

**INCENTIVE CONTRACTS TO MEET FUNCTIONAL
CHARACTERISTICS IN WHEAT PURCHASING**

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William W. Wilson, Brett J. Maxwell, and Bruce Dahl¹

INTRODUCTION

Consistency of functional performance in hard red spring (HRS) wheat is a problem confronting buyers and sellers. Lack of consistency 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. Buyers may pursue alternative 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) which provides a detailed statistical analysis of the costs and risks of conforming to end-use requirements using different strategies.

Functional trait test requirements exceed 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 can exert extra effort to procure wheat to meet and verify its functional requirements prior to shipping by selecting origins, 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 due to not being 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 results provide an interpretation of contractual mechanisms with suggested incentives to reduce problems related to quality consistency.

¹ 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 is a summary of a larger Agribusiness and Applied Economics Report of the same name by Wilson, Maxwell, and Dahl. For more detail, see the larger report, No. 545.

BACKGROUND

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).

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.

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. Examples of current IP systems being adopted are General Mills (Willis) and Warburtons.

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). 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 performed and certified by the USDA's Federal Grain Inspection Service or a private inspection company (U.S. Wheat Associates). 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). 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).

Wilson, Peterson, and Dahl 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 factors (i.e., variety, location, functional characteristics, cost). Six separate procurement strategy models were simulated.² 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%, peak time of 7 minutes, stability of 14

minutes, and loaf volume of 1,000 cubic centimeters.

Table 1 compares the costs 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 1. 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 (Loaf Volume)	0.81	481

* All strategies also include protein 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.

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). 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.

² 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.

Figure 1 illustrates a 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.

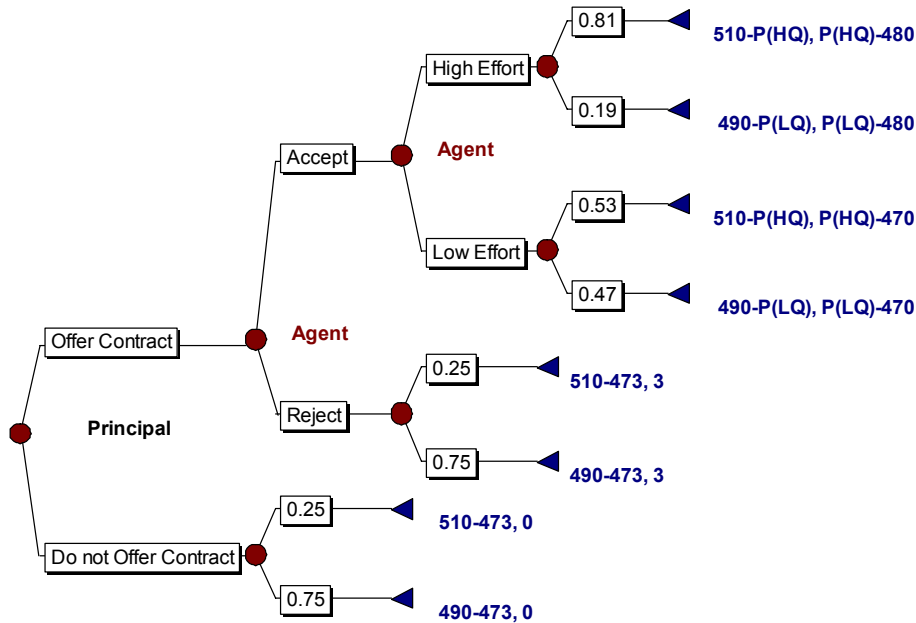


Figure 1. Principal Versus Agent, Imperfect Information Without Monitoring

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. The objective of the principal is to design a contract that maximizes expected profit but appeals to the agent and induces high effort actions. To satisfy these restrictions, two constraints are included (participation and incentive compatibility). The participation constraint represents the minimum incentive needed to induce the agent to accept the contract terms, rather than an outside opportunity. The incentive

compatibility constraint induces the agent to pick the desired effort. Incentive compatibility and participation constraints are developed below.

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. Mixed strategies indicate the likelihood of one strategy being adopted.

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. Second, tests for functional traits, while possible, require time that exceeds 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, 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 1. 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, 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.

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 for the principal that meets specifications. 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. The 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 an 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 were 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). Base case assumptions are shown in Table 2.

Table 2. Base Case Assumptions for Incentive Contract.

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

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

$$EV_{HE} = .81 P_{HQ} + .19 P_{LQ} - 480, \quad (1)$$

$$EV_{LE} = .53 P_{HQ} + .47 P_{LQ} - 470 \quad (2)$$

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 (1) pays more than the low effort

payoff (2). The incentive compatibility constraint with uncertainty is:

$$.81 P_{HQ} + .19 P_{LQ} - 480 > .53 P_{HQ} + .43 P_{LQ} - 470 \quad (3)$$

Solving the incentive compatibility constraint inequality (3) yields:

$$P_{HQ} > P_{LQ} + 35.71 \quad (4)$$

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 can be simplified to:

$$P_{HQ} > 560 - .24 P_{LQ}. \quad (5)$$

Figure 3 illustrates the incentive compatibility and participation constraints. Prices that satisfy both constraints lie above both lines. 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.

The minimum point that satisfies both 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.

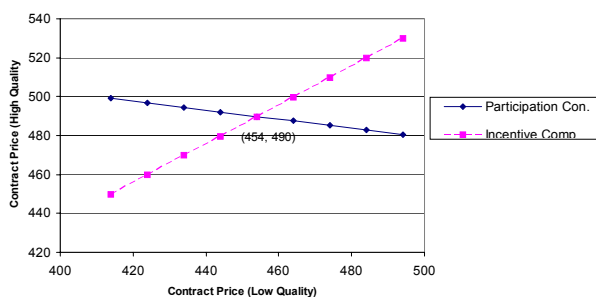


Figure 3. Principal versus agent, incentive compatibility and participation constraints, probability of meeting specifications for high effort = .81.

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 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 3). 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 3). 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.

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. 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. 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.

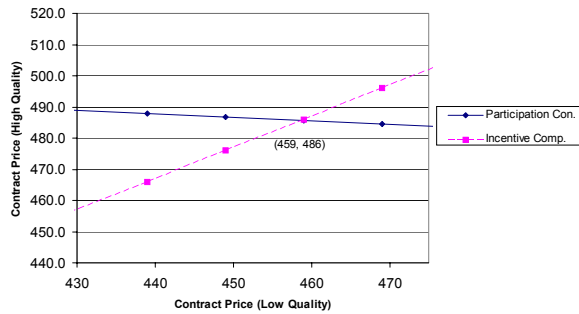


Figure 4. Principal versus agent, incentive compatibility and participation constraints, probability of meeting specifications for high effort = .9.

Table 3. Equilibrium Contract Prices: By Probability of Conformance with High Effort

Probability of Conforming 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

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 increases, equilibrium prices for high and low quality increase while maintaining the difference in contract prices between high and low quality at 36 c/bu. 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.

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.³

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) 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 above 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.

³ 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.

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 4. 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 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.

Table 4. 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
Principals' 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

The cost of procuring from alternative agents when not offering the contract also influences the decision of the principal. When costs of procuring from alternative agents 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.

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.

A 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. This model focused on effects of the principal's value for high and low quality, the agent's costs for high and low effort, and alternative options for both the principal and 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 have a value for 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 strategies for participants are sensitive to parameter values utilized. Small changes in many 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 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 not. 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 rail cars from the interior, could specify varieties in their purchase contracts, and/or could conduct functional tests at the export elevator prior to loading. Or, it 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 that 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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