Procurement Strategies: Impacts of Quality Risks in Hard Wheat

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Abstract

Analytical models were developed in this paper to evaluate cost/risk tradeoffs of three alternative procurement strategies in the case of hard red spring (HRS) wheat. Results indicate a naive strategy has the lowest expected cost, but a high probability of not conforming to end-use requirements. Two alternative specifications for the constant share strategy result in higher probabilities of meeting requirements, but at higher costs. The opportunistic strategy results in a higher probability of meeting requirements than either of the other two alternative strategies at a comparable cost.

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1.   Introduction

There has been a resurgence of interest among agricultural economists and agribusiness in recent years on alternative regimes for vertical management and control in the marketing system. While these have emerged and are fairly widely adopted in the livestock sector, they are less well defined in the grain sector. Issues of particular importance in the case of grain include quality levels and consistency, the prospect of "value-enhanced grains" (Sosland, 1999a,b) and the impacts of these on transaction costs (Hobbs and Young). There is a spectrum of alternative strategies for vertical control, ranging from spot transactions to longer-term contracting, joint ventures and ultimately complete integration. Many of these involve some form of integrated supply chain management, which seeks to reduce costs by reducing sources of uncertainty on the supply chain (Davis, Handfield and Nichols). All of these have had a renewed emphasis on issues related to quality, consistency and the efficacy of alternative procurement strategies.

Generally, quality uncertainty results from the cumulative effects of variety heterogeneity and proliferation (Dahl, Wilson, and Wilson), agronomic practices, climatic and marketing and handling practices. Ensuring consistency is problematic because end-use characteristics are not easily measurable and therefore are not easily contracted. Hence, typically buyers use more easily measurable grain characteristics as proxies for desirable end-use characteristics.

Product quality problems in grains are compounded by the numerous issues relating to the cost of information, moral hazard and adverse selection. Since end-use quality is essentially a random variable, obtaining information about end-use performance is costly and requires technology and expertise (*a-priori* knowledge). Since the cost of information is non-zero there is a double moral hazard problem (Phlips, pp. 57-60). The buyer is imperfectly informed about quality and the seller has imperfect information about buyers' use of the product. As a result, contracts and warranties are not easily adapted to resolve quality problems.

Procurement strategies vary in the case of hard wheat due to the fact that end-use quality characteristics are difficult to predict based on measurable grain qualities. Protein content (in addition to class and subclass) and locations are usually used as proxies for desirable end-use characteristics. Some wheat buyers simply specify grade factors and protein in their purchases. At the other extreme, a leading flour milling company indicated that an integral part of its future strategy would involve producing specific varieties under contract for handling and processing within their system (Sosland, 2000). Other firms have pursued vertical integration through asset ownership in targeted and diversified producing regions as an element of procurement strategy. For others, it is common to evaluate wheat and flour characteristics based on samples collected through the harvest season. After testing, this information is used to target locations for

procurement. However, use of pre-planting contracts for particular quality characteristics is not yet common.[1]

Procurement strategies are an important element of evolving interrelationships among competitors and suppliers in agricultural marketing. Indeed, these have been referred as "value clusters" but at least to date they have been difficult to realize (Ebbertt, p. 1). Some grain selling organizations have sought innovations to enhance and market quality differentials using information technology in the handling and processing of common grains.[2] These emerging innovations pose alternative procurement opportunities for food processors. In fact, due to these developments, procurement strategy has become a critical element of corporate strategy.

The purpose of this paper is to develop models that can be used to analyze costs and risks associated with different procurement strategies. Alternative procurement strategies include what we refer to as a naive strategy, constant share strategy and an opportunistic strategy. Section 2 motivates the problem and provides the necessary background for the mathematical specifications of alternative procurement strategies developed in Section 3. Results are presented and compared in Section 4 and conclusions and implications are drawn in Section 5.

2.   Quality Requirements, Risk, and Cost-Risk Tradeoffs

Not conforming to end-use requirements has important implications for food processors. These include 1) the risk of not conforming to contract specifications with downstream customers; 2) greater costs attributable to having to purchase a higher quality than required to assure ex-post performance; and 3) the effect of increasing operating costs due to an increased frequency and likelihood associated with shut down and/or inventory costs (generally referred to as stock-out costs in the logistics literature (e.g., Ballou, pp. 413-415) all due to the likelihood of non-conformance.

We analyze procurement strategies using a two-step process. The first step quantifies the procurement cost and risk of non-conformance associated with each origin. The probability of meeting quality requirements and the cost of delivered wheat are derived. Based on these, a *cost/risk tradeoff* is depicted among origins. The second step defines optimal combinations of

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[1] In numerous discussions of changes in agricultural marketing there is reference to the increasing percentage of products purchased under contract (e.g., see Barkema and Cook, and more recently, Sosland, 1999b). Sosland (1999b) indicated that poultry and pork have evolved to be 100% and 70% contracted during the past 10 years; and Hobbs and Young indicated that among agricultural commodities, contracting for grains in 1997 averaged from a low of 5% of the value for wheat to a high of 19% of value for barley. This compares to 70% of value for poultry, 36% for hogs and 28% for cattle. In just about all cases the percentage of grains grown under contract is very small relative to other commodities.

