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CONTRACTING STRATEGIES FOR EU TRACEABILITY REQUIREMENTS

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ABSTRACT

A principal-agent problem was specified to define the equilibrium solution of a contracting strategy for a U.S. supplier exporting wheat to meet EU traceability requirements. The buyer (principal) offers a contract, the supplier (agent) accepts the contract, and then the supplier decides whether to offer a contract to the farmer. Nature at each level of the supply chain represents uncertainty due to adventitious commingling and imperfect information. Results indicate farmers would require 9 c/bu and suppliers 8 c/bu to induce their participation in the contracting strategy.

Key Words: Traceability, Principal-Agent, Contracting, Genetically Modified, Wheat, European Union

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

INTRODUCTION [1]

The European Union (EU) recently adopted legislation that allows grain from countries using genetically modified (GM) seed under restrictive conditions. The measures of control and regulation for GM products include testing, tolerance, shipping, and segregation strategies. Simultaneously, the EU also required labeling of products containing more than 0.9% of GM material and required a high level of traceability. Traceability is thought to be a means to secure the supply channel and increase consumer confidence. Traceability in the production channel was initially optional, but it is obligatory with European Directive 2001/95 which became effective on January 1, 2005.

Traceability requirements are generally considered to be a means to restore consumer confidence in what is perceived to be a "broken food system." Moreover, regulations increasingly are aimed at reacting more quickly to natural or intentional food contamination (Kimmelshue as reported in *Milling and Baking News*, 2004). Traceability is a practice used to manage inputs, risk, and quality. A comprehensive, certified practice is thought to provide food producers with a competitive advantage to help maintain and expand market shares (Fagan, 2004).

Exporting U.S. wheat to meet EU traceability requirements would impose additional costs and risks on suppliers. This can be modeled as a principal-agent relationship between EU importers (principals) and suppliers (agents). Traceability requirements would likely require contractual relationships between buyers and sellers to facilitate transactions. A companion principal-agent relationship exists between suppliers (principals) and growers (agents) where supplier payoffs would be affected by grower actions. The purpose of this report is to analyze contracting strategies using a principal-agent framework, estimate equilibrium incentive premiums necessary to satisfy participation, and examine effects of selected factors on incentive premiums and market participation of suppliers and growers.

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[1] This is a companion piece to one titled "Costs and Risks of Conforming to EU Traceability Requirements: The Case of Hard Red Spring Wheat," (Wilson, Henry, and Dahl, 2005).

BACKGROUND

Traceability

The standard NF EN ISO 8402 was the first technical definition of traceability in 1987 and defined it as: "the ability to retrace history, use or location of an entity by the means of recorded identification" (Gencod EAN France, 2001). In 1997, the EU adopted a moratorium for ten years against marketing GMOs which came into force in 1999 and was designed to allow the European Community time to build 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. In 2004, a European directive opened the European market to grains from countries growing GM materials. The EU retained traceability as the main way to secure the supply channel and increase consumer confidence. Traceability in the production channel was initially optional, but became obligatory with the European Directive 2001/95 on January 1, 2005. The evolution of GM legislation and traceability in the EU is summarized in Figure 1.

The European Parliament (2003) indicated a traceability 'system' would facilitate:

- Withdrawal of products should an unforeseen risk to human health or the environment be established;
- Targeted monitoring of potential effects on human health or the environment, where appropriate; and
- Control and verification of labeling claims.

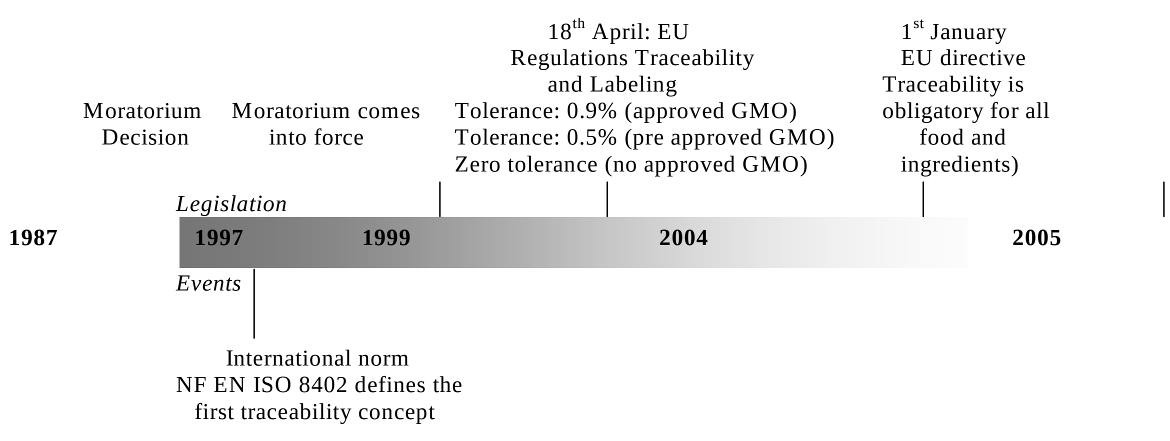

Figure 1. Evolution of GM Legislation and Traceability in the EU.

The EU commission defined three different management schemes for GM content in the production stage (Directorate-General for Agriculture, European Commission, 2002): 1) Voluntary Identity Preservation (IP) of specific GM traits (quality traits), 2) Compulsory IP for GM products (input traits), and 3) Voluntary IP of GMO-free products. Three pending regulations govern the traceability requirements.

- 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).

- 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.

- Operators shall retain specified information for a period of five years and make it available to competent authorities on demand.

In practice, two different approaches are considered (European Parliament, 2001): the traceability and labeling for GMOs (raw commodities) and products from GMOs.

