Agribusiness & Applied Economics Report No. 564 June 2005

COSTS AND RISKS OF CONFORMING TO EU TRACEABILITY REQUIREMENTS: THE CASE OF HARD RED SPRING WHEAT

William W. Wilson

Xavier Henry

Bruce L. Dahl

Department of Agribusiness and Applied Economics
Agricultural Experiment Station
North Dakota State University
Fargo, ND 58105-5636

ACKNOWLEDGMENTS

This project was completed with funding assistance for a project titled 'Traceability and Variety Marketing Strategies for Hard Red Spring Wheat', funded by the North Dakota State Board of Agricultural Research and Education (SBARE) and the North Dakota Wheat Commission, and the Center of Excellence for Agbiotechnology at North Dakota State University. Thanks go to our colleagues George Flaskerud, Cheryl Wachenheim and William Nganje for their comments, although errors and omissions remain the responsibility of the authors. Thanks also to Carol Jensen and Joan Peterson who aided in document preparation.

We would be happy to provide a single copy of this publication free of charge. You can address your inquiry to Carol Jensen, Department of Agribusiness and Applied Economics, North Dakota State University, PO Box 5636, Fargo, ND 58105-5636, (Ph. 701-231-7441, Fax 701- 231-7400). (e-mail; cjensen@ndsuext.nodak.edu) or obtain a copy electronically from our web site: http://agecon.lib.umn.edu/.

NDSU is an equal opportunity employer.

NOTICE:

Information on other titles in this series may be obtained from: Department of Agribusiness and Applied Economics, North Dakota State University, P.O. Box 5636, Fargo, ND 58105. Telephone: 701-231-7441, Fax: 701-231-7400, or e-mail: Carol.Jensen@ndsu.edu.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Stochastic simulation was used to determine the marginal cost and optimal testing strategy (location and intensity) for an integrator conforming to proposed European Union traceability requirements for imported hard red spring wheat. Cost, risks and premiums were determined for exports of non-genetically modified (non-GM) wheat from the U.S. to the EU. Cost components include certified seed, certification and auditing, testing, traceability, quality loss, and a risk premium for the added risk of a dual traceability system over a single non-traceability system. The optimal strategy is the one that maximizes the integrator's utility (minimizes disutility of integrator's additional costs). Adventitious commingling is defined stochastically. Results indicate that traceability requirements can be met with specified buyer and seller risk at a total cost of approximately 50 c/non-GM bushel. The risk premium for traceability along the vertically-integrated supply chain (farmer, integrator, and importer) is 21 c/non-GM bushel.

Key Words: traceability, genetically modified, hard red spring wheat, European Union requirements

COSTS AND RISKS OF CONFORMING TO EU TRACEABILITY REQUIREMENTS: THE CASE OF HARD RED SPRING WHEAT

William W. Wilson, Xavier Henry, and Bruce L. Dahl[*]

INTRODUCTION

Genetically Modified (GM) varieties are an integral part of the current production and marketing systems in many exporting countries including the United States, Argentina, Canada, China and Brazil for soybeans, cotton, corn, and canola (Fresco, 2001). In Argentina, 90 percent of the soybeans are from biotech varieties; the savings generated by the herbicide-tolerant and environmental preoccupations (fewer chemicals) motivate producers (Schnepf, Dohlman & Bolling, 2001). In the United States, GM production is common. About 97% of the world's genetically modified production originates from the United States (Seralini, 2002). Governments have adopted different policies to manage Genetically Modified Organisms (GMO's) throughout the world.

In 1997, the EU adopted a moratorium for ten years against marketing GMO's. This moratorium is a form of protectionism and came into effect in 1999 with the ratification of seven country-members and was designed to allow the EU time to develop a strong legal and political position. Five years later, no scientific proof had been advanced showing the danger or the offensiveness of the genetic manipulation on human health (Agence Science-Presse, 1999). Government positions are still a political expression of European consumers who reject GM food because of perceived risks for human health.

The EU has since adopted legislation that allows grain from countries using GM seed under restrictive conditions. These measures of control and regulation for GM products include testing, tolerance, shipping and segregation strategies. The EU requires the labeling of products containing more than 0.9% of GM material, and requires traceability. Conforming to these traceability requirements has the effect of adding costs and risks to suppliers.

The objectives of this paper are to document the evolution of traceability, identify the optimal strategy for non-GM wheat conforming to EU requirements and measure the costs and risks for an integrator[1] exporting non-GM hard red spring (HRS) wheat to Europe. A stochastic simulation model which jointly determines optimal test application and intensity is developed to

---

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

[1] Following Sheldon (1996), an integrator is interpreted here as a vertically integrated firm in the handling system that contracts with farmers to produce non-GM wheat, provides inputs and pays the additional costs compared to GM production.

compare costs and risks for an integrator, contracting with farmers and an importer, conforming to EU traceability requirements. The integrator contracts with the farmer and provides inputs for non-GM wheat production. To reduce his risk due to the EU traceability requirements, the integrator defines a testing strategy including where and how many tests to perform. Effects of critical factors including testing costs, and tolerance considerations are examined in order to define the optimal testing strategies for GM wheat.

The next section describes traceability and its application in the European market, and discusses previous studies on the economics of traceability. An analytical model of integrator costs and risks is defined in the next section including variables related to the European market, testing and segregation strategies allowing American grain to come into the market.

BACKGROUND

Traceability

Traceability is defined as "the degree to which a relationship can be established between two or more products of the development process" (Institute of Electrical and Electronic Engineers, 1990). The standard NF EN ISO 8402 was the first technical definition of the concept in 1987. It was defined as: "the ability to retrace history, use or location of an entity by the means of recorded identification." Consequently, the term traceability may refer to the origin of materials and parts; the history of processes applied to the product; or the distribution and placement of the product after delivery (GENCOD-EAN, France. 2001). Coordination between agents is a key concept of traceability.

Traceability was first used in order to improve industries' efficiency. Recent crises like Bovine Spongiform Encephalopathy (BSE), foot-and-mouth disease, and dioxin contamination have alerted consumers and traceability has been extended to secure and restore consumer's confidence in the food production system. Traceability is a set of practices used to inform agents and end-users about the product. Introduction of GMOs provides a new rationale for traceability. Traceability applied to GM management is the ability to trace GMOs and products produced from GMOs at all stages of their movement through the production and distribution chains (European Parliament, 2003).

In 2004, a directive opened the European market to grains from countries growing GM materials. The EU retains traceability as the main way to secure the supply channel and provide confidence to consumers. Traceability of domestic production and imports became obligatory with European directive 2001/95 which came into force on January 1, 2005. The evolution of GM legislation and traceability in the EU is summarized in Figure 1.

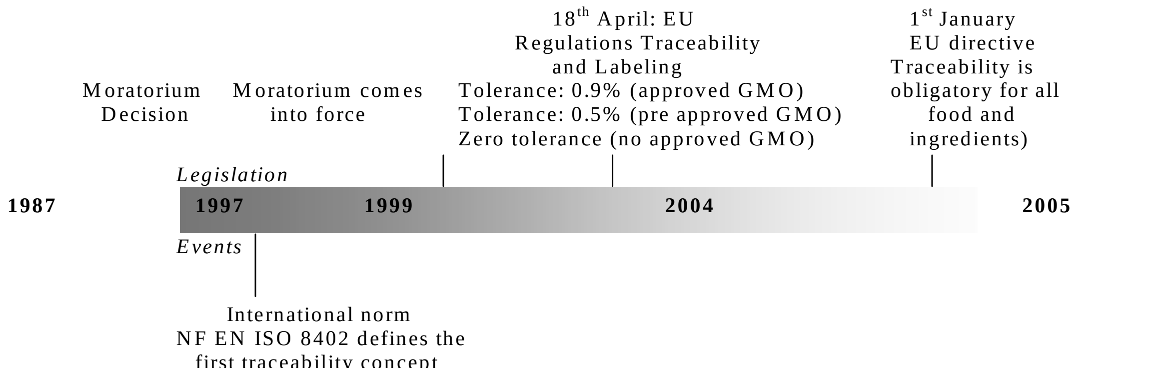

Figure 1. Evolution of GM Legislation and Traceability in the EU.

A traceability system must protect the identity of the product and be able to define liability if the security program fails in the supply chain. It is a process resulting in risk sharing between agents. To reduce risks, firms use quality control programs to protect the original characteristic of the product.

Kimmelshue indicated: traceability requirements of regulations are generally considered to be a means to restore consumer confidence in what is perceived to be a "broken food system," (as cited in *Milling and Baking News*, 2004*).* As the speed and presence of regulations picks up pace and consumers become more cognizant of changes to the food supply, the role of product traceability should continue to expand. Regulations increasingly are aimed at reacting more quickly to natural or intentional food contamination. (*Milling and Baking News*, 2004). The market advantage of a comprehensive, certified practice gives a food producer a competitive advantage to maintain and expand its market share (Fagan, 2004).

Identity Preservation (IP) is a complimentary system of crop management and trade, which allows the source, and/or nature of materials to be identified. IP is currently used to identify crop varieties that provide features concerning their content or composition. This system is common in the United States and could be used as the first step for traceability. Also called Identity Preserved Production and Marketing (IPPM), IP has evolved over time in the grain and oilseed industry. IP measures are initiated by private firms to extract premiums from a marketplace that has expressed a willingness to pay for an identifiable and marketable product trait or feature (Smyth and Phillips, 2002). There is a fundamental difference between segregation and IP as components of strategies to market GM crops. Segregation is the isolation of like products with particular attributes. Unlike IP, the identity of the grain is not preserved. Segregation is common in many grains and is evolving in response to the dichotomy on international market acceptance of GM crops (Wilson, Jabs, and Dahl, 2003). Segregation, traceability, and IP are product differentiation alternatives.

Application to Intra European Trade and Marketing

Traceability is not only applied to GM products, but also to non-GM products in the EU. This control system may be applied to all animal, vegetal or non-living production. General traceability provisions are in Community legislation concerning food, feed and more specifically a traceability for beef products following the recent BSE crisis with regulation in 2000,[2] which established a system for the identification and registration of bovine animals. The concept of traceability for GMOs was introduced into Community legislation for the first time in a directive in 2001[3]. Traceability applied to GMOs traces GMOs and products produced from GMOs at all market stages through production and distribution chains (European Parliament, 2003).

GMOs can only be introduced into the EU market after having been authorized. The authorization process is influenced by consumers, Non-Governmental Organizations (NGOs), producers, and retailers. Consumer groups, through NGO's activities, are very influential. GM products are officially accepted in the Union under authorization conditions. If in practice, GMOs are admitted in the market, few are accepted. The difficulties show the high degree of restrictions and constraints induced by this new legislature. The consumers' opportunity to choose between GM and non-GM products is important for the European Commission. With this view, Member States are required to ensure labeling and traceability of GMOs at all stages of production and distribution chains.

The EU defines three management schemas for GM content in the production stage (Directorate-General for Agriculture European Commission, 2002):

- <u>Voluntary IP of specific GM traits (quality traits)</u>: Commercialization of GM products in the EU market is very restricted. In addition to the labeling requirements under the novel food regulation, the identity of the product would be protected to preserve the additional value or quality given the genetic modification, and for which the consumer is willing to pay more.

- <u>Compulsory IP for GM products (input traits)</u>: This kind of behavior characterizes GM production. In this case, traceability could be a strategy to monitor the environmental and health effects of GMOs and to satisfy the GM product demand. This behavior requires testing to define the quantity of GM material.

- <u>Voluntary IP of GMO-free products</u>: This approach is used to track and label products. Current legislation requires compulsory labeling for food containing GMOs, but the introduction of food labeled as GMO-free would restore consumer confidence in the

---

[2] Regulation (EC) No 1760/2000.

[3] Directive 2001/18/EC.

production chain. Legislation to monitor this behavior is being prepared. Defining rules for traceability is one of the objectives of this document.

Objectives proposed by the Commission of the European Communities (2003b) for traceability were: 1) to allow for the withdrawal of products due to risks to human health, 2) to monitor potential environmental effects and 3) to facilitate accurate labeling. Three important requirements compose the base of this traceability. First, operators shall have in place systems and procedures to identify to whom and from whom products are made available (one step back and one step forward). Second, operators shall transmit specified information concerning the identity of a product in terms of the individual GMOs it contains or whether it is produced from GMOs. Third, operators shall retain specified information for a period of five years and make it available to competent authorities on demand (Commission of the European Communities, 2003b).

Two approaches were considered (European Parliament, 2001): the traceability and labeling for GMOs and traceability and labeling for products from GMOs. The distinction between GMOs and products from GMOs is important. According to the EU, produced from GMOs means, in whole or in part, from GMOs, but not containing or consisting of GMOs. GMOs means "an organism, with the exception of human beings, in which the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination" (European Parliament, 2001).

The first step in traceability for GMOs is identification. In order to specify the identities of GMOs, the European Directive refers to a system to be designed, using the appropriate committee procedure, for the assignment of a unique identifier (code) to GMOs. The European Parliament defines GMOs using "a simple numeric or alphanumeric code which serves to identify a GMO on the basis of the authorized transformation event from which it was developed and providing the means to retrieve specific information pertinent to that GMO" (Commission of the European Communities, 2003a; Kauffman, 2005). Operators are obliged to transmit to the next agent in the chain the information, including unique codes, specified for that initial assignment. The effectiveness of traceability requires that the identity of GMOs contained within a product be established at its first stage of market placement within the production or distribution chain. This should not present an undue problem for products that originate from within Community.

The proposal requires that operators placing prepackaged products consisting of, or containing GMOs on the market, at any stage of the production and distribution chain, have to ensure that such products are labeled with the words "This product contains genetically modified organisms." Where products, including bulk quantities that are not packaged make the use of a label impossible, operators have to ensure that this information is transmitted with the product to the next operator. Operators shall ensure that the following information is transmitted to the next operators:[4] 1) Contains or consists of GMOs, and 2) The unique identifier assigned to those GMOs, in the case that a mixture of GMOs compounds the product, the operators shall ensure the transmission of the list of unique identifiers for all those GMOs. The operators have to hold information for a period of five years.

The distinction between GM and GM-free is important as it is parallel to the concept of purity. That's why the EU established a tolerance level equal to 0.9%. If GM is found in a proportion less than 0.9%, provided that these traces are adventitious or technically unavoidable, the product is not labeled genetically modified. The threshold of 0.9% provoked many reactions. GM advocates consider this limit too constraining in terms of technical handling and economic costs. GM opponents protested against this threshold because it results in a non-labeling of products potentially with GM materials (in a proportion less than 0.9%).

