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Logistical Costs and Risks of Marketing Genetically Modified Wheat

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ABSTRACT

Genetically modified (GM) grains have increased in importance. Moving biotech grains from producers to processors is a challenge for the grain handling system that could involve increased segregations. The objective of this research is to determine how testing strategies affect the logistical costs of a grain pipeline when GM wheat is present. A logistical model was developed and simulated to analyze impacts of uncertainty in demand, receipts, test accuracy, rail deliveries, and transit time. Sensitivities were conducted on certain variables to determine their effects on logistical costs. Analysis revealed that logistical costs are impacted by the number of quality categories and uncertainties in the system. Adding GM grains increased costs due to testing requirements and increased segregation demands as the number of wheat categories rises.

Key Words: Genetically Modified (GM) Grains, Logistical Costs, Testing, Risk, Segregation

HIGHLIGHTS

There is continuing interest in the introduction of genetically modified (GM) grains (including wheat) into the marketing system. As a result of buyer concerns, introduction of GM wheat has been delayed until a method of keeping GM wheat separate within the marketing system is developed. Adoption of a system of testing and segregation would increase the number of wheat categories handled in the grain pipeline and would impose additional costs due to the need of testing for genetic content. In this study, a model of the grain supply chain is developed to evaluate the effects of increasing grain categories and introduction of GM wheat on the logistical costs of the grain marketing system.

Adding GM wheat to the marketing system increases costs. The extent of the increase in costs depends largely on the ability to control the adventitious commingling of genetic content in non-GM wheat segregations to meet required threshold levels. Important considerations within testing plans are test accuracies, testing intensity, and testing costs which affect logistical costs. Choice of the number of wheat categories handled also affects costs. Matching production to consumption is an important factor that provides assurance that non-GM demand can be satisfied.

The expected increase in cost to the system from the No-GM to the GM base case appears to be minimal. As the system is less able to keep GM and non-GM wheat paths segregated, costs increase. This is especially apparent when a low tolerance level is set which increases the percentage of non-GM wheat that is considered contaminated with GM wheat. Small amounts of adventitious commingling do not greatly increase logistical costs; however, as the adventitious commingling level rises, costs increase sharply. The choice of test implemented, along with the intensity of testing, affects costs in a manner that was expected. For example, the choice of the lower cost test at the export elevator actually increased average costs.

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INTRODUCTION

Genetically modified (GM) and differentiated grains have escalated in importance in recent years. GM or transgenic crops have specific inclusive traits that can allow for reduced input costs, ease of production, and/or specialized output characteristics. However, the prospective demand for segregation of these crops within the marketing system has many logistical implications, including increased quality testing, proliferation of product types, and identity preservation/segregation of conventional and specialty (biotech) commodities.

Moving biotech crops from the farm to the processor and end-user is a challenge for the U.S. grain handling and transportation system (Norton, 1998). Grain customers are clearly becoming more specific in what they purchase (Bevilacqua, 1999). Thus, the effect of an increase in the number of segregations on logistical costs must be considered. Introduction of GM grains to the grain handling system could potentially double the number of segregations that must be handled and transported (Bullock et al., 2000).

If segments for GM grains are demanded, a method to maintain segregations would be required. It is difficult to visually detect a commodity that has been genetically modified. Therefore, other means must be utilized to segregate GM grains. Specialized tests can be used to verify that the product conforms to a specific threshold level. Another option is to rely on claims by the producer (farmer). However, if a premium is being paid for non-GM crops, false representations could be made.

Testing provides quality assurance to the buyer as test results show that suppliers have delivered grain that has met the desired level of quality for specified characteristics. However, the cost and need to test commodities to assure conformance to a threshold for genetic material is a major area of concern for grain marketers. Costs of genetic segregation and identity preservation depend crucially on specified tolerance levels (Bullock et al. 2000). A low tolerance level for GM content in some identity preserved crops increases risk of non-conformance (Burchett, 2000). Industry experts have indicated that a 1 percent threshold is nearly impossible to achieve, while a 5 percent level would be manageable (Sonka et al., 2000). The Organization for Economic Cooperation and Development (OECD) Agriculture Committee (2000) found that a zero tolerance level could increase prices for a non-GM commodity up to 50 percent over the GM variety; whereas, a 1 percent tolerance level increases costs only about 15 percent above market prices.

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The purpose of this study is to analyze the prospective implications of marketing GM wheat and the logistical costs and risks. A stochastic simulation model of a hard red spring (HRS) wheat grain export chain was developed to examine logistical costs and risks. A Materials Requirement Planning (MRP) approach is used to pull grain through a supply chain from HRS wheat production regions through Pacific Northwest (PNW) ports to importers. The model is developed using @Risk to capture randomness in testing accuracy, demand, receipts, railcar placement, and transit times. An important aspect of the model is that it allows for substitution of high to low quality and non-GM to GM wheat to meet quality demands. Sensitivities are conducted to examine effects of testing cost and accuracy, incoming grain quality, and numbers of segregations handled on the logistical costs of marketing grain.

The next section reviews aspects of testing. This is followed by background on effects of adventitious commingling. Then the empirical model is presented. Data and simulation procedures are presented. Results are presented for a base case and followed by sensitivities on specific parameters. Finally, implications and conclusions are presented.

BACKGROUND

Testing

The current grain marketing system performs tests to determine grade characteristics, protein content, dockage, and other characteristics for a grain lot. Since the introduction of GM crops, additional testing for genetic content has been added for crops where there is demand for segregation of GM varieties. Buyer preferences drive the demand for testing and assures end-users that the supplier is achieving their specified preferences.

Accuracy, time requirements, and cost are crucial elements in testing for GM content. The National Grain and Feed Association (1999) states that tests should be accurate, repeatable, low cost, and be applicable to future releases of GM grains and oilseeds. Harl (1999) states that testing is necessary when GM grains are added to the marketing system. He adds that a dual marketing system would be ideal, one channel for GM hybrids and one for non-GM varieties. Harl (1999) also notes that zero tolerance by buyers on specifications would require testing at every point in the marketing channel where grain is commingled (Anderson, 1999).

There is no single, rapid, or inexpensive test to verify whether a crop is free of genetic modification (Magin et al., 2000). The National Grain and Feed Association (1999) states that if a single test capable of detecting the full range of biotechnology enhanced traits cannot be developed, then perhaps marker genes should be inserted into genetically altered crops that can be detected by a single test. Testing procedures currently vary by commodity. Soybeans are relatively easy to test since only one variety, glyphosate-resistance, has been grown; however, 16 different transformations exist in corn (Bullock et al., 2000).

Genetic Tests

Genetically enhanced testing accuracy has uncertainty due not only to the test, but also from the sampling methods used to obtain a representation of the lot.[1] There are two general categories of genetic tests, DNA and Immunoassay tests. If a tolerance level is adopted for labeling laws, quantitative results are necessary. Each test has positive and negative factors that need to be considered when choosing a testing technique. Genetic tests available currently include Polymerase Chain Reaction (PCR), Southern Blot Analysis, Immunoassay, and Herbicide Bioassay tests. In addition, a Near-Infrared (NIR) test is in development. Hurburgh et al. (2000) report that NIR results on Round-up Ready® soybeans could be obtained in about one minute with an estimated cost of only $3 to $5. The test is believed to be over 90 percent accurate on lots that are all Round-up Ready® or non-Round-up Ready®.

DNA Grain Tests

PCR tests are widely used in Europe and the United States to determine if a commodity has GM content. The main benefit of PCR is that it is able to detect all genetic modifications in one test (Schuff, 1999) because it searches for altered DNA rather than proteins. PCR tests produce higher accuracy ratings because DNA modifications are shown in all parts of the plant; whereas, proteins are expressed in only certain sections of a plant (Gachet et al., 2000). PCR tests are also able to give quantitative results in percentages rather than discrete results. The negative aspects of PCR are the time required to check a sample and the complexity and cost of the laboratory work. PCR's high sensitivity, along with very low levels of inadvertent commingling, can also result in false positives (Magin et al., 2000). This means that the sample may actually meet the requirements for being classified as non-GM but the sensitivity of the test returns a result stating that the sample contains too much genetic material. Lab work for PCR tests can be completed within 24 to 36 hours; however, the time requirement is generally three days (Genetic ID, 2000b). PCR testing requires specialized laboratory equipment and skilled personnel. PCR test costs range from $100 to $300 per sample and typically one day is required for sample analysis with results generally available within one to three days (Magin et al., 2000).

Southern Blot testing is a method used to determine if a commodity has been genetically modified by detecting specific DNA sequences. It costs $100 to $300 per sample and takes four to six days to obtain results. The test process is difficult to administer and requires special equipment and training, including radioactive material (Klose and Speich, 1999). Therefore, the Southern Blot test is generally not used for detecting genetic material in grains.

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[1] A 1998 ring trial by the Joint Research Center of the European Union found that 44 percent of detection laboratories could not complete a dioxybliec nucleic acid (DNA) analysis of genetically enhanced foods (Genetic ID, 2000c).

Protein Tests

Immunoassay strip tests use antibodies to identify proteins expressed as a result of genetic modification. These tests generally do not require an extensive amount of time to obtain a quantitative or yes/no result and are less expensive and easier to use than PCR tests. Biotechnology companies often use them to make sure that the gene in question was actually inserted in a plant (Genetic ID, 2000b). Immunoassay tests include Enzyme Linked Immunosorbent Assay (ELISA) tests, Lateral Flow Strip tests, and Multi-trait Strip tests.

An ELISA test is a complex immunoassay test that can provide quantitative test results, but can only identify one genetic modification per test. ELISA tests are able to detect and measure the amount of protein of interest in a sample using antibodies specific to those proteins (Magin et al., 2000). The ELISA test takes at least six hours to complete (Bullock et al., 2000). Benefits of the ELISA test are that it is less susceptible to false positives caused by inadvertent commingling and the sample cost per test is less than that for PCR tests. The ELISA test for herbicide resistant soybeans costs $100 per test; whereas, the PCR test costs $300 per test (Bullock et al., 2000). However, not all GM varieties exhibit proteins at a detectable level. Also, the development and generation of antibodies that are used to identify the genetic modification is timely and expensive.

Strip tests are quick and are less expensive than ELISA tests. Most strip tests are only able to detect one genetic modification; thus, crops with more than one GM trait require separate tests for each trait. Strip tests give a yes/no answer to the presence of the genetic material in question and are easy to administer. Lateral Flow Strip test analysis takes five to fifteen minutes per test and costs roughly $7.50 per test for soybeans and $7.00 per test for corn (Bullock et al., 2000). Multi-trait strip tests are in development and could potentially detect more than one event. In fact, Strategic Diagnostics Inc. (SDI) has developed a multi-trait strip test that is able to detect up to six events in one strip (SDI, 2000).