The first step of traceability for GMOs is identity. Operators are obliged to transmit information to the next agent in the chain, including unique codes,[2] specified for that initial assignment. The effectiveness of traceability requires that the identity of GMOs contained within a product be established at the first stage it is placed within the production or distribution chain. The proposal requires that operators placing pre-packaged product 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 are not packaged and use of a label is not possible, 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 about products produced from GMOs:[3]

- Contains or consists of GMOs.
- 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.

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[2] The European Parliament defines unique codes as "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" (European Parliament, 2003).

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

Operators have to hold information for a period of five years. Requirements for labeling products produced from GMOs are the same as those for GM products. The distinction between GM and GM-free is important and the reason why the European Commission established a tolerance level equal to 0.9%. Product is not labeled genetically modified provided that it is a proportion less than 0.9% and that these traces are adventitious or technically unavoidable.

Traceability of grains requires record keeping from the seed to the consumer (Commission of the European Communities, 2003). The identification of GMOs contained at the first stage they are placed in the marketing chain is the first step for efficient traceability. This obvious rule should not be problematic when the product originated from within the European Community because all Members States agree on the policy adopted.

The proposed rules for external trade are more complex. Identification at its first stage induces an identification of GM materials in the extra-community country. Importers will have to specify the identity of these products, namely in terms of the GMOs they contain. If the exporter lacks information about the genetic identity, the importer determines it by sampling and testing. Obviously, this scenario could be problematic for importers. This is additional proof that the identification of GM contents is crucial as soon as the first stage is placed in the market. After identification, operators would be obliged to transmit to the next operator in the chain the information, the unique code (European Parliament, 2003).

Previous Studies on Traceability

The grain supply chain is described in Figure 2. The country elevator is the point of first delivery for the grain export system and functions to assemble grains, to offer some merchandising services, to dry and store, to grade, to segregate or to blend, and to provide easy access to transportation. A sub terminal elevator provides a similar function as the country elevator where its main function is to access large domestic and export markets at competitive transportation rates. The function of the export elevator is basically to export. Export elevators have some storage capacity, but it is generally used for transferring grain and is generally used for short-term storage.

Golan et al. (2004) examined traceability systems in the U.S. food supply for fresh produce, grain and oilseeds, and cattle and beef. They indicate that while complete traceability is impossible, three characteristics are important for an efficient and useful control system. These include the *breadth* of information (amount of collected and transmitted information), the *depth* of the traceability (the degree of tracing forward and backward), and the *precision* of the information (accuracy). 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 (which tend to be correlated) should be higher than for other products.

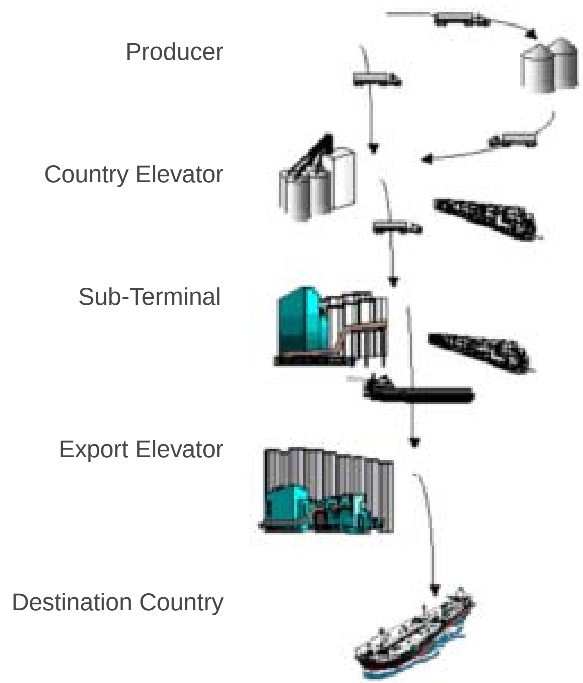

Figure 2. Movement of Cereals and Oilseeds for Export in the United States.
Source: U.S. Grains Council, 2001.

Traceability allows for tracing and identification of the origin of food safety problems and allows firms to reduce risk because traceability systems establish the extent of their liability in cases of food safety failure. 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 to ensure that cross-pollination does not result. Storage, harvesting, and other equipment are submitted to a defined use and handling (e.g., cleaning, flushing). Segregation of specialty crops is achieved with dedicated elevators using multiple bins or cleaning. 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.

Costs and benefits of traceability vary across the food industry (Golan et al., 2004). Across the grain industry, costs of record keeping and product differentiation are included. Segregation – defined as the total separation – induced an under-utilization of equipment, so average costs increase. Otherwise, if demand for differentiated products is sufficient, segregation costs are less important. The level of precision is another source of variation of product differentiation costs. Products are kept apart from production to packaging and consumption. Golan et al. (2004) indicates identity preservation is stricter than segregation systems because of requirements of containerization or other physical barriers to prevent any commingling. Record keeping and separation expenses also tend to rise with the complexity of the supply chain. Vertical integration and contracting are methods for reducing 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 for specialty crops (Golan et al., 2004). These traceability systems document the effort of each segment in the supply chain to segregate the high-value specialty product from conventional or other specialty products. Segregation and traceability documentation for specialty attributes may begin as early as the seed. Each stakeholder in the specialty grain chain must be able to record information about product identity, volume, lot numbers, test results, and suppliers/customer. 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 storage, harvesting, and other equipment between crop types. To verify that adequate precautions have been taken at the farm level to assure the quality of the grain, 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.

At the elevator level, segregation is achieved with dedicated elevators, multiple bins, or by thoroughly 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 line, 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 drawn up between the elevator and the buyer. Premiums must cover the additional cost and risk induced by measures of segregation and recording. Consumers are not interested in traceability just for the sake of traceability and they are not homogenously sensitive to the traceability matter. According to Ruth Kimmelshue, 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 have developed segregation and identity preservation programs to keep export opportunities with segregated markets (Japan and the EU). For corn, premiums generally range from $0.03 to $0.12 /bu. over the Chicago Board of Trade (CBOT) prices, depending on if there are contracts available (Swanson et al., 2003). This premium is supposed to compensate for additional costs (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/bushel.