All measures of 'safe' production, segregation and traceability involve additional costs. Nevertheless, vertical coordination facilitates long-term relationships. The risk of product rejection is reduced with increased access to information. The amount of information about product quality affects the degree of perceived risk. Traceability is one solution to increase vertical coordination and enhance information flows. Vertical coordination channels and traceability should facilitate long-term relationships and reduce transaction-costs or at least offset the additional costs of these techniques. To reduce transaction costs, long-term supply relationships and contracts should be able to offset additional expenditures.

Rules for External Trade

Identification of GMOs at the first stage it is introduced to the marketing system is the first step for efficient traceability. This should not be problematic when products originated from within the European Community because all Members States agreed on the policy adopted. Application of proposed rules for external trade is more complex. Identification at its first stage of the placing on the market would imply an identification of GM materials in the extra-community country. Operators importing such shipments into the Community have to specify the identity of these products, namely in terms of the GMOs that they contain. If the exporter has a lack of information about the genetic identity, the importer would have to determine it by sampling and testing. After identification, operators would be obliged to transmit to the next operator in the chain the information, the unique code identifying the GM content (European Parliament, 2003).

---

[4] Produced from GMs means derived, in whole or in part, from GMOs, but not containing or consisting GMOs. This restriction is highly criticized by consumer association because they are not informed about the specialty (GM or non-GM) of grain use to feed the livestock.

Previous Studies on The Economics of Traceability

Golan, et al. (2004) studied different traceability systems in three supply chains: fresh produce, grain and oilseeds, and cattle and beef. They noted that, whereas complete traceability is impossible, three characteristics (breadth, depth and precision) are important for an efficient control system. *Breadth* of traceability is the amount of information collected and transmitted. The *depth* of the traceability refers to the degree of tracing forward and backward from a given agent. Breadth and depth are largely correlated. Finally, the third characteristic is the *precision* of the information and of the traceability system. These points are very important for GM traceability, because they define the level of efficiency of the traceability system required.

Concerning GM production, traceability should be efficient because of the multiple sources of adventitious commingling. Hence, the depth and breadth should be higher than for other products.

The second objective of traceability systems is the management of food safety. When problems occur, tracing systems identify the origin of the problem. Removal of unsafe production minimizes production and distribution losses in terms of cost of production and reputation. Through the management of food safety, firms reduce risk because traceability systems establish the extent of their liability in cases of food safety failure. Basically, traceability is a way to enforce safety and quality control.

Traceability systems are a source of market differentiation. In the grain and oilseeds industry, traceability is applied from the farm to the consumer. At the farm level, documentation verifies the existence of specific traits and purity levels and farmers must segregate crops. Storage, harvesting and other equipment are submitted to a defined use and handling (eg., cleaning, flushing). Segregation of specialty crops is achieved with dedicated elevator(s) using multiple bins or cleaning between use. Documentation continues from the elevator to the final producer or consumer. Each player in the specialty chain is usually required to retain information on product identity, volume, lot numbers, test results and supplier/customers to ensure quality and allow for trace back if necessary.

Golan et al. (2004) discusses the costs of traceability, but does not provide cost estimates. In the grain industry, costs of record keeping and product differentiation are included. Segregation defined as the total separation, induces underutilization of equipment, so average costs increase. If demand for differentiated products is sufficient, segregation costs are less important. Identity Preservation is stricter than segregation systems because of requirements of containerization or other physical barrier to prevent commingling. Record keeping and separation expenses tend to rise with the complexity of the supply chain. Vertical integration and contracting are methods for reducing the costs of tracing and supply management.

For conventional grains, record keeping should include “one step forward, one step backward” while segregation and traceability may begin as early as the seed (Golan, el al. 2004).

Because of the risks of adventitious commingling, stakeholders have to extend their liabilities and reduce risks of economic losses in cases of food safety failure. Traceability is generally more precise for specialty grains than for conventional grains. These traceability systems document the effort of each segment of the supply chain in segregating the high-value specialty product from conventional or other specialty products (Golan, et al. 2004).

Each stakeholder in the specialty grain chain must be able to record information about product identity, volume, lot numbers, test results, and supplier(s)/customer(s). Target requirements differ, depending upon objectives. At the farm level, farmers must segregate crops to ensure that cross-pollination does not result in a crop that does not meet required specifications. In addition, farmers must dedicate certain storage, harvesting, and other equipment and storage units between different crop types. To verify that adequate quality precautions have been taken at the farm level, farmers may be asked to provide elevators with third-party (certified by the U.S. Department of Agriculture) certification. Farmers may be asked to submit their shipment for testing. Tests may be performed by the elevator or by independent third-party verifiers. Records including the identity of the farms that sold the commodities are registered (Golan, et al. 2004). Segregation is achieved with dedicated elevators, multiple bins or by cleaning bins and equipment after each crop passes through. Segregation and documentation for specialty crops continue from the elevator to the final consumer. All along the supply chain, either testing or process certification guarantees that quality attributes are maintained.

A number of third-party certifiers offer services to verify that specialty quality attributes have been adequately safeguarded throughout the supply chain (Golan, et al. 2004). Elevators typically contract with producers to grow certain varieties. The contract may specify that producers follow certain production and handling practices that are consistent with the traced products. Contracts are also used between the elevator and the buyer. Premiums must cover the additional cost and risk induced by measures of segregation and recording. Europe may be more willing to pay for certain traceability features as opposed to the United States (*Milling and Baking News*, 2004).

Many American suppliers use segregation and identity preservation to export to Japan and the EU markets. The premiums for corn generally range from $0.03 to $0.12 /bu over the Chicago Board of Trade prices (Swanson, et al. 2003). This premium is supposed to balance additional costs (certified seed, isolation, segregation, and storage). The 2004/05 non-GM corn premiums published by the M&M Service Company are similar: $0.07 to $0.08/bu.

Non-GM soybean production requires a higher premium than non-GM corn production. A 2004/2005 contract specification for non-GM soybeans indicates a premium over the contracting elevator bid of $0.50 for harvest delivery and $0.55 for after harvest delivery. The cooperative demands a 20-foot buffer strip from GMO grains. The Illinois Specialty Farm Products initial premiums ranged from $0.25 to $0.50 /bu and only requires isolation from uninspected and non qualifying soybeans. Premium contracts may require field inspection prior to harvest to determine varietal purity. The Michigan Agricultural Commodities announced a premium for the 2004 crop of non-GMO soybeans equal to $0.30 /bu with a level of purity of 98% (simple strip test performed on each load at time of delivery). These few examples on non-GM corn and soybean production show the importance of premiums to provide incentives for farmers and agents to segregate.

Traceability and Process Verification

Traceability programs exist for seed production. The Association of Official Seed Certifying Agencies (AOSCA) publishes seed production guidelines. The purpose of the AOSCA'S certification program is to assist the genetic and physical identity of grain by services (field inspection, storage facility inspections, laboratory analysis, record keeping and labeling). Protocols for non-GMO corn require production at a distance of 660 feet or more from any GMO corn.

Demand by consumers for process verification led to implementation of auditable certification processes. The U.S. Department of Agriculture proposed a *Process Verification Program* that conforms to ISO 9001 requirements and provides for USDA Certification. Enhanced consumer confidence is the objective of this certification. Grains are not the only products using Process Verification Programs; USDA already provides similar programs for fruits, vegetables, and livestock.

Segregation

Segregation involves marketing for differentiated products to different markets and involves a dis-aggregation of supply and demand (Commission of the European Communities, 2001). Segregation has evolved in response to international preoccupation with food safety.

Co-existence refers to 'the ability of farmers to make a practical choice between conventional, organic and GM-crop, in compliance with the legal obligations for labeling and/or purity standards.' The problem of co-existence of GM and non-GM crops may arise at three different levels (Commission of the European Communities, 2003a):

- GM and non-GM crops produced simultaneously or in successive years on a single farm;
- GM and non-GM crops produced on neighboring farms in the same year;
- GM and non-GM production types used in the same region, but on farms that are separated by some distance.

Contamination can arise because of seed impurities, cross pollination, but also, harvest, delivery, handling, storage, and transport to the end-user. From a technical viewpoint, requirements by institutions or governments are used to protect the product's identity. GM and GM free production have coexisted in Spain since 1998. Planting some of their crops to conventional varieties acts as a refuge for the target species and hence minimizes risk of pollen drift. At least four rows of conventional maize are planted between GM crops and 'vulnerable' non-GM crops (buffer crops); a limitation of GM production of 20% to 25% of total planting per farm was recommended for producers of GM grains. No segregation on the supply chain followed the segregation on-farm. That means, given that the destination was the animal feed sector, the GM crops have been invariably sold through normal marketing channels, without any special requirements.

Several studies provide a list of recommended practices (harvest and post harvest) including seed selection and adapted crop rotations. The isolation minimum recommended in corn production is 16 to 24 border rows (about 34 to 52 feet) around fields to eliminate cross-pollination (Swanson, et al. 2003). Because wheat is not cross-pollinated, the buffer crop requirements should be less than for corn production. Swanson (Swanson, et. al. 2003) recommends combining and keeping border rows separate for use as feed. On-farm storage facilities must be cleaned or new facilities must be provided to separate crops. To avoid mechanical commingling, segregation is required for handling, storage and transportation. Facilities must be cleaned between crops. The time and money spend on cleaning are fixed by the tolerance level required by the market.

The European Commission has created a non-exhaustive list of recommendations. Recommendations on farm measures are divided in four groups: Preparation for sowing, planting, and soil cultivation; Harvest and post-harvest field treatment; Transportation and storage; and Field monitoring. A part of the set of recommendation is presented in Table 1.

Table 1. European Recommendations on Farm Practices

Preparation for Sowing, Planting, and Soil Cultivation	Harvest and Post-Harvest Field Treatment	Transport and Storage	Field Monitoring
• Isolation distances between GM and Non GM fields of the same species; • Buffer zones, as an alternative or complement to isolation distances; • Pollen traps or barriers (e.g. hedgerows); • Managing populations in field borders through appropriate cultivation techniques (selective herbicide or integrated); • Using varieties with reduced pollen production, or male sterile varieties; • Sharing seed spillage when traveling to and from the field, and on field boundaries; • Control/destruction of volunteers, in combination with suitable sowing times for the following season to avoid the development of volunteers.	• Saving seeds only from suitable fields and field areas (e.g. field centres); • Minimising seed loss during the harvest (e.g. through optimization of the harvest time to minimize seed shedding); • Cleaning of harvesting machinery before and after use, to prevent any carry-over of seed from previous operations, and to avoid the unintended dispersal of seed; • Sharing harvest machinery only with farmers using the same production type; • The field margins could be harvested separately from the rest of the field if other measures are deemed insufficient to maintain the adventitious below the labeling threshold. The main crop should be segregated from the harvested on the field margins.	• Ensuring the physical segregation of GM and non-GM crops after the harvest up to the first point of sale; • Using adequate seed storage arrangements and practices; • Avoiding spillage during transport of the harvested crop on the farm and from the farm to the first point of sale.	• Monitoring of seed spillage sites, fields margins for volunteer development.

***Source: Commission of the European Communities, 2003*a**

An investigation of fifty Kansas grain elevators into the feasibility of segregating hard winter wheat (Herrman et al., 2001) revealed that country elevators often possess sufficient unused receiving capability. Consequently, segregation is possible. There are many reasons for failure of segregation systems. Poor logistical management of incoming trucks during the harvest peak period, lack of trained personnel, and poor allocation of available resources, labor, equipment, and time often affect failure. The maximum contamination potential for an elevator is reached when the number of grain segregations is twice the number of receiving pits. To minimize contamination, producers should implement logistical management such as assigning trucks with certain grain types (Maier, 2004).

Identity Preservation (IP) Techniques

Although there are a number of definitions of IP, the most widely accepted one is that 'Identity Preservation refers to a system of crop management which preserves the identity of the source or nature of the materials' (Glaudemans, 2001). This definition does not go into details and it is a source of confusion. Some systems are able to trace the crop from the precise field on which it was grown all the way down to the consumer product and vice versa. Others suffice with a statement about the country of origin or the factory in which it was first processed. Grain production is one of the only sectors where the IP is applied. Since there are many sources of contamination, IP techniques are important and constraining. IP practices within the supply chain are presented in Figure 2.

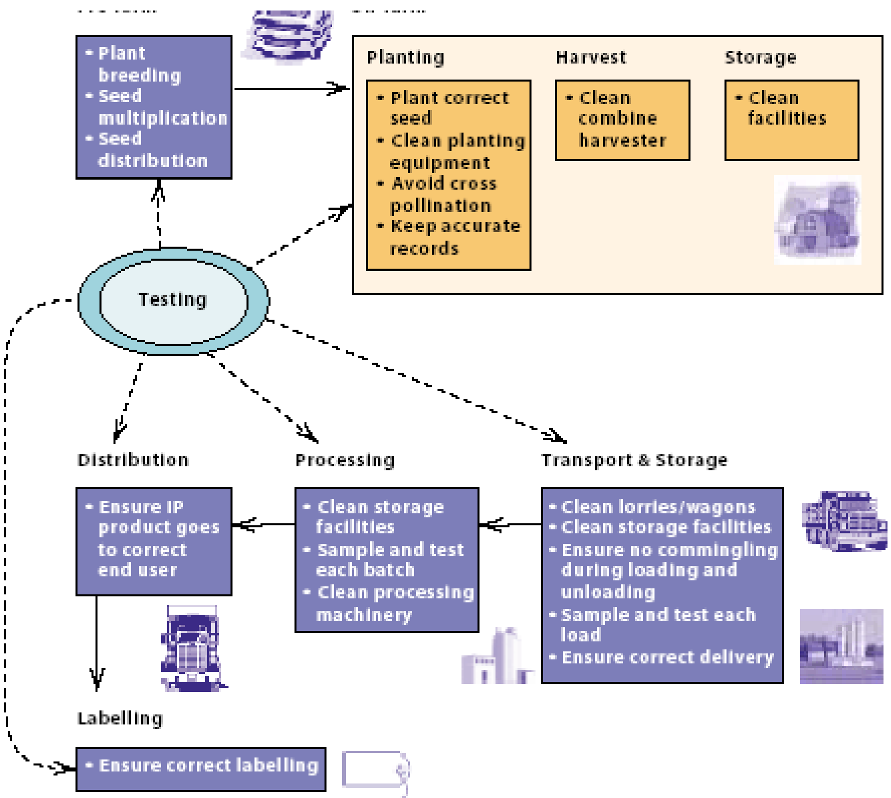

Figure 2. Identity Preservation Practices Within the Supply Chain. Source: Glaudemans, 2001.