Herbicide Bioassay tests are used to check samples for resistance to herbicides. A sample of seeds is sprayed with the herbicide in question to determine resistance. If the seedlings live, they are considered genetically modified and, if they do not live, the sample is determined to be non-GM. This test allows for quantification but takes time to complete as germination must occur. This test costs $30 and works only on seeds that germinate (Bullock et al., 2000).

Testing Impact on Logistics

The goal of logistics planning is to get a product from one point to another point at the right time and to ensure that the product delivered meets the specifications of the product requested. Adding another function or activity, such as testing for GM content, to this network increases logistical complexities. One cost associated with testing is that of queuing time or waiting. This is an *opportunity or carrying cost* that is incurred over the number of days the grain must be held while a test occurs and results are received. A strategy to avoid this cost is to send the shipment of grain while the test is being conducted and hope that it will conform to the quality requirements when received. A risk with this method is having the shipment be out of conformance at the destination. If the product fails to conform to the required specifications, a discount may be applied or the shipment may have to be reconsigned or diverted to alternative markets where there is a demand for this non-conforming product. Another method is to perform the test once the shipment arrives. This may lead to increased demurrage charges if the test requires a significant amount of time to complete.

Certification

Another alternative for grain handlers to ensure adequate quality levels and genetic threshold levels is certification programs. Certification involves tracking and documenting entire product lines in the production chain from farms to retail shelves, including sampling, testing, and inspection. A certification program, depending on product types, is expected to cost about $150,000 per year (Lo, 2000). A third party monitors and is responsible for inspection, testing, and verification during seed selection, planting, harvesting, transportation, storage, distribution, and processing (Argyle Rowland Worldwide, 1999).

Certification allows for every stage of the food chain, including farmers, processors, exporters, shippers, manufacturers, and retailers to maintain the purity of their non-GM products. Certification provides security and assurance to customers that the production process has been adequately segregated and inspected, that representative samples have been taken and tested, and that sufficient records have been kept to trace all finished products back to the raw materials used to produce them (Genetic ID, 2000a). Certification transfers the risk or liability from the producer to a third party certification agent. Certification may be the best selection in high-risk scenarios, those in which low tolerance levels are set. The advantage of certification is the detailed records and testing that are done to ensure shipments meet required specifications, whether it is for grade characteristics or GM content.

Examples of current certification programs include Cert-ID by Genetic-ID (a genetic testing company) and Northland Programs. Cert-ID ensures that commodities or foods will remain non-GM from planting to the finished product (Poulter, 1999). Northland uses a three-step process. The first step is the pre-planting phase in which seed purity is verified. The second step is the growing phase in which inspection and testing are implemented to guarantee that the varieties being grown do not contain undesired genetic material. In the third step, post harvest phase, product segregation is monitored in the storage and transportation systems including processing and packaging. More testing is completed to ensure that the commodity is free of genetic enhancements and samples are maintained for future analysis (Northland Seed and Grain Corporation, 1999).

Adventitious Commingling

A marketing system handling GM/Non-GM segregations would incur risks of blending or commingling GM and Non-GM segregations. Several studies have noted unintended or adventitious commingling effects in the grain marketing system. Hurburgh (1999) states that there are 20 to 30 points where mixing could occur. The American Corn Growers and Genetic-ID indicate that the following five measures should ensure adequate segregation: (1) clean harvesting equipment and storage facilities, (2) store and ship grain in cleaned, separate containers, (3) provide an adequate buffer between non-GM and GM fields for cross pollinating crops, (4) if genetically enhanced varieties were planted in the current year, rotate to another crop for the next two years to prevent commingling from volunteer genetically engineered plants, and (5) take careful and representative samples whenever genetic testing is done (Goldberg and Smith, 1999).

Potential contamination can occur at planting. Producers need assurance that the seeds they planted were not derived from a genetically altered source. No seed company guarantees 100 percent seed purity (Bullock et al. 2000). Soybeans have higher seed purity levels because they are self-pollinated. Seed purity for soybeans ranges from 99.8 percent to 99.9 percent (Bullock et al., 2000). Since corn is cross-pollinated, a lower purity level is common and on average corn seed is at least 99 percent of the variety on the label (Bullock et al., 2000). Genetic ID found that 10 percent of samples tested in their laboratory that were believed to be non-GM contained GM material between the levels of 0.1 percent to 1 percent (Goldberg and Smith, 1999). Midi Libre reported that in December 1999, French sources found that 45 percent of corn designated as non-GMO contained 0.1 percent or more DNA fragments from GMO hybrids (Hurburgh et al, 2000). In Germany, 82 food products were tested and one-third were found to contain GMOs, but only three products contained GMO content in excess of the 1 percent threshold level required for labeling (Genetic-ID, August 31, 2000d).

For grains, adventitious commingling is detrimental because it is virtually impossible to visually distinguish genetic content differences in grains. Storage, handling, and transportation equipment needs to be thoroughly cleaned to ensure that commingling does not occur. The USDA states that grain moves through a well-developed transportation system and before a bushel of grain reaches the market it has often been transported by two or more modes of transportation (USDA, *Transportation of U.S. Grains*). The chance of adventitious commingling occurring from improper cleaning increases when more than one mode of transportation is used.

METHODS

Materials Requirement Planning (MRP) methodology is used to model movement of grain, of different qualities (Stock Keeping Units or SKUs), through a supply chain from HRS wheat production regions through PNW export port elevators to importers. Two different models are developed. A No-Genetic (No-GM) model is used to determine logistical costs without GM wheat. A Genetic (GM) model is defined to calculate prospective logistical costs after the introduction of GM wheat into the logistical pipeline.

Demand forecasts for SKUs are developed based on weekly export inspections. The demand forecast pulls grain through the pipeline from the country elevator to the export elevator. Shipping decisions are based on this demand forecast. Wheat of different qualities (SKUs) are pulled through the system from an origination area that includes a number of country elevators. Railcars are ordered for placement due to forecast demand at the export elevator four weeks ahead of the current week. After railcars are placed at the country elevator, they are loaded with grain and transported to the export elevator. Transit time is defined as the time between when grain is loaded and ready to be shipped from the country elevator until the grain is in position to unload at the export terminal (Carlson, 1998).

When grain arrives at an export facility, it can be stored if storage capacity allows or loaded onto vessels to meet demand for specific qualities (SKUs). Demand at the export elevator is met from the grain in storage or from grain arriving by rail that week. Substitution of wheat SKUs is allowed at both the country elevator and export elevator to meet demand requirements. Substitution of higher quality segregations into lower quality segregations is allowed, but not vice versa, and when substitution occurs it is assessed an opportunity cost. At the export elevator, substitution is only allowed if the cost of doing so is less than the implicit demurrage cost.

If transportation equipment (railcars or vessels) are held longer than allowed by the carrier, demurrage is applied. Demurrage occurs at the country elevator when inadequate grain supplies are present to fill the number of railcars that are ready to load at the country elevator in the week. At the export facility, demurrage charges are applied when the demand cannot be attained for vessels from wheat on hand at the export elevator for a given week.

Testing for GM content is added at two points in the supply chain. Two testing methods are used, including PCR and Immunoassay tests, which include the ELISA test and the Lateral Flow Strip test. Costs for testing are applied based on the intensity of testing (number of tests conducted) and type of test utilized at both locations. The GM model is developed to quantify the costs associated with having to transport an increased number of segregations. Figure 1 provides an illustration of grain flows throughout the system.

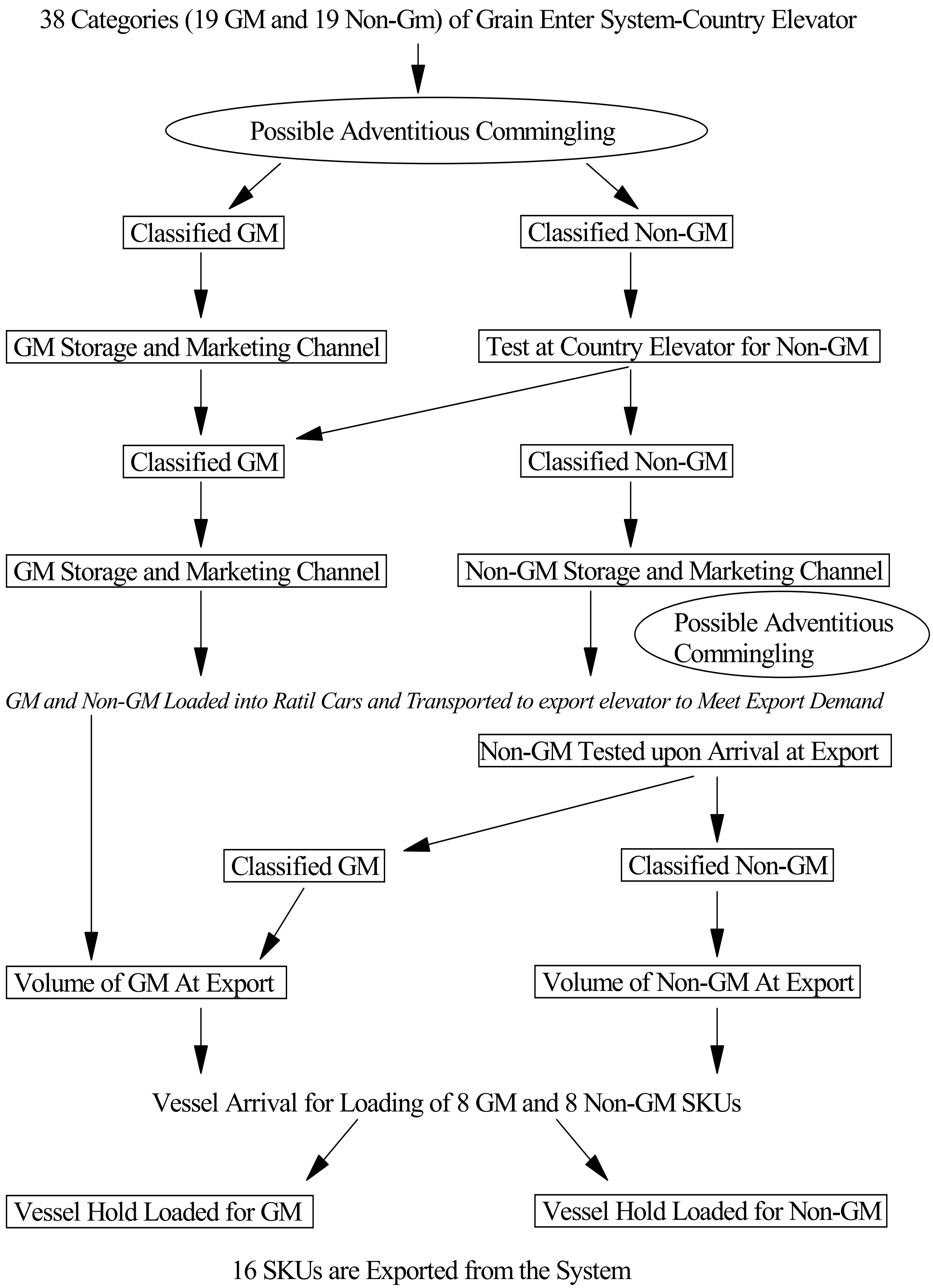

Figure 1. Grain Flow Diagram.