[2] Ebbertt cites a contemporary example whereby a grain marketer inventories wheat in storage with measures of end-use traits and uses this as the basis for marketing. This is also the practice of single-seller trading entities (e.g., Canadian and Australian Wheat Boards) in competing wheat marketing countries.

origins for targeting purchases. Given the cost/risk tradeoff, the analytical models are developed to explore the extent that risk and cost can be reduced by targeting some combination of origins for procurement. These results can be used to define a strategy of targeting multiple locations for grain origination.

Elements of the Problem. There are 22 origins (O_j) defined as Crop Reporting Districts (CRDs) throughout the hard red spring (HRS) wheat producing region. Prices at each origin are determined through inter-market competition between two markets, 1 and 2 generally representing movements to the east and west from the producing region. As a result of basis differentials and freight rate relationships, the purchasing costs vary geographically, generally increasing in the westerly origins. Futures are held constant, but basis values at the two markets are random and correlated.

The price at each origin j is derived as:

$$P_j = F + PP + Max[(B_{14,1} - S_{26,o \Rightarrow 1}), (B_{14,2} - S_{26,o \Rightarrow 2})]$$

Where F is futures and PP is the protein premium, each being a constant and independent of origin, $B_{14,1}$ is the basis for 14% protein wheat at terminal market 1, and $S_{26,o \Rightarrow 1}$ is the rail shipping cost for 26 car movements. Variables subscripted by 2 represent values for the competing market area. This relationship allows for the origin price to depend on either market 1 or 2, whichever yields the greatest net return to the shipper.

Basis values are treated as random variables in the simulations and are a source of risk. These distributions were derived using historical data for the marketing years 1993/94-1997/98 and were taken from annual reports of the Minneapolis Grain Exchange and the USDA Agricultural Marketing Service. Means and standard deviations with values in ( ) for market 1 and 2 were 80 cents/bu (45) and 125 cents/bu (46), respectively, and the basis had a correlation of .92 throughout this period. For simulation purposes, the futures price (F) was 340 cents/bu.

End-use quality requirements are those representative of a food processor using this type type of wheat for a specific set of products. Requirements include wheat protein 14.2%; test weight 57 lbs/bu minimum, with discounts applied from 58 lbs/bu; absorption 63%; peak time 6.5 minutes; and mix tolerance 12 minutes.

Wheat quality characteristics were derived using end-use and wheat data for individual origins throughout the producing region. All quality data were from public reports and/or original data collected for annual crop quality surveys (Moore, et al.). The data are from years 1980-1996.[3]

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[3] More recent data are available but the geographic delineations changed following 1996. For this reason we only used the years through 1996.

Wheat quality characteristics are measurable within the marketing system and are easily used for contracting. Of importance in this study are protein, test weight, and grade factors. Absorption, peak and mix time are all critical end-use characteristics of wheat flour that are not easily measurable within the grain marketing system. For that reason, it is not conventional to use these in any form for contracting wheat procurement. Measurable statistical relationships exist between these characteristics and wheat protein, which is specified in contracts. However, these relationships vary over time and across origins. These are an essential component of this analysis and are used to derive probability distributions for end-use conformance.

In concept, a level of wheat protein can be specified to achieve a targeted level of an end-use characteristic. For each end-use characteristic and origin a separate model of the following form was estimated: $U_t = á + â(X_t) + å$ where U_t is the quantity of the characteristic, X_t is the measurable wheat quality characteristic, in this case wheat protein, á and â are regression parameters, and å is the error term. The concept of consistency can be inferred from these statistics and is directly related to the value of å. Increases in å result in greater inconsistency, or variability that cannot be contracted using observable characteristics. An example of these regressions is illustrated in Figure 1 for a specific characteristic, absorption, for a specific origin region.[4]

Separate regressions were estimated for each quality parameter. Regressions included interaction terms for location (CRDs) and years to account for these effects. The average of effects across years was utilized to derive the intercept and slope parameters for each quality parameter. For purposes of the simulation, individual quality parameters were treated as random variables and the Root Mean Squared Error (RMSE) of regression equations was used as the measure of variability (or uncertainty).

Cost-Risk Tradeoffs. Costs and risks were derived for each origin, the combination of which was used to depict a cost/risk tradeoff among origins. These were derived using stochastic simulation procedures [*@Risk* (Palisade Corporation, 1997)]. Uncertainty was incorporated by including randomness of end-use characteristics as measured by RMSE for each characteristic (test weight, absorption, peak time, and mix tolerance), and basis values at alternate markets. For a given level of wheat characteristic, the end use characteristic was derived along with the uncertainty about its value measured by å.

Risk is measured by the joint probability of meeting all wheat and end-use quality requirements. This is a conditional probability given that the wheat purchase specification is

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[4] The issue of using wheat protein as a proxy for end-use quality has escalated in recent years. In a recent USDA-GIPSA memo it was indicated that "While developing a quick assay for either protein or wheat gluten quality has been on the wheat industry's wish list for quite some time, it is becoming increasingly urgent that we evolve this technology. This is primarily due to more sophisticated buyers demanding tighter end-use specifications in both domestic and international wheat markets and advances and acceptance of high-yielding/low quality wheat varieties ...." (USDA-GIPSA).

