allowed to be chosen at the country elevator for receiving and loadout and assumed to utilize a strip test. A PCR test was conducted for every lot received at the domestic user. The optimal testing plan was to test every 5th unit at the country elevator when receiving and every unit loading out (Table 13). Rejection rates at the domestic user were higher (2.24 percent) than for the importer in the base case (1.75 percent) (Figure 11).

Costs on all measures were higher for the domestic user model than for the base case. Costs of testing and rejection across all bushels for the domestic market (3.21 cents/bu) were more than double those for the export market (1.39 cents/bu). This increase is largely due to the additional testing costs required for intensive testing of smaller lots at the domestic user in the domestic model. For example, the cost of testing in the base importer case was .037 cents/bu when loading at the country elevator, .282 cents/bu for testing when loading at the export elevator, and .259 cents/bu for testing at the importer. In contrast, in the domestic model, costs for testing were .153 cents/bu and .177 cents/bu at the country elevator when receiving and loading out, respectively, and 2.698 cents/bu when receiving at the domestic user. The risk premium required for decision makers to be indifferent between a GM/Non-GM system and a

Non-GM system for the domestic market was 2.31 cents/bu, again more than twice the size of the premium for the export market (0.91 cents/bu). Total costs for Non-GM bushels in the domestic market were 7.6 cents/bu, nearly double costs of the base case for the export market.

Table 13. Domestic Market

	Base Case (Export)	Domestic
Utility	1.0097	1.0151
Test (1=yes/0=no, Every nth unit)		
Country Elevator Receiving	0-0	1-5
Country Elevator Loading	1-5	1-1
Export Elevator Receiving	0-0	NA
Export Elevator Loading	1-1	NA
Probabilities		
GM in Importer Flows/Domestic User Flows	.02%	0.02%
Rejection at Importer/Domestic User	1.75%	2.24%
Costs		
Additional Costs/All bu	1.39	3.21
Additional Costs/Non-GM bu	1.99	4.42
Certainty Equivalent (Premium)	0.96	2.31
Total (Add + Prem)/All bu	2.35	5.52
Total (Add + Prem)/ Non-GM bu	3.36	7.60
Percent of Flows Non-GM by Location		
Adoption Rate	80.0%	80.0%
Farmer in Bin	80.0%	80.0%
Country Elevator in Store	81.7%	77.7%
Country Elevator Loaded on Track	76.8%	73.6%
Importer/Domestic User after test	69.6%	72.5%