Mathematical Model Description

The mathematical model includes those logistical costs described previously to capture costs of increasing quality categories handled by the pipeline. Costs included in this study are rail tariff rates, interest costs of storage, substitution costs, demurrage costs, and testing costs associated with the adoption of GM wheat. The costs are calculated for 52 weeks as:

$$TC = \Sigma\,(RC \bullet RC_N + T_{CE} \bullet QT_{CE} + T_{EE} \bullet QT_{EE} + Dem_{CE} \bullet Dem_{RC} + Dem_{EE} \bullet Dem_{REE} + (S_{iCE} + S_{iEE}) \bullet SC + IR \bullet VSku_i)$$

Where:

TC = Total cost of system over 52 weeks
RC = Railcar tariff rate
RC_N = Number of railcars loaded at country elevator
T_{CE} = Test cost per lot at country elevator
QT_{CE} = Number of lots tested
T_{EE} = Export elevator testing cost per lot
QT_{EE} = Number of lots tested
Dem_{CE} = Number of railcars demurrage is applied on at country elevator
Dem_{RC} = Demurrage charge applied per railcar
Dem_{EE} = Number of bushels on which demurrage is applied at export elevator
Dem_{REE} = Export Elevator demurrage rate per bushel
S_{iEE} = Quantity of SKU_i substituted at export elevator
S_{iCE} = Quantity of SKU_i substituted at country elevator
SC = Forgone Premium of substituting to a lower quality SKU
IR = Interest Cost Applied
$VSku_i$ = Price Paid for SKU_i by System Participants

The cost of cleaning for substitution of high dockage to low dockage SKUs is included as a forgone premium cost. In addition, costs of elevation are not included and considered constant.

Detailed Description of Model [2]

In the GM model, a test occurs on non-GM wheat at the country elevator, which is the point of entry into the pipeline. There is no need to test known GM wheat. The test is represented by a binomial distribution, which is the probability of accepting a lot based on its genetic content and test accuracy. Results from the test are used to determine grain allocation for storage of each particular SKU.

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[2] Details of the basic model and data are contained in Schlecht, Wilson, and Dahl (2004).

Export Elevator Model Details

As railcars arrive, they are allocated to meet the SKUs export vessel demand or to specific SKU storage bins. The content of each railcar by SKU is considered known upon its arrival from the country elevator. In the GM model, non-GM railcars are tested prior to arrival at the export elevator and allocated to storage based on these results. Storage is based on throughput, so higher volume SKUs receive more storage capacity. This allows for an optimal storage configuration at the export elevator. It is assumed that there are a sufficient number of storage bins at the export elevator to receive and handle all quality categories.

The SKUs are categorized by using grade factors, protein, dockage levels, and GM content. Four segregations were utilized for grades (U.S. No. 1, No. 2, No. 3, and salvage). Three segregations were utilized for protein (high, medium, and low). Two segregations were utilized for dockage content (high dockage and low dockage), and two segregations were utilized for GM content (yes and no). Break points for classifying the SKUs are shown in Table 1.

Table 1. SKU Breaks

Classifying Characteristic	Percentage Break
Grade	
U.S. No. 1	Grade Factor Limits
U.S. No. 2	
U.S. No. 3	
Less than No. 3 to Salvage	
Protein	
High Protein	Above 14.5%
Medium Protein	Between and including 13.7% and 14.5%
Low Protein	Below 13.7%
Dockage	
High Dockage	Above 0.7%
Low Dockage	Below and including 0.7%
GM/Non-GM	
Non-GM	Below Threshold
GM	Above Threshold

Acceptance levels of GM wheat are uncertain. Adoption levels by export customers or those customers willing to accept GM wheat are represented by a percentage level. This value was calculated from EGIS data and a U.S. wheat survey (Sands, 2000) that indicates which countries are willing to accept GM wheat. The percentage level lowers the non-GM SKU by the percentage amount and transfers that volume to the GM SKU. The production is matched to the export percentage in the base case and sensitivities are performed on both parameters due to their uncertainty of this value. Sensitivities allow an evaluation of how changes in these parameters affect the logistical costs of transporting grain. Introduction of genetic wheat increases the number of SKUs the logistical system must handle from 19 to 38 SKUs at the country elevator and from 8 to 16 SKUs at the export elevator.

Each SKU has a value due to the composition of its various quality characteristics. A base wheat price of $3.25 per bushel is utilized in the model [Minneapolis futures contract price for HRS for the December 2000 (Z0) contract on September 29, 2000]. The market values for the various SKUs are calculated by adding the premiums and discounts for grade factors, protein content, dockage level, and GM content to the base wheat price.

Discount and premium values for protein content were taken from a survey made of export grain merchandisers during the fall of 2000 to find the value associated with each SKU level. Values between grades are calculated from current premium/discount values for grade factors and applied to the North Dakota crop quality data to determine an average cost per grade. The grade factor premium and discount values are applied to current classifications of samples already labeled as Grade 1, 2, 3, and less than 3 to find the average value of wheat classified as Grade 1, 2, 3 or less than 3. Industry participants also estimated the discounts between similar SKUs of different grades and the calculated values were comparable. Dockage discounts are cleaning costs of 3.3 ¢/b to bring dockage content to below 0.7 percent (Wilson and Dahl, 2001). Dockage cleaning costs are applied to high dockage SKUs if they must be substituted to a low dockage SKU. Also, a forgone cost is applied if a low dockage SKU is used to fill high dockage SKU demand. For the GM SKUs, a discount of ten cents is applied in the base case model. This value is comparable to the premium that has evolved for non-GM corn. The following discounts or forgone premiums in Table 2 are utilized to determine the flow of goods for substitution possibilities.

Testing

Testing is added to the GM model at two points. First, at the country elevator where grain is first received. Second, at the export elevator when railcars arrive for unloading. Testing is added to ensure product conformance to the required demand specifications. Test type, accuracy, and costs used in this study are in Table 3.

Table 2. Discounts or Forgone Premiums

Substitution	Forgone Premium
	c/b
Grade 1 for Grade 2	06.0
Grade 2 for Grade 3	06.0
Grade 1 for Grade 3	13.0
Grade 1 for Salvage	37.0
Grade 2 for Salvage	31.0
Grade 3 for Salvage	25.0
High Protein to Medium Protein	07.5
High Protein to Low Protein	18.5
Medium Protein to Low Protein	10.5
High Dockage to Low Dockage	03.3
Low Dockage to High Dockage	03.3

Table 3. Summary of Genetic Tests

Test Type	Accuracy	Cost
Strip Test	95%	$7.50 per test
ELISA	95%	$100 per test
PCR	99.9%	$200 per test

A binomial distribution with a calculated percentage of accepting the lot is included to account for randomness in adventitious commingling levels and testing accuracy. The binomial distribution calculation is based on the test accuracy and the level of GM adventitious commingling in the non-GM wheat lot. If the amount of genetic material exceeds a threshold level of acceptance, it is defined as a lot of wheat that contains GM material and diverted to a similar GM segregation.

There are two sources of adventitious commingling in the model. One is due to cross pollination, farmer mishandling, and farmer accountability. This value is unknown so sensitivities are performed. In the base case, the value is set at a 10 percent for wheat entering the system. The second possibility occurs after the grain enters the logistical system and is labeled as pipeline commingling. This may occur as GM wheat is mixed with non-GM wheat. In the base case, adventitious commingling for this second type was restricted to reflect the accuracy of tests applied and sampling intensity (i.e., proportion of false negative tests (GM indicated as non-GM) remaining in non-GM flow after tests at the country elevator). This value represents a closed loop system or a possible vertically integrated system in which separate grain paths or parallel marketing channels are in place and information is shared among participants at the different supply chain points. A second case is also modeled where GM adventitious commingling in the pipeline is increased to represent an open system in which information and profits may not be shared among participants. Sensitivities are performed on the pipeline adventitious commingling level due to the uncertainty of its value and to determine its effect on the logistical system after the introduction of GM wheat.

In the base case, every 4,000 bushels (5 truck deliveries) of non-GM wheat are tested at the country elevator. The 4,000 bushels are separated into a temporary holding area and tested. After the results of the test are received, the lot is channeled to its appropriate storage and marketing channel. The same concept is used at the export elevator; however, here a larger lot is tested for classification as GM or non-GM. Every 19,800 bushels (6 railcars) are tested at the export elevator and allocated to the appropriate channel upon test results. Since testing strategies on intensity can vary widely, sensitivities are performed to show the effect of different testing intensity strategies.

Simulation Procedures

The model is developed as a stochastic simulation model utilizing @*Risk* software (Palisade Corporation, 2000). The model is developed to cover a 58-week period, allowing 6 weeks for railcar and barge ordering strategies to initialize and then costs are monitored for the remaining 52-week period, simulating one year of operation for the marketing chain. The model was specified with initial parameters for inventories representing continuing operations. Initial parameters for beginning inventories, capacities, etc., are described below. Models are simulated for 1,000 iterations at which time output distributions for total costs over the 52-week period had converged and appropriate stopping criteria were indicated.

Data

Demand

The model is representative of an export facility of average size in the PNW. There are nine export facilities in the PNW with varying storage capacities. The average storage size was estimated from GIPSA (2000) data on export facility capacity. This average export facility is taken to represent 11 percent of the PNW wheat throughput.

