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INCENTIVE CONTRACTS TO MEET FUNCTIONAL CHARACTERISTICS IN WHEAT PURCHASING

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ABSTRACT

Consistency of functional characteristics in hard red spring (HRS) wheat is a concern confronting sellers and buyers. This research analyzes contract incentives for importers with respect to cost and potential risk of acceptance. A principal-agent framework is utilized to examine contract incentives. In the principal-agent contract, the principal offers the contract, the agent rejects or accepts the contract, and then decides how much effort to apply. All this is subject to risk for the agent and moral hazard for the principal. An example is presented, for which equilibrium contract terms are a base price of 454 cents per bushel for low quality wheat and a premium of 36 cents per bushel if high quality is achieved. The premium for high quality is unchanged as the agent's outside option increases, but increases as the probability of conformance with high effort declines or as the agent's cost of high effort increases. Small changes in several of the parameter values (agent's outside option, agent's cost of high/low effort, principal value for high/low effort, and principal's outside options if the contract was not extended or if the agent rejects the contract) result in the principal not offering a contract.

Key Words: Incentive Contact, Functional Characteristic, Wheat, Principal-Agent

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INTRODUCTION

Increased privatization of wheat importing firms has led to increased demand for high-quality U.S. wheat with a focus on greater quality consistency (Wilson, Dahl, and Johnson, 2000). Functional performance consistency in hard red spring (HRS) wheat is a problem confronting buyers and sellers. Lack of consistency can be interpreted as uncertainty which arises from a combination of varietal differences, varying production practices, environmental conditions, handling, and marketing. Given the uncertainty and asymmetry in information on quality between buyers and sellers, buyers are exposed to quality risk involving moral hazard when purchasing grain. Guarantees for quality of functional characteristics in the marketing system are problematic because many characteristics require laboratory testing and, therefore, are not available on a timely basis. As such, tests for functional characteristics are not commonly used in procurement contracts.

Buyers may pursue alterative purchase strategies such as limiting purchases to specific locations, varieties, combinations of variety and location, or requirement of specific functional tests in an effort to reduce costs and risks. These alternatives have been examined in a companion paper (Wilson, Peterson, and Dahl, 2004) which provides a detailed statistical analysis of the costs and risks of conforming to end-use requirements using different strategies. Further, tests for functional traits have a time requirement that exceeds the normal logistical requirements of receiving grain, storing, loading, and shipping vessels. Thus, there is a time lag between the transaction and documentation necessary to use functional trait tests as a means to reject lots. However, suppliers could exert extra effort to procure wheat to meet and verify its functional requirements prior to shipping by selecting origins and pre-testing grain for functional traits in-transit and/or in storage prior to loading. Suppliers would confront risk and buyers may be subject to moral hazard, if they are not able to observe or verify this effort.

Contract mechanisms are an alternative for buyers choosing to reduce costs, risks, and moral hazard problems. In this study, a principal-agent model was developed and analyzed using game theory methods. These models were used to estimate incentives required for principals and agents to accept contract terms. The model was used to evaluate effects of factors including the probability of achieving tolerance levels with agent effort, agent effort costs, the payoff to the agent of an outside option to the principal's contract, and the value of high revenue to the principal on the agent adoption of contracts. The major contribution of this study is that it provides an interpretation of contractual mechanisms with suggested incentives to reduce problems related to quality consistency.

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* Wilson is Professor, Maxwell is a former Graduate Research Assistant, and Dahl is a Research Scientist in the Department of Agribusiness and Applied Economics, North Dakota State University, Fargo, ND. This project extends results of an earlier Master's Thesis by Del Albert Peterson, the results of which are reported in Wilson, Peterson, and Dahl (2004).

BACKGROUND AND PREVIOUS STUDIES

Wheat-Quality Consistency Problems

Research on quality consistency has become more common as the heterogeneity of the U.S. wheat market continues to expand. Dahl and Wilson (1998) documented and examined the effects of quality consistency for HRS wheats at different points throughout the production and marketing system. They found that variability in the quality of U.S. spring wheat was reduced as it moved from farm-level production to the U.S. export level. Variability for many wheat and functional characteristics at the producer level was impacted largely by year-to-year variability (i.e., environment), followed by location and variety. Variability in the mix tolerance index (MTI) and wet gluten were found to be affected more by location and variety; whereas, mix time was largely affected by environment and variety. Their results indicate buying strategies that focus on location and/or varieties would improve quality consistency.

Effects of variability in export quality were also examined to determine effects on alternative pricing methods (Dahl and Wilson, 1999). They utilized three alternative pricing methods including: buying on a "net wheat" price, valuing wheat lots based on a millable wheat index, and valuing lots based on the net profit (value added) in milling. These pricing methods largely focus on effects of variability in wheat characteristics (e.g., moisture content, dockage, foreign material, shrunken and broken, damaged kernels), although the value added in milling also incorporates effects of flour extraction rates. None of the methods consider variability in functional characteristics.

Wilson and Preszler (1992) utilized the input characteristic model (ICM) to analyze effects of price and quality on competition in the U.K. wheat import market. The U.K. market was targeted for this analysis because it illustrates the fierce competition between the U.S. and Canadian export markets, and the U.K. is characteristic of numerous markets in which higher-protein wheat from the United States and Canada compete for use in blends with lower-quality native wheat. For most characteristics, the expected values of functional characteristic performance for U.S. wheat had variances which exceeded those of Canadian varieties. The Canadian varieties possessing the lower variances in quality characteristics lowered the overall costs because a greater proportion of cheaper wheat could be used in the blending process. This occurrence resulted in shifting from U.S. to Canadian wheat. However, the impact of quality characteristics for the U.K. or any importing country cannot be assessed without considering the impact of price on these purchasing practices, as well as functional quality. Thus, both quality characteristics and price impact the distribution of market shares and are strategic variables for exporter countries.

Procurement Strategies and Practices

Procurement strategies utilized by wheat end-users range from simple spot market transactions to vertical integration. Strategies in between these two extremes are numerous and are more common. Examples include contracting, testing and segregation practices, targeting of origins and varieties, contracting production practices and identity preservation (Wilson and Dahl, 2002).