Many of the risks and potential liabilities of GM crops are only partially manageable. Failure costs are potentially high and an inability to manage the risks and control the liabilities are such that GM technology may be infeasible (Smyth, Khachatourians, and Phillips, 2002). Liabilities may arise from terms implied into relevant contracts by the Sale of Goods Act. The presence of GM elements (even trace elements) in foods, particularly without appropriate labeling, may breach this implied term (Freshfields Bruckaus Deringer, 2001). There are no specific liabilities established for GM crops; hence legal liabilities associated with GM crops are debated.

In 2000 a United Kingdom private member's Bill proposing strict liability for damage caused by GMOs intensified the liability debate in the UK. While the Bill was rejected, a sub-group of the UK's Agriculture and Environment Biotechnology Commission (AEBC) is currently exploring issues of liability relating to GMOs. More generally, the European Commission recently issued non-binding recommendations on guidelines for the development of national strategies and approaches to ensure the co-existence of GM, conventional and organic crops. The guidelines encourage Member States to examine their civil liability laws when developing national strategies and ensure that farmers, seed suppliers and other operators are fully informed about the liability criteria that apply in their country in the case of damage caused by unintended presence (Australian Government Department of Agriculture, Fisheries and Forestry, 2003).

Costs Induced by Identity Preservation Measures

The cost of IP is impacted by many factors including the level of potential commingling, the number, location and type of tests applied, all of which depend on market requirements. Many studies have estimated additional charges for IP.

Segregation and IP Practices at the Farm Level: Segregation on farm is the first level to establish an efficient IP program. For a typical farm, the per-bushel costs of planter and combine cleaning are small, approximately 6c/ metric ton of soybeans or 0.027c/bu[5] (Bullock et al., 2000). The cost is small because soybeans do not cross-pollinate. Corn segregation may have additional costs to discouraging cross-pollination.

Segregation Measures Between County Elevator and Export Elevator: Direct costs are generated by changes in the production process and indirect or hidden costs are generated by the underutilization of commodities production, storage, transport (Kalaitzandonakes, 2004). Estimation of IP costs are dependent on the level of accuracy required by the market. Three case studies of identity preservation (Maltsbarger and Kalaitzandonakes 2000) at the elevator level (representing small, medium, and large elevators) suggest the importance of hidden or opportunity costs that can occur from adapting current commodity operations to IP. Total IP is equal to the sum of coordination costs (farmer search costs, advertising, follow-up calls, farm visits, buyer call delivery, weekly meeting, and farmer calls), segregation costs (sample analysis

[5] 1 metric ton = 36.7 bushels; http://www.smallgrains.org/WHFACTS/convert.htm.

cost, misgrades, maintenance, and disputes/labor), and opportunity costs (underutilized storage, lost grind margin, and spread opportunity). Total IP costs average 28 c/bu and ranged from 16 c/bu to 37 c/bu for a medium elevator with 500,000 bu of high oil corn and a large elevator with 200,000 bu during peak harvests, respectively. A significant problem for larger elevators is the underutilization of bins.

USDA estimated that it costs 54 c/bu between the county elevator and the export elevator to segregate identity-preserved. Lin (2002) estimates IP costs from country to export elevator for non-biotech maize and soybeans at respectively 22 c/bu and 18 c/bu.

The results highlight that even for a loose threshold, IP costs can be significant. Hidden costs (efficiency losses) comprise, on average, 55% of IP costs and range from 29% to 75% (Wilson et al., 2003). Additional operational changes such as sealed bins, additional cleaning of pollen and grain residue, dedicated delivery dates, insurance or non-compliance penalties add extra costs to IP not accounted for in this study. In addition, testing the presence of GM material at the protein and DNA levels is more expensive than for the value-added compositional analysis used (Maltsbarger and Kalaitzandonakes, 2000).

Grain traders indicated that the premium for non-biotech U.S. grain since harvest rose to a high around 10 c/bu in late fall and has since declined to 5-8 c/bu (Brookins, 2000). The costs of logistics and segregation between GM and non-GM grains creates new challenges and cost burdens in the movement of commodities from the farmer to the processor and end-user. Moreover, certification of bulk commodities in the existing marketing system is difficult and costly when considering the risks. The risk of compliance and viable certification can lead to costly litigation because existing testing procedures for biotechnology are imperfect at best and take time to perform and add costs to the marketing chain. There needs to be agreement between buyers and sellers about what type of test should be used. More important, the tolerance must be established.

Lin examined the economics of segregation for non-GM corn and soybeans based on the survey results for specialty corn and soybeans (Bender et al. 1999). The costs of segregation or IP were estimated for a typical marketing channel that moves corn or soybeans from country elevators to sub-terminals, and export elevators. Segregation of specialty grains was adjusted to estimate the costs of segregation of non-biotech maize. Segregation costs were about 22 c/bu (excluding premiums to producers). These estimates do not account for additional costs that could be associated with segregation at the farm level and shipment costs beyond export elevators to foreign markets. Two important adjustments to reflect two-tier segregation requirements were made. First, segregation between GM and non-GM varieties and second, for GM varieties which are EU approved and unapproved. These adjustments increased handling costs for non-biotech maize at country elevators to 3 c/bu, higher than the 2 c/bu reported by Bender et al., 1999. Segregation imposed no additional handling cost above the 2 c/bu, incurred at sub-terminals and export elevators because operators know the destination of grain shipment at those facilities. Consequently, the handling cost for maize (corn) segregation is 7 c/bu and only 6 c/bu for soybean segregation.

Table 2 presents a summary of previous studies on IP and segregation costs at the elevator level.

Table 2. Previous Studies on IP and Segregation Costs at the Elevator Level.

Researcher	Methodology/Scope of Analysis	Estimated Cost of Segregation/IP
Askin, 1988	Econometric model of costs for primary elevators	Increase of 2 grade handled increase costs <0.5 c/bu
Jirik, 1994	Survey of elevator mgrs. 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, Boland, and Heishman, 1999	Stochastic simulation model	1.9 to 6.5 c/bu
Maltsbarger and Kalaitzandonakes, 2000	Simulation model for high oil handlers	1.6 to 3.7 c/bu
Nelson et al., 1999	Survey of grain handlers	6 c/bu corn, 18 c/ bu soybeans
Bullock, Desquilbet, and Nitsi, 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 mgrs. for wheat	15 c/bu
Smyth and Phillips, 2001	Analysis of GM IP system for canola in Canada, 1995-96	21 to 27 c/bu
Gosnell, 2001	Added transportation and segregation costs for dedicated GM elevators	15 to 42 c/bu high throughput 23 to 28 c/bu wooden elevators
Sparks Companies, 2000		Non-GM canola 38 to 45 c/bu Non-GM soybean 63 to 72 c/bu

Source: Wilson and Dahl, 2002

The European Commission studied IP costs at the elevator level. Table 3 (Directorate-General for Agriculture European Commission, 2002) shows their estimates of costs and is adjusted at the rate of one euro for one dollar.

Table 3. Previous Studies on IP and Segregation Costs at the Elevator Level

Researcher	Crop	IP approach	Country	Year	IP cost $/MT
Buckwell et al., 1998	Soybean	GM quality traits: low linolenic, high oleic, low saturate, high protein, high sucrose	USA	(1997)	1.6-3.3
Bender et al., 1999	Soybean	Non GM STS herbicide tolerant	USA	1998	6
Lin, Chambers and Harwood, 2000	Soybean	Non GM (ERS estimation)	USA	2000	20.6
Buckwell et al., 1998	Corn	Quality trait (conv.) waxy maize	Europe	(1997)	3.2-8
Buckwell et al., 1998	Corn	Quality trait (conv.) high oil content	USA	1997	1-1.8
Bender et al., 1999	Corn	Quality trait (conv.) high oil content	USA	1998	2.1
Lin, 2002	Corn	Non-GM (ERS estimation)	USA	2000	9
Buckwell et al., 1998	Oilseed rape	GM traceability herbicide resistance	Canada	1996	4.7-6.9
Buckwell et al., 1998	Sunflower	Quality trait high oleic	USA	1997/98	1.6-3.3

Source: Directorate-General for Agriculture European Commission, 2002.

The additional transport costs range from 1 to 9 $/MT for the different products and IP approaches (Directorate-General for Agriculture European Commission, 2002). The key factors are the amount of crop traded under the different IP systems and the tolerance level for contamination.

GM Testing Methods: A GMO can be distinguished from a non-GMO because it contains either unique novel deoxyribonucleic acid (DNA) sequences and/or unique novel proteins not present in its conventional counterpart. Two methods are available: a PCR (Polymerase Chain Reaction) test based on DNA detection and the ELISA (Enzyme Linked ImmunoSorbent Assay) test based on protein detection (Directorate-General for Agriculture European Commission, 2002).

The Polymerase Chain Reaction is based on the detection of DNA fragments that are inserted in the plant genome. This method allows amplification in a few hours of specific DNA fragments to a degree that they can be analyzed qualitatively and quantitatively by common laboratory techniques (e.g., electrophoresis). It requires specialized equipment and training. PCR testing is applicable and extremely sensitive in the case of unprocessed food where DNA is still intact. This is not the case for processed food where it is more difficult to isolate high quality DNA and where GM material from more than one GM species can be present. In the latter, the method is laborious and costly. PCR requires little development time compared to immuno-logical assays (primer synthesis vs. antibody production), but it can still take one to three days (Querci, 2001). The test is estimated to be about 99.9% accurate (Directorate-General for Agriculture European Commission, 2002).

The ELISA method is able to detect and quantify the amount of a certain protein which is of interest in a sample that may contain numerous other dissimilar proteins. ELISA uses antibodies to bind specific proteins. Antibodies are soluble proteins produced by the immune system of animals in response to exposure to a foreign substance (called antigen). For GMOs, the antigen can be the newly synthesized protein. A colorimetric or fluorometric reaction can visualize and measure when the antigen and specific antibody bind together. One restriction for using the ELISA test is denaturization of proteins in some food processes. Similar to PCR, the ELISA method requires trained personnel and specialized equipment. This method also requires high investment to develop the assay and to generate antibody standards. However, once reagents are developed, the cost per sample is low. The test is reported to be 95% accurate (Directorate-General for Agriculture European Commission, 2002).

IP costs must account for testing costs. PCR take two to ten days at a cost of $200 to $450 per test, higher than most country elevators can afford because of small volume per truck load (around 900 bushels). In contrast, ELISA takes two to eight hours and costs up to $10 per test. ELISA test cost estimated at 1 c/bu for one specific trait. For example three traits are tested on maize, increasing the testing cost to 3 c/bu. At sub-terminal and export elevator, PCR testing is more common than ELISA because it is very sensitive and can be used to detect the presence of several gene modifications in one set of tests.

ANALYTICAL MODEL

This paper measures costs and risks of the proposed EU traceability requirements on exports of hard spring wheat (HRS) from North America for an integrator. Since a traceability system does not currently exist for wheat to the EU, a prototypical supply chain is developed composed of growers, an integrator and the importer. The integrator is a vertically integrated firm in the handling system that contracts with farmers to produce non-GM wheat, provides inputs and pays the additional costs compared to GM production. The GM trait is Roundup-Ready wheat, which was proposed first, but has since been deferred. However, this trait as well as others in development including fusarium resistance, may be introduced in the future. To reduce risks of not conforming to the EU traceability requirements, the integrator requires tests throughout the system. The integrator’s choice set is where to prescribe tests and how intensively to test.

Additional Costs

Additional costs were included for on and off-farm practices required to meet EU traceability protocols. Additional on farm costs included certified seed, costs due to isolation, buffer strips, cleaning/flushing, auditing and certification, traceability and monitoring costs. Off-farm practices included traceability costs.

Certified Seed: Certified seed price was estimated to be $1.45/bu higher than for conventional seeds (Personal communication with the North Dakota State Seed Department). The cost of certified seed use is paid by the integrator as are other additional costs. This parameter is included in the calculation of the additional costs for 100 percent certified production. Hence, in the base case, the cost of certified seed is equal to 6.22 c/non-GM bu produced.

Buffer Strips: Additional costs due to buffer strips are calculated using two assumptions: the average yield in North Dakota is equal to 28 bu/A (Swenson and Haugen, 2003), and the average size field is 80 acres. According to Hucl and Matus-Cadiz, out-crossing varies by variety but pollen drift can occur from 5 to 48 meters. They indicate that to isolate non-GM and GM wheat, buffers of 3 to 10 meters are higher than acceptable levels of segregation (Wilson and Dahl, 2002). The buffer strips' width is specified by the contract between the integrator and the farmer. The base case uses a uniform distribution of 3-10 meters. The grain harvested from the buffer strips are sold in the market as either non-certified GM free grains or GM grains. The opportunity cost is the difference between the non-GM and non-certified GM free/GM prices. This cost represents income lost by the farmer on the buffer strip production. The market price of certified non-GM wheat is assumed to be equal to $3.40/bu the market price for wheat is estimated equal to $3.29/bu (Swenson and Haugen, 2003).

Additional cost induced by cleaning the combine, from Bullock, Desquilbet, and Nitsi (2000), is $7.5. There are 366 wheat farms supplying the 5,000,000 bushels. Hence, the cleaning cost is equal to $3,434 (5,000,000 bushels produced). The cleaning cost is divided by the buffer strip production to obtain a cost per bushel shift to the secondary market (non-certified GM free).

The improvement in segregation measures presented previously (buffer strips, certified seeds) impacts the distribution of on-farm adventitious commingling, defined as the grower risk distribution. Wilson, Jabs and Dahl assumed grower risk was represented by a triangular distribution with minimum, most likely and maximum values of 1, 2.5 and 5%, respectively. Considering that the certified seeds guarantee a level of purity equal to 99%, and the buffer strips around the field have an impact on contamination from pollen drift, a base case distribution for grower risk was assumed triangular from minimum, most likely and maximum values of 0.1, 0.2 and 0.5%, respectively.

Segregation: The base case assumed adequate capacities, and no requirement of new storage facilities on-farm.