Non-GM soybean production requires a higher premium than the non-GM corn production. The 2004/2005 contract specification of the Grand Prairie Coop Inc. paid a premium of $0.50 for harvest delivery and $0.55 after harvest delivery over the contracting elevator bid. The cooperative required 20-foot buffer strips from GMO grains. The Illinois Specialty Farm Products paid premiums ranging from $0.25 to $0.50/bushel and required isolation only from un-inspected and non-qualifying soybeans. Contracts may require field inspection prior to harvest to determine varietal purity. Michigan Agricultural Commodities paid a premium for 2004 non-GMO soybeans equal to $0.30/bushel with a level of purity required equal to 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 incentive premiums to farmers and agents for segregated production and distribution systems.

PRINCIPAL-AGENT ANALYSIS OF CONTRACTING STRATEGY

A contracting strategy for Non-GM wheat conforming to EU traceability requirements is developed using game theory. Commercialization of Non-GM and GM requires segregation and traceability inclusive contracts to allow co-existence of grains. The principal/agent framework applies when one party (the agent) is hired by another (the principal) to take actions or make decisions that affect the payoff to the principal (Besanko et al., 2004). Contracts define the conditions of the exchange. Specifications in a grain contract include the quality of grain to be delivered, the date by which delivery is to be completed, the location, the price or formula to be used in determining the net price, price adjustments if you are unable to meet the specified quality, the quantity being contracted, and signatures of both parties and date of signing (Wisner and Kordick, 1996).

While contracts are common in agriculture and have been increasing, they are less common in small grains and wheat in particular (Golan et al., 2004). Producers routinely enter into grower contracts with firms to grow a particular variety of grain or oilseed to seek price premiums or agronomic benefits. This results in a relationship between U.S. supply chain stakeholders requiring participation of all agents. The contracting problem for traceability should include additional costs generated by tracking and segregating measures and risks. This paper defines incentive premiums and how they are split among supply chain agents.

Principal-Agent Problem

A game is developed with four players, three representing participants in the supply chain and the fourth (nature) to represent uncertainty. The first player is the European buyer/importer, the principal. The second is the elevator/exporter representing the supplier. The third player is the farmer. Suppliers and farmers are agents but the supplier is also a principal to the farmer. The principal has perfect information about the agents' decisions and the supplier gets perfect information about farmer choice. However, there is uncertainty about levels of adventitious commingling which occurs at three levels throughout the supply chain: between the farmer and the supplier, between the supplier and the buyer, or after the grain purchase by the supplier.[4] To allow for imperfect information, a fourth player (nature) is incorporated to represent the uncertainty in adventitious commingling which can occur at these three levels in the marketing chain. Probabilities for these uncertainties are taken from Wilson, Henry, and Dahl (2005).

The game is modeled as a sequential move game which proceeds as follows: the principal offers a contract to the supplier; the supplier either accepts or rejects the contract; if the supplier accepts the contract, he can offer or not offer a contract to a farmer; the farmer can accept or reject the contract. Each player has outside payoffs (i.e., outside options) when the contracting strategy fails before them or if they reject the contract.

The model is solved using *Gambit* (McKelvey, McLennan, and Turocy, 2005), a solution algorithm that is used to analyze the problem and determines the logic of sequential actions of players that optimize payoffs or utility in a game containing uncertainty. Probabilities representing uncertainty are employed to define adventitious commingling risks. The equilibrium used is a sequential Nash equilibrium and defined as the pair of strategies (a*,b*), in a two-player game if a* is an optimal strategy for A against b*, and b* is an optimal testing strategy for B against a* (Nicholson, 2002).

Sometimes a pure strategy equilibrium does not exist in a finite game, but there will be a mixed strategy equilibrium (Sridhar, 1985). A mixed strategy is a probability distribution on the firm's feasible set of pure strategies. A mixed Nash equilibrium strategy, or a strategy that involves chance, eliminates some of the predictability in a principal-agent relationship (Gardner, 1996). Mathematically, a mixed strategy is a probability distribution over pure strategies (Watson, p. 38, 2002). Players select their strategy amongst pure strategies based on a probability distribution and payoffs are the expected value given the probability of each pure strategy being selected. Gibbons (p. 36, 1992) defines the payoff as:

$$v(p_1, p_2) = \sum_{j=1}^{J} \sum_{k=1}^{K} p_{1j} \cdot p_{2k} u(s_{1j}, s_{2k})$$

where p1 and p2 are probability vectors composed of elements (p_{11}, p_{12}, .. p_{1J}) which represent the probability that player 1 or 2 plays pure strategy s_{1j} and s_{2k}. Therefore, p_{1j}*p_{2k} is the probability that player 1 plays s_{1j} and player 2 plays s_{2k} and $u(s_{1j},s_{2k})$ is the payoff from player 1 playing s_{1j} and player 2 playing s_{2k}. Thus, $v(p_1,p_2)$ is the weighted average payoff from playing mixed strategies described by p_1 and p_2 where the weights are the probability that individual strategies are played.

[4] Extensive move games with imperfect information are often associated with moral hazard problems. Certified seed used, certification, and auditing are actions observable by the principal. There is no hidden action that affects utility of parties. Hence, in this case there is no moral hazard problem.

A subgame mixed Nash equilibrium can be found by choosing the optimal decision for the agent at that node, in our case, the farmer (Besanko et al., 2004). Using the same method, the next player's decision in the sequential move game is defined. Then the buyer's optimal decision is defined. The set of optimal decisions results in the mixed Nash equilibrium. Mixed strategies reflect randomness while implying that an agent may decide to accept the contract 70% of the time and reject it 30% of the time. A principal that is not satisfied with the acceptance rate has to change contract terms to make the contract more appealing.