Normal distributions are assumed for weekly export demand and the forecast of export demand. The mean and standard deviation for each week are derived from weekly wheat export inspections at the PNW from the Grain Transportation Report (1996-2000). The model evaluates demand only for HRS wheat, so a percentage value of 29.67 percent of the total wheat weekly inspections at the PNW is taken to represent the amount of HRS wheat demanded at the PNW. This percentage is calculated from the Export Grain Inspection Service (2000) data by evaluating the volume of different classes of wheat exported per year from the PNW. Figure 2 provides a representation of demand characteristics for HRS wheat exported from the PNW.

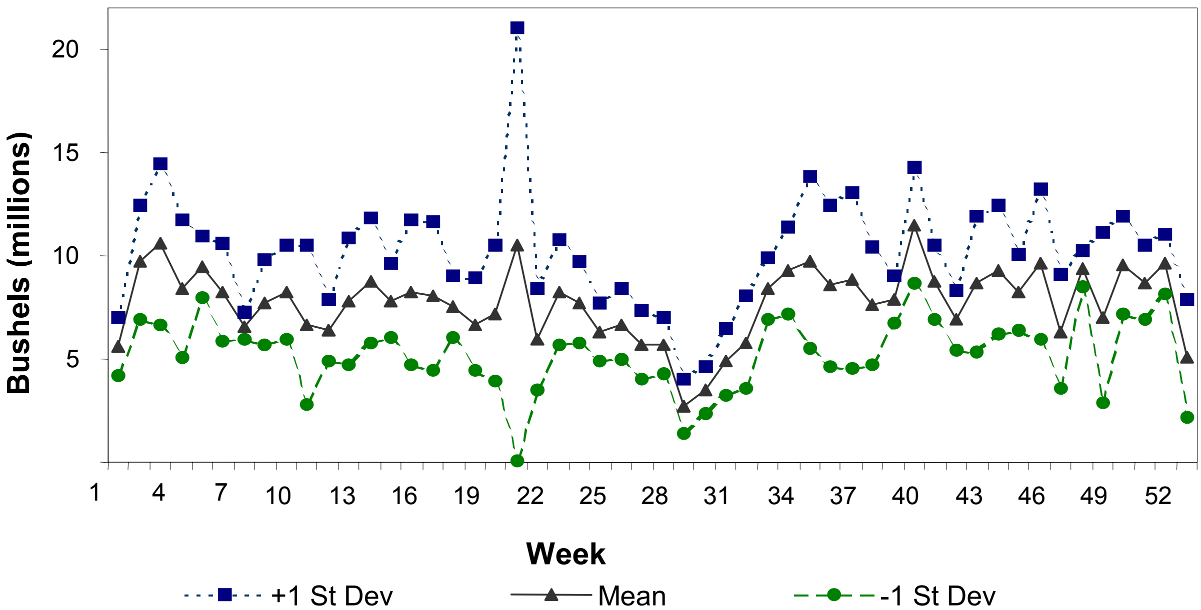

Figure 2. HRS Demand Distribution at the Pacific Northwest.

Receipts

North Dakota Agricultural Statistics Service data from 1991-1995 were used to derive distributions for farmer deliveries to an elevator. Means and standard deviations for the percent of annual sales within a month were converted to weekly distributions which were utilized within the model. Means were converted to a weekly average by dividing by the number of weeks in the month. A weekly standard deviation was derived by dividing the variance of the monthly deliveries by the number of weeks in the month and converting this back to a standard deviation. A normal distribution was assumed to represent the uncertainty about weekly producer deliveries. Weekly deliveries were estimated by multiplying random draws from these distributions (one for each week) by annual deliveries.

Figure 3 represents the distribution of receivables at a country elevator or point of origin. The figure represents the distribution for one country elevator. The origination for one country elevator is multiplied by a scalar to ensure enough supply in the pipeline to meet the demand for an average size export facility in the PNW. This scalar value is unknown, so sensitivities are conducted to determine the effects of larger and smaller origination capacities. The scalar value implemented for the origination volume affects both the mean and standard deviation of the distribution for receipts. As the scalar increases, the mean value of receipts increases, but the volatility of receipts increases as well.

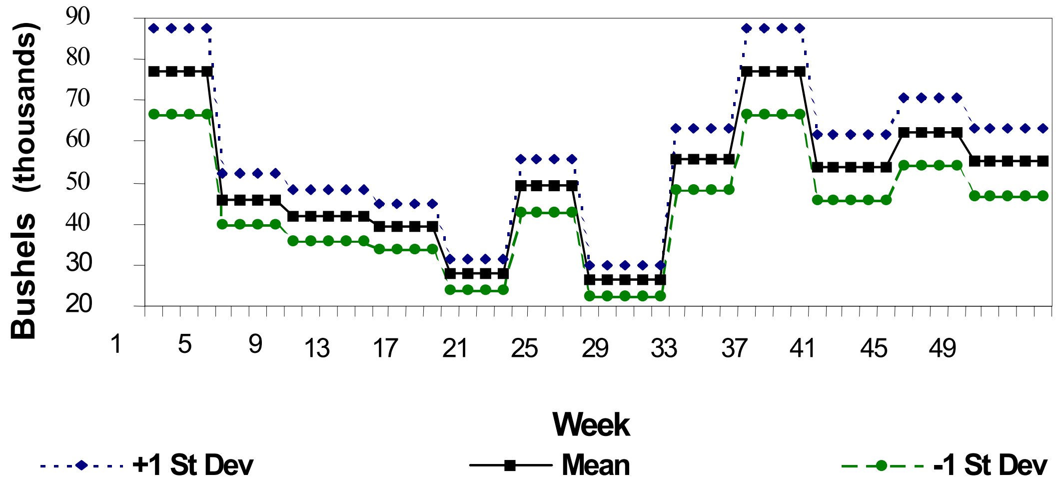

Figure 3. Distribution of Receivables at the Country Elevator.

Quality SKUs

All SKUs derived from the breakdown by grade, protein, and dockage level are incorporated in the system. For receivals at the country elevator, 19 SKUs were included and the receivals are allocated to each SKU based on the percentages shown in Figure 4, ranked highest to lowest for the percent of receivals allocated to a SKU. This shows 16.6 percent of receivals are allocated to SKU 2, 12.1 percent to SKU-6, etc. Percentages for allocating outbound or demand SKUs are shown in Figure 5. These percentages were applied to forecast demand to estimate demand for each of the 8 outbound SKUs.

Storage Capacities and Shipping Costs

Storage capacities for the elevators are estimated from data obtained from the Burlington Northern Santa Fe (BNSF) *Grain Elevator Directory* for 1999 and the Federal Grain Inspection Service (2000) export elevator directory. Table 4 illustrates the average storage capacity for the country elevators and the export elevators. It is assumed that 50 percent of overall storage capacity at both country and export elevators are dedicated to wheat.

Storage capacity for each SKU is calculated on a percentage basis. The percentage of throughput for each SKU is applied to the overall storage capacity for wheat to determine that SKU's respective storage capacity. Storage is calculated in this manner due to the difficulty in obtaining storage configurations and bin size. Due to this method of storage allocation, there is always an optimally sized bin and number of bins for the given number of SKUs and their volumes.

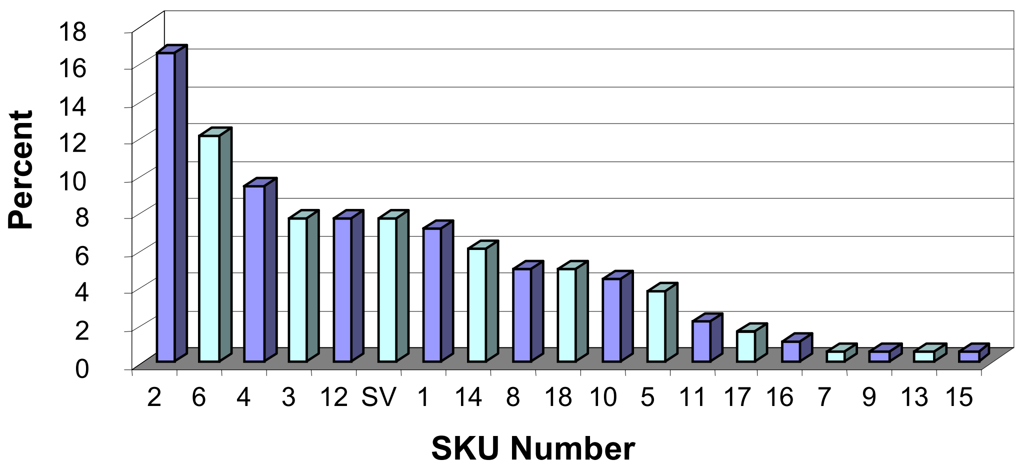

Figure 4. Percent of Receivals Allocated to Each SKU at Point of Receipt, By SKU (Inbound SKUs).

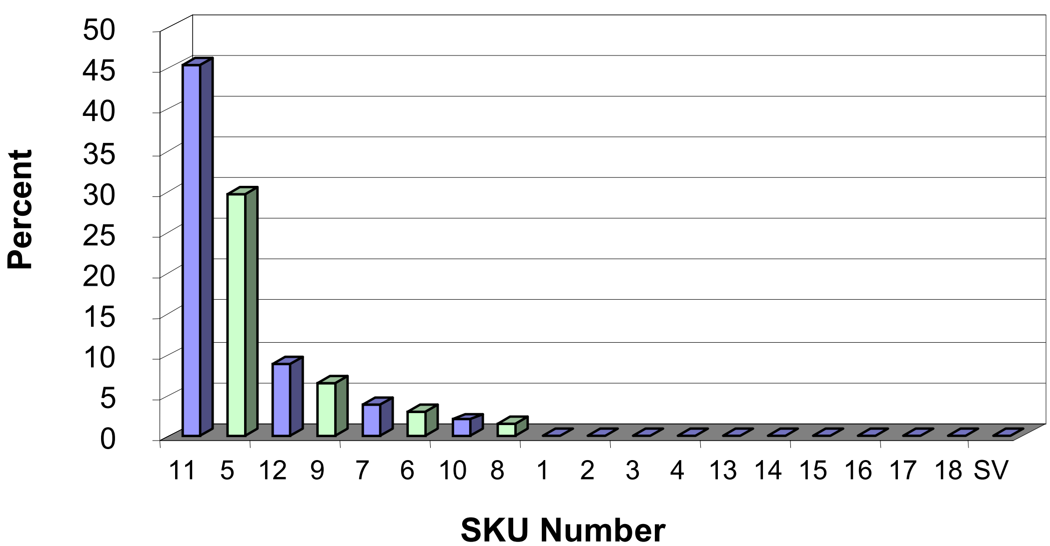

Figure 5. Percent of Demand Allocated to SKUs at Point of Demand, by SKU (Outbound SKUs).