Auditing and Certification: Auditing and certification provide confidence between producers, elevators and consumers, in meeting the requirements (www.cert-id.com/industry_why_certify.htm). The auditing cost is equal to 1$/acre (Peterson, 2002), or 3.6 c/bu.

For non-GM IP wheat, the certification cost is estimated at $2.75 per acre plus $15 per producer (assuming the IP producer is only growing one variety) by the Oklahoma Crop Improvement Association (Wright and Tilley, 2004), and represents the cost of certification. The average farm size in North Dakota is 1,300 acres (www.agclassroom.org/nd), total spring wheat acreage is equal to 6,640,000 acres (North Dakota Wheat Commission, www.ndwheat.com/wi/markstat/prod_hrs.asp) and 17,000 farms produce spring wheat (www.worc.org/pdfs/WORCproductionfactsheet.pdf). Consequently, the average wheat acreage per farm is 390 acres. The average cost per non-GM bushel for certification was estimated assuming 20% GM adoption (both in acres and number of producers) and an average yield of 28 bu/a. The estimated certification cost for non-GM wheat is equal to 9.958 c/bu.

Traceability: Traceability cost refers to record keeping, labeling and the logistic cost (computer, software equipment) of conforming to requirements. ESRI a company specializing in geographic information systems, developed software (ArcView) using a geographic information system to track production and preserve the identity of production (ESRI, 2004). If a standardized code for GM free crops were instituted, a unique value could follow that crop from the seed to the final destination or the end-user. The result would be a digital history utilizing maps, reports, etc. documenting the process of that crop. The ESRI software covers large functions and is easily customized to stakeholder needs. This product can be adapted at the farm or elevator level. Each copy of ArcView costs $1,500 with depreciation over three years. Hence, for the farm level, the cost per bushel is equal to the annual farm volume divided by the annual depreciation of the software: $(1500 / 3) / (28 \cdot 390) \cdot 100 = 4.6$ c/bu. For elevators and importers, the cost of the software is similar, but volumes differ. From USDA studies, we defined that two country elevators are sufficient to supply five millions bushels (USDA North Dakota Agricultural Statistical services, 2004). Total cost is twice $1,500 or 0.06 c/bu. We model one exporter with adequate facilities to trade the production (USDA Grain Inspection, Packers and Stockyards Administration. 2003). Hence, the traceability cost for the exporter is about 0.04 c/bu.

Summary of Additional Variables: These costs are paid by the integrator to the farmer to induce his participation and are summarized in Table 4.

Table 4. Cost Summary

Item	Source	Value
Farm Level Costs		cents/bu
Certified Seed	Swanson, 2004	6.22
Auditing	Peterson, 2002	2.86
Certification	Wright and Tilley, 2004	7.97
Opportunity	Swenson and Haugen, 2003	11.00
Traceability	ESRI	3.66
Total		31.71
Traceability Cost		
Country Elevator	ESRI and USDA	0.06
Export Elevator	ESRI and USDA	0.04
Importer	ESRI	0.04
Total		31.87

Empirical Model

It is unclear how grain handlers would organize their procurement and marketing strategy to conform to the EU traceability requirements. Two alternatives are posed here. In one case, the supplier operates as an integrator (e.g., as discussed in Sheldon). The supplier sells to the importer and must conform to the EU requirements, and subject to a penalty if out of contract. In this capacity, the supplier (i.e., supplier to the EU importer) performs four functions: 1) contracts with the grower to produce the grain conforming to the EU traceability requirements; 2) provides relevant inputs to the grower to conform to EU requirements, including certified seed and an explicit premium to offset the additional/forgone agronomic costs associated with buffer strips, etc.; 3) hires a 3rd party firm to perform auditing and certification; and 4) conducts tests throughout the system as a check against the risks of nonconformance. The model determines the optimal testing strategy which indicates where and how intensely to test. In this case, the supplier seeks to maximize utility of the change in wealth which is defined as the initial wealth less integrator costs incurred.

The alternative is for the supplier to simply act as a handler. In this capacity, the supplier buys wheat from growers to conform to the EU requirements. The supplier also conducts tests throughout the system as above, with the objective of minimizing costs. Each of these are modeled.

Tolerance is defined as the maximum deviation from a nominal specification within which the component is still acceptable for its intended purpose (Wilson, 2003). In the GM grains, tolerance refers to its maximum allowable percentage GM. The model chooses the optimal testing strategy that maximizes portfolio utility by minimizing costs for the integrator handling a portfolio of segregations (non-GM and GM).

Additional Integrator's Cost

The integrator's additional cost is the cost generated by the choice of testing strategy, traceability costs for all locations, added grower costs (certified seed use, certification and auditing practices) that the integrator reimburses to the grower. Cost of non-GM is defined in equation (1). The additional cost of GM is presented in equation 2 and assumed equal to 0.

(1) $C_{NGM} = \sum [T_{\mu} \cdot TC_{\mu} \cdot S_{\mu} \cdot V_{NGM\mu}] + D_{\mu} \cdot V_{NGM\mu} + [CS + AC + CC + TrC_{\mu}] \cdot V_{NGM\mu}$

(2) $C_{GM} = 0$

Where

μ is the location within the system where tests can be applied (on-farm, country elevator receiving, country elevator loading, export elevator receiving, export elevator loading, importer receiving);
T_{μ} is a binary choice variable reflecting whether tests are applied at location μ;
$Tc\mu$ is the cost of individual test for location μ;
S_{μ} is the choice variable reflecting the sampling intensity (number of samples per lot) at location μ;
CS is the cost per bushel of certified seed use;
AC is the auditing cost per bushel on-farm;
CC is the certification cost per bushel;
TrC_{μ} is the traceability cost per bushel for location μ;
D_{μ} is the discount if the limit is exceeded; and
$V_{NGM\mu}$ is the volume (number of lots) of non-GM handled at location μ.

The discount if the limit is exceeded is the quality loss. Discounts for GM corn are historically 10 percent of the value, which translates to about 40 c/bu in the case of wheat. Additional charges are considered for re-shipping grain to an alternative market that is 50 c/bu in many geographic locations internationally. The quality loss occurs only at the final destination point because of the vertical integration of the supply chain. The quality loss is modeled by the estimation of the rejection risk at the importer. The value is a uniform distribution ranged between 40 c/bu and 90 c/bu. This is the cost applied when the GM presence exceeds the importer tolerance (1%) and represents the penalties applied to suppliers for non-conforming lots.

Risk Premium and Utility

The risk premium (π) compensates the grain handler for potential risks emanating from detection of GM content in a non-GM flow. The risk premium is derived from the expected value of the system as follows:

(3) $$\pi = EV_{NGM} - CE_{GM/NGM}$$

Where

EV_{NGM} is the expected additional cost of a non-GM system assumed to be zero, and
$CE_{GM/NGM}$ is the certainty equivalent of additional system costs for a dual system.

The premium is the value required to offset the additional costs and risks induced by dual system.

The objective function is expressed in equation (4). The model maximizes portfolio utility by minimizing the disutility of additional Integrator costs by choosing where to test and how intensive to test:

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

Where:

δ_i is the proportion of flows devoted to each segregation;
e is the base of the natural logarithm;
λ is a parameter that determines positiveness of the utility function; λ=2 according to Wilson, Jabs and Dahl, and Serrao and Coelho, (2002);
Φ and η are parameters that affect the absolute and relative risk aversion of the utility function; Φ is fixed at 0.01 and η is allowed to vary from 0.4 to 0.9 and is equal to 0.5 in the base case (Wilson, Jabs and Dahl, 2003, and Serrao and Coelho, 2000);
C_i is the additional integrator costs generated by each segregation;
i is states of segregation non-GM=1 and GM=2;
j represents set of choice variable: test application T_μ, and sampling intensity S_μ, at location μ.

Seller's risk is the probability of rejection of a satisfactory batch. Buyer's risk is the probability of accepting a lot with unsatisfactory quality. In order to quantify seller's and buyer's risk, the model simulates product flows through the system tracking the level of commingled and non-commingled flows within the non-GM segregation while considering uncertainty arising from sampling plans, test accuracies, adventitious commingling and grower truth telling at various stages in the system.

The choice variables are test application and intensity for all location. Test intensity is 1:1 (test every lot) at importer (base case), but may vary from 1:1 to 1:5 (test every fifth lot) at intermediate points. Others distributions and parameters were from Wilson, Jabs and Dahl (Appendix A).

The total cost is the summation of the additional system cost, and the premium.

$$\text{Total Cost} = C_{NGM} + \pi \quad (5)$$

Data and Simulation Procedures

Data and Assumptions

Data and assumptions are summarized in Table 5. The market price of non-GM wheat is assumed higher than the actual current price in 2003. The difference between the current market price and the assumed non-GM market price is integrated in the opportunity cost calculation.

Table 5. Data and Assumptions Used

Item	Source	Distribution	Value Used
Farm Level			
Grower Risk	Modified from Wilson, Jabs and Dahl Model (2003).	Triangular	0.1%;0.2%;0.5%
Average acres / field	Assumption		80 Acres
Prod acreage / wheat farm	www.worc.org		390 Acres
Buffer Strips Prod	Assumption		3 meters
Testing cost	Wilson, Jabs, and Dahl. 2003		$3.5 ; 99%
Elevator Level (CE)			
ND average capacity	USDA North Dakota Agricultural		648,457 bu
Turn over	Statistical services 2004		6.2
Testing cost and accuracy	Wilson, Jabs, and Dahl. 2003		$3.5, 99%
Exporter (EE)			
U.S. production export	USDA Grain Inspection, Packers		260 mil
Number of exporters	and Stockyards Administration. 2002		41 exporters
Testing cost	Wilson, Jabs, and Dahl. 2003		$250 ; 99%
Importer			
Number of Importer	Assumption		1
Testing cost	Wilson, Jabs, and Dahl. 2003		$250 ; 99%
Penalties	Wilson, Jabs, and Dahl. 2003	Uniform	40 c to 90 c/bu
Wheat Market Values			
Market Price	Swenson et al., 2003		$3.29/bu
Non-GM Market Price	Assumed for GM cost differential calculation.		$3.4/bu
GM Market Price	Assumed for GM cost differential calculation.		$3.4/bu

Simulation and Optimization Procedures

The model maximizes utility by minimizing disutility of integrator costs which are composed of costs for testing, quality loss, segregation, auditing, certification, certified seed use, traceability and a risk premium. The objective function is minimized by adjusting choice variables: test application location, test intensity, and test tolerance. Test application specifies whether a test is applied, and is represented as a binary: 1=Test, 0=No test; and the test intensity specifies the frequency the test is applied: 1:1 (every lot sampled), 1:2 (every second lot sampled), 1:3, 1:4, 1:5 (every fifth lot sampled).

Risk Optimizer utilizes simulation and a genetic algorithm-based optimization technique to optimize a model containing uncertainty. Probability distribution functions representing uncertainty are employed to define risk for model components and are entered into specific spreadsheet cells in lieu of a formula or number (Palisade, 1998). Within Risk Optimizer, one thousand iterations were conducted per simulation. The software calculates the buyer and the seller risk and the premium necessary to give supply chain an incentive to participate.

Base Case Results

The base case is defined to reflect the most likely system and protocols for a dual marketing system. The model and the base case use data representing previously a typical northern farm of North Dakota, with adequate storage capacities, producing non-GM certified wheat. The base case results are shown in Table 6.

The estimated risk premium is 20.56 c/non-GM bu, which represents the additional risk premium required by the integrator to be indifferent between a single non-GM marketing system and the dual GM/non-GM system. In the base case, buyer risk is minimal with a probability of adventitious presence at 0.01% meaning that 0.0% of product bought and not detected as GM product contains GM material exceeding tolerance. For the seller, 1.7% of the shipments would be rejected by the importer.

The optimal testing strategy is to test on-farm, at the country elevator receiving and loading, and at the export elevator when loading. Optimal tests at the farm and country elevator are at low intensities (every fifth lot) but at the export elevator when loading grains are tested with a high intensity (every lot). The importer testing strategy is required for every lot. A summary of control points, techniques used, testing costs, and sample size is presented in Table 7.

Table 6. Base Case Results

	Base case
Utility	1.0373
Optimal Strategy	
Test (1=Yes, 0=No)-Intensity	
On-Farm	1-5
Country Elevator Receiving	1-5
Country Elevator Loading	1-5
Export Elevator Receiving	0-NA*
Export Elevator Loading	1-1
Probabilities	
Buyer Risk	0.0128%
Seller Risk	1.7332%
Costs(c/non-GM bu, unless indicated)	
Integrator Cost/All bu	20.84
Integrator Cost/non-GM bu	29.56
Cert Prod (F)	5.29
Auditing (F)	4.05
Certification (F)	11.30
Buffer Strips (F)	0.64
Traceability (F)	5.19
Traceability (CE)	0.09
Traceability (EE)	0.06
Traceability (I)	0.06
Total Testing	1.74
Quality Loss/non-GM bu	1.15
Certainty Equivalent (Premium)/All bu	14.46
Certainty Equivalent (Premium)/non-GM bu	20.56
Total Cost/All bu	35.29
Total/non-GM bu	50.12
Location Percentage of non-GM flow	
Adoption rate	80%
Farmer in Bin	79%
Country Elevator Received	78%
Country Elevator Loaded	76%
Export Elevator Received	76%
Export Elevator Loaded	72%
Importer Received	70%

*NA-Not Applicable

Table 7. Cost of Testing Strategy

Control Point	Intensity	Cost c/Non-bu	Volume per Lot
On-Farm	1-5	0.0159	5000 bu/bin
CE receiving	1-5	0.1005	800 bu/truck
CE loading	1-5	0.0237	3,300 bu/railcar
EE receiving	NA	0	3,300 bu/railcar
EE loading	1-1	0.8246	33,000 bu/hold
Importer	1-1 (required)	0.7744	33,000 bu/hold

This testing strategy results in an integrator cost of 30 c/non-GM bu which is composed of 1.74 c/bu cost for testing, 1.15 c/bu for quality loss and the remainder from additional traceability costs. Reimbursement of additional on-farm costs are costly to the integrator for certification, certified seed use and auditing. Traceability costs at the farm level are also more expensive than for other locations. The quality loss cost (1.15 c/non-GM bu) is an opportunity cost assessed on lots diverted at the importer when identified as containing GM content exceeding limits. This cost covers higher costs of finding an alternative buyer, shipping to an alternative destination, etc.