Testing and segregation practices by end-users often include location segregation techniques accompanied by either pre-shipment or pre-processing testing, or a combination of the two. Targeting origins and varieties consists of purchasing wheat from a given county or region, purchasing a particular variety, or both. More elaborate contracts may specify production practices, overseeing the production practices on desired acreage, and requiring the final product to meet functional quality requirements.

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Identity Preservation (IP) practices are growing for select varieties of U.S. wheat classes. The IP revolution involves identifying desirable quality attributes which are not widely available. Some believe that incentives to the IP system should provoke expansion to the point that those qualities will become commonplace, displacing varieties that do not offer desirable characteristics. Examples of current IP systems being adopted are General Mills, which is in the process of converting all of its cereal plants for IP handling of wheat and oats (Willis, 2001) and Warburtons, a bread baker in England that contracts for purchase of specific varieties and locations of wheat from the Canadian Wheat Board.

Contract Alternatives

Wheat is usually marketed based on grades, factor limits, and other specifications. Buyers desiring specific wheat classes and quality needs specify minimum requirements upon which all price offerings are based. The specifications become part of the purchase contract and impact price. The grain grading and inspection agency is required to certify the specifications of the wheat to insure that the buyer and seller both know that the buyer is receiving what was agreed to be purchased (Oades, 2001). Quality factors routinely certified on export cargoes are numerical grade, class, moisture content, protein content, and dockage content. Certification of additional quality factors can also be specified in the contract and be performed and certified by the USDA's Federal Grain Inspection Service or a private inspection company (U.S. Wheat Associates, 2001). Wheat buyers normally specify easily measurable wheat characteristics as an element of purchase quality specifications for technological reasons. The effectiveness of these specifications relies on the correlation between the desired functional characteristics and the wheat characteristics specified. Poor correlations result in greater uncertainty in functional performance.

Some end-users have begun contracting for selected wheat varieties. Variety specific procurement strategies help end-users meet functional quality requirements which they are unable to capture through normal commodity market channels (Dahl and Wilson, 1998). Producers, in turn, receive a premium for producing those wheats, which may compensate for lesser yield and for possible risks associated with conditions, which may inhibit them from meeting minimum contract specifications.

Cost and Risk of Purchasing Strategies

Not conforming to end-use requirements has important implications for food processors. Implications include the risk of not conforming to contract specifications, greater costs associated with higher quality purchases, and the effect of increased operating costs associated with likely stock-out costs due to nonconformance (Wilson, Dahl, and Johnson, 2000).

Wilson, Peterson, and Dahl (2004) analyzed effects of alternative purchase strategies on costs and probability of meeting buyer specifications. They developed a stochastic simulation model to evaluate cost risk tradeoffs of alternative purchase strategies. These strategies include buying HRS based on wheat protein levels, varieties, locations, and functional characteristics. The models determine the probability of a wheat shipment meeting end-user needs based on different variables (i.e., variety, location, functional characteristics, and cost). Six separate procurement strategy models were simulated.[1] Strategies were evaluated for specifications for a typical end-user buying 14% HRS at the Pacific Northwest (PNW) and required minimums for protein of 14.2%, absorption of 63%, peaktime 7 of minutes, stability of 14 minutes, and loaf volume of 1,000 cubic centimeters.

Their analysis found procurement strategies using variety, location, or both, increase the probability of conformance and reduce the costs over traditional procurement strategies relying on protein specifications. For example, purchase of the variety McNeal increased the joint probability of conformance from .59 for protein specifications only, to .62 while reducing the cost of procurement from 478 to 468 c/bu. (Table 1). For buyers at the PNW, Montana locations were preferred to those in Minnesota, Eastern North Dakota, and South Dakota, due in part to location, but also the potential of conforming to specifications. A strategy of purchasing only from Montana CRD 2 increased conformance to .67. Purchasing by both variety and location (McNeal from Montana CRD 9) further increased conformance to .69, although costs of procurement where higher than for the location only strategy of buying from Montana CRD 2.

Table 1. Probability of Meeting Specifications (Comparison Between Base Case and Location, Variety Models)

Functional Characteristic	**Base Case**	**Varieties McNeal**	**Locations MT2**	**Varieties & Locations McNeal & MT9**
Absorption	0.95	0.95	0.89	0.99
Peaktime	0.98	0.71	0.88	0.84
Stability	0.71	0.80	0.90	0.79
Loaf Volume	0.90	0.99	0.87	0.99
Joint Probability	0.59	0.62	0.67	0.69
Average Cost PNW C/bu	478	468	463	467

Strategies were also analyzed that focused on pre-testing for functional end-use characteristics. The models determined the cost and probability of meeting specifications when functional characteristic tests were included. Testing costs of $40/sample for a farinograph test and $30/sample for a loaf volume test were included. All tests had a 95% accuracy assumption, and 5 samples for every 10 grain cars were tested.

[1] Strategies included additional costs for location = 1.5 c/bu, variety = 4.6 c/bu, and functional tests farinograph = 0.6 c/bu, and loaf volume = 0.5 c/bu.

Two functional characteristic models were analyzed. One included tests for absorption, peaktime, and stability. The second included testing for absorption, peaktime, stability, and loaf volume. Comparing results (Table 2) to the base case indicates that the joint probability of meeting all specifications increased from .59 to .75 when the farinograph test was conducted. Procurement costs increased by 2 c/bu when the farinograph test was performed. Results indicate that adding testing for loaf volume, although it does not have as much impact on the results as the farinograph test, improved the joint probability of conforming to end-user specifications. The joint probability increased from .75 to .81 when tests for loaf volume were included and average costs increased 1 c/bu (Table 2).

Results indicated purchase strategies that include pre-testing for functional characteristics can improve joint probabilities of meeting buyer requirements. Strategies that rely on pre-testing improved joint probabilities of conformance (i.e, reduced buyer's risk) more than purchase by variety, location, or variety by location strategies.