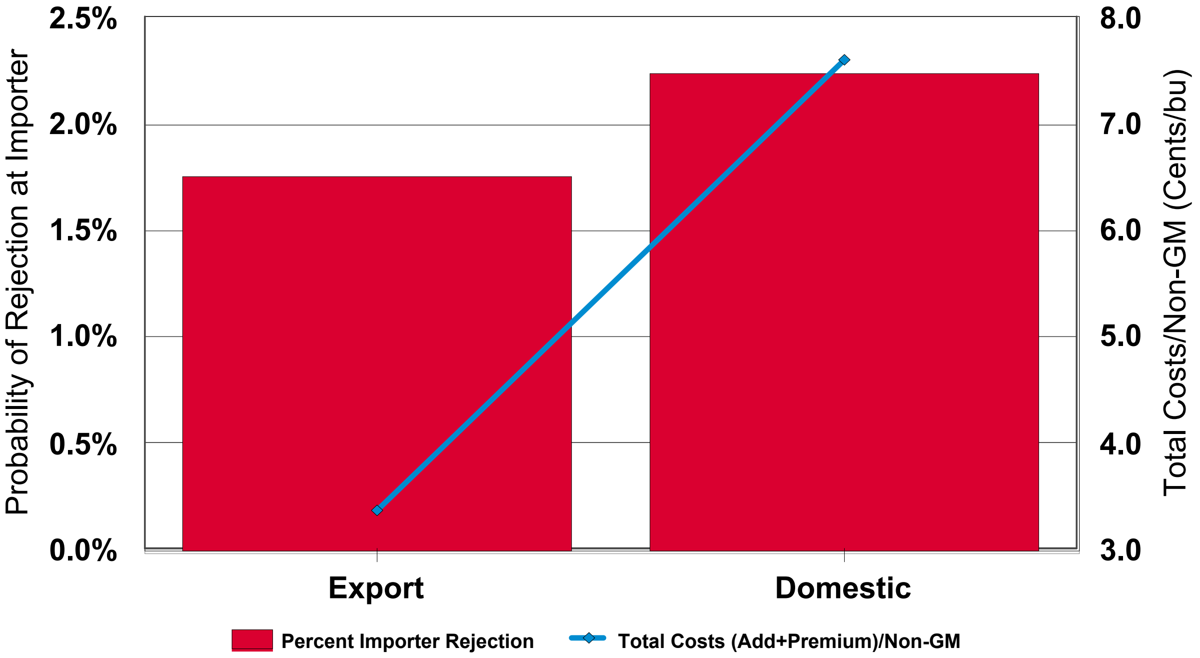

Figure 11. Comparison of Optimal Export and Domestic Market Strategies for Rejection Rates at Importer and Total Costs per Non-GM Bushel.

Summary and Implications

Development and commercialization of genetically modified (GM) crops has challenged the functions and operations of the grain marketing system. While these have already been confronted and (partially) resolved in other grains and oilseeds, none of these issues have been resolved regarding the anticipated commercialization of GM wheats. While the focus of the GM debate currently in North America is on the *Round-up Ready*® wheat trait, there is extensive research suggesting that other traits will be similarly proposed in the coming years. The purpose of this paper is to determine the optimal testing strategy and to quantify the costs and risks of the system.

Problem

Pressures for adopting GM wheat, specifically RRW, come from a combination of cost reduction, reduced dockage, increased profitability of competing crops (being recipients of GM technology), and the prospect of 2nd and 3rd phase benefits associated with GM wheats. Virtually all of the major stakeholder groups have taken positions essentially pointing to the desirability of GM wheats, conditional upon developing a system involving IP and testing to satisfy needs of buyers. In addition, in this case the technology developer has indicated not commercializing the trait until such a system is adopted. Beyond these positions, the asynchronous regulations and indigenous differentiated demands resulting in buyer resistance ultimately suggest that some type of dual marketing system will need to evolve to facilitate coexistence. Ultimately, this will likely be a system in which buyers specify limits or a tolerance on GM content measured using some type of prescribed test. Then, testing would be adopted at varying points in the marketing system to facilitate segregation and assure contract conformance. Given that testing and segregation entail costs and risks, there is a fundamental tradeoff confronting shippers and buyers. In light of this, there are important operational questions such as the optimal location to test, how intense, the test type, and how numerous factors impact these strategies.

Analytical Model

A stochastic optimization model was developed of the export and domestic marketing system. All the elements of the system, including costs and risks, were included in the model. Of particular importance were the costs and risks at each node of the system, as well as the risk imputed upon the shipper. Specifically, we had a focus on the risk premium necessary to induce a shipper to handle Non-GM wheat and to be exposed to the risks and penalties of being out of contract.

The model was posed as the utility for a portfolio representing additional testing and rejection costs of a combined Non-GM/GM system. The results indicated the optimal testing strategies for supplying export and domestic markets and provided an estimate of the additional risk premium required for decision makers to be indifferent to the Non-GM/GM system and a Non-GM system. A model was developed for the export market and sensitivities conducted to evaluate impacts of risk attitudes, variety declaration, levels of rejection costs, GM adoption rates, grower truth-telling, and tolerances. A second model was developed for the domestic market to evaluate differences between optimal testing strategies and costs for export and domestic markets. Sensitivities of all the critical variables were conducted.

Major Conclusions

The base case was defined to represent a likely set of situations. Important amongst these were: GM adoption by growers in a region was 20 percent; growers declared GM content at delivery, subject to some uncertainty; and testing was allowed at varying intensities and locations throughout the system. Alternative testing technologies were also included, as well as penalties for being out of contract.

Results indicated the optimal testing strategy was to test every 5th unit at the country elevator when loading and every unit loading at the export elevator. This results in additional costs of testing and rejection for Non-GM bushels of 1.99 cents/bu. Adding the risk premium increased total costs per Non-GM bushel to 3.36 cents/bu. The risk premium in this case was 0.96 cents/bu which is interpreted as the implicit cost accrued by the shipper to be indifferent between a handling system involving Non-GM and GM wheat, versus the current Non-GM system. The testing strategy would result in minimal GM content at the import market, and only 1.75 percent of the shipments would be rejected.