14.2% protein and test weight is at least 57 lbs./bu. Results are shown in Figure 2. Values for Origin 15 are used for illustration. For that origin, there is a joint probability of meeting all quality requirements of 73%, and the expected cost is 452 cents/bu. Probabilities of meeting the individual requirements are also calculated. There is nearly 100% certainty of meeting minimum requirements for test weight (57 lbs/bu); a 99% chance of meeting the absorption target (63); a 79% chance of satisfactory peak time (6.5 minutes); and 85% chance of satisfactory mix tolerance (12 minutes).

Compared to other origins, it is notable that origins 5, 6, 7, and 8 have the greatest likelihood of meeting requirements, though at a higher cost. Generally, more easterly origins have a lower cost but a lesser probability of meeting requirements. Taken together these can be interpreted as a cost/risk tradeoff. Moving from left to right, there is a greater likelihood of meeting quality requirements, but at a greater cost. Origins highest and furthest to the left dominate origins that are lower and further to the right.

3.   Models for Analyzing Procurement Strategies

Analysis of cost/risk tradeoffs is complicated by the fact that quality behavior is correlated across origins, but in general choosing the lowest cost origins results in greater risk that quality will not conform to requirements. In order to reduce that risk, it is necessary to target higher cost origins. Alternatively, specific origins could be targeted for purchases over time. This section specifies the mathematical models used to analyze three procurement strategies. We first describe common elements of the problem.

Three procurement strategies are modeled and results compared in terms of cost and risk. These are referred as the naive, constant share, and opportunistic strategies. The naive strategy specifies easily measurable wheat quality characteristics without reference to origin or any other requirements. This is included as a base case for purposes of comparison; it reflects the approach used by most domestic end-users, importers and some milling firms. The other two strategies seek to reduce risk through targeted procurement. The efficacy of these depends on correlations of quality deviations across origins.

Naive Strategy. The "naive" strategy is to buy from the least cost origins in any year, providing that specifications are met for wheat protein and test weight. This represents the case where an end-user/miller may not have the ability to specify or identify end-use quality differences across origins. It should be viewed as the base case for comparison with other strategies. The problem in a year is to find j that minimizes:

$$\left[\begin{array}{c} Min \\ j \end{array} (P_j + S_{j,1} + S_{1,P}) * W_j + (1 - W_j) * d \right]$$

where P_j is the purchase price at origin j (defined above), W_j is a random variable which equals 1 if quality specification for protein and test weight is met in region j and 0 otherwise, $S_{j,1}$ is the cost of

shipping from origin j to market 1, $S_{1,P}$ is the spread or additional shipping costs from market 1 to the destination and ä is a scalar to preclude inclusion of locations not meeting specifications.

Cost is determined as in the preceding cost/risk tradeoff analysis so long as the specifications are met; otherwise it is assigned an artificially high value (ä=$10 per bu) to preclude its inclusion in the solution. This allows identification of least cost origin in each simulated year. The model was simulated 1,000 times to estimate the proportion of time each CRD (j) was utilized and the probability that other end-use characteristics (peak time, mix tolerance, and absorption) were also met with this strategy.

Constant Share Strategy. An alternative would be to target specific origins over time. The strategy would be to target a portfolio of origins and identify shares from each origin which would result in a least cost combination for a given level of risk. Constant shares of wheat from targeted origins are purchased. This would generally be consistent with a strategy which for whatever reason a constant share would be purchased from targeted origins and generally would be consistent with vertical integration or pre-harvest contracting on a routine basis. As such, it is likely more appropriate if some type of irrevocable commitment (e.g., vertical integration through elevator ownership, contract terms involving minimum annual shipments, or pre-planting contracts) is an element of the strategy. Two alternative models of this constant share strategy are developed and solved. These differ slightly in their assessment of acceptable risk as described below.

The first specification (Specification 1) assumes risk is defined as meeting requirements on average over time. Thus, some purchases within a year may not meet specifications and there may be years when the percent of purchases not meeting specifications exceed á, however, on average purchases will meet specifications greater than á. The model for Specification 1 is then to identify the least cost combination of origins which minimizes cost for a specified level of acceptable risk-- interpreted as the probability of meeting requirements (=á) over time on average. The problem is to choose values of X_1, ..., X_n to minimize:

$$E\left[\sum_{j=1}^{n} (P_j + S_{j,1} + S_{1,P}) * X_j \right]$$

Subject to:

$$Y_j = \prod_{i=1}^{m} Y_{ij}$$

$$E\left[\sum_{j} X_j Y_j \right] \geq a$$

$$X_j \geq 0 \qquad\qquad j = 1, \ldots, n$$

and

$$\sum_{j=1}^{n} X_j = 1$$

where variables are as previously defined and E is the expectation operator, Y_{ij} is a random variable equal to 1 if quality specification i is met in region j and 0 otherwise, $Y_j = 1$ if all quality specifications are satisfied in region j, X_j is proportion of quantity derived from origin j, and á is a chosen probability level.

Specification 2 differs slightly and requires identifying origins which would result in the least cost combination for a given level of risk where risk is defined as the proportion of time that all purchases from all targeted origins would meet specifications. This is a more restrictive version of the above model because the percent of time that all purchases from all origins have to meet specifications must exceed a prescribed probability. In contrast, the previous model only requires that through time, an average of purchases meet specifications.