Finally, at each stage in the supply chain, the proportion of flows that are designated as GM and non-GM are determined. Results (lower portion of Table 6) show that as grain flows through the supply chain, the proportion of flow that is non-GM declines from an assumed 80% adoption to 70% at the importer. These changes in proportion of flows are due to diversions of lots that are identified within the sampling process as having GM content above limits, effects of truthtelling, adventitious commingling, etc. Further, since costs are calculated per non-GM bushel, as the proportion of non-GM in the supply chain arriving at the importer declines, costs per non-GM bushel increase.

Sensitivities on Stochastic Variables

Stochastic variables were included to reflect the risks inherent in the dual marketing system. The model uses several stochastic variables to define adventitious commingling risks for stakeholders at locations in the system. Sensitivity of commingling rates is examined at the farm level because measures for segregation and contamination risk are located at this supply chain
level. A second sensitivity is performed to measure the impact of penalties (quality loss costs) when the level of contamination exceeds the tolerance limit.

Adventitious Commingling at the Farm Level

Farmers segregate and preserve the crop identity with handling measures (cleaning and harvesting protocols) and with production constraints (buffer strips). The impact of these practices is modeled by the distribution for adventitious commingling on farm. The base case distribution for on-farm risk of adventitious commingling is a triangular distribution (0.1%,0.2%,0.5%). Two sensitivities were conducted with higher probabilities of adventitious commingling. The first reflects increased risks of adventitious commingling and represented by a triangular distribution (0.5%,1%,3%). The second is more risky and is represented by a triangular distribution (1%, 2.5%, 5%). Results for the two sensitivities are presented in Table 8.

Table 8. Sensitivity of Adventitious Commingling at the Farm Level

	Base Case (0.1%,0.2%,0.5%)	Increased Risk (0.5%,1%,3%)	More Risk Case (1%,2.5%,5%)
Utility	1.0373	1.0369	1.0360
Optimal Strategy			
Test (1=Yes, 0=No)-Intensity			
On-Farm	1-5	1-5	1-5
Country Elevator Receiving	1-5	1-5	1-5
Country Elevator Loading	1-5	1-5	1-5
Export Elevator Receiving	NA	NA	1-5
Export Elevator Loading	1-1	1-1	1-1
Probabilities			
Buyer Risk	0.0128%	0.0129%	0.0129%
Seller Risk	1.7332%	1.7466%	1.7692%
Costs(c/bu)			
Integrator Cost/All bu	20.84	20.81	21.75
Integrator Cost/non-GM bu	29.56	30.14	34.54
Cert Prod (F)	5.29	5.40	5.91
Auditing (F)	4.05	4.13	4.53
Certification (F)	11.30	11.53	12.62
Buffer Strips (F)	0.64	0.65	0.72
Traceability (F)	5.19	5.30	5.80
Traceability (CE)	0.09	0.09	0.10
Traceability (EE)	0.06	0.06	0.07
Traceability (I)	0.06	0.06	0.07
Total Testing	1.74	1.75	3.51
Quality Loss/non-GM bu	1.15	1.16	1.17
Certainty E (Prem)/All bu	14.46	14.13	13.43
Certainty E (Prem)/non-GM bu	20.56	20.51	21.38
Total Cost/All bu	32.29	34.94	35.19
Total/non-GM bu	50.12	50.64	55.93
Location Percentage of non-GM flow			
Adoption rate	80%	80%	80%
Farmer in Bin	79%	78%	78%
Country Elevator Received	79%	78%	76%
Country Elevator Loaded	76%	75%	72%
Export Elevator Received	76%	75%	68%
Export Elevator Loaded	72%	70%	64%
Importer Received	70%	69%	63%

Adventitious commingling risk affects the optimal testing strategy and the integrator's costs. When the risk distribution increases, a lower proportion of grain flows arrives at the importer as non-GM. When the risk of adventitious commingling increases, system costs increase because the non-GM costs are applied to less production. Buyer and seller risks are greater in each of the sensitivities than in the base case. The risk premium per non-GM bushel is lower for the intermediate risk case and higher for the more risk case. The change in risk premium from the intermediate risk case to the more risk case is also affected by the change in optimal testing strategy that occurs between these two sensitivities.

Supplier Penalties

The base case model assumes penalties are uniformly distributed (40-90 c/bu). To measure the response of stakeholders to discount practices, sensitivities are performed. The first sensitivity uses lower penalties (0-10 c/bu), and the second uses higher penalties (100-150 c/bu). Distributions are assumed uniform. Results are presented in Table 9.

Table 9. Sensitivity on Supplier Penalties

	0-10 c/bu	**Base Case 40-90 c/bu**	**100-150 c/bu**
Utility	1.0356	1.0373	1.0379
Optimal Strategy			
Test (1=Yes, 0=No)-Intensity			
On-Farm	1-5	1-5	1-5
Country Elevator Receiving	1-5	1-5	1-5
Country Elevator Loading	1-5	1-5	1-5
Export Elevator Receiving	NA	NA	NA
Export Elevator Loading	1-5	1-1	1-1
Probabilities			
Buyer Risk	0.0606%	0.0128%	0.0128%
Seller Risk	6.1448%	1.7332%	1.7332%
Costs(c/bu)			
Integrator Cost/All bu	19.78	20.84	21.58
Integrator Cost/non-GM bu	29.49	29.56	30.62
Cert Prod (F)	5.55	5.29	5.29
Auditing (F)	4.25	4.05	4.05
Certification (F)	11.84	11.30	11.30
Buffer Strips (F)	0.67	0.64	0.64
Traceability (F)	5.45	5.19	5.19
Traceability (CE)	0.09	0.09	0.09
Traceability (EE)	0.06	0.06	0.06
Traceability (I)	0.06	0.06	0.06
Total Testing	1.13	1.74	1.74
Quality Loss/non-GM bu	0.33	1.15	2.21
Certainty Equivalent (Premium)/All bu	13.08	14.46	14.97
Certainty Equivalent (Premium)/non-GM bu	19.48	20.56	21.33
Total Cost/All bu	32.86	35.29	36.55
Total/non-GM bu	48.97	50.12	51.96
Location Percentage of non-GM flow			
Adoption rate	80%	80%	80%
Farmer in Bin	79%	79%	79%
Country Elevator Received	79%	79%	79%
Country Elevator Loaded	76%	76%	76%
Export Elevator Received	76%	76%	76%
Export Elevator Loaded	72%	72%	72%
Importer Received	67%	70%	70%

When penalties are low, the optimal testing strategy changes. A less intensive testing strategy (1:5) at the export elevator when loading is adopted rather than the high intensity (1:1) strategy in the base case. When the level of penalties is high, the optimal testing strategy is unchanged. However, costs increase due to the higher quality loss costs from penalties.

Penalties have an impact on supplier strategies, costs and risks. At low penalties, the testing strategy differs, and a low intensity testing strategy is preferred to a more intensive one. Costs are less but seller risk is higher because grains are tested with a lower intensity strategy at the exporter level. With greater penalties, the strategy is unchanged, costs and risk premiums increase but buyer and seller risks are unchanged.

Sensitivities on Agronomic Variables

Sensitivities on agronomic variables are performed to determine changes in optimal testing strategies, risks and costs. Agronomic variables analyzed include GM adoption rate, and certified seed used traditionally.

Adoption Rate

In the base case, the adoption rate of non-GM is equal to 80 percent of grain flows. In our model, this means that growers plant non-GM varieties, which amount to 80 percent of production and GM grains (or non-certified GM free) on the remaining 20 percent of production. To simulate the impact of the adoption rate on optimal strategies, four sensitivities were performed ranging from 60 to 100 percent non-GM adoption. Results are presented in Table 10.

When the non-GM adoption rate is lower, the optimal testing strategy is to test with higher intensity at the export elevator when loading and at all other locations in the supply chain at a low intensity. When the non-GM adoption rate is 80% (base case) or higher, the test at the export elevator when receiving is excluded from the optimal testing strategy. Buyer's risks decrease as the non-GM adoption rate increases, however seller's risk is highest at 70% non-GM adoption due to the discrete nature of the shift in testing strategy that occurs between 70% and 80% adoption of non-GM. The integrator cost (per non-GM bushel) decreases as the rate of non-GM adoption increases. All system cost components are sensitive to the adoption rate and decrease when the adoption of non-GM increases.

The level of non-GM adoption affects the premium required. As non-GM adoption increases, the premium required increases. Economies of scale explain the decrease in system costs per non-GM bushel. The premium increases as non-GM adoption increases. Another impact of the adoption rate is the percentage of GM grain - or non-certified - in the supply chain. Percentages of GM grain in the supply chain decrease when the adoption rate increases.

Table 10. Sensitivities to Non-GM Adoption Rate

			Base Case		
	60%	**70%**	**80%**	**90%**	**100%**
Utility	1.0270	1.0323	1.0373	1.0423	1.0474
Optimal Strategy					
Test (1=Yes, 0=No)-Intensity					
On-Farm	1-5	1-5	1-5	1-5	1-5
Country Elevator Receiving	1-5	1-5	1-5	1-5	1-5
Country Elevator Loading	1-5	1-5	1-5	1-5	1-5
Export Elevator Receiving	1-5	1-5	NA	NA	NA
Export Elevator Loading	1-1	1-1	1-1	1-1	1-1
Probabilities					
Buyer Risk	0.0130%	0.0129%	0.0128%	0.0127%	0.0126%
Seller Risk	1.9431%	2.2577%	1.7332%	1.6485%	1.5968%
Costs(c/bu)					
Integrator cost/All bu	1645	19.35	20.84	23.40	25.98
Integrator Cost/non-GM bu	34.96	33.86	29.56	28.98	28.54
Cert Prod (F)	5.93	5.71	5.29	5.20	5.12
Auditing (F)	4.54	4.37	4.05	3.98	3.92
Certification (F)	12.65	12.20	11.30	11.09	10.93
Buffer Strips (F)	0.72	0.69	0.64	0.63	0.62
Traceability (F)	5.82	5.61	5.19	5.10	5.03
Traceability (CE)	0.13	0.10	0.09	0.07	0.07
Traceability (EE)	0.11	0.08	0.06	0.04	0.03
Traceability (I)	0.11	0.08	0.06	0.04	0.03
Total Testing	3.59	3.53	1.74	1.72	1.71
Quality Loss/non-GM bu	1.27	1.50	1.15	1.09	1.06
Certainty E /All bu	7.53	10.78	14.46	18.71	23.55
Certainty E /non-GM bu	15.77	18.87	20.56	23.12	25.76
Total Cost/All bu	23.97	30.13	35.29	42.11	47.53
Total/non-GM bu	50.73	52.72	50.12	52.10	54.30
Location Percentage of non-GM flow					
Adoption rate	60%	70%	80%	90%	100%
Farmer in Bin	59%	69%	79%	89%	99%
Country Elevator Received	59%	69%	79%	89%	98%
Country Elevator Loaded	55%	66%	76%	86%	97%
Export Elevator Received	52%	62%	76%	86%	97%
Export Elevator Loaded	48%	58%	72%	82%	92%
Importer Received	47%	57%	70%	81%	91%

On-farm Testing

To estimate the impact of on-farm testing on costs and risks, a sensitivity without on-farm testing was performed. The on-farm test in the base case was a PCR test with a 99 percent accuracy and a cost equal to $3.5/test. Results are summarized in Table 11.

Table 11. Sensitivity to On-farm Testing

	Base Case	Without On-farm Testing
Utility	1.0373	1.0374
Optimal Strategy		
Test (1=Yes, 0=No)-Intensity		
On-Farm	1-5	NA
Country Elevator Receiving	1-5	1-5
Country Elevator Loading	1-5	1-5
Export Elevator Receiving	NA	NA
Export Elevator Loading	1-1	1-1
Probabilities		
Buyer Risk	0.0128%	0.0128%
Seller Risk	1.7332%	1.7384%
Costs(c/bu)		
Integrator Cost/All bu	20.84	20.83
Integrator Cost/non-GM bu	29.56	29.37
Cert Prod (F)	5.29	5.26
Auditing (F)	4.05	4.03
Certification (F)	11.30	11.22
Buffer Strips (F)	0.64	0.63
Traceability (F)	5.19	5.16
Traceability (CE)	0.09	0.08
Traceability (EE)	0.06	0.06
Traceability (I)	0.06	0.06
Total Testing	1.74	1.72
Quality Loss/non-GM bu	1.15	1.14
Certainty Equivalent (Premium)/All bu	14.46	14.55
Certainty Equivalent (Premium)/non-GM bu	20.56	20.55
Total Cost/All bu	35.29	35.38
Total/non-GM bu	50.12	49.92
Location Percentage of non-GM flow		
Adoption rate	80%	80%
Farmer in Bin	79%	80%
Country Elevator Received	79%	79%
Country Elevator Loaded	76%	77%
Export Elevator Received	76%	77%
Export Elevator Loaded	72%	72%
Importer Received	70%	71%

When no on-farm testing was allowed, the optimal testing strategy for other locations was unchanged from the base case testing strategy. System costs decreased without on-farm testing. However, seller risks increased slightly. Hence, not testing on-farm slightly lowered system costs, but increased seller's risks. This sensitivity shows the degree of tradeoffs between costs and risks from base case to a strategy without on-farm testing are minimal.

Certified Production

Traditionally (base case), 40% of growers utilized certified seed on farm (Kalaitzondonakes, 2004). To measure the impact of this variable, three sensitivities were performed, one with a lower value than the base case (30%), and two with values higher, (60% and 80% certified seed use). Results are presented in Table 12.