Several factors were examined using sensitivity analysis. Dropping variety declaration at the country elevator increased the intensity of the optimal testing plan, increased costs and premiums, and resulted in a higher proportion of Non-GM flows being diverted to GM within the marketing chain. Increasing the risk aversion of the decision maker increased the risk premium required, but resulted in the same optimal testing strategy. Decreasing the risk aversion resulted in more testing, a higher proportion of flows being diverted to GM, a lower risk premium, and lower total system costs. Decreasing the cost of rejection at the importer reduced the intensity of testing, increased rejection rates to 7.9 percent at the importer, and lowered costs and the risk premium. Adding additional costs at interior loading points representing additional handling charges increased the intensity of testing, test costs, and the risk premium, while lowering the proportion of flows diverted from Non-GM to GM within the system.

Changes in prospective tolerance levels of tests for adventitious commingling indicated changes in optimal testing strategies as tolerances tightened. More testing was required for tighter tolerances, and tests were shifted from the country elevator when loading to the export elevator when receiving as tolerances tightened from 1 percent to 0.5 percent. Costs, premiums, rejection rates, and the proportion of flows diverted to GM within the system increased as tolerances tightened. Total costs including the risk premium increased from 1.45 cents/bu with a 5 percent tolerance to 4.25 cents/bu with a 0.5 percent tolerance. While the results for tolerance are illustrative, more research would be useful on the effects of tolerance tightening on adventitious commingling, rejection rates, and their effects.

The optimal testing strategy for the domestic market had higher rejection rates, costs, and risk premiums than did the export market. Additional costs, when measured over all bushels or over Non-GM bushels and risk premiums, were about double those for the export market. These were higher for the domestic market largely due to increased testing costs arising from smaller lot sizes for domestic users (railcars) versus importers (ship holds).

Implications

There are several implications from these results. First, a system based on testing and segregation can very efficiently assure buyers of GM content at a quite low cost. While nil tolerance cannot be achieved through a system based on testing, the GM content can reasonably be assured at levels of .5 percent and 1 percent. Second, the cost of a system based on optimal testing and segregation inclusive of a risk premium are much less than most systems that have been proposed on IP and other means to control GM content. Third, there are many factors that will affect the elements of an optimal testing system, costs, and risks. Most important amongst these include price discounts/costs for being out of contract and GM declaration at delivery. Fourth, strict interpretation of the risk premium would indicate that this is the premium required for grain handlers to be indifferent between a dual system of Non-GM and GM or the current Non-GM system. In order for Non-GM to gain a premium, sellers will have to provide proof that it is in fact Non-GM, buyers must be willing to pay this cost and, eventually through competition, price differentials will emerge to approximately reflect these costs. Fifth, an IP system to resolve marketing of GM would be much more elaborate in terms of monitoring, administration, etc., than a system involving tolerances and testing, and, as a result, would be much more costly.

Finally, these results are suggestive of some mitigation strategies that could be adopted in the wheat marketing system. Ultimately, the purpose of these would be to facilitate conditioning of probabilities assumed in this study and would involve a number of contract type mechanisms necessary to control the costs and risks in the system. These risks are summarized in Table 14. The most crucial elements of the system would be: declaration of GM content at delivery, testing for GM throughout the Non-GM system, buyers' aversion to GM, contract specifications for some tolerance level, and the test(s) adopted.

Table 14. Risks and Mitigating Strategies for Introducing/Marketing GM Wheat

Risk Factor	***Mitigation Strategy***
Breeding, seed production contamination	Breeding protocols
Volunteers	Contract requirements about sequential planting
Pollen Drift	Buffer requirements in planting
On-Farm Risks	Grower education, contract terms, monitoring
Farmer Accountability (truth-telling or retention/leakage)	Contract terms/obligations, incentives
Handling (receiving, segregating, loading, and transport)	Variety declaration, testing, car tagging, and other protocols
Testing/Accuracy	Protocols requiring testing at some (though selected) points; frequency/intensity of testing. Not important for known RRW shipments

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