The model for Specification 2 identifies a combination of origins which minimizes cost for a specified level of acceptable risk--interpreted as the probability of meeting all requirements on all purchases over time (=á). The problem is to choose values of X_1, ..., X_n to minimize:

$$E\left[\sum_{j=1}^{n} (P_j + S_{j,1} + S_{1,P}) * X_j \right]$$

Subject to:

$$Y_j = \prod_{i=1}^{m} Y_{ij}$$

$$\text{Prob}\left[\prod_{j:X_j>0} Y_j = 1 \right] \geq a$$

$$X_j \geq 0 \qquad\qquad j = 1, \ldots, n$$

and

$$\sum_{j=1}^{n} X_j = 1$$

where variables are as previously defined and á is the probability that all quality specifications for all purchases are satisfied in chosen regions.

There is an important interpretation of this model from a strategic perspective. Results would prescribe regions in which all purchases would satisfy all specifications with a certain probability. For example, if á=.9, then purchases from all of targeted regions would meet specifications in 9 out of the 10 years. This strategy penalizes purchases from regions that tend to have production of higher quality wheats but, which are negatively correlated for production of wheat meeting desired specifications (high quality in region 1 tends to occur when lower quality production is realized in region 2).

The essential difference between these two specifications is the second constraint (restriction) imposed on each of the models. In Specification 1, risk is defined as

$E(\sum_{j} X_j Y_j) \geq a$ meaning specifications on average over time would have to exceed some critical value. In Specification 2, this is replaced by $\text{Prob}\left[\prod_{j:X_j>0} Y_j = 1\right] \geq a$ meaning the percent of time specifications for all purchases from all origins would be met would exceed some critical value.

Opportunistic Strategy. In the opportunistic strategy, wheat is purchased each year from the origin having the lowest cost, and would meet quality requirements with a minimum acceptable probability (=á). The origin of the shipments may change each year, in contrast to the previous model which requires the same proportion to be bought each year from each origin. In the opportunistic strategy, shipments can shift among origins each year to seek out the lowest cost wheat that meets requirements.

This strategy does not involve irrevocable commitments; the buyer has the ability to shift origins from year to year to take advantage of market conditions. In addition, there must be some form of pre-shipment quality evaluation, similar to harvest surveys from which end-use quality is evaluated. Using this information the buyer determines the distribution of quality and its relationship to measurable wheat characteristics. There is no commitment to buy from each region every year. Instead, 100% of purchases would be made in the lowest cost origin meeting specifications with an acceptable probability.

Two important differences are incorporated in this model. First, instead of choosing fractions of shipments from each origin, a set of origins is chosen to target. The model was initially simulated using all origins and then reduced to evaluate their effect. This is relevant because in come cases it may not be cost effective to execute this strategy using all origins – there may be fixed costs per origins associated with quality evaluation and/or in monitoring supplier relationships across a large number of origins. Second, the procurement cost is as in the naive model. If specifications are met, the original procurement cost is utilized; otherwise, it is assigned

an arbitrarily high value (ä=$10/bu). This allows identification of least cost origin in each simulated year. The procurement cost and percent of time that origins are targeted are derived.

The model is technically called a simulation optimization model (a hybrid of a chance-constrained optimization and simulation models) (Winston). The problem is to choose a subset of regions R_k to minimize

$$E\left[\begin{array}{c} Min \\ j \in R_k \end{array} (P_j + S_{j,1} + S_{1,P}) * Y_j + (1 - Y_j) * d\right]$$

Subject to:

$$Y_j = \prod_{i=1}^{m} Y_{ij}$$

and

$$\text{Prob}\left[\sum_{j \in Rk} (Y_j) \geq 1\right] \geq a$$

where k is the number of CRDs to target (the number of elements in subset R)..

Restrictions and Solution Techniques. Uncertainty was incorporated as in the cost/risk tradeoff model. Wheat and end-use characteristics (test weight, absorption, peak time, and mix tolerance), and basis values at alternate markets were treated as random. In addition, two sets of correlations were imposed during the simulations. The first was among the error terms from the end-use characteristic regressions within regions. This accounts for the fact that quality variables are correlated which affects any strategy involving targeting. The second set of correlations was imposed between basis values in competing markets.

In all cases a restriction was imposed that total wheat demand must not exceed 30% of production of HRS in the CRD. It is unlikely that any single buyer could penetrate purchases of more than 30% of a CRD's production. The effect of this restriction is to eliminate CRDs where it would be difficult to acquire significant volumes.

The model was solved using *RiskOptimizer* (Palisade), a program designed to solve optimization problems with uncertainty. The optimization simulation models employ a genetic search algorithm to identify optimal solutions. This type of problem is similar to a chance-constrained optimization as described in St. Pierre and Harvey and used previously by Wilson and Preszler (1993a,b) in the case of grain quality. However, the chance-constrained formulation utilizes the parameters of the distribution of random variables in the solution and the problem becomes exceedingly complex as random variables are added. The methodology used here utilizes simulation and the addition of more random variables and/or variables with distributions other than normal can be handled more easily.