Table 12. Sensitivities to Certified Seed Use by Farmers

		Base Case		
	30%	**40%**	**60%**	**80%**
Utility	1.0378	1.0373	1.0362	1.0351
Optimal Strategy				
Test (1=Yes, 0=No)-Intensity				
On-Farm	1-5	1-5	1-5	1-5
Country Elevator Receiving	1-5	1-5	1-5	1-5
Country Elevator Loading	1-5	1-5	1-5	1-5
Export Elevator Receiving	NA	NA	NA	NA
Export Elevator Loading	1-1	1-1	1-1	1-1
Probabilities				
Buyer Risk	0.0128%	0.0128%	0.0128%	0.0128%
Seller Risk	1.7332%	1.7332%	1.7332%	1.7332%
Costs(c/bu)				
Integrator Cost/All bu	21.46	20.84	19.59	18.35
Integrator Cost/non-GM bu	30.45	29.56	27.80	26.03
Cert Prod (F)	6.17	5.29	3.53	1.73
Auditing (F)	4.05	4.05	4.05	4.05
Certification (F)	11.30	11.30	11.30	11.30
Buffer Strips (F)	0.64	0.64	0.64	0.64
Traceability (F)	5.19	5.19	5.19	5.19
Traceability (CE)	0.09	0.09	0.09	0.09
Traceability (EE)	0.06	0.06	0.06	0.06
Traceability (I)	0.06	0.06	0.06	0.06
Total Testing	1.74	1.74	1.74	1.74
Quality Loss/non-GM bu	1.15	1.15	1.15	1.15
Certainty Equivalent (Premium)/All bu	14.89	14.46	13.60	12.75
Certainty Equivalent (Premium)/non-GM bu	21.17	20.56	19.34	18.13
Total Cost/All bu	36.34	35.29	33.20	31.09
Total/non-GM bu	51.61	50.12	47.14	44.16
Location Percentage of non-GM flow				
Adoption rate	80%	80%	80%	80%
Farmer in Bin	79%	79%	79%	79%
Country Elevator Received	79%	79%	79%	79%
Country Elevator Loaded	76%	76%	76%	76%
Export Elevator Received	76%	76%	76%	76%
Export Elevator Loaded	72%	72%	72%	72%
Importer Received	70%	70%	70%	70%

As the use of certified seed increases, the optimal testing strategy and risks to buyers and sellers are unchanged. However, integrator costs per non-GM bushel and risk premiums required decrease as certified seed use increases. A 10% drop in certified seed use by growers increased the premium required by .61 c/non-GM bu, increased integrator costs .89 c/non-GM bu and total costs by about 1.50 c/non-GM bu.

Higher Isolation Distance

A recent study demonstrated that gene flow in wheat is a minor contributor to product admixture, and that a tolerance level of 0 percent transgenic wheat in a non transgenic wheat is unrealistic (Matus-Cádiz, Hucl, Horak and Blomquist 2004). They recommend increasing the isolation distance from 3 meters to at least 30 meters to limit off-type impurities to 0.01 percent. This sensitivity increases the distance for isolation from the base case (uniform distribution of 3-10 meters) to a uniform distribution of 3 to 30 meters. Results are presented in Table 13.

Table 13. Sensitivity to Buffer Strips Width

	Base Case 3-10m	**3-30m**
Utility	1.0373	1.0378
Optimal Strategy		
Test (1=Yes, 0=No)-Intensity		
On-Farm	1-5	1-5
Country Elevator Receiving	1-5	1-5
Country Elevator Loading	1-5	1-5
Export Elevator Receiving	NA	NA
Export Elevator Loading	1-1	1-1
Probabilities		
Buyer Risk	0.0128%	0.0128%
Seller Risk	1.7332%	1.7332%
Costs(c/bu)		
Integrator Cost/All bu	20.84	21.42
Integrator Cost/non-GM bu	29.56	30.40
Cert Prod (F)	5.29	5.29
Auditing (F)	4.05	4.05
Certification (F)	11.30	11.30
Buffer Strips (F)	0.64	1.47
Traceability (F)	5.19	5.19
Traceability (CE)	0.09	0.09
Traceability (EE)	0.06	0.06
Traceability (I)	0.06	0.06
Total Testing	1.74	1.74
Quality Loss/non-GM bu	1.15	1.15
Certainty Equivalent (Premium)/All bu	14.46	14.86
Certainty Equivalent (Premium)/non-GM bu	20.56	21.14
Total Cost/All bu	35.29	36.29
Total/non-GM bu	50.12	51.53
Location Percentage of non-GM flow		
Adoption rate	80%	80%
Farmer in Bin	79%	79%
Country Elevator Received	79%	79%
Country Elevator Loaded	76%	76%
Export Elevator Received	76%	76%
Export Elevator Loaded	72%	72%
Importer Received	70%	70%

The buffer strip width does not impact the optimal testing strategy, and buyer and seller risks are unchanged. The cost of buffer strips increases from 0.64 c/bu to 1.47 c/bu. The integrator cost (per non-GM bushel) increases by 0.84 c/bu. To compensate for additional costs/risks of the wider buffer strips, the risk premium required increases by 0.58 c/bu. Varying the width of buffer strips did not have an important impact on costs, risks or premiums.

Sensitivities on Model Parameters

Parameters assumed for the base case include risk aversion, traceability cost and market price.

Risk Aversion

This parameter should vary among handlers/shippers depending upon their aversion to risk. Two sensitivities were conducted representing integrators that had lower and higher risk aversion than in the base case. Results are presented in Table 14.

When the integrator has lower risk aversion (η equal to 0.4), the optimal testing strategy adds testing at the export elevator when receiving and changes to a less intensive testing strategy when loading ocean vessels. This change in strategy increases buyer and seller risks, and integrator's costs including quality loss costs. Due to the lower risk aversion, a lower risk premium is required, yet, the net effect is to increase total system costs.

In the higher risk averse sensitivity, the optimal testing strategy remains unchanged from the base case. Buyer and seller risks and integrator costs are unchanged. A higher risk premium is required which also results in higher total costs.

Traceability Cost

Traceability costs used in the base case are from interviews with ESRI. Other sources of traceability costs included, AGRIS Company, a John Deere Company producing traceability software specialized for elevators. These costs differ from ESRI. Consequently, a sensitivity including different traceability costs for country elevator, export elevator and importer was performed. The AGRIS price for traceability is composed of $30,000 costs for hardware, $25,000 for software, and $2,500 for training. These costs are depreciated over 3 years. Hence, the annual traceability cost is equal to $17,666 per agent. Results are presented in Table 15.

Table 14. Sensitivities to Risk Aversion

	Less Risk Averse	Base Case	More Risk Averse
Utility	1.0266	1.0373	1.1339
Optimal Strategy			
Test (1=Yes, 0=No)-Intensity			
On-Farm	1-5	1-5	1-5
Country Elevator Receiving	1-5	1-5	1-5
Country Elevator Loading	1-5	1-5	1-5
Export Elevator Receiving	1-5	NA	NA
Export Elevator Loading	1-4	1-1	1-1
Probabilities			
Buyer Risk	0.0497%	0.0128%	0.0128%
Seller Risk	5.1739%	1.7332%	1.7332%
Costs(c/bu)			
Integrator Cost/All bu	23.06	20.84	20.83
Integrator Cost/non-GM bu	35.31	29.56	29.56
Cert Prod (F)	5.70	5.29	5.29
Auditing (F)	4.37	4.05	4.05
Certification (F)	12.17	11.30	11.30
Buffer Strips (F)	0.69	0.64	0.64
Traceability (F)	5.60	5.19	5.19
Traceability (CE)	0.09	0.09	0.09
Traceability (EE)	0.06	0.06	0.06
Traceability (I)	0.06	0.06	0.06
Total Testing	2.94	1.74	1.74
Quality Loss/non-GM bu	3.57	1.15	1.15
Certainty E (Prem)/All bu	12.01	14.46	19.33
Certainty E (Prem)/non-GM	18.03	20.56	27.41
Total Int. Cost/All bu	35.07	35.29	40.29
Total Int. Cost/non-GM bu	53.34	50.12	56.92
Location Percentage of non-GM flow			
Adoption rate	80%	80%	80%
Farmer in Bin	79%	79%	79%
Country Elevator Received	79%	79%	79%
Country Elevator Loaded	76%	76%	76%
Export Elevator Received	73%	76%	76%
Export Elevator Loaded	69%	72%	72%
Importer Received	65%	70%	70%

The alternative traceability cost does not impact the optimal testing strategy. The effect of the traceability cost is mainly observable at the elevator levels and at the importer level because the new equipment is specific to their needs and not adapted to the farm level. Due to increased traceability costs, the total integrator's cost is higher than for the base case. Only traceability costs at the country elevator, the export elevator and the importer change. Other changes are due to a small variation in the proportion of non-GM in the grain flow. Buyer and seller risks are similar to the base case. The main consequence of a higher system cost is a higher premium to compensate for the extra-expense. The difference between premiums is about 2 c/bu.

Table 15. Sensitivities to Traceability Cost

	Base Case	AGRIS
Utility	1.0373	1.0385
Optimal Strategy		
Test (1=Yes, 0=No)-Intensity		
On-Farm	1-5	1-5
Country Elevator Receiving	1-5	1-5
Country Elevator Loading	1-5	1-5
Export Elevator Receiving	NA	NA
Export Elevator Loading	1-1	1-1
Probabilities		
Buyer Risk	0.0128%	0.0128%
Seller Risk	1.7332%	1.7341%
Costs(c/bu)		
Integrator Cost/All bu	20.84	22.23
Integrator Cost/non-GM bu	29.56	31.54
Cert Prod (F)	5.29	5.29
Auditing (F)	4.05	4.05
Certification (F)	11.30	11.30
Buffer Strips (F)	0.64	0.64
Traceability (F)	5.19	5.19
Traceability (CE)	0.09	1.00
Traceability (EE)	0.06	0.66
Traceability (I)	0.06	0.66
Total Testing	1.74	1.74
Quality Loss/non-GM bu	1.15	1.15
Certainty Equivalent (Premium)/All bu	14.46	15.42
Certainty Equivalent (Premium)/non-GM bu	20.56	21.92
Total Cost/All bu	35.29	37.65
Total/non-GM bu	50.12	53.46
Location Percentage of non-GM flow		
Adoption rate	80%	80%
Farmer in Bin	79%	79%
Country Elevator Received	79%	79%
Country Elevator Loaded	76%	76%
Export Elevator Received	76%	76%
Export Elevator Loaded	72%	72%
Importer Received	70%	70%

Cost Minimization

Previous sensitivities performed used a utility model. An alternative model was specified where the supplier acts simply as a handler. In this capacity, the supplier buys wheat from growers to conform to the EU requirements. The supplier also conducts tests throughout the system as above, with the objective of minimizing costs. In this sensitivity, the optimization model defines the testing strategy that minimizes costs (certified seed use, certification, auditing, traceability, testing). Utility and risk premiums are not included in this analysis.

The objective of this model is to compare results from the optimization base case and a sensitivity that solely minimizes costs. Results are presented in the Table 16.

Table 16. Cost Minimization Sensitivity

	Base Case	Cost Minimization
Utility	1.0373	NA
Optimal Strategy		
Test (1=Yes, 0=No)-Intensity		
On-Farm	1-5	1-5
Country Elevator Receiving	1-5	NA
Country Elevator Loading	1-5	1-5
Export Elevator Receiving	NA	NA
Export Elevator Loading	1-1	1-1
Probabilities		
Buyer Risk	0.0128%	0.0129%
Seller Risk	1.7332%	1.7238%
Costs(c/bu)		
Integrator Cost/All bu	20.84	20.80
Integrator Cost/non-GM bu	29.56	28.96
Cert Prod (F)	5.29	5.19
Auditing (F)	4.05	3.98
Certification (F)	11.30	11.09
Buffer Strips (F)	0.64	0.63
Traceability (F)	5.19	5.09
Traceability (CE)	0.09	0.08
Traceability (EE)	0.06	0.06
Traceability (I)	0.06	0.06
Total Testing	1.74	1.64
Quality Loss/non-GM bu	1.15	1.14
Certainty Equivalent (Premium)/All bu	14.46	NA
Certainty Equivalent (Premium)/non-GM bu	20.56	NA
Total Cost/All bu	35.29	20.80
Total/non-GM bu	50.12	28.96
Location Percentage of non-GM flow		
Adoption rate	80%	80.0%
Farmer in Bin	79%	80.0%
Country Elevator Received	79%	81.7%
Country Elevator Loaded	76%	78.3%
Export Elevator Received	76%	78.7%
Export Elevator Loaded	72%	73.5%
Importer Received	70%	72.1%

Results from the cost minimization problem differ from the utility optimization. Testing at the country elevator when receiving is not included as part of the testing strategy for the cost minimization problem. Risks to the buyer increased from 0.0128% to 0.0129%, while seller risks decline from 1.73% to 1.72%. Changes in testing strategy also result in an increase in the proportion of non-GM (or undetected GM) in the grain flow. So, testing cost per non-GM is lower for the cost minimization model than for the base case.

The main difference between the cost minimization model and the utility model (base case) is that integrator costs are over 50% lower in the cost minimization model, largely due to not having a risk premium which composed half of the total integrator cost in the base case. According to the definition, the risk premium compensates the grain handler for potential risks emanating in the dual system over those in a non-GM system. When risks are not valued, the optimal testing strategy is less intensive (conducted at fewer locations) and integrator costs are lower. These results show that degree of risk aversion is important in the decision making process of the agent.

SUMMARY AND IMPLICATIONS

The objectives of this research were to determine optimal testing strategies and measure the costs and risks of conforming to EU traceability requirements. A stochastic optimization model (maximizing utility) was developed to quantify costs and risks subject to uncertainty in sampling/testing, test accuracies, adventitious commingling which can occur at all stages in the supply chain.

U.S. and EU Food Safety System: Two Different Approaches

To restore consumer confidence in public services, authorities in the EU used the precautionary principle, defined by the Maastricht treaty, and in 1998 placed a moratorium on GM products and ingredients. Different backgrounds about food safety between the US and EU resulted in two strategies. The American model designates a product as safe until proven otherwise, and the food safety system is based on public organisms and authorities management of food safety. The European strategy employs the precautionary principle, and the food safety system is based on private initiatives and labels.

Hence, the absence of consensus about practices among international institutions placed emphasis back on national legislation. The result has been a distinctly different response to the issue of traceability between the EU and the U.S. Distinctions exist, even in the definition of traceability. The EU defines traceability as ‘the ability to trace and follow a food, feed, food-producing animal or substance intended to be or expected to be incorporated into a food or feed, through all stages of production, processing and distribution.’ Traceability is defined by U.S. agribusiness firms and producers as ‘the efficient and rapid tracking of physical product and traits from and to critical points of origin or destination in the food chain necessary to achieve specific food safety and, or, assurance goal’ (Farm Foundation, 2004).

The EU’s new regulations on GM labeling and traceability came into force last April, ending the European moratorium and attenuates world trade conflicts. Many food and agricultural producers in the U.S. and elsewhere expressed the view that segregation and IP of non-GM materials and derivatives could not be done, or it could be done at a prohibitively high cost.