Table 2. Probability of Meeting Specifications (Comparisons Between Base Case and Functional Models)

Functional Characteristic	Base Case	Farinograph	Loaf Volume
Absorption	0.95	0.95	0.95
Peaktime	0.98	0.95	0.95
Stability	0.71	0.95	0.95
Loaf Volume	0.90	0.88	0.95
Joint Probability	0.59	0.75	0.81
Average Cost PNW C/bu	478	480	481

Table 3 compares the cost and risks of all procurement strategies. Functional testing yields the highest joint probability of conformance but comes with the highest price due to high testing costs. Buying based on high protein yields high joint probabilities as well, but protein premiums are costly. Inclusion of location and variety are less costly and yield similar results, providing evidence that this strategy is optimal when the cost of delivering HRS to the PNW is considered.

Table 3. Comparison of Results

Strategy*	Probability of Conformance (Joint)	Cost/Bushel Delivered PNW
Base Case	0.59	478
Wheat and Protein 13%	0.25	469
Wheat and Protein 14%	0.53	477
Wheat and Protein 15%	0.62	485
Location	0.67	463
Variety	0.62	468
Location and Variety	0.69	467
Functional Tests	0.81	481

* All strategies also include specifications for protein.

Specifying greater wheat protein, which is used extensively by end-users, results in greater cost (protein premiums) to buyers. Protein levels are easy to measure, allowing for transactions with few hurdles to overcome. More specific strategies such as location and variety involve greater communication between suppliers and end-users. Long-term relationships would likely develop within such a contract. End-users could agree to buy agreed-upon lots of HRS for a stated period of years from a producer. Premiums and discounts could then be applied to transactions that meet, or fail to meet, specifications.

INCENTIVE CONTRACTS FOR IMPROVING FUNCTIONAL TRAITS

Contracts can be designed by wheat buyers to address cost/risk tradeoffs involving moral hazard and analyzed as a principal-agent problem where the buyer is the principal and the seller is the agent. Asymmetric information is present and most grain buyers are unable to monitor producers and handlers (agents) throughout the production and transportation process. A principal-agent model was used to examine the application of contracting for wheat functional traits. A theoretical representation is made first and then results are generated using distributions from Wilson, Peterson, and Dahl (2004) to evaluate the terms of an incentive contract.

Principal-Agent Theory and Contracting for Functional Traits

The agent has information that is not available to the principal. The opportunity and technology costs of performing the task are elements that may be better known to the agent than the principal (Laffont and Martimort, 2002). Moral hazard exists because the principal cannot monitor the effort of the agent. A feature of a principal-agent contract under imperfect information is that the agent does not bear the full consequences of his own actions because there is unobservability by the principal. The goal for the principal is to design a contract to induce desired effort by the agent.

Figure 1 illustrates the principal-agent game with moral hazard and hidden actions. The principal can either offer a contract or not and the agent either accepts or rejects it. If the agent accepts, the agent decides how much effort to exert. Nature creates randomness and outcomes are represented as payoffs for each player and node.

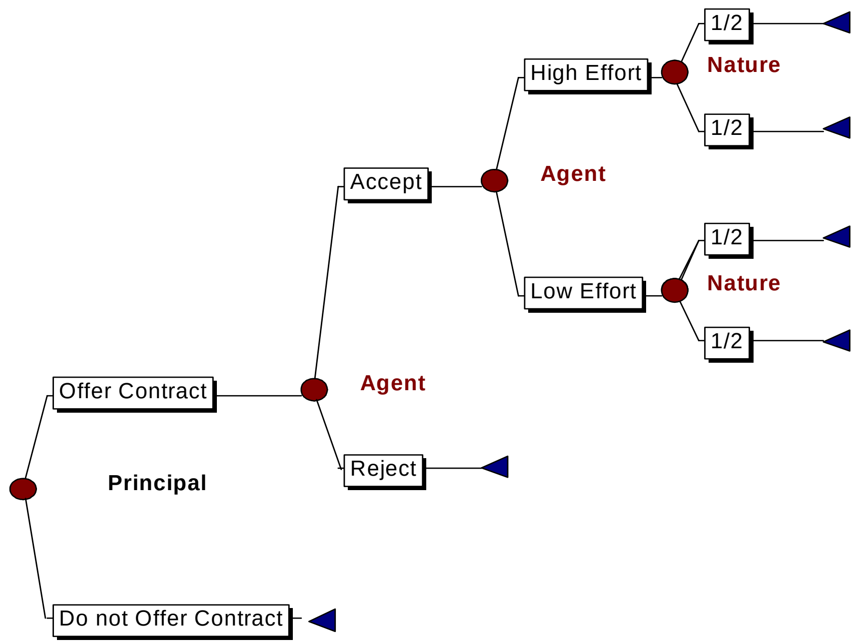

Figure 1. Principal-Agent Game with Moral Hazard and Hidden Action

Payoffs for the principal are impacted by the effort of the agent. If the agent expends high effort, high payoffs are likely to accompany his effort and vice versa. Nature influences the outcome in that even if high effort is put forth by the agent, a low payoff may be realized due to risks in performing functions. Designing a contract that maximizes the expected utility/profit but appeals to the agent and induces high effort actions is the objective of the principal. Mathematically (Rasmusen, 2001, pp. 172-173), the principal's problem is:

Maximize $EV\,(q(\hat{e},\theta) - w(q(\hat{e},\theta)))$

where EV is the expected utility for the principal; output *q* is a function of effort $\hat{e}$ and nature θ; and payoff *w* is also a function of effort and nature.
Subject to:

$\hat{e} = \operatorname{argmax} EU\,(e,w(q\,(e,\theta)))$ (incentive compatibility constraint)

$EU\,(\hat{e}\,,\, w(q(\hat{e}\,,\theta))) \geq U$ (participation constraint)

where *EU* is the expected utility for the agent and *U* is the reservation utility for the agent or the value of some outside opportunity. The incentive compatibility constraint induces the agent to pick the desired effort (Rasmusen, 2001). The participation constraint represents the incentive needed to induce the agent to accept the contract terms, rather than an outside opportunity. Incentive compatibility and participation constraints are developed below.

Mixed Strategies

In deterministic extensive form games such as the principal-agent problem, decisions are discrete. An agent either accepts or rejects the contract, and exerts high or low effort. However, strategies are not always deterministic, or pure Nash equilibrium. A mixed Nash equilibrium strategy, or a strategy that involves chance, eliminates some of the predictability in a principal-agent relationship (Gardner, 1994). Mathematically, a mixed strategy is a probability distribution over pure strategies. Mixed strategies indicate the likelihood of one strategy being adopted (Watson, 2002). Player *a* believes with a υ probability that strategy *s* is the best strategy (Watson, 2002). The expected value for player *a* is his payoff if strategy *s* is played. Mathematically:

$$EV(s, \upsilon) = \upsilon^*(s) + (1 - \upsilon)^*(b).$$

The payoff is the expected value given the probability of each strategy being selected.