4. Results

The results for each of the individual strategies are presented first, along with sensitivities of interest. In the final section comparisons are made and results are discussed.

Naive Strategy Results. The naive strategy was simulated under two protein specifications. The base case requires 14.2% protein; and the alternative calls for 15%. This strategy is that used by most buyers without overt strategies regarding procurement. The implicit assumption is that buyers are not vertically integrated and simply specify desired protein and test weight, along with grade. Confronted with problems of quality risks and the inability to pursue more targeted location strategies, buyers normally specify higher protein levels to achieve a greater likelihood of achieving desired end-use levels, but at a greater cost.

The results are summarized in Table 1. With a protein specification of 14.2%, the average wheat cost is 444 cents/bu. This strategy resulted in a joint probability of meeting end-use specifications of .61. However, this probability varies for individual years, with most likely values ranging between .33 and .89. One way to increase the likelihood of conforming to end-use requirements is to increase the wheat protein specification. This would correspond to the function illustrated in Figure 1. Increasing the wheat protein specification to 15% has the effect of increasing average cost to 462 cents/bu and results in a joint probability of meeting end-use specifications of .76.

The origins utilized are spread throughout the region with only origins 5 through 8 excluded. The most any origin would supply over time would be 7%. Purchase of wheat without the ability to discriminate end-use qualities results in a low cost for wheat; however, there is a high risk that end-use quality characteristics will not be met. Increasing protein levels to 15% increases the probability of meeting end-use characteristics by 15%, but procurement costs increase by 18 cents/bu.

Constant Share Strategy Results. In the first specification of this model, the base case constant share strategy was restricted to meet end-use specifications 85% of the time (i.e., á.≥.85). In this case the average procurement cost is 460 cents/bu (Table 2). Purchases were concentrated among 5 origins with shares ranging from .01 to .58, and 89% coming from two of the origins, (5 and 21). Increasing the probability of meeting specifications to .9 increased cost to 470 cents/bu, with 97% of purchases from Origin 5 and the remainder from Origin 21. Decreasing the probability of meeting specifications to .8, reduced procurement costs to 445 cents/bu, with 87% of purchases from Origin 21 and 13% from Origin 17.

One of the more restrictive end-use requirements is absorption. The base case requirement was increased to 64% to examine the effect on purchasing strategies and costs. Results are illustrated in Figure 3 and resulted in lower probabilities of meeting specifications. The relationship between probability of meeting specifications, procurement costs, and mix of origins

is similar to trade offs in the base case: as probabilities increase, procurement costs increase, and less of the purchases are from Origins 15, 17, 19, and 20 and more are from Origin 5.

In the second specifications of the constant share strategy, the base case was simulated at different probabilities of meeting specifications for all purchases across years (i.e., á was varied from .6 to .9). At a confidence level of .9, all purchases would be targeted in origin 5 and would have a average procurement price of 471 cents/bu (Table 3). This solution holds as the confidence level is reduced to .75. At a confidence level of .7, 20% of purchases would be targeted at origin 5 and 80% from origin 19 with the average procurement price declining to 451 cents/bu. Further reducing the confidence level to .6 reduces the average procurement price to 445 cents/bu and targets procurement from origin 17 (79%) and origin 19 (21%).

Opportunistic Strategy Results. The base case was simulated at different probabilities of meeting requirements (i.e., á was varied from .90 to .99) with the maximum number of targeted origins equal to 5 (i.e., N=5). At a confidence level of .90, á =.90, the average procurement cost was 444.5 cents/bu (Table 4). In this case, purchases over time would be spread among five origins (14, 16, 17, 19, and 21) in percentages ranging from 15%-23%. Purchases are targeted in these 5 origins, only with purchases in any given year determined by lowest procurement cost after post-harvest evaluation of quality. Increasing (decreasing) probability of meeting specifications increases (decreases) average procurement costs minimally, but shifts the mix of origins.

Increasing the number of origins in which to target reduces the average procurement cost slightly. This occurs because in each year, the lowest cost origin that meets specifications is targeted. Conversely, by reducing the number of origins, higher cost origins meeting specifications have to be utilized in some years. The average procurement costs decline quickly from n=3 to n=4 or 5. Adding potential targeted regions beyond 4 or 5 has less value in terms of lowering expected costs. As the number of origins declines, the optimal mix changes. Similarly as the number increases, more origins from the south and east are utilized.

Comparison of Results Across Strategies. Common goals of any form of procurement are to efficiently reduce costs and risks. We evaluate procurement strategies using three measure: cost, risk, and resulting targeted origins. These results suggest that a Naive strategy with wheat protein specified at 14.2% has a relatively low cost, but a high risk of not conforming to end-use requirements. Specifying higher protein, while retaining the naive approach, increases the probability of meeting requirements, but at a higher cost.

The results for the constant share strategy (Specification 1) which requires the same volume to be purchased from the same origins each year are substantially different. Costs are greater than either the Naive or opportunistic alternatives but less than for specification two of the constant share strategy. The probability of meeting requirements, though greater than the naive strategy, are less than the opportunistic or specification two of the constant share strategies. In addition, the number of targeted origins decreases substantially as the probability of meeting

requirements increases, as does the cost. The second specification for the constant share model is the most restrictive of the strategies and targets the least number of origins. In contrast to the other alternatives, the opportunistic model results in a minimum cost, and a very high probability of meeting requirements.

