THE LOGISTICAL COSTS OF MARKETING IDENTITY PRESERVED GM WHEAT

William Wilson and Bruce Dahl
North Dakota State University

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ABSTRACT

Development of genetically modified crops is challenging the functions of the grain marketing system. A stochastic optimization model was developed in this study 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 dual marketing of GM/Non-GM segregations over a Non-GM system. Cost elements include testing, rejection, and risk premium and were estimated for a grain export chain. The model includes elements of costs and risks within the marketing chain including that of adventitious commingling at all stages of the marketing chain, variety declaration, grower truth-telling and accuracy of testing technologies. Sensitivities were evaluated for effects of GM adoption, risk parameters, variety declaration and tolerance levels.

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

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 wheat is more elongated for numerous reasons.[1] In contrast to the other grains and oilseeds, commercialization of GM wheat 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 for GM content, efficient marketing of GM wheat will require protocols for contract limits, testing, and segregation.

Implicit in these insinuations are that some buyers, for varying reasons including regulations and product marketing, may choose to limit the GM content 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. 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, of which there are several technologies and varying accuracies, involves costs and risks to both buyers and sellers. For buyers, there is risk in that GM wheat varieties would be commingled and detected in shipments that have limits on GM content. For sellers, there is a risk of a shipment being rejected that shouldn't. 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 include 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 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. 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.

GM Wheat

There are several initiatives for the development of GM wheat. In North America these have been primarily on the *Round-up Ready*[7] wheat trait, though there is extensive research elsewhere on a wide range of GM wheat traits (e.g., fusarium resistance by Syngenta, drought resistance by Dupont, and varying forms of end-use trait enhancement are being developed). Virtually all development in North America is currently on Hard Red Spring (HRS) wheat.

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 trait is approved in Japan, wheat 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), 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, EU ministers agreed to a plan requiring labeling of food as GM if 0.9% of ingredients are GM (down from 1%) and 0.5% tolerance on GM material that is "unavoidable present", but also declared safe by EU scientific advisors or the European Food Safety Authority (Elliott). 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.

All of the important stakeholder groups have positions about the commercialization of GM wheat. 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 wheat are desirable, mostly looking to 2nd stage benefits; research on biotechnology wheat should continue; but, GM wheat (particularly RRW) should not be commercialized until systems involving IP and testing are developed to satisfy needs of buyers.

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 would exist internationally between countries with and without tolerance limits, and/or other requirements for the traits, and those with approved traits. 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.[2] 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.

Elements of a Dual Marketing System and Sources of Risks

Definitions of what constitutes an Identity Preserved (IP) system typically focus on documentation and verification of the process of segregating flows (Dye; Strayer; Wilcke; Buckwell, Brookes and Bradley; Lin, Chambers and Harwood; Sonka, Schroeder and Cunningham; and Bean; among others). The economics of IP and segregation have been studied extensively in a growing body of literature (Bullock, Desquilbet, and Nitsi; Dahl and Wilson; Directorate General, Commission for the European Community; Hermann Boland and Heishman; Kennet, Molder and Fulton; Hurburgh et al.; Lentz and Akridge; Maltsbarger and Kalaitzandonakes; McPhee and Bourget; Smyth and Phillips; Sparks Company; and Wheeler).

IP and traceability would provide process verification and retain segregations, yet may or may not contain testing protocols and tolerances. 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 was included, and contracts used appropriately, then IP and traceability systems would be unnecessary.

An alternative to a regulated system is dual marketing channels. 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. 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.

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 following years.[3]

Pollen drift, in the case of self-pollinated GM wheat, is relatively modest compared to cross pollinated crops like corn. Previous studies for wheat have suggested that the rate of out crossing 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 out crossing varies by variety with Oslo and Roblin having higher out crossing rates which may require isolation strips larger than for low-out crossing 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 marketing function, there is added risk of handling GM grains due to the possibility of adventitious commingling. A recent 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 0.002) (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.

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, Tolerance, and Trade Practices

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 already known to be GM. Thus, testing would only occur for those shipments that are thought to be Non-GM. 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.

End-users and buyers express their demand and aversion to GM in contracts with tolerances. This is critical. Ultimately, it is incumbent on buyers wanting to limit GM content in Non-GM shipments, for whatever reason (commercial or regulatory), to specify limits in their purchase contracts. Those not averse to GM would not. For others, restrictions could be implemented in existing contract forms and in a way similar to other factor limits. 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.

A second component is that 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.