Mixed strategies reflect randomness in a principal-agent game. Randomness can result in mixed strategies 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.

Grain Contracting for Functional Traits

Incentive contracts for functional traits in grain marketing is nonconventional, but can be motivated by a number of factors. First, conventional contracting on grain (grade, protein, location, variety) is not completely effective in reconciling functional trait requirements (as illustrated by Wilson, Peterson, and Dahl, 2004). Second, tests for functional traits, while possible, have time requirements that exceed the normal logistical standards of receiving grain, loading, and shipping vessels. Thus, there is a time lag between the transaction and documentation necessary to use functional tests as a means to reject lots. Further, these are subject to risk. Third, suppliers can exert effort to procure wheat to meet and verify its functional requirements prior to shipping. This can be done by selecting origins and pre-testing grain for functional traits in-transit and/or in storage prior to loading. However, buyers are not able to observe or verify this effort. An incentive contract requires the buyer to specify a base price along with a reward or bonus for meeting targeted functional requirements. This could be awarded after a ship is loaded (or in-transit) during which time the functional trait would be evaluated by a designated lab. Upon confirming these values, the agent or shipper would receive an ex-post (shipping) bonus, or not, depending on the results of these tests.

The problem is illustrated in Figure 2. The principal chooses whether to offer a contract or not, where he may have an outside option if he does not offer the contract. Presumably, this would simply be to continue buying on generic commodity contract terms (no effort). The agent can either accept or reject the contract; where, if rejected, the agent may have alternative offers and the principal may again have the option of continuing to buy on generic contract terms (no effort). If the agent accepts, the agent decides whether to exert high or low effort. High effort could involve conducting pre-shipment tests for functional traits and additional effort in searching for specific qualities of grain, etc. Low effort could entail doing limited activities and simply taking a chance of meeting the function trait (this could imply specifying a higher protein level). Payoffs and probabilities are assigned throughout the representations. The problem would be solved through backward induction to arrive at a sub-game perfect Nash equilibrium.

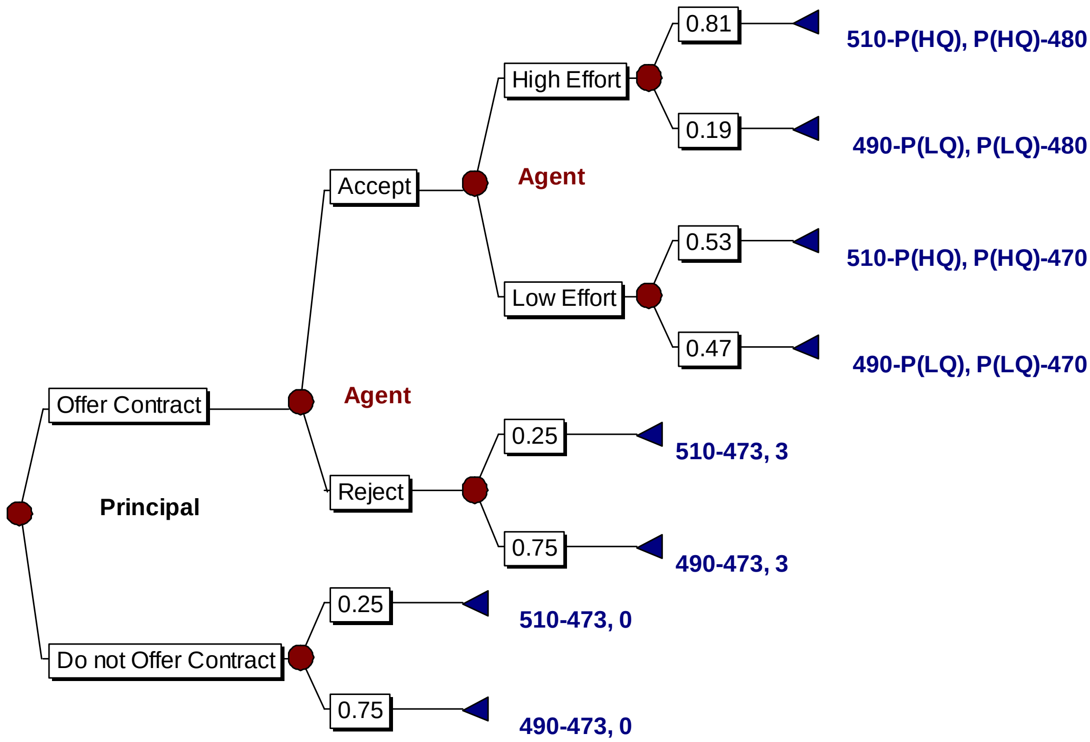

Figure 2. Principal Versus Agent, Imperfect Information Without Monitoring

The principal specifies a contract in which the price depends on performance which is based on an ex post evaluation of quality. This can be interpreted as, for example, upon loading, a sample is taken at the export port or at the import port and a third party evaluates it for functional performance. The contract may state that X composite samples will be retained from the ship loading and used to conduct functional tests. If the tests conform to functional requirements, the shipper receives a bonus. If not, the shipper receives the base price. Agents may or may not exert additional effort to procure grain that meets specifications for the principal. This effort may include 1) conducting their own tests for functional characteristics when gathering lots for sale or 2) searching for specific qualities of wheat, etc. Both would likely involve higher costs to the agent.

We develop an example where the payoff, or value, to the principal, of wheat that meets functional requirements is \$5.10/bushel and \$4.90/bushel if not. Agent's costs of procuring supplies for sale are \$4.70/bushel and \$4.80/bushel for low and high effort, respectively (implying the cost of high effort was 10 c/bu). The principal has the outside option of buying on grain specifications only (no effort) from other agents for \$4.73/bushel. Outside options are available if the principal either does not extend a contract or if the agents reject the contract. Agents have an outside option of selling to an alternative principal for \$4.73/bushel with no effort for a payoff of 3 c/bu. Since the agent has risk in meeting desired specifications with a given level of effort, the potential of achieving outcomes was represented by probabilities, conditional on the level of effort extended. Initially, probabilities of achieving high quality with high, low, and no effort were .81, .53, and .25, respectively, using probabilities derived from Wilson, Peterson, and Dahl (2004). Base case assumptions are shown in Table 4.