This regulation brings to light the lack of international trade policies on traceability issues. Because stakes are important, market participants are increasingly influencing the determination of acceptable levels. U.S. farmers say the closed EU market costs them $300 million a year in lost exports, mostly maize (Farm Foundation, 2004). Export market response to the commercialization of GM seeds was unexpected; the grain handling industry was unprepared for the rejection of these products. Even if the first-mover advantage in reaching the market with a new innovation or new practices is a critical strategic decision (need to recover the cost of innovation), the implementation of a traceability system is a competitive advantage in the international trade. It is a source of differentiation. The competitive advantage created by traceability is remarkable in Europe, where dramatic events have motivated traceability systems and private quality label development to restore consumer confidence. Traceability is a strategic commitment.

European studies on consumer concerns about food risk issues indicate that labeling is perceived as a means of correcting for lack of transparency in the regulatory system. Consumers are aware and knowledgeable enough to request more information about the food they are purchasing. Traceability implementations from retail to the producer are established in response to consumer demands. However this strategy is also contested because this practice slows down the innovative process necessary to sustain competitiveness in a global market.

Traceability Objectives and Issues

Two essential elements are needed for U.S. food producers who want to comply with the new EU GMO labeling and traceability regulations. The first is a well documented traceability system that demonstrates that all reasonable precautions and all due diligence were undertaken to exclude GM material from the product. Such a traceability system satisfies the EU requirements that any traces of GMO detected are adventitious and technically unavoidable. The second element is GMO testing to verify the level of adventitious GM in ingredients and other process inputs and final products are below the relevant thresholds (0.9% and 0.5%) (Fagen, 2004).

Certification and auditing have a main function in a traceability system. Independent certification affirms that an IP system is producing non-GM products, and conforming production to EU requirements. Third party certification is an added layer of risk reduction and provides additional protection in case of failure. Third-party certification demonstrates commitment to quality, increases consumer confidence in the product and enhances the producer’s credibility. Without an acceptable third party to verify or certify that the protocols met the required standards, and were implemented correctly, the USDA was required to provide oversight.

Stochastic Utility Model and Results

A stochastic optimization model was developed to measure risks and integrator costs for the introduction of North American HRS wheat into the EU market. Certified seed purchase, certification and auditing, buffer strips and traceability costs were added to farm management. Traceability costs were also added to country elevators, export elevators and importers. Testing costs have been updated and adjusted to conform to EU tolerances. Distributions for on-farm adventitious commingling were modified to reflect the impact of segregation practices.

Results indicate that buyer risks (probability of accepting a lot whose quality is unsatisfactory) can be managed and result in a very low level of GM content, (less than 0.05%). Seller risks (probability of rejection of a satisfactory batch), are limited. Results indicate a probability lower than 2%. These low risks show the efficiency of the testing strategy.

Generally, tests are recommended on-farm, at the country elevator (receiving and loading), at the export elevator (receiving only) and at the importer level. The last test is forced and its intensity is maximal. Test intensity is low (20%) from the farmer to the CE loading and high at the EE loading (100%). Adjustments are necessary to adapt the theoretical testing strategy (base case) to reality. Sensitivities are examples of adjustments. Testing at the export elevator receiving and intensity at the export elevator loading are adjustments most frequently done. Total costs for the supply chain are in the area of 50 c/non-GM bu, with a risk premium equal to 21 c/non-GM bu. Costs on-farm are important.

The objective of this research was to measure the costs and risks for the introduction of U.S. grain into the EU market by an integrator. The model evaluated risks and integrator costs, reimbursing additional costs (use of certified seeds, auditing and certification costs, buffer strips, traceability, testing, and quality loss), to conform to European requirements.

Results indicate that buyer risks can be managed and result in a low level of rejections and adventitious presence. Even a low risk aversion coefficient did not have a large affect on buyer risks. All sensitivities performed result in a buyer risk lower than 0.07%. Seller risks are generally low. Most of the sensitivities performed result in less than 2% of rejection at the importer level. A seller risk equal to 5.2% was derived when the risk aversion coefficient was low. The difference between the seller risk and the buyer risk shows the efficiency of the optimal testing strategy. Costs however increase, and for the likely case are in the area of 50 c/bu. The dominant costs are the risk premium and on-farm costs for certification, certified seed use, and auditing.

Among sensitivities performed, a few are interesting and give more additional information on parameter effects on optimal testing strategies, costs and risks.

- Penalties to exceed tolerances: Higher penalty costs increase quality loss costs for the volume of non-GM flows diverted in the system. Sensitivities for penalty costs showed that high penalties increase costs without changing the optimal testing strategy, or increasing the supply chain efficiency. Lower penalty costs resulted in reduced testing, higher rejection rates/costs. An effect not measured by this model would be to discourage agents from utilizing the supply chain.

- Adoption rate: When the adoption rate for non-GM production is lower, it becomes more difficult to remove the risk of commingling; hence, integrator cost is minimized when the production area is fully dedicated to non-GM grain. Certified seed use, certification and reimbursement of cost differential are costly practices for the integrator. These sensitivities show the importance of production area characteristics for the system cost. As adoption rates for non-GM increase, premiums per non-GM bushel decline and integrator costs increase. The net effect on total costs is for total costs to decline when testing strategies are the same as non-GM adoption declines, however, the net effect is also affected by discrete changes in testing strategies.

- Without on-farm testing: costs are not reduced significantly (the on-farm cost is minimal), but detections of adventitiously commingled lots in the non-GM flows are delayed. These differences are the determinants in the optimal testing strategy choice.

- The risk aversion parameter (η): when the decision maker risk aversion is lower, the manager takes risks, in this case the optimal strategy is less restrictive than the base case. The EE loading intensity is low (1:4) instead of high (1:1). Buyer and seller risks are significantly different from the base case. Because the manager is ready to take risks, the premium to compensate for risks is lower.

Costs and risks, for the introduction of North American grain into the EU market, depend on many stochastic, strategic and parametric variables. To compensate for additional costs and risks generated by segregation and traceability, the model recommends premiums generally equal to 21 c/non-GM bu. The additional integrator's cost per non-GM bushel to conform to EU requirements in the case of HRS is in the area of about 30 c/non-GM bu. Hence, the total cost to conform to requirements is about 50 c/non-GM bu.

The results indicate risks can be managed along the critical control points in the system to maximize utility and shows the risk premium necessary for the decision maker (integrator) to be indifferent between the dual system with traceability and a single non-GM system.

Segregation and traceability are costly practices, and even if testing strategy manages risks, costs are not homogenous between supply chain agents. Risk premiums being calculated are for the whole supply chain. In practice, how is this risk premium going to be shared between stakeholders?

Implication Private/Public

Failure or success of traceability systems is dependent on the ability of companies to implement such systems at low cost. Companies will have debates to determine whether or not to implement such protocols, given the low willingness-to-pay by consumers. Tracking and source verification cannot stimulate willingness-to-pay, while characteristics related to nutrition and health could possibly generate premiums (Farm Foundation, 2004). Even if record keeping and knowledge acquired are common justifications for implementation of traceability systems between the private and public sector, there are several sector implications. Locations and intensities of testing strategy are recommended, but decision makers in determining their strategies have choices. Costs and small premiums can affect the testing strategies, increasing risk. Private companies having minimal size efficiencies that implement traceability systems without premiums justify their choice by the value attached to extrinsic and intrinsic characteristics of the product, the reducing insurance premium and liability costs due to decreased claims, and the increase in their competitive advantage.

REFERENCES

Agence Science-Presse. 1999. "L'Avenir incertain du transgenique." Article.

Askin, Tom. 1988. *The Cost of Grade Segregating to Primary Elevators*. Canadian Grain Commission, Winnipeg, Manitoba, October.

Australian Government Department of Agriculture, Fisheries and Forestry. 2003. *Liability Issues Associated with GM Crops in Australia*. Science and Economic Policy Branch. September.

Bender, K. L., Hill, B. Wenzel, and R. Hornbaker. 1999. *Alternative Market Channels for Specialty Corn and Soybeans*. University of Illinois.

Besanko, David, D., Dranove, M. Shanley, and S. Schaefer. 2004. *Economics Of Strategy. 3rd Ed.* John Wiley & Son, New York. November.

Brookes, Graham, and P. Barfoot. 2003. *Co-existence of GM and non-GM arable crops: Case study of the UK.*

Brookins, C. "Biotechnologies and International Trade Issues." USDA Outlook Forum, Feb 24, 2000. Chairman and CEO World Perspective, Inc; Arlington, Virginia. 2000.

Buckwell, A., G. Brookes, and D. Bradley. 1998. *Economics of Identity Preservation for Genetically Modified Crops*. CEAS 1745/GJB. Wye, UK: CEAS Consultants, Ltd.

Bullock, David s., Marion Desquilbet, and Elisavet I Nitsi. 2000. *The Economies of Non-GMO Segregation and Identity Preservation*. University of Illinois, Department of Agricultural and Consumer Economics, Urbana, IL.

Commission of the European Communities. 2003a. *Guidelines for the development of national strategies and best practices to ensure the co-existence of genetically modified crops with conventional organic farming*. July 23.

Commission of the European Communities. 2003b. "Regulation (EC) No 1830/2003 of the European Parliament and of the Council of 22 Septembre 2003 concerning the traceability and labeling of genetically modified organisms and amending Directive 2001/18/EC." *Official Journal of the European Communities*. 18/10/2003.

Commission of the European Communities. 2001. *Regulation of the European Parliament and of the Council concerning traceability and labeling modified organisms and traceability of food and feed products from genetically modified organisms and amending. Directive 2001/18/EC.*

Dahl, Bruce L., and William W. Wilson. 2002. *The Logistical Costs of Marketing Identity Preserved Wheat*. Agribusiness and Applied Economics Report No. 495, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo.

Directorate-General for Agriculture European Commission. 2002. *Economic Impacts of Genetically Modified Crops on the Agri-Food Sector*. European Commission.

ESRI. 2004. Identity Preserve of Agricultural Crops. Environmental Systems Research Institute, Redlands, CA. Http://www.esri.com/agriculture. Accessed Feb, 2004.

European Parliament. 2001. "Directive 2001/18/EC on the deliberation release into the environment of genetically modified organisms and repealing Council Directive 90/220/EEC." *Official Journal of the European Communities*.

European Parliament. 2003. "Call for proposals for indirect RTD actions under the specific programme for research, technological development and demonstration: 'Integrating and strengthening the European Research Area.'" *Official Journal of the European Union*, 05/11/2003.

Fagan, John. 2004. "Getting IP in Place." *World Grain*. April.

Fagen, John. 2004. *GM faces the EU challenge*. IFI Online. www.ifi-online.com.

Farm Foundation. 2004. *Food Traceability and Assurance in the Global Food System*. Farm Foundation's Traceability Panel Report. July.

Fresco, Louise. 2001. *Genetically modified crops*. Food and Agriculture Organization of the United Nations.

Freshfields Bruckaus Deringer. 2001. *Regulatory and liability issues on the deliberate release of GMOs*. August.

GENCOD-EAN France. 2001. "Traceability in the Supply Chain From Strategy to Practice." April.

GENCOD-EAN France. 2001. "Traceability in the Supply Chain From Strategy to Practice." Press release October 5, 2001. http://www.eannet-france.org/download/nonprotege/kf_news/cp_ouvr_traca_va.pdf. Accessed in February, 2004.

Glaudemans, Heleen. 2001. *Identity Preservation Dealing with Specificity F&A Review*. Rabobank International.

Golan, Elise, N. Krissoff, F. Kuchler, L. Calvin., K. Nelson, and G. Price. 2004. *Traceability in the US Food Supply: Economic Theory and Industry Studies*. USDA , Agricultural Economic Report No.830.

Gosnell, D. 2001. *Non-GM Wheat Segregation Strategies: Comparing the Costs*. Unpublished Dissertation. University of Saskatchewan, Saskatoon.

Herrman, Tim, S. Baker, and F. Fairchild. 2001. "Characterization of receiving systems and operating performance of Kansas grain elevators during the wheat harvest." *Applied Engineering in Agriculture* 17(1):77-82.

Herrman, Tim, Michael Boland, and Adam Heishman. 1999. Economic Feasibility of Wheat Segregation at Country Elevators. *National Wheat Industry Research Forum Proceedings*. Nashville, TN. Feb 4-5. http://wheatimprovement.org/Forum/2/herman.html.

Hurburgh, Charles. R., Jr., Jeri L. Neal, Marty L. McVea, and Phillip Baumel. 1994. The Capability of Elevators to Segregate Grain by Intrinsic Quality. Presented at the 1994 ASEA summer meeting, Paper No. 946050, St. Joseph, MI.

Institute of Electrical and Electronics Engineers. 1990. *IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries*. New York, NY.

Jirik, Patrick J. 1994. *Identity Preserved Grain Marketing*. Unpublished Master's Thesis, St. Mary's College, Winona, MN.

Kalaitzondonakes, N. 2004. *Grower Survey Results about Cost Savings and Adoption Potential for Roundup Ready Wheat*. University of Missouri.

Kauffman, Kristin. 2005. "Face of Grain Handling Changing with Push to Develop, Implement IP Program." *Feedstuffs.* Vol. 77(10, March 7):27-31.

Lin, William W., William Chambers, and Joy Harwood. 2000. "Biotechnology: U.S. Grain Handlers Look Ahead." *Agricultural Outlook*. U.S. Department of Agriculture, Washington, DC, April.

Lin, William, W. 2002. *Estimating the Costs of Segregation for Non-biotech Maize and Soybeans*. ERS, USDA.

Maier, Dirk. 2004. "Segregation grain, methods to keep corn, soybeans separate can also maintain genetic purity." *Grain Journal*. Vol.32(2, March/April):48-49.

Maltsbarger, Richard, and Nicholas Kalaitzandonakes. 2000. "Direct and Hidden Costs in Identity Preserved Supply Chains." *AgBioForum*, 3(4):236-242.

Matus-Cadiz, M. A., P. Hucl, M. J. Horak, and L. K. Blomquist. 2004. "Gene Flow in Wheat at the Field Scale." *Crop Science Society of America* 44:718-727.

McPhee, Terry L., and Anita Bourget. 1995. *Cost of Grain and Grade Segregation at Terminal Elevators in Canada*. Canadian Grain Commission, Winnipeg, Manitoba.

Milling and Baking News. 2004. *Product traceability offers great potential benefits, faces hurdles*. April 13.