EMPIRICAL MODEL

A model of grain flows reflecting the structure of a dual system with testing and segregation of GM/Non-GM flows from growers to importers was developed. The model assumes adventitious commingling occurs throughout the grain marketing chain with given probability distributions. A level of GM/Non-GM adoption by farmers is assumed and farmers may or 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 to detect a level of GM content. In practice this would be interpreted as a contract violation and subject to 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 contract. We estimate the value of this risk premium (p) as the expected costs for a Non-GM system (EV_{NGM}) less the certainty equivalent ($CE_{GM/NGM}$) of the utility of additional costs of a system containing both GM and Non-GM segregations and include it in our cost function.

(1)
$$p = EV_{NGM} - CE_{GM/NGM}$$

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

Model specification

The model is a stochastic optimization model of a grain marketing chain and uses an objective function to quantify a risk premium (Saha). 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:

(2)

s.a. $\mathbf{X_j}$?$\mathbf{K_j}$

where:

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

This model is flexible and allows for changes in both absolute and relative risk aversion.

It 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 ?, f, and ?. A value of ? = 2 in the objective function above allows for a positive utility function. The parameters f and ? affect absolute and relative risk aversion. Increasing the risk parameter f while holding ? constant increases the absolute risk aversion, but does not affect the optimal solution. Increasing ? while holding f constant increases relative risk aversion and its effect on the objective function is larger than that for f. Thus, we followed Serrao and Coelho and fixed values for ? and f and sensitivities were conducted for ?.

The risk premium is derived from the expected value of the system of GM and Non-GM segregations as follows:

(3)

Where

(4)

and p is the risk premium for the GM/Non-GM system, EV_{NGM} is the expected additional costs of a NonGM only system (assumed nil), is the certainty equivalent of additional system costs for a dual GM/NonGM system, and other parameters are as previously defined. The risk premium is interpreted as the additional revenue necessary for decision makers to be indifferent between a system handling both GM and Non-GM segregations and a 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:

(5) , and

(6) $$C_{GM} = 0$$

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),
- $\mathbf{T_k}$ is cost of individual test applied at location k,
- $\mathbf{S_k}$ is sampling intensity at location k,
- $\mathbf{V_{NGMk}}$ is volume (number of lots) of Non-GM handled at location k,
- $\mathbf{D_k}$ is discount or penalty applied to grain diverted from Non-GM to GM flows at location k, and

$\mathbf{V_{DGMk}}$ 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 the flow of segregations throughout the system, and derives statistical properties on the proportion of shipments with GM exceeding specifications in end-use flows.[4]

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 in the grain handling system utilizing a hypergeometric distribution.[5] 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 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 is 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 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 several 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.

Information on these was from other published research, a survey of market participants, and/or industry judgment and was supplemented by information contained in recent studies on adventitious commingling (Table 1). 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. To get some judgment 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. There are several elements 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. 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. Thus, these likely reflect a worst case scenario.

The risk aversion parameter values for ? and f were assumed to be 2 and .01, respectively (following Serrao and Coelho). For the risk parameter, ?, 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.

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

RESULTS

Results from the base case 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.

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 ? = .5; and finally, no additional costs of segregation were included.[6] 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. 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 and an average of .02 percent of importer flows had GM content greater than tolerances. This .02 percent represents the buyers risk of accepting quality that doesn't=t meet tolerances.

The proportion of flows in the Non-GM channel declined from 80 percent at the farm level to an average of 70 percent at the importer. Thus, on average, 10 percent of Non-GM shipments are diverted to the GM segregation throughout the handling system. 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 illustrates to a large extent the seller's risk of having shipments rejected throughout the system. Most of the diversions occur after unloading at the export elevator and are due to adventitious commingling which occurs in the system, through effects due to test accuracy and large samples containing units with both adventitious commingling and Non-GM which are represented by a single test.

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. 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.

Additional system costs for testing and discounts for rejection at the importer in the base case were 1.4 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.

Variety Declaration and Testing

In the base case, mechanisms are used to elicit information from growers on the GM content of their grains. 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, first handlers would have greater uncertainty upon receipt, which in turn would 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.

In this case, the optimal testing strategy included testing of every 5th unit at the country elevator, both when receiving grain and loading railcars; and testing every 5th railcar when received at the export elevator and every hold when loaded at the export elevator. Rejection rates at the importer increased from 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 31 percent of flows were identified as Non-GM. Thus, a system with no variety declaration results in significant misgrading and diversion of flows from Non-GM to the GM segregation (i.e. the sellers risk is high). 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.