Data and Assumptions

Data used in the analysis are extracted from Wilson, Henry, and Dahl (2005), a companion study that derived optimal testing strategies, costs, and risks to meet EU traceability requirements. Data used in the base case and sensitivities are summarized in Table 1.

The base case models the contracting problem without premiums. Hence in this simulation, players are not compensated for the additional costs and risk induced by Non-GM production and traceability requirements, including testing, segregation, auditing, certification, production, and traceability costs. Three scenarios are considered for the principal payoffs. If the principal does not offer the contract, if players reject the contract, or if GM materials are detected at the farmer or at the supplier, the principal uses his outside option. If contracts are established between players and grain is not adventitiously commingled, the principal payoff is equal to grain valuation less system cost: 353 c/bu. If adventitious commingling occurs at the principal level, payoff is equal to the Non-GM payoff, less the quality loss at the importer, 352 c/bu.

Four different payoffs are considered for the supplier payoffs. If the supplier does not offer the contract or if players reject the contract or if adventitious commingling occurs on-farm, the supplier payoff is equal to his outside option, 14 c/bu. If adventitious commingling occurs at the buyer level or there is no commingling, his payoff is equal to his net margin less system costs, 13 c/bu. If the supplier does not offer a contract, his payoff is equal to his net margin less penalties, -51 c/bu. If there is adventitious commingling at the supplier level, his payoff is equal to his net margin less system cost and penalties: -52 c/bu.

Four scenarios are considered for the farmer payoffs. If supplier does not offer a contract, or if the farmer rejects it, his payoff is equal to his outside payoff: 329 c/bu. If there is adventitious commingling but not at the farm level, the farmer payoff is equal to the Non-GM market price less system cost: 320 c/bu. If adventitious commingling occurs on farm, the payoff is equal to the GM wheat price less system cost implemented: 310 c/bu. Finally, the payoff is equal to Non-GM market price less system cost when there is no commingling: 320 c/bu.

Table 1. Base Case Data and Assumption used in the P-A Problem

Items	Units	Value	Source
Farmer			
System cost	c/Non-GM bu	18.83	Wilson, Henry, and Dahl, 2005
Testing cost	c/Non-GM bu	0.01	Wilson, Henry, and Dahl, 2005
Market price	c/Non-GM bu	340	Assumed
Outside payoff	c/bu	329	Swenson and Haugen, 2003
Failure cost	c/bu	19.96	System cost and testing cost
Nature	%	99.13	Wilson, Henry, and Dahl, 2005
Supplier			
System cost	c/Non-GM bu	0.11	Wilson, Henry, and Dahl, 2005
Testing cost	c/Non-GM bu	0.74	Wilson, Henry, and Dahl, 2005
Net margin	c/bu	14.25	Wilson, Johnson, and Dahl, 1995
Failure cost	c/bu	65	Wilson, Jabs, and Dahl, 2003 (penalties)
Nature	%	90.54	Wilson, Henry, and Dahl, 2005
Buyer			
System cost	c/Non-GM bu	0.1	Wilson, Henry, and Dahl, 2005
Testing cost	c/Non-GM bu	0.62	Wilson, Henry, and Dahl, 2005
Market price	c/bu	354	Summation of supplier & farmer market prices
Outside payoff	c/bu	0	Summation of supplier & farmer outside payoffs
Failure cost	c/bu	0.92	Wilson, Henry, and Dahl, 2005 (quality loss)
Nature	%	98.19	Wilson, Henry, and Dahl, 2005

Nature is the fourth player in the model whose actions reflect uncertainty about possible adventitious commingling at three locations in the handling system. Probabilities for nature for each sensitivity are contained in Appendix Table 2. Base case payoffs for each of the strategies are summarized in Table 2.

Table 2. Base Case Payoffs Without Strategic Premium (c/bu)

Strategies	Buyer	Supplier	Farmer
Buyer does not offer a contract	0	14	329
Supplier rejects the contract	0	14	329
Supplier does not offer a contract	0	(51)	329
Farmer rejects the contract	0	14	329
Adventitious commingling on-farm	0	14	310
Adventitious commingling at the supplier level	0	(52)	320
Adventitious commingling at the buyer level	352	13	320
No adventitious commingling	353	13	320

The incentive premium is an extra payment to compensate the player for the added costs required by the contract. The premium is paid only when the contract is fulfilled. Premiums are included in payoffs calculus of the supplier and the farmer when the adventitious commingling occurs at the buyer level and only to the farmer payoff calculus when commingling occurs at the supplier level. Base case payoffs expressed with supplier premium (P_S) and farmer premium (P_F) are in Figure 3.

Direct costs (certified seed, auditing, certification, traceability, and testing) are included in the model. The risk premium is the only cost that is not integrated in the contracting simulation. The simulation defines a strategic premium necessary to induce suppliers and farmers participation conforming to the EU traceability requirements.

Base Case Equilibrium

Two versions of the base case were simulated. This first uses incentive premiums equal to 0. The base case equilibrium is when the buyer offers a contract to the supplier who rejects it. The rejection occurs 53% of the time. The rest of the time, the supplier accepts and offers a contract to the farmer who rejects it 95% of the time. The acceptance probability for the supplier is high without a premium, because he knows that the farmer will reject the contract without premium 100% of the time, so his expected payoff in case of acceptance is equal to his expected payoff in case of rejection. This simulation shows that without a premium, the equilibrium violates the participation constraint. It shows that the supply chain cannot use contracts without a premium.

In the second version of the base case, premiums were adjusted and a mixed Nash equilibrium is found when the strategic premium for the farmer is equal to 9 c/bu and equal to 8 c/bu for the handler. With those premiums, the buyer offers a contract to the supplier. The supplier accepts it 51% of the time and offers a contract to the farmer who accepts it 56% of the time. The buyer and the supplier offer a contract to the sequential player 100% of the time. Figure 4 presents the equilibrium.