Table 4. Elevator Storage Capacities

Elevator type	Total storage capacity (bushels)	Capacity dedicated to wheat (bushels)
Country Elevator (52-train)	930,395	465,197
Export Elevator	3,250,000	1,625,000

Country Elevator

Country elevator characteristics are determined from the BNSF *Grain Elevator Directory* (1999). Elevators that have the ability to load a 52-unit train are used to derive the elevator parameters. The base case country elevator has a configuration that is able to accommodate all incoming SKUs, which include separate bin space for each of the 19 SKUs in the Pre-GM base case and the 38 SKUs in the Post-GM base case. Storage capacity for spring wheat is set at 50 percent of overall storage capacity for wheat. Beginning inventories for each SKU at the country elevator are assumed to be 50 percent total SKU storage capacity.

Export Elevator

Export elevator characteristics for the Pacific Northwest are derived from the Federal Grain Inspection Service (FGIS) *Directory of Export Elevators* publication (2000). There are 9 export elevators located in the PNW. On average, these facilities have 3 million bushels of storage capacity, or 81.5 thousand metric tonnes. Capacity is used to determine the throughput, or amount of demand, for that facility. Through calculations from the FGIS data, the average size export facility is found to account for roughly 11.5 percent of overall storage capacity. This value is the best estimate of throughput for HRS wheat shipments for a facility from the PNW. Fifty percent of the facility is dedicated to HRS wheat in the model. The export elevator configuration is able to accommodate all SKUs with separate storage. In the Pre-GM base case for the export elevator, there are 8 separate storage bins, and in the Post-GM base case there are 16 storage bins. Beginning inventory levels are 50 percent of the storage capacity for each SKU.

Rail Tariff Rates

An approximate tariff rate value is taken from the Rate Book section of the Burlington Northern Santa Fe (BNSF) website. The charge applied is for a wheat shipment originating in Jamestown, North Dakota, that is destined for the PNW. The tariff charge per railcar is set at $4,400, which is 133 ¢/b when a 3,300 bushel railcar size is assumed.

Railcar Performance and Ordering

Rail performance data are taken from Carlson (1998), which includes general tariff placements upon ordering the cars. Other rail data used in the model are the estimation of transit time from the country elevator to the export elevator.

Shippers order railcars to transport the grain from the country elevator to the export terminal. In the rail industry, shippers are allowed to specify a want date within a shipping period. Carlson (1998) estimated the distribution for general tariff car placement was estimated from data provided by the Burlington Northern Santa Fe (BNSF) railroad. He found a gamma distribution with parameters (8.38,1.42) best fit the data. This distribution is incorporated into the model to simulate uncertainty for railcar arrivals at the country elevator.

Transit time is defined as the time required for the railcars after they have been loaded to arrive at the export facility. Carlson (1998) used a uniform discrete distribution of one to three weeks to allow for uncertainty in transit time. Average transit time estimated for rail shipments from North Dakota to the PNW is found to be slightly less than two weeks. For this reason, a discrete distribution is introduced to the model to allow for transit time variability of one to three weeks. There is a 33 percent chance of railcars arriving within 7 days, a 34 percent chance of the railcars arriving in week 2, and a 33 percent chance of them arriving after 14 days.

Demurrage Calculations

Demurrage policies are incorporated in the model. Demurrage is applied to railcars at the country elevator and to bushel shortages to fill demand at the export elevator. Demurrage charges are applied at the country elevator when a railcar that has arrived at the origination facility for loading is not filled within the week that it arrived. Demurrage is applied at the export facility when there is not enough grain on hand to meet the weekly demand.

Rail demurrage charges are taken from the BNSF Demurrage Book (2000). A value of $50 per car per day is the charge applied in the model. The $50 value is the average of the peak-season rate of $75 per car per day and the off-peak season rate of $25 per car per day. Rail demurrage charges are only applied at the country elevator when cars arrive and the elevator is unable to fill the railcars. The model keeps track of how many weeks a car sits idle and applies a demurrage charge until the car is filled and transported to the export elevator.

Export demurrage charges are calculated on bushels of demand at the export elevator that are not satisfied. Carlson (1998) found that a typical demurrage charge for vessels is $1.40 per metric ton per week, or 3.8 cents per bushel per week assuming that there are 36.74 bushels per metric ton. This export demurrage charge is applied to all export demand that is not satisfied for each week. The model carries shortages to the next week and adds the amount short from the previous week to the new week's demand. Export demurrage charges are applied to each bushel of demand not satisfied for each week.

Storage Costs

An annual interest rate of 7 percent is applied to the value of inventories to determine the interest cost of having inventory in the system. The value of inventories was calculated by summing the calculated value for each SKU held in storage in the system.

Data Sources

Various reports and contacts were used for data collection. Table 5 provides a summary of data sources used in this research.

Table 5. Data Sources

Model Component	Data Source
Demand	Grain Transportation Report (1996-2000)
Receipts	North Dakota Agricultural Statistics Service (1991-95)
SKU Percentages	Export Grain Inspection Service (2000) and the Cereal Chemistry & Technology at North Dakota State University (1999)
General Tariff Placement	Carlson (1998), Burlington Northern Santa Fe
Rail Transit Time	Carlson (1998), Burlington Northern Santa Fe
Rail Tariff	Burlington Northern Santa Fe
Testing Accuracy and Costs	Bullock et al. (2000)
Premium/Discounts for SKUs	Export Grain Inspection Service (2000), the Cereal Chemistry & Technology at North Dakota State University (1999), and Industry Participants (2000)
Country Elevator Statistics	Burlington Northern Santa Fe–*Grain Elevator Directory* (1999)
Export Elevator Statistics	Federal Grain Inspection Service–*Directory of Export Elevators* (2000)
Rail Demurrage Policy	Burlington Northern Santa Fe–Demurrage Table (2000)
Export Demurrage Charges	Carlson (1998)

Data Distributions

Stochastic variables included in the No-GM and GM models are randomness in demand at the export terminal and receipts at the country elevator. In addition, uncertainty is included for railcar placement at the country elevator and transit time from the country elevator to the export terminal. Testing randomness is implemented in the GM model. Distributions and parameters utilized in the GM base case model are summarized and shown in Table 6.

Table 6. Base Case Parameters for the GM Model

Variable Name	Value
Export Demand – Actual and Forecasted - (weekly)	Normal Distribution
Country Elevator Receipts – (weekly)	Normal Distribution
Railcar Placement at Country Elevator	Gamma Distribution (8.38, 1.58) with a mean of 13.24 days and a Standard Deviation of 1.98 days
Railcar Transit	Discrete Distribution with a 33% chance of cars arriving in week one, 34% chance in week two, and 33% chance in week three
Railcar Order Placement for Export Elevator Delivery	Order railcars for forecasted demand four weeks in advance
Scalar for Origination Capacity	14 Elevators to Originate Receipt Volume
Number of Inbound SKUs or Bins at Country Elevator	Estimated from ND Crop Quality Data – 38 SKUs
Number of Outbound SKUs at Point of Export	Estimated from EGIS Data – 16 SKUs
Country Elevator Storage Capacity per SKU	SKU Percentage Multiplied by Overall Country Elevator Storage Capacity
Export Elevator Storage Capacity per SKU	SKU Percentage Multiplied by Overall Export Elevator Storage Capacity
Beginning Inventories of SKU – at Country Elevator	50% of the Country Elevator Storage Capacity allocated for the SKU
Beginning Inventories of SKU – at Export Elevator	50% of the Export Elevator Storage Capacity allocated for the SKU
Adventitious commingling of GM in non-GM arriving in the system	10%
Pipeline adventitious commingling after receipt into the system	0.58%
Test Accuracy and Cost at the Country Elevator	Accuracy = 95%.; Cost = $7.50 per lot
Probability of Accepting a lot at the Country Elevator	86% - Binomial Distribution
Test Accuracy and Cost at the Export Elevator	Accuracy = 99.9%; Cost = $200 per lot
Probability of Accepting a lot at the Export Elevator	99.3% - Binomial Distribution
Lot Size to Test at Country Elevator	4,000 bushels, 5 Truck Unloads
Lot Size to Test at Export Elevator	19,800 bushels, 6 Railcars
Producer Acceptance Level	15%
Export Acceptance Level	15%
Discount applied for GM wheat	10 ¢/b

RESULTS AND SENSITIVITIES

This section presents the results from the base case models and examines the impacts that various strategy and random variables have on the logistical costs of marketing grain. The base case models are designed to represent a typical logistical grain flow for HRS production through PNW ports to importers. The Genetic (GM) base case is presented and results are summarized. A comparison between the No-GM and GM base case results is shown in the following section. Results for sensitivities of selected variables within the GM model are presented later.

Base Case Definition and Results – Post GM

A base case model is developed to analyze the prospective impacts that GM wheat may have on the logistical costs of marketing wheat. Strategy and stochastic variables are identified in the base case and sensitivities are performed on these variables.

Functions added to the GM model include adventitious commingling and testing. Adventitious commingling levels for grain arrivals at the country elevator are highly uncertain and the ambiguity includes farmer accountability in their deliveries, adventitious commingling, cross-pollination, and testing error. Adventitious commingling is included in the model as a percentage value in the SKUs classified as non-GM. Adventitious commingling levels for non-GM fields were found to have unapproved GM content between 0.1 percent and 1 percent in 10 percent of the samples (Goldberg and Smith, 1999). This value is chosen as a starting point in the base case.

The size of the lot to test is also included in the strategy section. There are a large number of testing decisions from which to choose. In the base case model, the country elevator tests every 4,000 bushels of grain received or every 5-truck unloads. A lot size of 6 railcar unloads or 19,800 bushels is tested at the export facility. Since testing plans are left to the discretion of the manager, sensitivities are performed on these base case settings.

The base case parameters for buyer and producer are estimated to represent a most likely adoption strategy by importing countries and producers. The value of adoption by foreign countries is estimated at 15 percent from current stances on accepting GM wheat and the amount of wheat exported to these countries. This percentage is derived from Export Grain Inspection Service data on exports to countries and a U.S. Wheat Associates survey on country acceptance of GM wheat. In the base case, producer acceptance is matched to the buyer adoption value.

We assumed that adding GM wheat would double the number of SKUs handled in the system. The breaks on grade, dockage, and protein are the same as in the No-GM model except one more split is added to account for GM wheat. The derived value of acceptance for GM wheat is 15 percent of the non-GM organisms from the No-GM SKU percentages. Table 7 provides the base case SKU percentages of incoming receipts and export demand on a percentage basis that represents the throughput or presence of that SKU in the system.