Table 4. Base Case Assumptions for Incentive Contract

Assumption	Item
Payoff to Principal if	
Specifications met	510 c/bu
Specifications not met	490 c/bu
Cost to Principal for procuring from outside agent with no effort when contract rejected or no contract extended	473 c/bu
Payoff to Agent for alternative market with low effort	3 c/bu
Agent cost of	
High effort	480 c/bu
Low effort	470 c/bu
Probability of Meeting Specifications with	
High effort	.81
Low effort	.53
No effort	.25

The minimum base price and premium that should be offered to the agent to induce high effort can be derived from the incentive compatibility and participation constraints. If we assume that there is no uncertainty in achieving high quality with high effort, the incentive compatibility constraint is:

$$P_H - 480 > P_L - 470 \quad (1)$$

where the prices paid to the agent based on high and low effort are P_H and P_L, respectively, meaning that the agent's revenue for high effort must exceed the revenue for low effort. The participation constraint with no uncertainty is:

$$P_H - 480 > 3 \quad (2)$$

meaning that the net revenue for high effort must be greater than alternative offers to other principals which require no effort (in this case, the alternative offer is 3 c/bu), or the agent rejects the contract and sells to the alternative principal.

Given that Nature affects the outcomes of effort by the agent, the agent's expected payoffs for high and low effort are:

$$EV_{HE} = .81\ P_{HQ} + .19\ P_{LQ} – 480, \tag{3}$$

$$EV_{LE} = .53\ P_{HQ} + .47\ P_{LQ} – 470 \tag{4}$$

where EV_{HE} and EV_{LE} are the expected payoff for high and low effort, respectively, and P_{HQ} and P_{LQ} are prices paid to the agent if high quality and low quality are realized, respectively. To induce high effort, the principal must make sure that the high effort payoff (3) pays more than the low effort payoff (4). The incentive compatibility constraint with uncertainty is then:

$$.81\ P_{HQ} + .19\ P_{LQ} – 480 > .53\ P_{HQ} + .43\ P_{LQ} – 470 \tag{5}$$

Rearranging and solving the incentive compatibility constraint inequality (5) yields:

$$P_{HQ} > P_{LQ} + 35.71 \tag{6}$$

The agent is paid more for producing high quality whether he/she applied high effort or not. Given that the agent puts forth high effort, the principal must make sure that the contract is accepted. The participation constraint after accounting for the effects of Nature must then be satisfied. The participation constraint is then:

$$0.81P_{HQ} + 0.19P_{LQ} – 480 > 3 \tag{7}$$

which can be simplified to:

$$P_{HQ} > 560 - .24\ P_{LQ}. \tag{8}$$

Figure 3 is derived to illustrate the incentive compatibility and participation constraints, which are as follows:

Incentive compatibility constraint: $P_{HQ} = P_{LQ} + 35.71$ (9)

Participation constraint: $P_{HQ} = 560 - .24P_{LQ}$ (10)

Prices that satisfy both constraints lie above both lines (Figure 3). Prices above the participation constraint are required for the agent to choose to accept the contract versus the outside alternative. Prices above and to the left of the incentive compatibility constraint are required for the agent to choose the desired action. The feasible set contains any/all points above the intersection of the two lines and because the principal decides the contract terms, the principal will choose that which is minimum. Prices higher than these constraints would be acceptable to agents; however, they would impose higher costs on the principal.

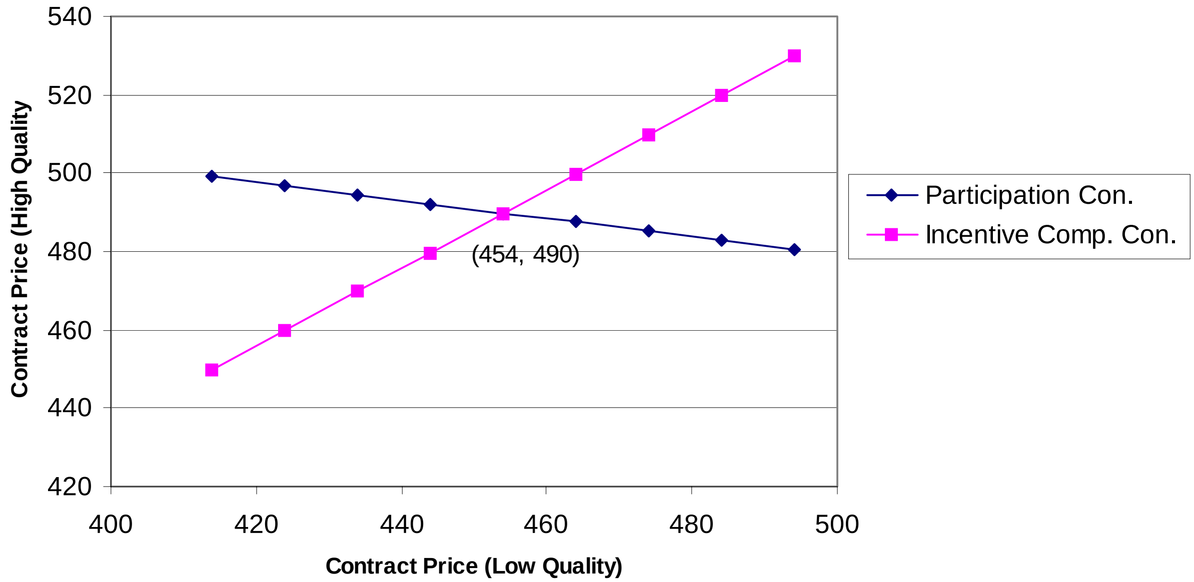

Figure 3. Principal Versus Agent, Incentive Compatibility and Participation Constraints, Probability of Meeting Specifications for High Effort = .81.