This result shows premiums equal to 8 c/bu and 9 c/bu to the supplier and farmer, respectively, which are sufficient to meet the participation constraints at least 50% of the time. The probability that the buyer offers a contract is 100%. If players want to increase the probability of participation, premiums need to be increased further. Acceptance probabilities increase as incentive premiums for the supplier and farmer are increased (Figure 5). Supplier contract acceptance probabilities are calculated with a premium equal to 9 c/bu for the farmer (acceptance minimum), and farmer acceptance probabilities are calculated with a handler premium equal to 8 c/bu for the handler. At a premium of 14 c/bu for the supplier and 14 c/bu for the farmer, probabilities of accepting a contract are 85% for farmers and about 72% for suppliers.

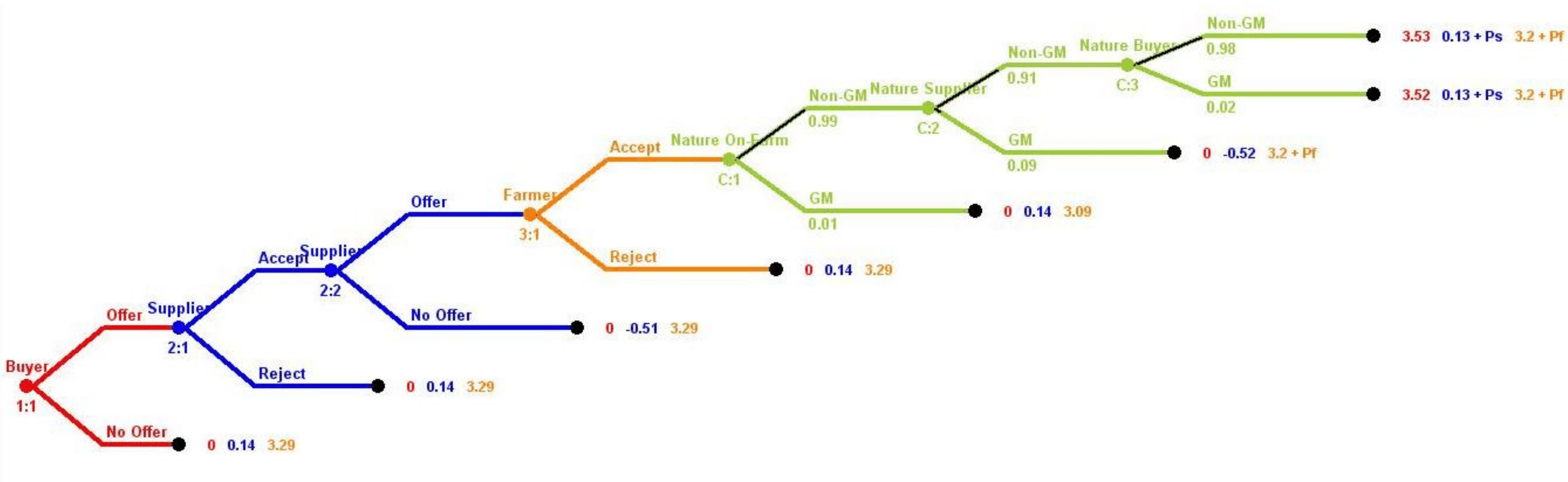

Figure 3. Base Case Tree and Theoretical Payoffs ($/bu).

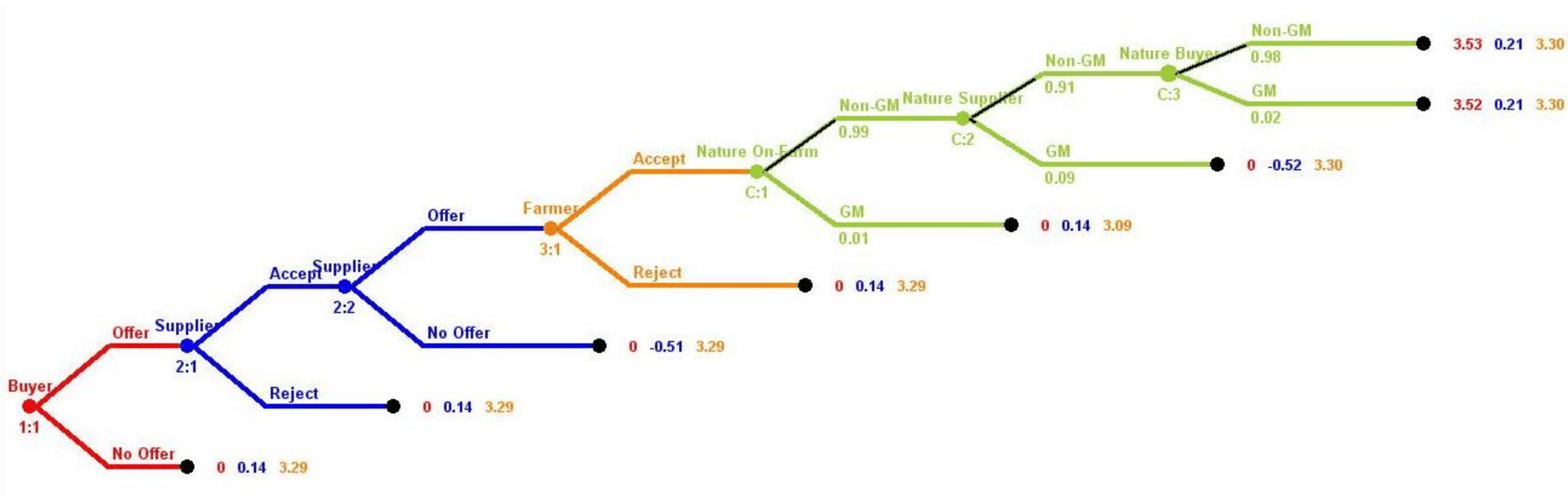

Figure 4. Base Case Equilibrium with Strategic Premium ($/bu).