5.   Summary and Implications

Development and organization of procurement strategies have escalated in importance with maturity of the food processing industry, as well as with the prospect of increased choices attributable to variety development and information technology. With the increased emphasis on integrated supply chain management, procurement strategies and their costs and risks have escalated in importance. Conventional alternatives for procurement range from spot purchases with specifications for easily measurable wheat characteristics, to varying forms of pre-commitment. Examples of procurement strategies with pre-commitment include pre-harvest contracts and vertical integration into asset ownership. There have been varying views among agricultural economists about the shift in procurement regimes, but there is generally a greater emphasis on contracting and/or vertical integration.

In the case of grains these choices are complicated by two factors. First, there is intrinsic uncertainty about end-use quality. There is substantial variability in end-use characteristics due to climatic conditions, but also variety choice and agronomic and marketing practices. These are not easily measurable. Consequently, buyers make purchases based on more easily measurable wheat quality characteristics such as protein and absorb the risk of not conforming to requirements. Second, grain prices and therefore procurement costs vary spatially due to competing market regions. Thus, shifting origins usually involves a cost due to having to bid the grain away from its next best market. The combination of these factors has resulted in far less grain being contracted than in the case of livestock. Also, vertical integration into asset ownership is far less common in grains than in other agricultural commodities.

We posed three alternative procurement strategies and developed analytical models to evaluate their risks and costs. One procurement strategy assumes that buyers specify easily measurable wheat quality characteristics. This is the strategy used by most buyers and is referred to as the naive strategy. The second strategy, the constant share strategy, involved targeting locations for purchases and buying a constant portion from each region over time. Two specifications were developed for this strategy. One required average levels of risks be satisfied over time, the other more restrictive version of the constant share strategy required 100 percent of purchases to meet specifications within a year to meet requirements. The third strategy was called the opportunistic strategy and involves targeting of origins based on post-harvest quality evaluations, from which conditional quality distributions are derived. In general, this spectrum of alternatives reflects different levels of commitment to a particular region. The first involves no commitment. The two forms of the second strategy involve some form of irrevocable commitment and the third entails negligible commitment.

Stochastic simulation models were developed for each strategy with an objective of cost minimization subject to different levels of acceptable risk. Results indicated that the least cost solution would be the naive strategy. However, this involves a fairly high probability of not conforming to end-use requirements. To overcome this, buyers could (and conventionally do), specify a higher level of quality than is actually needed, but in doing so they incur a greater cost. The two specifications for the constant share strategy result in a higher probability of meeting requirements, but at a substantially higher cost. This would be reflective of strategies involving some form of pre-commitment contract, or vertical integration into asset ownership. The opportunistic strategy results in a lower cost and higher probability of meeting requirements than the other two strategies. In contrast to the naive strategy, the expected cost would increase by about ½ cents/bu, but the probability of conforming to requirements would increase from .61 to .99. In contrast to the constant share strategy, the expected cost would decrease from 470 to 444.5 cents/bu at a .90 probability of meeting end-use requirements. Finally, compared to the second specification for the constant share model, procurement costs for the opportunistic strategy would decline from 471 to 444.5 cents/bu at .9 probability of meeting specifications.

This paper was motivated in part to develop and analyze the efficacy of different procurement strategies in the case of grains. Although there has been an escalation of contracting in numerous agricultural commodities, this has been notably absent in the case of small grains. While there are likely numerous reasons for this, the results of this analysis suggest that a moral hazard problem discourages use of contracting and warranty types of mechanisms for procurement. Indeed, the results suggest that strategies requiring pre-commitment are generally inferior to those that are more opportunistic. It is likely for these reasons that there has been minimal contracting and vertical integration in the case of small grains relative to other agricultural commodities. Instead some sellers have evolved a marketing strategy based on end-use characteristics that are evaluated post-harvest and transactions made based on specific lots of grain. Similarly, some buyers have adjusted their procurement strategies based on post-harvest quality evaluation to identify targeted origin strategies.

Several features of this analytical approach are particularly important and could be applicable in many other agricultural (grain) commodities. First, the end-use performance in quality characteristics is random, and even if conditioned on easily measured proxies, there is a risk of not meeting quality requirements. Second, the cost-risk trade off is critical and reflects spatial cost differentials and risks, and provides for a primary motivation for the problem. Third, whether combinations of targeted locations compound or offset variability in end-use characteristics may affect the efficacy of geographical diversification. Opportunistic results are likely more appropriate for domestic end-users, though more sophisticated importers working closely with their suppliers could achieve some of these efficiencies. Finally, it is important to acknowledge that climatic conditions are a source of uncertainty in end-use performance. This reduces incentives for contracting and vertical integration, and poses a challenge to any form of integrated supply chain management.