Nelson, Gerald C., Timothy Josling, David Bullock, Laurian Unnevehr, Mark Rosegrant, and Lowell Hill. 1999. *The Economics and Politics of Genetically Modified Organisms in Agriculture: Implications for WTO 2000*. Bulletin 809, Research Consumer and Environmental Science Department, University of Illinois at Urbana-Champaign.

Palisade. 1998. *Risk Optimizer: Optimization with Simulation for Microsoft Excel*. Palisade Corporation, Newfield, NY.

Peterson, Del. 2002. *Procurement Strategies for End-Users to meet Functional Characteristics*. Master's Thesis, North Dakota State University, Department of Agribusiness and Applied Economics. December.

Querci, M. 2001. *The Analysis of Food Samples for the Presence of Genetically Modified Organisms*. European Commission Joint Research Center, World Health Organization.

Schnepf, Randall, Erik Dohlman, and Christine Bolling. 2001. *Agriculture in Brazil and Argentina: Developments and Prospects for Major Field Crops*. Chap 6, ERS, USDA.

Seralini, G. 2002. Maitrise des diffusions, seuils et résidus. BIO Agency meeting of July 2002. Http://www.agence-bio.org/upload/pagesEdito/fichiers/seminaire_ogm.pdf. Accessed in March, 2004.

Serrao, Amilcar, and Luis Coelho. 2000. "The role of area-yield crop insurance in farmers' adjustment against risk in a dryland region of Portugal." Paper presented at the American Agricultural Association Annual Meeting. 1-13, 2000.

Sheldon, I. "Contracting, Imperfect Information, and the Food System." *Rev. Agr. Econ.* 18 (January 1996): 7-19.

Smyth, Stuart, and Peter W.B. Phillips. 2001. *Identity-preserving production and marketing systems in the global agri-food market: Implications for Canada*. Working Paper, University of Saskatchewan, Saskatoon. Aug.

Smyth, Stuart, and Peter Phillips. 2002. "Product Differentiation Alternatives: Identity Preservation, Segregation, and Traceability." *AgBioForum*.

Smyth, Stuart, George Khachatourians, and Peter Phillips. 2002. "Liabilities and economics of transgenic crops." *Nature Biotechnology*, Vol.20(6, June): 537-541.

Sparks Company. 2000. *The IP Future: Identity Preservation in North American Agriculture*. Sparks Company, Memphis, TN.

Swanson, Burton, Andrew Sofranko, Darrel Good, and Emerson Nafziger. 2003. *Non-Corn Update for 2003*. Illinois Specialty Farm Products.

Swanson, Jim. 2004. Personal Communication. Regulatory Program Manager, North Dakota State Seed Department. March 3.

Swenson, Andrew, and Ron Haugen. 2003. *Projected 2004 Crop Budgets North Central North Dakota*. Farm Management Planning Guide. NDSU Extension Service., Fargo.

USDA, Grain Inspection, Packers and Stockyards Administration. 2003. *Directory of Export Elevators at Export Port Locations Including Facilities Data*. Updated July 7.

USDA, North Dakota Agricultural Statistical Service. 2004. *December 1, 2003 Grain Stocks Report. January 12, 2004*. http://www.nass.usda.gov/nd/jangrstk.pdf.

Wilson, William and Bruce Dahl. 2001. *Evaluation of Changes in Grade Specifications for Dockage in Wheat*. Agribusiness and Applied Economics Report No. 458, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo.

Wilson, William and Bruce Dahl. 2002. *Costs and Risks of Testing and Segregation GM Wheat*. Agribusiness and Applied Economics Report No. 501, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo.

Wilson, William, Eric Jabs, and Bruce Dahl. 2003. *Optimal Testing Strategies for Genetically Modified Wheat*. Agribusiness and Applied Economics Report No. 520, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo.

Wilson, William, William Nganje, and Bruce Dahl. 2003. *Market Mechanisms to Facilitate Commercialization of Genetically Modified Grains: Testing, Tolerances, Segregation, Traceability and Contracting*. Department of Agribusiness and Applied Economics, North Dakota State University, Fargo.

Wright, Yancy, and Marcia Tilley. 2004. *Wheat Segregation and Identity-Preservation Cost*. Department of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma.

APPENDIX A. MODEL DISTRIBUTIONS

Table A.1. Base Case Adventitious Commingling Distributions

Location	**Distribution**	**Minimum**	**Most Likely**	**Maximum**
Grower Risk	Triangular	0.01	0.025	0.05
Country Elevator				
Receiving	Triangular	0.001+3*GM	0.01+3*GM	0.02+3*GM
Loading		0.001	0.01	0.025
Export Elevator				
Receiving	Triangular	0.001	0.01	0.025
Loading		0.001	0.01	0.025

Source: Wilson, Jabs and Dahl, 2003

Table A.2. Transportation Mode Assumptions

Location	**Mode**	**Unit Size (Bushels)**
Country Elevator		
Receiving	Truck	800
Loading	Rail	3,300
Export Elevator		
Receiving	Rail	3,300
Loading	Barge Hold	33,000
Importer Elevator		33,000
Receiving	Barge Hold	

Source: Wilson, Jabs and Dahl, 2003

APPENDIX B. OPTIMIZATION SIMULATION RESULTS

Table B.1. Optimization Simulation Results

	Adoption Rate					Buffer Strips
	Base case	**30%**	**60%**	**70%**	**90%**	**3-30m**
Utility	1.0373	1.0119	1.0270	1.0323	1.0423	1.0378
***Optimal Strategy* Test (1=Yes, 0=No)-Intensity**						
Farm	1-5	1-5	1-5	1-5	1-5	1-5
Country Elevator Receiving	1-5	1-5	1-5	1-5	1-5	1-5
Country Elevator Loading	1-5	1-5	1-5	1-5	1-5	1-5
Export Elevator Receiving	NA	1-5	1-5	1-5	NA	NA
Export Elevator Loading	1-1	1-5	1-1	1-1	1-1	1-1
Probabilities						
Buyer Risk (%)	0.0128%	0.0143%	0.0130%	0.0129%	0.0127%	0.0128%
Seller Risk (%)	1.7332%	14.0550%	1.9431%	2.2577%	1.6485%	1.7332%
Costs(c/bu)						
System/All bu	20.84	9.56	16.45	19.35	23.40	21.42
System/ non-GM bu	29.56	61.78	34.96	33.86	28.98	30.40
Cert Prod (F)	5.29	8.59	5.93	5.71	5.20	5.29
Auditing (F)	4.05	6.58	4.54	4.37	3.98	4.05
Certification (F)	11.30	18.34	12.65	12.20	11.09	11.30
Buffer Strips cost (F)	0.64	1.04	0.72	0.69	0.63	1.47
Traceability (F)	5.19	8.43	5.82	5.61	5.10	5.19
Traceability (CE)	0.09	0.18	0.13	0.1	0.07	0.09
Traceability (EE)	0.06	0.73	0.11	0.8	0.04	0.06
Traceability (I)	0.06	0.73	0.11	0.8	0.04	0.06
Total Testing	1.74	3.90	3.59	3.53	1.72	1.74
Quality Loss	1.15	10.53	1.27	1.50	1.09	1.15
Certainty E (Premium)/All bu	14.46	1.47	7.53	10.78	18.71	14.86
Certainty E (Premium)/non-GM bu	20.56	8.95	15.77	18.87	23.12	21.14
Total Cost/All bu	35.29	11.03	23.97	30.13	42.11	36.29
Total/non-GM bu	50.12	70.74	50.73	52.72	52.10	51.53
Location Percentage of non-GM flow						
Adoption rate	80.0%	30.0%	60.0%	70.0%	90.0%	80.0%
Farmer in Bin	79.3%	29.7%	59.4%	69.5%	89.2%	79.3%
Country Elevator Received	78.7%	29.5%	59.0%	69.0%	88.6%	78.7%
Country Elevator Loaded	76.0%	25.4%	55.5%	65.7%	86.3%	76.0%
Export Elevator Received	76.5%	22.5%	52.2%	62.4%	86.5%	76.5%
Export Elevator Loaded	71.8%	18.9%	48.2%	58.5%	82.2%	71.8%
Importer Received	70.5%	16.3%	47.2%	57.2%	82.8%	70.5%

Table B.1. (Continued)

	Base Case	Certified Seed Use			Risk Aversion		Traceabiltiy
		30%	60%	80%	0.4	0.9	AGRIS
Utility	1.0373	1.0378	1.0362	1.0351	1.2636	1.5528	1.1244
***Optimal Strategy* Test (1=Yes, 0=No)-Intensity**							
Farm	1-5	1-5	1-5	1-5	1-5	1-5	1-5
Country Elevator Receiving	1-5	1-5	1-5	1-5	1-5	1-5	1-5
Country Elevator Loading	1-5	1-5	1-5	1-5	1-5	1-5	1-5
Export Elevator Receiving	NA	1-5	NA	NA	1-5	NA	NA
Export Elevator Loading	1-1	1-1	1-1	1-1	1-4	1-1	1-1
Probabilities							
Buyer Risk (%)	0.0128%	0.0128%	0.0128%	0.0128%	0.0497%	0.0130%	0.0130%
Seller Risk (%)	1.7332%	1.7332%	1.7332%	1.7332%	5.1739%	1.7066%	1.7066%
Costs(c/bu)							
System/All bu	20.84	21.46	19.59	18.35	23.06	20.83	22.23
System/ non-GM bu	29.56	30.45	27.80	26.03	35.31	29.56	31.54
Cert Prod (F)	5.29	6.17	3.53	1.76	5.70	5.29	5.29
Auditing (F)	4.05	4.05	4.05	4.05	4.37	4.05	4.05
Certification (F)	11.30	11.30	11.30	11.30	12.17	11.30	11.30
Buffer Strips cost (F)	0.64	0.64	0.64	0.64	0.69	0.64	0.64
Traceability (F)	5.19	5.19	5.19	5.19	5.60	5.19	5.19
Traceability (CE)	0.09	0.09	0.09	0.09	0.09	0.09	1.00
Traceability (EE)	0.06	0.06	0.06	0.06	0.06	0.06	0.66
Traceability (I)	0.06	0.06	0.06	0.06	0.06	0.06	0.66
Total Testing	1.74	1.74	1.74	1.74	2.94	1.74	1.74
Quality Loss	1.15	1.15	1.15	1.15	3.57	1.15	1.15
Certainty E /All bu	14.46	14.89	13.60	12.75	12.01	19.33	15.42
Certainty E /non-GM bu	20.56	21.17	19.34	18.13	18.03	27.41	21.92
Total Cost/All bu	35.29	36.34	33.20	31.09	35.07	40.16	37.65
Total/non-GM bu	50.12	51.61	47.14	44.16	53.34	56.97	53.46
Location Percentage of non-GM flow							
Adoption rate	80.0%	80.0%	80.0%	80.0%	80.0%	80.0%	80.0%
Farmer in Bin	79.3%	79.3%	79.3%	79.3%	79.3%	79.3%	79.3%
Country Elevator Received	78.7%	78.7%	78.7%	78.7%	78.7%	78.7%	78.7%
Country Elevator Loaded	76.0%	76.0%	76.0%	76.0%	76.0%	76.0%	76.0%
Export Elevator Received	76.5%	76.5%	76.5%	76.5%	72.9%	76.5%	76.5%
Export Elevator Loaded	71.8%	71.8%	71.8%	71.8%	69.0%	71.8%	71.8%
Importer Received	70.5%	70.5%	70.5%	70.5%	65.5%	70.5%	70.5%

Table B.1. (Continued)

	Base Case	Risk Grower		No Test	Supplier Penalties	
		1%,2.5%,5%	0.5%,1%,3%	On-Farm	Low	High
Utility	1.0373	1.0360	1.0369	1.0374	1.0356	1.0379
***Optimal Strategy* Test (1=Yes, 0=No)-Intensity**						
Farm	1-5	1-5	1-5	NA	1-5	1-5
Country Elevator Receiving	1-5	1-5	1-5	1-5	1-5	1-5
Country Elevator Loading	1-5	1-5	1-5	1-5	1-5	1-5
Export Elevator Receiving	NA	1-5	NA	NA	NA	NA
Export Elevator Loading	1-1	1-1	1-1	1-1	1-5	1-1
Probabilities						
Buyer Risk (%)	0.0128%	0.0129%	0.0129%	0.0129%	0.0606%	0.0128%
Seller Risk (%)	1.7332%	1.7692%	1.7466%	1.7259%	6.1448%	1.7332%
Costs(c/bu)						
System/All bu	20.84	21.75	20.81	20.83	19.78	21.58
System/ non-GM bu	29.56	34.54	30.14	29.37	29.49	30.62
Cert Prod (F)	5.29	5.91	5.40	5.26	5.55	5.29
Auditing (F)	4.05	4.53	4.13	4.03	4.25	4.05
Certification (F)	11.30	12.62	11.53	11.22	11.84	11.30
Buffer Strips cost (F)	0.64	0.72	0.65	0.63	0.67	0.64
Traceability (F)	5.19	5.80	5.30	5.16	5.45	5.19
Traceability (CE)	0.09	0.10	0.09	0.08	0.09	0.09
Traceability (EE)	0.06	0.07	0.06	0.06	0.06	0.06
Traceability (I)	0.06	0.07	0.06	0.06	0.06	0.06
Total Testing	1.74	3.51	1.75	1.72	1.13	1.74
Quality Loss	1.15	1.17	1.16	1.14	0.33	2.21
Certainty E (Premium)/All bu	14.46	13.43	14.13	14.55	13.08	14.97
Certainty E (Premium)/non-GM bu	20.56	21.38	20.51	20.55	19.48	21.33
Total Cost/All bu	35.29	35.19	34.94	35.39	32.86	36.55
Total/non-GM bu	50.12	55.93	50.64	49.92	48.97	51.96
Location Percentage of non-GM flow						
Adoption rate	80.0%	80.0%	80.0%	80.0%	80.0%	80.0%
Farmer in Bin	79.3%	77.7%	78.8%	80.0%	79.3%	79.3%
Country Elevator Received	78.7%	75.9%	77.8%	79.3%	78.7%	78.7%
Country Elevator Loaded	76.0%	72.2%	74.7%	76.5%	76.0%	76.0%
Export Elevator Received	76.5%	68.5%	75.2%	77.0%	76.5%	76.5%
Export Elevator Loaded	71.8%	64.2%	70.3%	72.2%	71.7%	71.8%
Importer Received	70.5%	63.1%	69.1%	71.0%	67.3%	70.5%