Table 7. GM Base Case Percentage Values for SKUs

Non-GM SKU	Export SKU %	Inbound SKU %	GM-SKU %	Export SKU %	Inbound SKU %
SKU 1	0.0	6.1	SKU 21	0.0	1.1
SKU 2	0.0	14.1	SKU 22	0.0	2.5
SKU 3	0.0	6.6	SKU 23	0.0	1.2
SKU 4	0.0	8.0	SKU 24	0.0	1.4
SKU 5	25.2	3.3	SKU 25	4.4	0.6
SKU 6	2.4	10.3	SKU 26	0.4	1.8
SKU 7	3.2	0.5	SKU 27	0.6	0.1
SKU 8	1.2	4.2	SKU 28	0.2	0.8
SKU 9	5.5	0.5	SKU 29	1.0	0.1
SKU 10	1.6	3.8	SKU 30	0.3	0.7
SKU 11	38.6	1.9	SKU 31	6.8	0.3
SKU 12	7.5	6.6	SKU 32	1.3	1.2
SKU 13	0.0	0.5	SKU 33	0.0	0.1
SKU 14	0.0	5.2	SKU 34	0.0	0.9
SKU 15	0.0	0.5	SKU 35	0.0	0.1
SKU 16	0.0	0.9	SKU 36	0.0	0.2
SKU 17	0.0	1.4	SKU 37	0.0	0.3
SKU 18	0.0	4.2	SKU 38	0.0	0.8
Non-GM Salvage SKU	0.0	6.6	Genetic Salvage SKU	0.0	1.2

Strip tests are implemented at the country elevator at a cost of $7.50 per test and an accuracy rating of 95 percent. A binomial distribution is used to account for the probability of accepting a lot based on a given adventitious commingling level and accuracy rating. In the base case, a 10 percent adventitious commingling level is assumed and the test accuracy is 95 percent. This results in an 86 percent probability of classifying a non-GM lot as non-GM. A similar calculation is performed on the export side. In the base case, 0.58 percent of the non-GM wheat passed through the country elevator is still contaminated with GM wheat due to testing errors. The export test accuracy is 99.9 percent. A binomial distribution is calculated that gives a 99.3 percent probability of accepting the non-GM lot as non-GM at the export elevator. The binomial distribution is calculated by evaluating test accuracy and the level of GM wheat classified as non-GM.

Base Case Results – Post GM

Average logistical cost for the GM base case is 153.9 ¢/b. The largest component of costs is the rail tariff expense, followed by the interest cost of inventory, country elevator forgone premiums, and testing. Demurrage costs are not very large due in part to the large draw volume and ability to meet export requirements.

Average logistical costs increase by 2.1 ¢/b when moving from the No-GM marketing system to a GM marketing system (Table 8). The increase in cost is due in part to the added cost of testing which accounts for almost 50 percent of the increase. Rail shipping costs increase due to more wheat being transported from the country elevator to satisfy the demand at the export elevator, which includes safety stock orders. The export elevator is ordering railcars to satisfy demand and a safety stock level of one week of average demand. The volume of demand satisfied actually decreases. The increased volume shipped from the country elevator is used to satisfy safety stock requirements instead of being used directly to satisfy export vessel loading demand. The country elevator is able to ship the grain needed to meet the safety stock levels due to increased substitution possibilities from the increase in the number of SKUs, which is indicated by the increase in country elevator forgone premiums and the decrease in export elevator demurrage.

Table 8. Cost Comparison of Base Cases

Category	No-GM Base Case	GM Base Case	Change in Costs	No-GM Base Case	GM Base Case	Change in Costs
	--------$000's-------			-------¢/b--------		
Interest Cost of Inventory	1,254	1,222	-32	9.1	8.9	-0.2
Demurrage:						
Country Elevator	79	2.5	-76.5	0.6	0.0	-0.6
Export Elevator	37	34	-3	0.3	0.2	-0.1
Foregone Premiums:						
Country Elevator	621	680	59	4.5	4.9	0.4
Export Elevator	1	1.5	0.5	0.0	0.0	0
Testing Cost:						
Country Elevator	0	33	33	0.0	0.2	0.2
Export Elevator	0	122	122	0.0	0.9	0.9
Rail Tariff Costs	18,847	19,094	247	137.3	138.6	1.3
Total Costs	20,848	21,190	342	151.8	153.9	2.1

Country elevator demurrage decreases dramatically from the No-GM to GM base case. When more SKUs are present, the country elevator is better able to meet the lower volume demand level of the increased number of SKUs due to the diversity of the production in the draw area. Demurrage is also decreased due to a greater possibility of substitution. In the GM base case, forgone premiums increase over the No-GM values due to the increased possibility to substitute SKUs with the greater number of SKUs present. Interest costs of holding inventory decrease from the No-GM to GM situation. This is due to the lower value associated with the GM wheat. Fifteen percent of the No-GM inventory is decreased by 10 ¢/b, the premium for non-GM wheat, which lowers the market value on which the interest cost is based.

The cost increase in the GM model over the No-GM results does not appear to be large. The base case assures that 85 percent of buyers would limit their purchases to exclude GM content. If the additional system-wide cost increase of 2.1 ¢/b is applied only to non-GM bushels, the actual cost increase is 3.04 ¢/b to those system participants requiring non-GM SKUs.

The effect of less than optimal elevator configurations are shown in the sensitivity presented in the No-GM SKU effect, in which both inbound and outbound SKUs are varied to show alternative possibilities of storage bin space and outbound SKUs. Increased managerial expenses due to more complexity in the pipeline are not known and not included. Handling costs are considered to be constant and not included as well. It is possible that handling costs will increase if a strict threshold level for GM material in non-GM lots is implemented. A queuing cost, or the expense of waiting for a test result, is also not included in this model.

Sensitivities

Stochastic variables on which sensitivities are performed include adventitious commingling levels at the point of entry into the system and adventitious commingling that occurs within the pipeline. Producer and consumer acceptance levels of GM wheat are also unknown and varied to determine their effects on the logistical costs of the system. In addition, the discount associated with GM wheat is unknown and varied to determine the effect on logistical costs. Strategy variables on which sensitivities are performed include testing intensity at the country elevator and the export elevator. The type of test used at the country or export elevator is included as a sensitivity. A PCR test, Lateral Flow Strip tests, and the ELISA test are alternatives that may be implemented. Table 9 provides a summary of the sensitivities performed.

Table 9. GM Sensitivities

Variable	Base Case Value	Decreased Value	Increased Value
Genetic Tests:			
Country Elevator	$7.50 per test, 95% Accurate	No Decreased Sensitivity	$200 per test, 99.9% Accurate
Export Elevator	$200 per test, 99.9% Accurate	$100 per test, 95% Accurate	No Decreased Sensitivity
Testing Intensity:			
Country Elevator	4,000 bushels	8,000 bushels	800 bushels
Export Elevator	19,800 bushels	42,900 bushels	3,300 bushels
Adventitious commingling:			
Point of Entry	10%	5%	20% and 40%
Pipeline/System	0.58%	No Decreased Sensitivity	30% and 60%
Adoption:			
Consumer	15%	5%	25%
Producer	15%	5%	25%

Testing Intensity at Country Elevator

Testing intensity is introduced by testing various lot sizes and accepting or rejecting the entire lot based on the outcome of the test. The lot sizes to test are varied to determine the effect of testing either small or large lot sizes. In the base case, tests are conducted every 4,000 bushels. The logistical costs increase by 0.97 ¢/b when tests are conducted for every 800 bushels and decrease by 0.11 ¢/b when every 8,000 bushels are tested (Figure 6).

The sensitivity shows that as the testing intensity increases (number of trucks in test lot decreases), the average cost of the logistical system increases. This is due to the increased number of tests that must be performed. The decrease in costs diminishes at a slower rate when moving from 4,000 bushels (5 truck lots) to 8,000 bushels (10 truck lots) in the test lot. The benefits of reduced testing costs are offset mostly by increases in forgone premiums at the country elevator. In addition, as the intensity decreases or the test lot volume increases, country elevator demurrage costs increase. However, the rise in demurrage is not very large, which shows that there is an abundant supply of the different wheat categories in the origination area to meet export demand as the shipment quantities can be achieved through substitution.

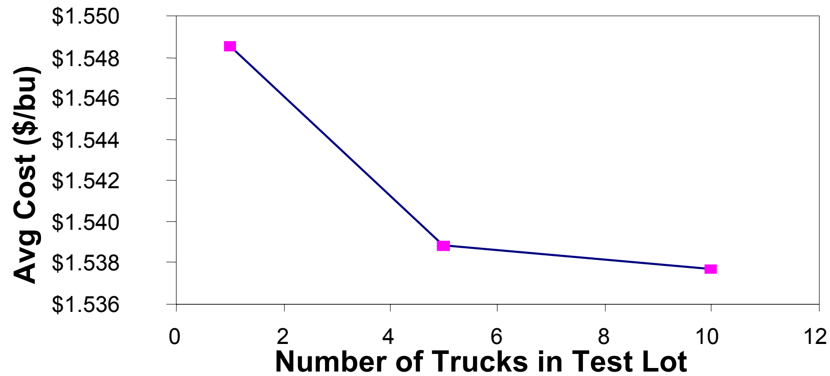

Figure 6. Country Elevator Testing Intensity.

Testing intensity at the export elevator is introduced in the same manner as it is at the country elevator. Different lot sizes, represented by a number of railcars, are tested and either accepted or rejected. In the base case, 6 railcars are grouped together and tested for a total lot size of 19,800 bushels. Lot size intensity is increased to every railcar, so every 3,300 bushels is tested and accepted or rejected. The lot size intensity is also decreased to every 13 railcars, so every 42,900 bushels are tested and either accepted or rejected based on the test.

As the intensity increases (number of railcars in test declines), logistical cost to the system increases. Average costs rise by 4.32 ¢/b as the intensity increases from the base case of 6 railcars to testing every railcar. Costs decrease by 0.44 ¢/b from the base case when the intensity is decreased to every 13 railcars. The results of this sensitivity are shown in Figure 7.