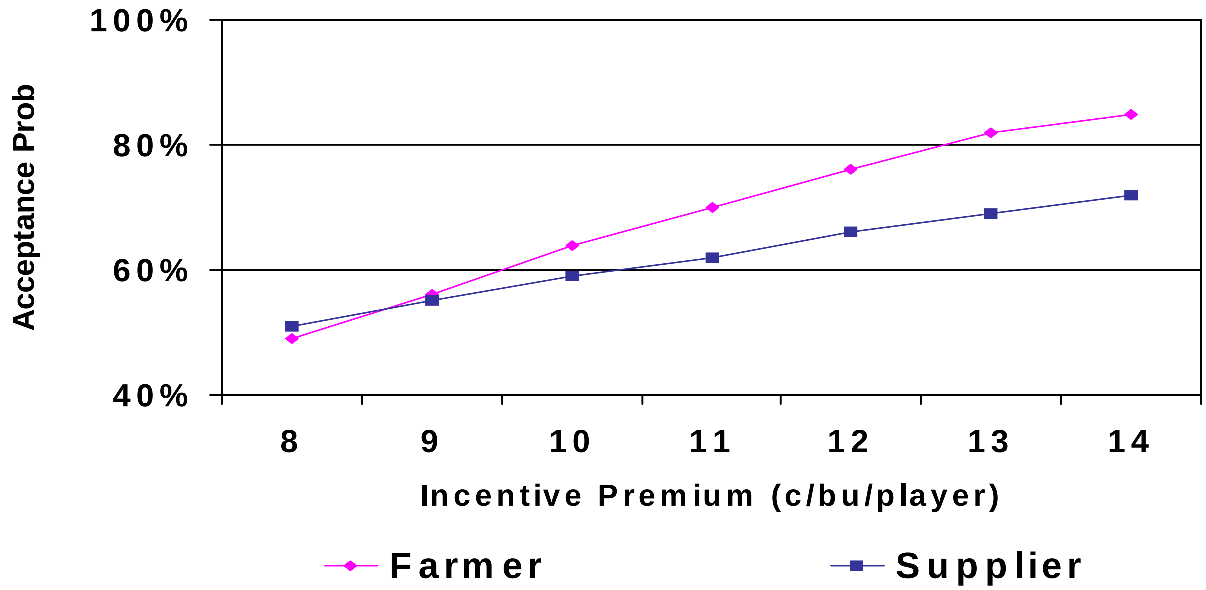

Figure 5. Supplier and Farmer Incentive Premiums' Effect on Acceptance Probabilities.

From a strategic point of view, a contracting strategy requires a total premium equal to 17 c/bu, split between the handler and the farmer with respectively 8 c/bu and 9 c/bu. The mixed Nash equilibrium shows a sharing strategy. In this situation, a set of individuals face genuine uncertainty concerning certain losses, they can reduce their risk exposure by a mutual risk sharing agreement without any probability assessments (Holm, 1999).

Sensitivities and Equilibrium

Sensitivities are performed to define the mixed Nash equilibrium strategies when parameters differ. Sensitivities of critical assumptions are performed to compare their effect on premiums and sharing of supply chain premiums. The contract equilibrium occurs when several actions are confirmed: the principal offers a contract to the supplier, the supplier accepts the contract and offers one to the farmer, and the farmer accepts the contract. The sensitivities define the premiums necessary for players to be at least indifferent between participating or not. Then premiums are adjusted until the equilibrium is found. Adventitious commingling on-farm affects the probabilities. Hence, to study the impact of reasonable variation of adventitious commingling on-farm on the equilibrium, sensitivities are performed. Gross results are presented in Appendix Table 1.

Adventitious Commingling at the Farm Level

Adventitious commingling on-farm is the risk of Non-GM grain being mixed with GM grain. This sensitivity is performed to determine a strategic premium and determine how it is split among players. Two distributions – pessimistic and intermediate – are performed. High adventitious presence refers to on-farm GM detection probability of 3.13% and intermediate adventitious presence refers to it as the probability equal to 1.25% (Wilson, Henry, and Dahl, 2005). Premiums required for the mixed Nash equilibrium are presented in Figure 6.

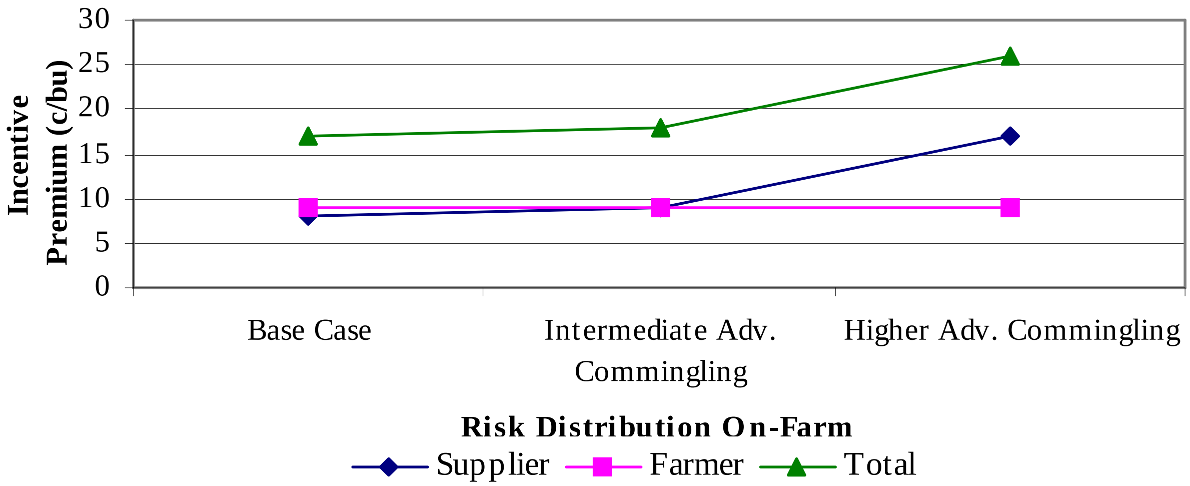

Figure 6. Incentive Premiums Required for Contracting Strategy Depending on the Risk Grower Distribution.