Substituting the right-hand side of Equation 10 into Equation 9 for P_{HQ}, and rearranging allows for us to solve for the minimum value of P_{LQ} and P_{HQ} which satisfies both Equations 9 and 10. The minimum point that satisfies both constraints is (454, 490). These represent the minimum prices principals should offer to pay agents for a shipment that does not meet specifications (454) and for meeting specifications (490). The minimum acceptable incentive contract in this case would specify a base price of 454 with a 36 c/bu (490-454) premium for meeting buyer specifications for functional characteristics.

Sensitivity of Minimum Equilibrium Contract Terms

Probability of Conformance with Effort

The results of this model are highly sensitive to several of the parameters assumed. One of these parameters is the probability of conformance with high effort by the agent. Minimum equilibrium contract terms (prices for high quality and low quality) were derived for alternative probabilities of conformance given high effort by the agent. These were varied from a probability of .9 to .6 of meeting high quality with high effort. In the base case, a probability of conformance of .81 resulted in contract prices for high and low quality of 490 c/bu and 454 c/bu (Table 5). If the probability of meeting specifications with high effort increased from 0.81 in the base case to 0.9, the minimum acceptable price principals would offer for lots not meeting specifications increases from 454 to 459 c/bu (Figure 4, Table 5). The price principals would offer for lots meeting specifications decreases from 490 to 486 c/bu, implying a decline in the premium if high quality is realized to 27 c/bu.

Table 5. Equilibrium Contract Prices: By Probability of Conformance with High Effort

Probability of Conformance with High Effort	Price High Quality Realized	Price Low Quality Realized	Price Difference
.6	540	397	143
.7	501	442	59
.8	490	453	37
.9	486	459	27

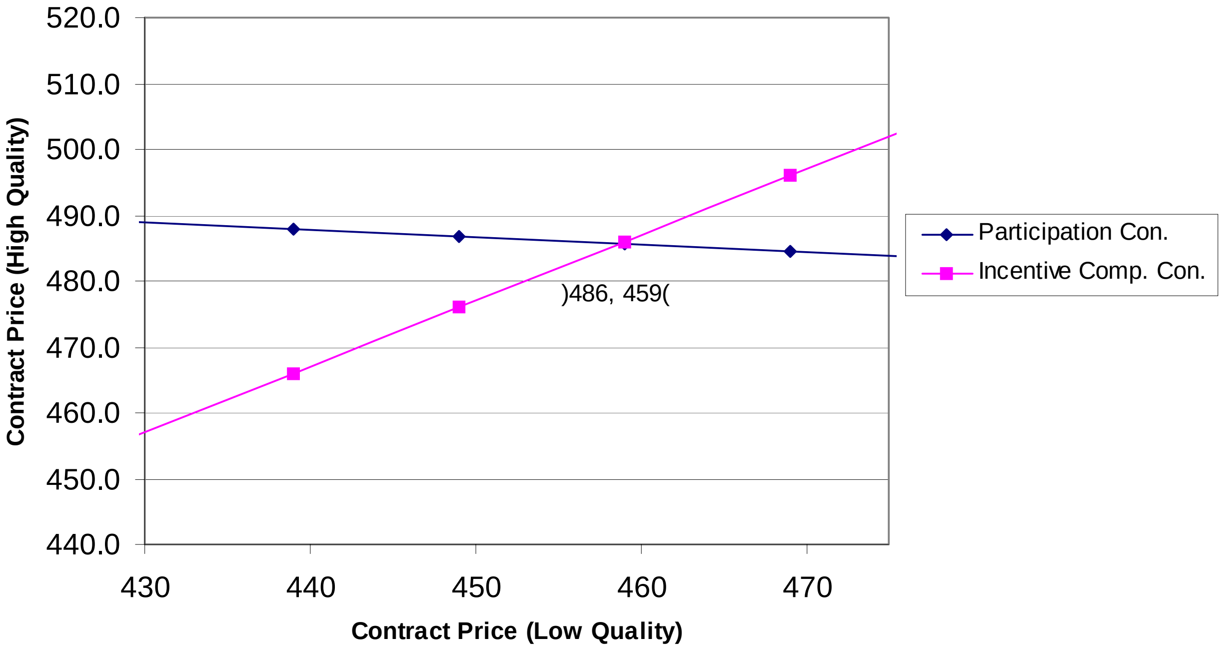

Figure 4. Principal Versus Agent, Incentive Compatibility and Participation Constraints, Probability of Meeting Specifications for High Effort = .9.

Similarly, if an agent were able to adopt an effort strategy that reduced the probability of conformance with high effort to .7, the equilibrium contract terms for high quality would be increased to 501 c/bu, and the price for low quality would decrease to 442 c/bu implying a premium for high quality of 59 c/bu. If the probability of conformance with high effort further declines to .6, the premium for high quality increases to 143 c/bu. These results illustrate, as the probability of meeting contract specifications decreases (i.e., due to greater risk), the price for meeting specifications increases and for failing to meet specifications decreases because there is a higher probability that low quality will be realized. In order for the supplier to accept such a contract, he/she must be sure to exert enough effort to receive the bonus or not accept the contract specifications. The key point is that, if it is more risky for the agent to perform, a higher bonus is required to induce him to expend high effort.

Outside Option for Agent

In the base case, the agent has an outside option to exert low effort and obtain a payoff of 3 c/bu. The value of this outside option was varied from 0 to 10 c/bu to determine effects on equilibrium contract prices for high and low quality. As the value of the outside option increased, equilibrium prices for high and low quality increased while maintaining the difference in contract prices between high and low quality at 36 c/bu (Table 6). The effect on equilibrium contract terms of the agent's outside option is on the level of prices for high and low quality, but does not affect the premium for high quality.

Table 6. Equilibrium Contract Prices: For High/Low Quality by Value of Agent's Outside Option

Value of Agent's Outside Option (c/bu)	Price High Quality Realized	Price Low Quality Realized	Price Difference*
0	487	451	36
3	490	454	36
5	492	456	36
7	494	458	36
10	497	461	36

* May not add due to rounding.