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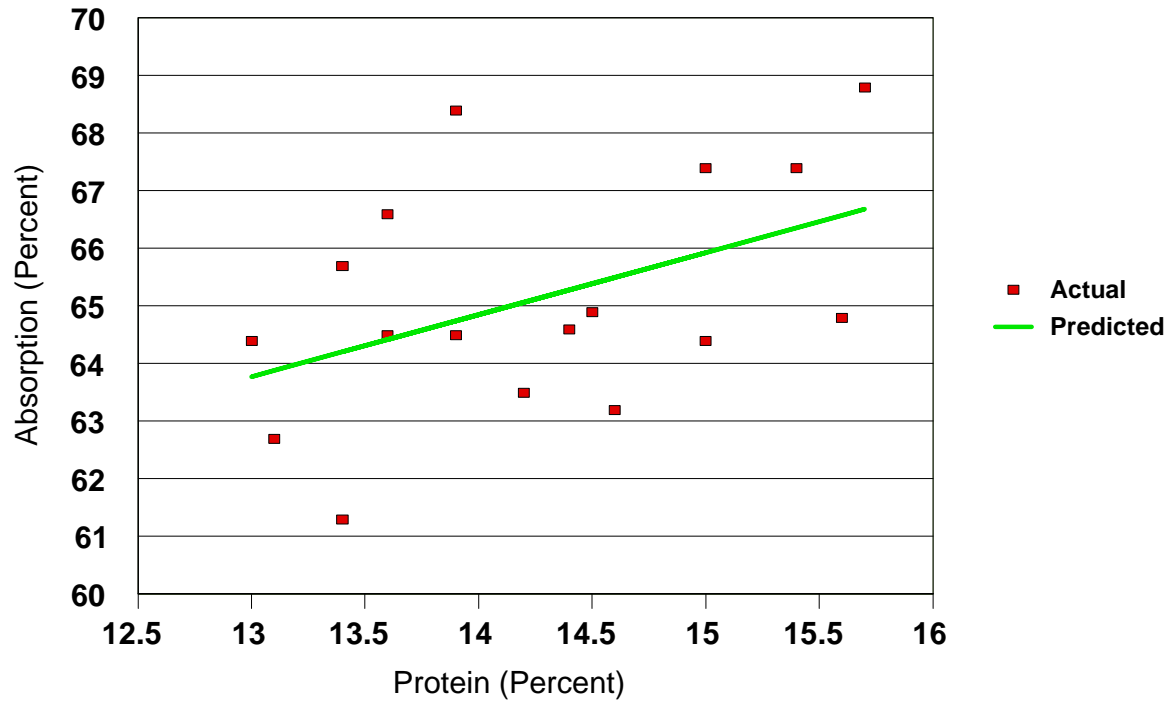Winston, Wayne. 1999. Decision Making Under Uncertainty with RiskOptimizer. Palisade Corporation. Newfield, NY.

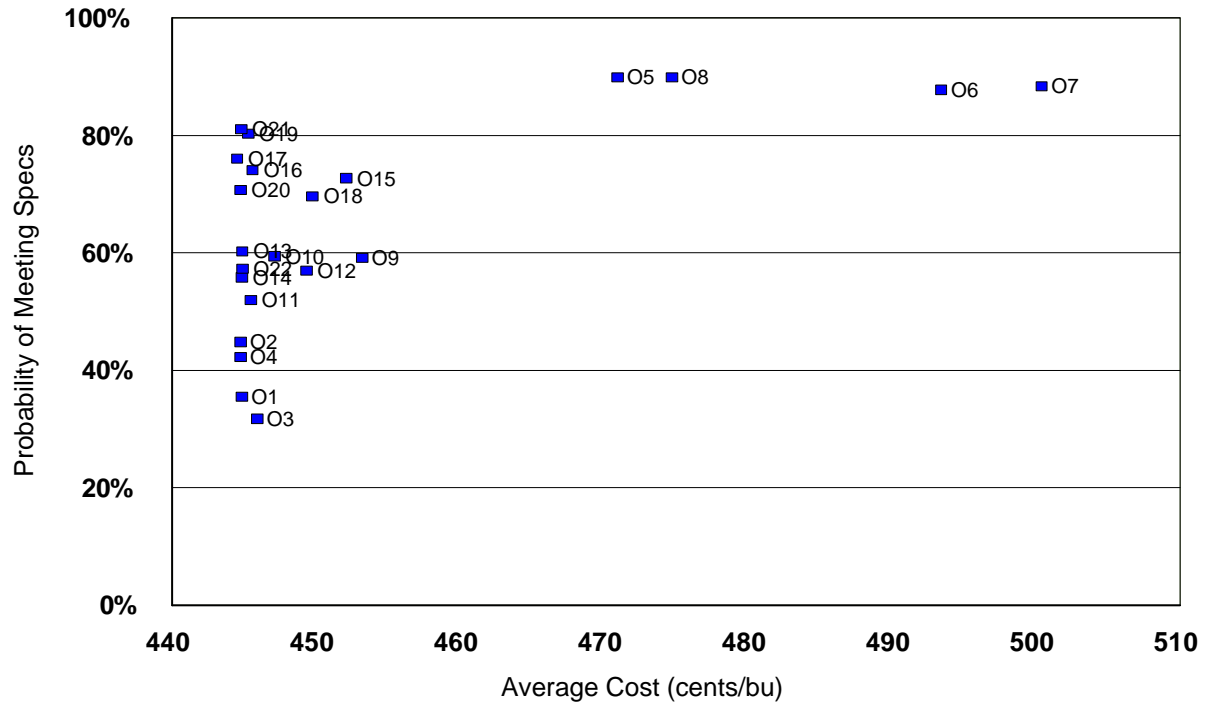**Figure 1. Relationship Between Protein and Absorption at One Selected Origin, 1980-1996.**