As the risk of on-farm adventitious commingling increased, the premiums required by the farmer remain unchanged (9 c/bu). Premiums required by the supplier increase when the adventitious commingling risk increases. Thus, as commingling risks increase, suppliers require a higher proportion of the total incentive premium. Total strategic premiums for the supplier and grower are lower than the risk premium estimated for a vertically integrated supplier in Wilson, Henry, and Dahl (2005). One way to explain this is the difference in the valuation of risk by the two methods. The premium calculated by the Principal-Agent problem does not value buyer and seller risks. The grower's risk affects the supplier strategy and not the farmer strategy. When the distribution is pessimistic, the supplier needs to test grains one more time than in the base case and with lower adventitious commingling. So, the increased testing costs affect the risk premium.

Adoption Rate

Adoption rate is the proportion of production dedicated to the Non-GM production. Sensitivities are performed to verify the impact of this variable on the premium. Results are presented in Figure 7.

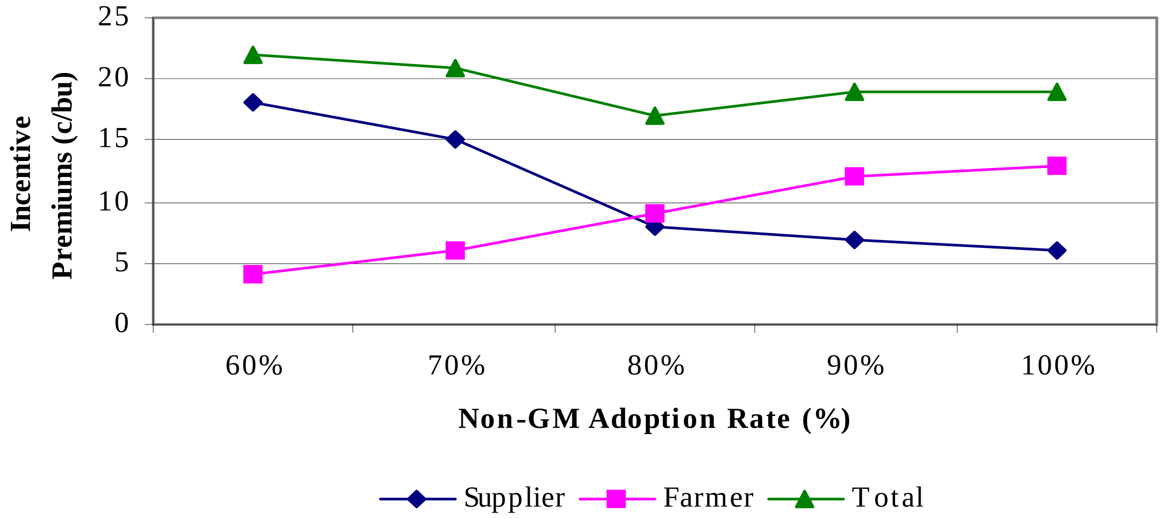

Figure 7. Incentive Premiums Required for a Contracting Strategy Depending on the Non-GM Adoption Rate.

When Non-GM adoption increases, costs per unit decrease but the farm becomes more dependent to this market, so the farmer is highly sensitive to the premium to compensate costs and risks. Hence, the premium necessary for the farmer's participation to the contracting strategy increases from 4 c/bu at 60% Non-GM adoption to 13c/b at 100% Non-GM adoption. The premium required by the supplier is sensitive to the adoption rate. In response to the decrease of GM presence in the grain flow, his premium decreases from 17 c/bu to 6 c/bu when adoption rate changes from 60% to 100%. Therefore, as GM adoption increases, farmers require a lower proportion of incentive premiums while suppliers require a higher proportion.

Penalty Costs

Penalty costs are generally used to stimulate quality improvement. Base case penalties were equal to 65 c/bu. Sensitivities were performed to find the contracting equilibrium when low penalties (5 c/bu) and when high penalties (125 c/bu) are applied to the handler. The farmer penalties are kept equal to the summation of the system cost and the opportunity cost. Premiums necessary for the equilibrium are in Figure 8.