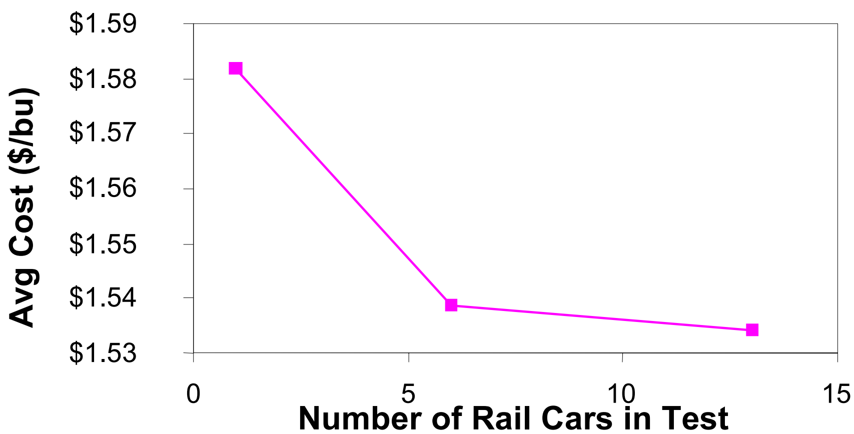

Figure 7. Testing Intensity at the Export Elevator.

The increase in costs associated with an increase in intensity at the export elevator has to do with the expense of the test. At the country elevator, the testing cost per lot is only $7.50 while at the export elevator it is $200 per test. The results show that costs decrease as the intensity decreases but at a much lower rate than the decrease from one to six railcars. The gain in reduced testing costs is offset by an increase in export demurrage charges and a reduced volume of demand satisfied. In addition, the amount of grain shipped from the country elevator increases as the testing intensity decreases at the export elevator because an increased volume of wheat is needed at the export elevator due to the rejection of larger lot sizes. Larger volumes of wheat are being classified by the test as not conforming to the non-genetic requirements when the lot sizes are larger. Forgone premiums at the export elevator also increase as the testing intensity decreases.

There is a significant increase in costs when the testing includes inspection of every railcar. Figure 8 provides an illustration of the distribution of costs for the different intensity levels of testing for the export elevator. It is notable that the distribution of costs for testing every 6 and 13 railcars are similar, although the distribution of costs for sampling every railcar are about 5¢/b more at each probability level.

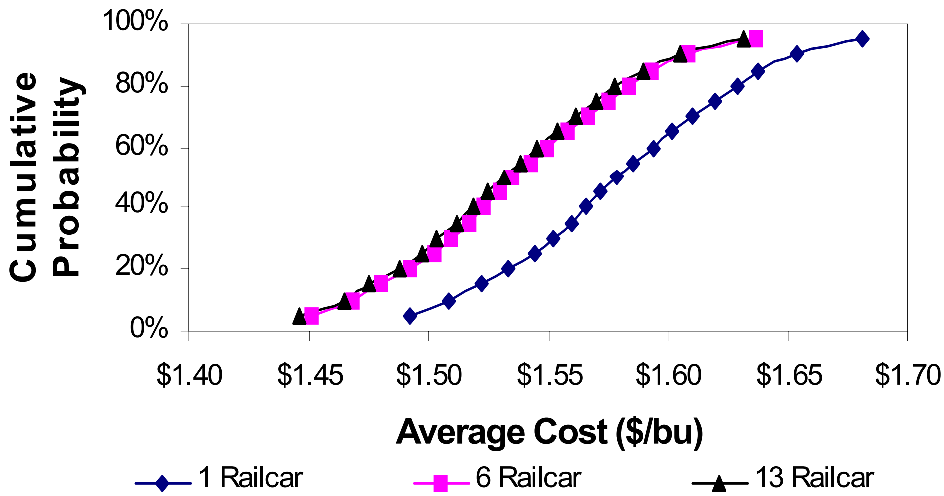

Figure 8. Distribution of Costs for Export Elevator Testing Intensity.

Test Performed at Country Elevator

There are three different genetic tests that may be implemented. At the country elevator, there is less of a concern about the percentage of material that is GM so a simple discrete test such as a Lateral Flow Strip test is often implemented. The other protein test is the quantitative ELISA test, which has the same accuracy but a much higher cost and allows for quantification of genetic content in the lot. However, if the goal of the system is to remove all genetic material from the non-GM marketing channel, a test with a higher accuracy rating is needed. In the model, this scenario of high accuracy at the country elevator is implemented by introducing the PCR test in place of the protein strip test.

The results are quite dramatic. The increased system cost is 5.34 ¢/b when using PCR tests at both the country elevator and export elevator. The increase in cost to the system is the cost of the test. Demurrage charges, forgone premiums, and rail tariffs decrease with the more accurate test. The PCR test would increase queuing costs and time due to the time requirements of this test. PCR tests require a minimum of 24 hours to obtain results and most estimates say that one to three days are necessary. The queuing cost is not included in the estimate that shows an increase in cost to the system of 5.34 ¢/b.

Test Performed at Export Elevator

There are two different quantitative tests that may be implemented at the export elevator. The PCR test is most commonly used in the industry. However, an ELISA test that also allows for quantification but has a lower accuracy rating is another alternative. The lower accuracy rating is offset by the cost of the test. The ELISA test costs $100 per test whereas the PCR test costs $200 per test. The ELISA test is implemented at the export elevator by changing the accuracy and cost to determine the cost effect of implementing this test versus the PCR test.

Logistical costs actually increase when the lower cost test is implemented. The average cost increases by 2.25 ¢/b compared to the base case. This is due to the decreased accuracy of the test, which results in false classifications of non-GM lots. The lower cost of the test is offset by increases in demurrage charges and forgone premiums at the export and country elevator. In addition, more grain must be shipped to the export elevator due to the misclassifications, which increases total tariff costs.

Receipt Uncertainty

An important source of uncertainty is the GM content of wheat coming into the system. In the base case, the non-GM lot contains GM wheat 10 percent of the time in excess of a given threshold. As the threshold level increases or becomes less strict, the number of lots containing GM wheat in excess of the threshold falls or, put in another way, adventitious commingling decreases. As the threshold level decreases, the amount of lots that are contaminated increases due to the strict adherence of the lower threshold level. The adventitious commingling level is increased and decreased to represent changes in the threshold level and to determine the effect that the threshold level has on the logistical costs of transporting grain.

When the threshold level increases (higher levels of GM content allowed) and the adventitious commingling level decreases to 5 percent from the base case value of 10 percent, the average cost decreases by 0.20 ¢/b. Increasing the adventitious commingling level to 20 percent, increased average costs by 0.59 ¢/b. Increasing adventitious commingling to 40 percent illustrates a significant difference from the base case and increased average logistical costs by almost 20 cents (Figure 9).

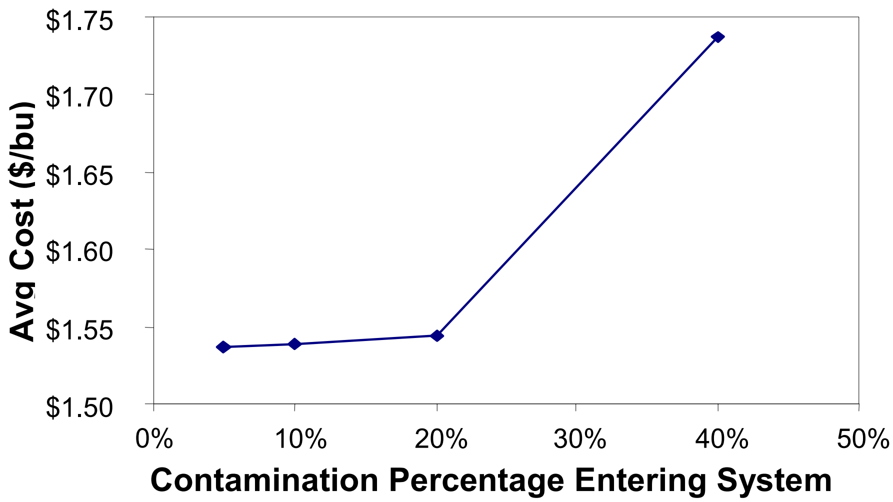

Figure 9. Effects of Adventitious Commingling at the Country Elevator.

Testing costs increase as the adventitious commingling level increases due to the need to bring more non-GM wheat into the system to meet demand. Country elevator and export elevator demurrage charges increase as the adventitious commingling level increases. Forgone premiums at both elevators increase. The amount of grain shipped increases when adventitious commingling levels rise from 5 percent to 20 percent but decreases when moving to 40 percent; however, this decrease in rail tariff expense at the 40 percent level is more than captured by the large increase in demurrage costs. The volume of export demand satisfied remains constant in the base case, 5 percent, and 20 percent sensitivities. In the sensitivity in which the adventitious commingling level is placed at 40 percent, the volume of export demand satisfied decreases.

The distribution of costs and export volume shipped or export demand satisfied are influenced greatly by the incoming adventitious commingling level. As adventitious commingling increases, costs rise at all levels (Figure 10).

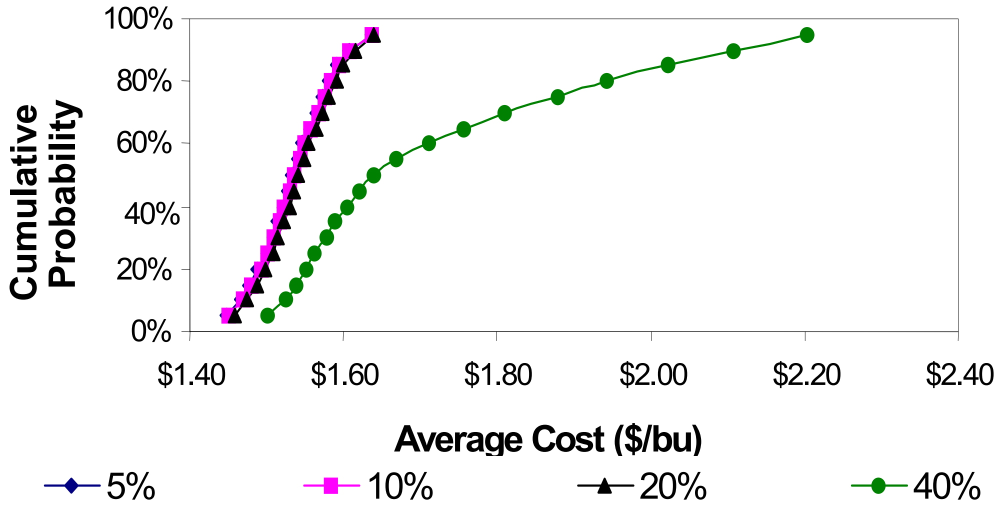

Figure 10. Distribution of Costs for Adventitious Commingling Levels for Receipts at Country Elevator.