Cost to Agent of High Effort

In the base case, the cost of high effort by the agent was 480 c/bu., while the cost of low effort was 470 c/bu. implying additional costs for high effort of 10 c/bu. The cost of high effort was varied from 472 c/bu to 490 c/bu to determine effects on equilibrium contract prices for high and low quality. Results indicate that as the cost of high effort increases, the prices paid for high quality increase, prices for low quality decrease, and the premium for high quality becomes larger (Table 7). Other sensitivities such as varying the value to the principal for high effort or the value of the principal's outside option affect the principal's decision to extend the contract or not, but do not affect the equilibrium contract prices for high and low quality.

Table 7. Equilibrium Contract Prices: For High/Low Quality by Cost of High Effort for Agent

Cost of High Effort by Agent (c/bu)	Price High Quality Realized	Price Low Quality Realized	Premium For High Quality
472	476	469	7
474	480	465	15
476	483	462	21
478	486	458	28
480	490	454	36
482	493	450	43
484	497	447	50
486	500	443	57
488	503	439	64
490	507	435	72

Analysis of Participation Strategies for Equilibrium Contracts

Equilibrium contract terms are those required for the agent to participate in the contract and to provide the incentive to choose the right effort. Participation is also impacted by outside options, especially in the case of the principal, which affect whether the principal will offer the contract. Results for equilibrium contract terms, payoffs, probabilities of meeting requirements by effort level, and outside options from the prior model were input into the game theory analysis software *Gambit* (McKelvey, McLennan, and Turocy, 2004) to determine optimal strategies for both principals and agents. Solutions consisted of pure and mixed equilibrium strategies for the principal and the agent. The game analysis is similar to the earlier analysis but, instead of limiting results to the payoffs and incentive compatibility and participation constraints, equilibrium strategies were evaluated for a range of factors and assumptions which focused on factors affecting the principal's decision whether to extend the contract or not.

In the base model, the principal has the option to purchase on grain specifications only for $4.73/bu either when the principal does not offer the contract or when the agent rejects the contract. The payoff for the principal from this outside option assumes the same values for high and low quality, the same probabilities for achieving high quality with no effort, and has an expected payoff of 21 c/bu which is applied both if the contract is not extended and if the agent rejects the contract.

Optimal strategies by the principal and agent are influenced by a number of factors including the probability of achieving tolerance levels with agent effort, agent effort costs, the payoff to the agent of an outside option to the principal's contract, and the value of high revenue to the principal. Sensitivities were conducted to determine how adjustments in these factors will influence the optimal strategies for equilibrium contract terms.

The probability of conformance with high effort by the agent was varied from .6 to .9. Optimal strategies were solved for both the principal and agent for these simulations using equilibrium contract terms, payoffs, and probabilities of conformance. Results indicate that varying the probability of conformance does not impact the principal's decision to extend the contract. Table 8 summarizes the equilibrium strategies of the buyer (principal) and supplier (agent) and the coinciding changes in payoffs for high and low effort. At all probabilities the equilibrium is one of mixed strategies. A mixed strategy of 0.50 of accepting the contract indicates that 50% of the time, the supplier will accept the contract offered by the principal. This occurs because by definition, these are equilibrium values or alternatively, are point at which the agent would be indifferent between these two choices.

Table 8. Equilibrium Strategies as Risk of Conformance Changes

Conformance Probability	Equilibrium Contract Payoff High Qual/ Low Qual (c/bu)	Premium High - Low Quality (c/bu)	Probability Principal Offers Contract	Probability Agent Accepts Contract	Probability Agent Exerts High Effort
Sensitivity of Probability of Conformance for Agent High Effort					
0.6	540, 397	143	1.00	0.50	0.50
0.7	501, 442	59	1.00	0.50	0.50
0.8	490, 453	37	1.00	0.50	0.50
0.9	484, 472	27	1.00	0.50	0.50
Sensitivity of Probability of Conformance for No Effort (Principal's outside options of no contract and contract rejected)					
0.25	490, 453	37	1.00	0.50	0.50
0.30	490, 453	37	1.00	0.50	0.50
0.35	490, 453	37	1.00	0.50	0.50
0.40	490, 453	37	0.99	0.50	0.50
0.45	490, 453	37	0.01	0.50	0.50

Sensitivities were also examined for the probability of conformance for no-effort within the principal's outside options if the contract is rejected by the agent and if the principal does not offer a contract. Results show that as probabilities for no effort increase over .40, the equilibrium strategy shifts so that the principal does not extend the contract. Thus, for this example, the probabilities of conformance for different effort levels affect payoffs, equilibrium contract terms, and also impact the principal's optimal strategies.

Sensitivities were conducted to evaluate the impact of some of the important factors impacting equilibrium strategies. These include the payoff for the outside option of the agent, the agent's cost of high and low effort, the principal's value for high and low quality, and the principal's costs for procuring from alternative agents, either if the contract is rejected or no contract is extended. Results are summarized in Table 9. If an outside option to the agent exceeds 5 c/bu, this will induce the buyer to not offer the contract. When the cost of exerting high effort is greater than 486 c/bu or the cost of low effort is greater than 476 c/bu, the buyer would not offer the contract. If the value to the principal of high quality decreases to less than 502 c/bu or the value of low quality is greater than 498 c/bu, the buyer would not offer the contract. If the cost of procuring from alternative agents decreases to less than 472 c/bu or if the costs of procuring from alternative agents when the agent rejects the contract are greater than 476 c/bu (implying a maximum cost for development of the contract of 3 c/bu), the principal would not offer a contract.

When a principal offers a contract and it is rejected, the principal's cost of procuring from an outside agent would likely be higher than when the contract is not offered due to the fact that the principal may have costs in developing the contract that he would not incur if no contract were extended. Therefore, it is important to determine how this cost influences the decision of the principal. As Table 10 implies, increased disparity between the principal's cost of procuring from alternate agents when the contract is rejected and when contract is not offered influences the principal's equilibrium strategy. As the cost for alternative agents when the contract is rejected increases relative to the costs when no contract is offered, the likelihood of the principal offering the contract declines. When the costs for procuring from outside agents exceed 476 c/bu, the principal would not offer the contract. Therefore, in this case the cost of developing the contract must be 3 c/bu or lower for the principal to offer the contract.