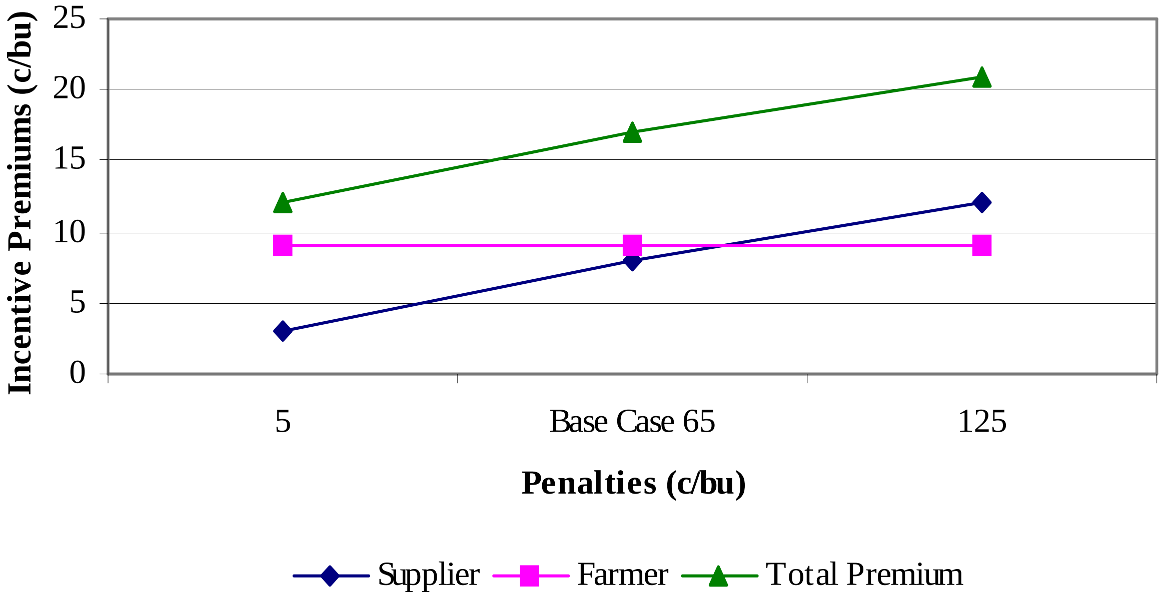

Figure 8. Incentive Premiums Required for a Contracting Strategy Depending on the Level of Penalties.

With low penalties, a mixed Nash equilibrium is reached when the supplier premium is equal to 3 c/bu and when the farmer premium is equal to 9 c/bu. The supplier accepts the contract 52% of the time and the farmer 56%. With high penalties, the supplier needs 14c and the farmer 9c to accept the contract at least 50% of the time. The farmer strategies are not affected by these sensitivities. Additional penalty charges result in the supplier requiring a higher premium. Variations are due to differences in that result due to different optimal strategies which impact the Non-GM percentage in the grain flow.

Risk Aversion

Risk aversion has an essential function in strategic decisions. Because of moves by nature – representing adventitious commingling risks - the sequential move has uncertainty. Nevertheless, seller and buyer risks are not directly included in the *Gambit* simulation. Results of sensitivities for risk aversion equal to 0.7 and 0.9 are unchanged from the base case. When the risk aversion coefficient is equal to 0.4, strategic premiums recommended are 11 c/bu for the supplier and 8 c/bu for the farmer. The reason for this difference is the change in risk aversion parameter results in a different optimal sampling/testing strategy from the base case.

SUMMARY AND IMPLICATIONS

Exporting U.S. wheat to meet EU traceability requirements would impose additional costs and risks on suppliers whose actions would impact EU importer payoffs. Additional traceability requirements would likely require contractual relationships between buyers and sellers. Contracting strategies in this study are evaluated with a Principal-Agent model and used to estimate equilibrium incentive premiums necessary to satisfy market participation and to examine how some factors affect incentive premiums and participation by suppliers and growers. Three players are modeled within the supply chain (buyer, supplier, and farmer). The sequential move game includes moves by nature (random events), including adventitious commingling on-farm, at the supplier level, and at the importer (buyer) level.

Results indicate that without incentive premiums, or very low premiums, a no contract strategy is the equilibrium. An equilibrium was found where the acceptance probabilities were at least 50%, indicating agents were indifferent between contracting and not contracting. The farmer required an incentive premium equal to 9c/Non-GM bushel and the supplier required an incentive premium in the area of 8c/Non-GM bushel.

Premiums necessary to establish a contracting strategy with the farmer depend on the profitability of Non-GM production. A Non-GM market price too low or a high Non-GM adoption rate increases or decreases the premium required by the farmer. Supplier participation in the contracting strategy is dependent on the penalties applied when adventitious commingling exceeds the limit allowed, to the risk distribution on-farm, and the adoption rate. Moreover, the supplier participation is also dependent on the acceptance probability of the farmer.

The risk premium required by the farmer is generally higher than the one required by the supplier. Results confirm the necessity of premiums for participation of agents in the supply chain contracting strategy. Moreover, premiums can deviate from the base case results depending on market characteristics, specialization of Non-GM production in the area, or penalty costs.

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APPENDIX: GAMBIT SIMULATION GROSS RESULTS

Appendix Table 1. Gross Results of Gambit Simulations

Sensitivity	Farmer Premium (c/bu)	Acceptance Probability (%)	Supplier Premium (c/bu)	Acceptance Probability (%)
Base Case	9	56	8	51
Risk Grower Pessimistic	9	52	17	51
Risk Grower Intermediate	9	55	9	54
Adoption Rate 60%	4	55	18	53
Adoption Rate 70%	6	53	15	52
Adoption Rate 90%	12	62	7	52
Adoption Rate 100%	13	52	6	51
Penalties Low	9	56	3	52
Penalties High	9	56	14	50
Risk Aversion 0.4	8	50	11	51
Risk Aversion 0.7	9	56	8	51
Risk Aversion 0.9	9	56	8	51
Market Price ($3.7/bu)	18	51	8	51
Without Test On-Farm	8	53	9	51

Appendix Table 2. Nature Event Probabilities*

Sensitivity	Nature On-Farm (%)	Nature Supplier (%)	Nature Buyer (%)
Base Case	99.13	90.54	98.19
Risk Grower Pessimistic	97.13	82.63	98.29
Risk Grower Intermediate	98.50	89.21	98.29
Adoption Rate 60%	99.00	81.14	97.13
Adoption Rate 70%	99.29	84.17	97.78
Adoption Rate 90%	99.11	92.15	98.30
Adoption Rate 100%	99.10	93.44	98.38
Penalties Low	99.13	90.42	93.86
Penalties High	13.13	90.54	98.19
Risk Aversion 0.4	99.13	87.01	94.93
Risk Aversion 0.7	99.13	90.54	98.19
Risk Aversion 0.9	99.13	90.54	98.19
Market Price ($3.7/bu)	99.38	90.68	98.17
Without Test On-Farm	100.00	90.25	98.34

* Nature Event Probabilities are those indicating product at this stage is within limits for adventitious commingling. Thus, in the base case, there is a 0.87% risk that product will contain adventitious commingling exceeding buyer tolerances at farm level and would be rejected.