Figure 2. Relationship Between Joint Probability of Meeting Specifications and Average Procurement Price.
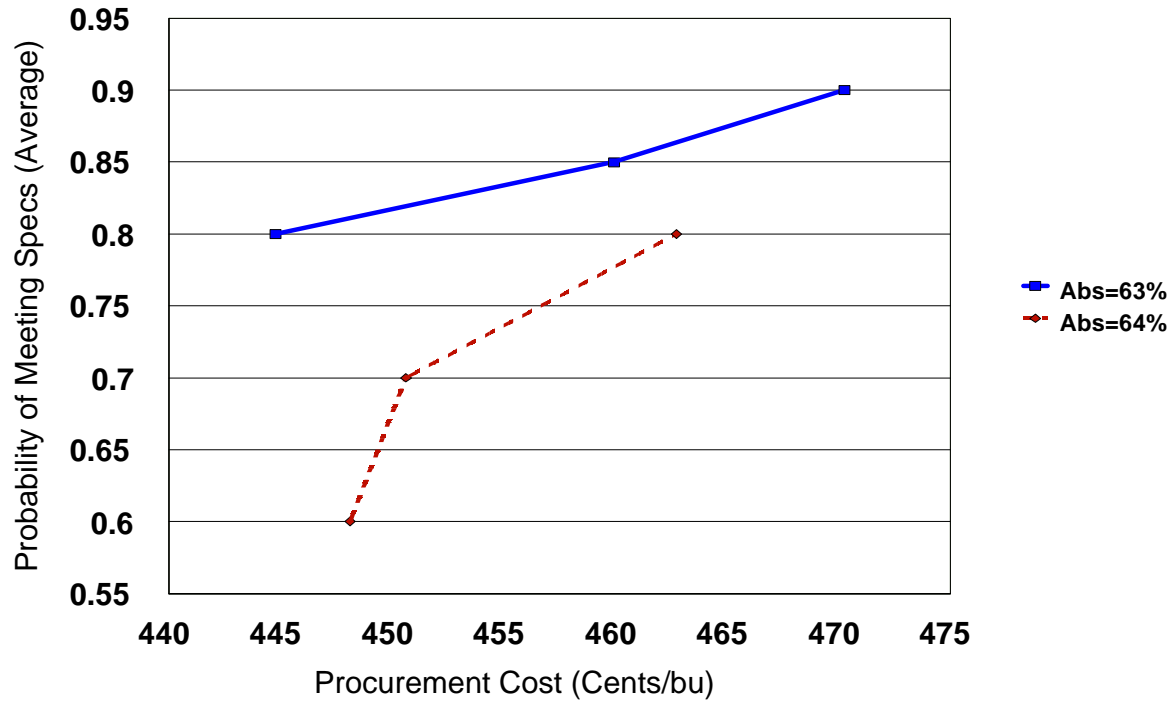
Figure 3. Constant Share Model Sensitivity (Specification 1): Relationship Between Probability of Meeting Specifications and Average Procurement Costs, by Absorption Level.

Table 1. Naive Strategy Results

Wheat Protein Specification (%)	14.2	15.0
Probability of Meeting Specifications	.61	.76
Average Procurement Cost (cents/bu)	444	462
Targeted Origins	--------------shares----------------	
O_1	.06	.05
O_2	.07	.06
O_3	.04	.02
O_4	.07	.06
O_5	.00	.00
O_6	.00	.00
O_7	.00	.00
O_8	.00	.00
O_9	.03	.03
O_{10}	.05	.05
O_{11}	.05	.04
O_{12}	.04	.05
O_{13}	.07	.08
O_{14}	.07	.07
O_{15}	.03	.04
O_{16}	.06	.07
O_{17}	.07	.08
O_{18}	.04	.04
O_{19}	.06	.07
O_{20}	.07	.06
O_{21}	.06	.06
O_{22}	.06	.05

Table 2. Constant Share Strategy Results: Specification 1

Probability of Meeting Specifications	.8	.85	.9
Average Procurement Cost (cents/bu)	445	460	470
Targeted Origins		---------------shares-----------------	
O_2		0.01	
O_5		0.58	0.97
O_{17}	0.13	0.08	
O_{20}		0.02	
O_{21}	0.87	0.31	0.03

Table 3. Constant Share Strategy Results: Specification 2

Probability of Meeting Specifications in all years	.6	.7	.75-.9
Average Procurement Cost (cents/bu)	444.71	450.53	471.07
Targeted Origins		---------------shares-----------------	
O_5		20	100
O_{17}	79		
O_{19}	21	80	

Table 4. Opportunistic Strategy Results

Probability of Meeting Specifications	.90	.95	.99
Average Procurement Cost (cents/bu)	444.5	444.5	444.6
Targeted Origins		---------------shares-----------------	
O_2			.15
O_5			.02
O_{14}		.15	
O_{16}	.18	.18	.24
O_{17}	.23	.23	.31
O_{19}	.20	.22	
O_{20}	.18		
O_{21}	.21	.22	.28