The cost of procuring from alternative agents when not offering the contract also influences the decision of the principal. Table 11 indicates that when costs of procuring from alternative agents when not offering the contract decrease relative to the costs if the agent rejects or accepts the contract, it is more likely that principal will not offer the contract. For example, a decrease in the cost of procuring from outside agents when the contract is not offered to 471 c/bu results in the principal preferring to not extend the contract. Increases in the cost of procuring from alternative agents when no contract is extended over the base value of 473 have no effect on the principal's optimal strategy to extend the contract.

Table 9. Sensitivities for Equilibrium Contract Terms

Contract Terms	Base Case Value	Buyer Will Not Offer Contract If:
Agent's Parameters		
Outside Option for Agent	3 c/bu	If outside option >5 c/bu
Cost of High Effort	480 c/bu	If high effort costs > 486 c/bu
Cost of Low Effort	470 c/bu	If low effort costs > 476 c/bu
Principal's Parameters		
High Quality Value	510 c/bu	If high quality value < 502 c/bu
Low Quality Value	490 c/bu	If low quality value > 498 c/bu
Principal's Outside Option When No Contract Extended	473 c/bu	If the expected cost of procuring supplies from alternative agents when no contract is extended declines to less than 472 c/bu
Principal's Outside Option When Agent Rejects Contract	473 c/bu	If the expected cost of procuring supplies from alternative agents when the contract is rejected increases to more than 476 c/bu

Table 10. Equilibrium Strategies as Principal's Costs for Procuring From Outside Agents Varies if Agent Rejects Contract (Agent Payoff Fixed at 3 c/bu)

Principal's Cost for Purchase From Outside Agent				
When no contract offered	When contract offered and agent rejects	Probability that contract offered by principal	Probability that contract accepted by agent	Probability that agent exerts high effort
473 c/bu	473 c/bu	1.00	0.50	0.50
473 c/bu	474 c/bu	1.00	0.50	0.50
473 c/bu	475 c/bu	1.00	0.50	0.50
473 c/bu	476 c/bu	1.00	0.50	0.50
473 c/bu	477 c/bu	0.00	0.50	0.50

Table 11. Equilibrium Strategies as Payoffs to Principal Change When Contract is Not Offered.

Cost of procuring from alternative agent when contract not offered (c/bu)	Cost of procuring from alternative agent when contract offered and agent rejects (c/bu)	Probability that contract offered by principal	Probability that contract accepted by agent	Probability that high effort exerted by agent
471	473	0.00	0.50	0.50
472	473	1.00	0.50	0.50
473	473	1.00	0.50	0.50
474	473	1.00	0.50	0.50
475	473	1.00	0.50	0.50

SUMMARY

Quality consistency is a major evolving problem in international grain marketing competition, particularly in the case of HRS wheat. To confront this problem, buyers have a number of strategies. These include: purchase by grade and protein, or supplementing these with specifications of either varieties, locations and/or values for desired functional traits. However, functional characteristics are not easily measurable at the point of sale due to the time required for tests. An alternative is for buyers to offer incentive-based contracts to induce unobservable effort by suppliers. In this study, principal-agent models were developed to analyze factors affecting the equilibrium contract terms of incentive contracts for wheat procurement.

An example principal-agent model was developed to estimate the minimum equilibrium contract terms for low quality and for high quality. This model was examined to determine the effect of selected parameters on minimum acceptable incentive prices. A second principal-agent model was developed and analyzed for mixed strategies to evaluate the principal's and agent's optimal strategies. This model focused on effects of the principal's value for high and low quality, agent's costs for high and low effort, and alternative options for both the principal and the agent on probabilities for the principal extending the contract, agent acceptance, and agent adoption of high effort.

A base case was presented where the minimum acceptable incentive contract would provide a base price paid by the principal to the agent of 454 c/bu for low quality lots and a premium of 36 c/bu if quality specifications are met. Results of sensitivities for equilibrium contract terms indicated:

- Buyers must know the value of higher quality that sufficiently offsets added costs and risks to suppliers. If not, it would not be in their interest to offer incentive contracts.

- The premium required to induce the agent to accept a contract increases with the risk of not conforming to specifications and/or if the agent's cost of exerting high effort increases.

- The premium for high quality is not impacted by the agent's outside option.

Results indicated optimal strategies for participants are sensitive to parameter values utilized. Small changes in several of the parameter values (agent's outside option, agent's cost of high/low effort, principal's value for high/low effort, and principal's outside options if the contract is not extended or if the agent rejects the contract) impact whether it is in the principal's interest to offer a contract.

Though represented here as a principal-agent problem and solved using game theory techniques, the concept of the contract has applications in the grain marketing industry. One way to interpret the implementation of such a contract is as follows. The buyer offers to buy grain with a particular level of a functional characteristic. The offer provides for two prices, a higher price if the level is met, and a lower price if it is not met. The supplier can exert effort to affect the level of the functional characteristic. As an example, the supplier could target purchases from certain locations with known levels of the attributes, could conduct pre-shipping tests prior to or concurrent with loading of railcars from the interior, could specify varieties in their purchase contracts, and/or could conduct functional tests at the export elevator prior to loading. Or, the supplier could exert no or low effort, and just take a chance on meeting the higher quality specifications. Of importance here is that the buyer cannot observe the level of effort of the agent. But, the principal could test the functional characteristics after loading and/or while in transit. Based on the results of these tests, the payment would be made, inclusive of the bonus implied in the payment scheme. For example, the contract may read that in order to receive the bonus, 80% of the samples must conform to the targeted level of the functional characteristic.

While contract specifications with explicit premiums and discounts for grain quality are routine in grain trading, contracts for functional characteristics are less common, though growing in use, and are necessarily more complex. This research explored how such contracts would be conceived and specified. There are several implications from these results. First, contract terms can be designed, inclusive of incentives to induce agents to provide additional effort to supply improved quality in markets where moral hazard and quality uncertainty exist. Second, the contracts must be conceived by buyers who have a value for higher functional quality grains and necessarily require a price schedule implying a premium and discount and some risk sharing with the supplier. Third, it is important that small changes in any of the model parameters can result in different contract terms and can alter the principal's and agent's equilibrium strategies. This is compounded by the likelihood that the probability of conformance for strategies changes over time due to environmental effects, changes in varieties adopted, etc.

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