Adventitious commingling can also occur after wheat enters the system and is referred to as pipeline adventitious commingling. In the base case, the value is set at the adventitious commingling level passed through after the country elevator test. The base case value is 0.58 percent. However, this assumes a closed loop system in which no mishandling of the grain occurs and railcars, storage bins, elevators, barges, and all storage, transportation systems, and grain paths are thoroughly cleaned and free of genetic material. The value is increased to 30 percent and 60 percent to show the effects of adventitious commingling within the system after the wheat has been classified as non-GM or GM at the point of entry.

An increase from the base case to 30 percent pipeline adventitious commingling increases logistical costs by 53 ¢/b. An increase from the base case to 60 percent pipeline adventitious commingling increases average costs by 305 ¢/b.

Testing costs increase at both the country elevator and export elevator due to a larger amount of non-GM material being brought into the system to meet export demand. Demurrage charges at both the country and export elevator increase dramatically as the pipeline adventitious commingling level increases. Forgone premiums also increase from the base case values as more substitution occurs. Rail tariff charges increase due to additional non-GM lots being shipped from the country elevator as more lots are classified as GM at the export elevator and cannot be used to meet non-GM export demand.

Pipeline adventitious commingling levels have a significant affect on logistical costs due to the uncertainty of the category's classification when it arrives at the export elevator to meet export demand. Adventitious commingling levels influence the distribution of average costs and the amount of export demand that is satisfied.

Buyer Acceptance

Export adoption refers to the volume of GM wheat that export customers will accept. It is introduced into the export demand SKU percentages in the same manner that producer acceptance percentages are changed for the incoming SKU receipts. The acceptance level is increased to 25 percent and decreased to 5 percent to evaluate the affect that consumer acceptance has on logistical costs. As the acceptance level of GM wheat increases, the logistical costs decrease by 0.78 ¢/b. If consumers are less willing to accept GM wheat, the logistical costs increase by 2.61 ¢/b (Figure 11).

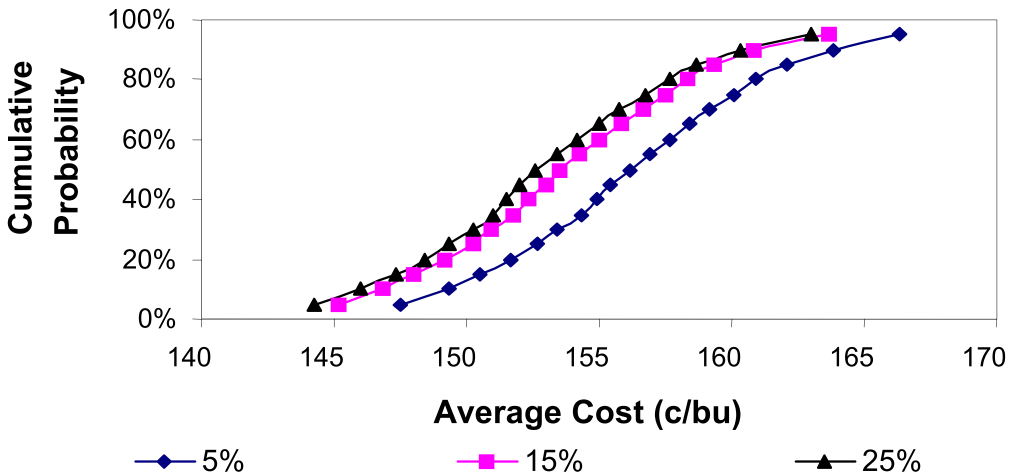

Figure 11. Distribution of Average Costs for Levels of Buyer Adoption.

The diminished acceptance of GM wheat increases the logistical costs of the system. Testing costs at both locations rise due to more non-GM wheat being brought into the system to meet demand. Demurrage charges increase at both locations due to the inability to meet the more specific requirements. Forgone premiums increase at the country elevator due to more substitution occurring to meet railcar loadings. Tariff costs also increase which shows that more grain is brought into the system and transported to the export elevator for meeting the rise in non-GM demand requirements of the consumer. The volume of demand satisfied at the export elevator remains constant across all levels of buyer acceptance of GM wheat.

There is a more significant affect in buyer adoption on logistical costs than producer adoption. The following figure provides an illustration on the distribution of costs for different levels of buyer acceptance. It is apparent that as fewer buyers adopt GM wheat, logistical costs increase for a given level of adoption by producers.

SUMMARY

An increase in the number of wheat categories handled in the grain pipeline raises the average logistical costs of the marketing system. Adding GM wheat to the current system imposes higher costs due to the need for genetic content testing. Logistical costs of the grain marketing system are dependent on the configuration of the elevators, number of categories handled, and ability to keep GM wheat separated from non-GM wheat. The grain supply chain is modeled in this study to evaluate the affects that increasing grain categories for wheat and the addition of GM wheat have on the logistical system. The issues of testing and increasing grain categories form the major contribution of this research.

Adding GM wheat to the marketing system increases costs. The extent of the increase in costs depends largely on the ability to control the adventitious commingling of genetic material in non-genetic material to meet required threshold levels. Testing plans that include accuracy, intensity, and costs also affect logistical costs. Determining how many categories of wheat to handle will also affect costs. Matching production to consumption is an important factor that provides assurance that non-GM demand can be satisfied.

It was expected that costs would increase when GM wheat was added to the logistical system. The SKU literature states that costs increase as more grain categories are added, so this occurrence was anticipated. The expected increase to the system from the No-GM to the GM base case appears to be minimal, however, costs do increase. As the system is less able to keep GM and non-GM wheat paths segregated, costs increase. This is even more apparent when a low tolerance level is set which increases the percentage of non-GM wheat that is contaminated with GM wheat. Small amounts of adventitious commingling do not greatly increase logistical costs; however, as the adventitious commingling level rises, costs increase sharply. Deciding which test to implement, along with the intensity of testing, affects costs in a manner that was expected. The surprise was that the lower cost test at the export elevator actually increased average costs.

The introduction of GM wheat to the logistical system adds complexity and cost to the system. Genetic testing is included in this new system along with an increase in the number of wheat categories. Adding genetic wheat can as much as double the number of categories handled in the logistical system.

A number of sensitivities were conducted due to the uncertainty surrounding the impact of GM wheat on the logistical system. Testing accuracy is vital to the identification of genetic material in non-genetic lots. Different tests are evaluated to determine their impact on logistical costs. There are trade offs with accuracy and costs among the tests. The expensive and accurate PCR test is found to be most effective at the export elevator while the simple strip test is the best alternative for the country elevator. Decreasing accuracy and cost at the export elevator by switching to a quantitative ELISA test actually increased average logistical costs. The decrease in testing cost is offset by increases in demurrage charges at both country and export elevators, forgone premiums at both elevators, and a rise in tariff costs due to the need to transport more wheat to the export elevator because of the higher mis-classification rate of the low accuracy test. The high accuracy, high cost test at the country elevator increases testing costs but lowers all other cost categories. However, these reductions are not enough to compensate for the increased cost of $192.50 per test.

Testing intensity is evaluated due to the many combinations that are possible in deciding the volume or lot size to test. When testing intensity is increased, a rise in testing costs occurs. This rise in testing cost is offset by a decrease in demurrage charges and a reduction in forgone premiums. In addition, rail tariff charges are reduced when a higher intensity program is implemented at the export elevator.

Adventitious commingling is the element included in the model to account for various threshold levels. As adventitious commingling increases, it is assumed that the threshold level has been reduced or made stricter. When adventitious commingling levels increase at the point of entry, testing costs increase due to a higher volume of non-GM wheat needed at the point of origin for the pipeline. Export elevator testing costs increase as well due to more genetic content being passed through at the country elevator and being identified and rejected at the export elevator. Demurrage charges increase at both points in the pipeline as well as forgone premiums due to more substitution being required to meet demand shortfalls which result from the higher rejection levels of non-GM SKUs when adventitious commingling levels rise.

Pipeline adventitious commingling is examined to determine its impact on logistical costs. Pipeline adventitious commingling occurs once the wheat has already entered the system. This value is unknown and depends on the level of GM wheat that is present in the system that has not been channeled appropriately to the GM marketing and storage channel. Pipeline adventitious commingling also depends on the ability of the logistical system to eliminate commingling of the wheat once it is in the system. As pipeline adventitious commingling levels increase, testing costs increase at both elevators due to the need for more non-GM wheat to enter the system and the larger volume of non-GM wheat that doesn't meet requirements at the export elevator. Demurrage charges increase due to the inability of the system to meet specified requirements. Forgone premiums increase because substitution occurs to meet demand shortfalls. Rail tariff costs increase dramatically as more non-GM wheat is needed in the system to meet non-GM requirements. This increased volume that is transported and contaminated while in the pipeline is a critical expense to the system.

The introduction of GM wheat has many logistical implications. The major change to the system is the introduction of genetic testing to ensure product conformity. This step increases complexity due to uncertainty in test accuracy and the time required to obtain test results. The second implication isn't addressed thoroughly in this research but other studies have shown that queuing time increases costs. Separate storage facilities are required to safeguard against adventitious commingling between the two categories of grain. As shown above in the No-GM models, elevators that are better able to accommodate more incoming SKUs have smaller increases in logistical costs as more separation is required. Determining a strategy on testing intensity is important to control testing costs and the risk of not having the correct volume of a non-GM SKU to meet demand requirements. Testing every lot translates into high testing costs while testing larger lots leads to increases in demurrage charges and forgone premiums. Choosing which test to implement based on cost of the test and its accuracy also affects logistical expenses. Having a more accurate test at the point of export resulted in a lower logistical cost.

Adventitious commingling levels impact logistical costs significantly. The adventitious commingling issue is tied to the threshold level. As adventitious commingling increases, which means that the threshold becomes more strict, logistical costs rise. Controlling the adventitious commingling levels within the system keeps logistical costs from increasing greatly. However, if the system is unable to prevent the commingling of non-GM and GM wheat, costs rise dramatically. This is because the non-GM lots do not conform to the buyer's requirements at the export elevator, which increases the volume of wheat that is transported in the system. Demurrage charges rise and more substitution occurs to meet demand shortages as more adventitious commingling is present, which results in more non-GM lots being rejected because they do not meet the non-GM classification requirements.

Ensuring that producers do not adopt GM wheat at a higher level than that of GM wheat buyers keeps logistical costs from increasing to a high rate. Matching production to export adoption levels or keeping GM production below the level of buyer adoption results in a lower logistical cost to the system.

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