A case was also developed where testing and variety declaration did not occur. 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 percent, 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).

Effect of Risk Parameter (?)

The risk parameter, ?, would likely vary across handling firms, some more and some less willing to assume risks. To illustrate these we conducted sensitivities for the base case with more/less risk aversion. Two cases, ? = .9 (more risk averse) and ? =.1 (less risk averse) were developed and optimal solutions derived and compared to results from the base case (?=.5). 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 by 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 1). 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, ?, 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 ?=.9, the risk premium was 1.3 cents/bu, but declined to only 0.04 cents/bu when

?=.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.

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 1).

Effect of Price Differentials (Discounts)

In the base case, discounts were applied which represent 10 percent of the value of wheat and added logistical costs 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).

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 3). Higher penalties resulted in the same optimal testing strategy as the base case.

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 (Table 3).

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 [80,95,and 100]. To examine the effect of reductions in farmer truth-telling we changed the triangular distribution [40, 50, and 60].

As farmer truth-telling declined, optimal 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. Rejection rates at the importer increased from 1.75 percent in the base case to 1.91 percent for the lower truth-telling case. Also, the proportion of flows at the importer that were Non-GM declined from 70 percent in the base case to 58 percent with the lower truth-telling case. Thus, there are 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.

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 wheat. 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 wheat, 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.

A stochastic optimization model was developed of the export and domestic marketing system. Elements of the system, including costs and risks, were included at each node of the system. We focused on the risk premium necessary to induce a shipper to handle Non-GM wheat and 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. Sensitivities were conducted to evaluate impacts of risk aversion, variety declaration, levels of rejection costs, and grower truth-telling.

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.

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, 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. Fourth, 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. Fifth, 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.

FOOTNOTES

1. We use the term GM wheat throughout this paper to be general and recognize that several traits may be adopted. At the forefront is *Round-Up Ready*7 wheat (RRW), but others including fusarium resistant (Syngenta), drought resistant (DuPont), and varying forms of end-use trait enhancement are being developed.
2. 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.
3. An average infestation rate of 9 plants/sq. meter equals 36,434 plants/acre. Converting this to a seed equivalent at 14,000 seeds/lb., would require 2.6 lbs. or 0.04 bu to generate 36,434 plants/acre. At 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.
4. System costs excludes other costs for IP verification which would be highly autonomous and not affect the results.
5. 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).
6. 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.

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Table 1. 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	Survey
Handlers	Triangular	0.95	0.99	1.00	Survey
Testing		Cost	Accuracy		Test Type
Country Elevator		$7.50/Test	0.95		Strip Tests
Export Elevator		$120/Test	0.99		PCR

Table 2. 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 n^{th} 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
Buyers Risk of Flows Exceeding GM Tol.	.02%	.01%	0.10%
Rejection at Importer	1.75%	2.34%	10.10%
Percent of Flows Non-GM by Location			
Adoption Rate	80%	80%	80%
Country Elevator in Store	82%	78%	82%
Country Elevator Loaded on Track	77%	51%	82%
Export Elevator in Store	77%	39%	82%
Export Elevator after Loading	71%	31%	82%
Importer after Test	70%	31%	74%
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

Table 3. Sensitivity to Alternative Rejection Penalties

Penalty	0-10 c/bu	Base Case 40-90 c/bu	100-150 c/bu
Utility	1.0063	1.0097	1.012
Test (1=yes/0=no, Every nth unit)			
Country Elevator Receiving	0-0	0-0	0-0
Country Elevator Loading	1-5	1-5	1-5
Export Elevator Receiving	0-0	0-0	0-0
Export Elevator Loading	1-5	1-1	1-1
Buyers Risk of Flows Exceeding GM Tol.	.08%	.02%	.02%
Rejection at Importer	7.87%	1.75%	1.75%
Percent of Flows Non-GM by Location			
Adoption Rate	80%	80%	80%
Country Elevator in Store	82%	82%	82%
Country Elevator Loaded on Track	77%	77%	77%
Export Elevator in Store	77%	77%	77%
Export Elevator after Loading	71%	71%	71%
Importer after Test	65%	70%	70%
Costs			
Additional Costs/All bu	0.63	1.39	2.13
Additional Costs/Non-GM bu	0.97	1.99	3.07
Certainty Equivalent (Premium)	0.41	0.96	1.47
Total (Add + Prem)/All bu	1.04	2.35	3.60
Total (Add + Prem)/ Non-GM bu	1.60	3.36	5.19