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Procurement Strategies to Improve Quality Consistency in Wheat Shipments

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Consistency of functional characteristics in wheat is a concern confronting buyers and sellers. This research analyzes the cost and risk of different procurement strategies for importers. A stochastic simulation model is used to determine the probability of functional characteristics being satisfied subject to quality targets and costs for alternative purchase strategies. Stochastic efficiency was employed to identify purchase strategies that dominate others and to determine the extent of preference. As more specific characteristics are incorporated into a contract, results indicate that the probabilities of meeting end-use requirements increase.

Key words: buying strategies, costs, functional characteristic tests, location, risks, simulation, stochastic efficiency, variety

Introduction

Changing competition among wheat buyers, in part due to the increased privatization of wheat importing functions, has led to increased demand for high quality wheat. Concurrently, suppliers are subject to a more diverse supply of wheat varieties and production processes. Taken together, consistency of functional characteristics (absorption, peak time, loaf volume, and stability) in wheat has emerged as a problem of quality uncertainty confronting buyers and sellers (as summarized recently by Sosland Publishing, 2006a, b). Quality uncertainty usually refers to variability in functional performance and arises from a combination of varietal differences, environmental conditions, and agronomic, handling, and marketing practices. Assuring functional quality characteristics is problematic because these are not easily measurable, require laboratory testing, and therefore are not commonly used in procurement contracts.

Alternative procurement strategies have emerged to mitigate the inherent risk in grain purchasing. Examples include varying forms of specifying greater values for grain characteristics and identity preservation (IP), specifying varieties, targeting locations, or specifying limits on functional characteristics. Each of these factors has differing impacts on costs and risks of meeting requirements. For buyers, it is important to assess how costs and risks vary across alternative specifications and strategies.

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The purpose of this article is to analyze the cost and risk of alternative procurement strategies that can be used by international wheat end-users to mitigate quality inconsistency. We develop a model to quantify costs and risks for different procurement strategies and apply it to the case of hard red spring (HRS) wheat. The model poses procurement strategies inclusive of grade and protein, targeted varieties and locations, and several functional trait tests. Then stochastic efficiency is applied to determine which purchase strategies dominate others and to estimate risk premiums for each strategy. A background discussion overview is provided in the following section. The next sections describe the quality, price, and cost statistics used in the analysis, the empirical model, and the results. The final section draws some implications for buyers and sellers. This work contributes to the literature on risk and grain quality and evaluates strategies to mitigate risk.

Background and Previous Studies

Dahl and Wilson (1998) defined three elements of quality consistency. The first is quality variability due to sampling and grading errors. Second is the variability of grain characteristics in shipments taken from different regions and climatic areas. Grain characteristics such as protein and damage are easily measurable, but functional characteristics have greater measurement error. For characteristics that are susceptible to greater measurement error, there are greater risks. The third quality consistency element relates to functional performance (i.e., mixing and baking characteristics). End-users see this inconsistency as a major hurdle which is reflected in the relationship between functional performance and measurable characteristics. The role of end-use characteristics was addressed from a breeding strategy in Dahl, Wilson, and Johnson (2004) and Dahl, Wilson, and Nganje (2004). Buyers normally specify easily measurable characteristics which are correlated with desirable functional characteristics. Poor correlations result in greater uncertainty in functional performance, or greater inconsistency.

The shift toward privatization of wheat imports is affecting changes in quality purchased (Wilson, 1996a, b). Privatization results in a tendency for more specificity in purchase contracts. Generally, private buyers have incentives to assess the value of higher quality and are more willing to pay premiums (and discounts) if that greater (lower) quality enhances (reduces) their profits. Procurement strategies, i.e., the combination of price and quality specifications, are critical factors in the HRS wheat market, with some importers using more stringent contract specifications than U.S. domestic millers. Contract specifications have considerable strategic importance, particularly in view of competition among buyers (Johnson, Wilson, and Diersen, 2001). In addition to wheat protein, some countries have been working to purchase identity-preserved shipments and/or specified varieties including Wharburtons from the Canadian Wheat Board (Kennett et al., 1998) and General Mills in the United States (Taylor, Brester, and Boland, 2005).

International competition in wheat is quickly having to focus on consistency. The market is more sophisticated in segregating for quality, and more demanding buyers generally have more specific contracts (Oades, 2001a, b; Shipman, 2001). Procurement strategies utilized by wheat end-users range from simple spot market transactions to elaborate vertical integration techniques. Strategies that fall in between these extremes are numerous, with examples including contracting, testing (Johnson, 2005; Johnson and

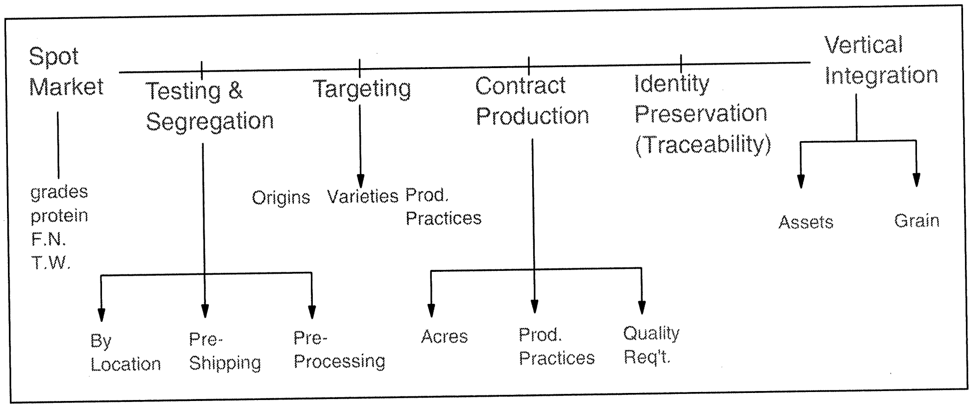

Figure 1. Spectrum of procurement strategies

Lin, 2005; Wilson, Dahl, and Johnson, 2007), and segregation practices, targeting of origins and varieties, contracting production practices, and identity preservation (figure 1). Though contracting is currently less common in the wheat sector (McDonald et al., 2004), the results here suggest the importance of contracting to assure improved consistency.

Testing and segregation practices by end-users involve pre-shipment or pre-processing testing. Targeting origins and varieties consists of purchasing a particular variety from a given region. Specified production practices involve contracting a desired acreage to be produced, overseeing production practices, and stipulating the final product meets desirable quality requirements. IP requirements include specifying variety (or excluded varieties) and preserving wheat characteristics throughout the entire production and transportation process (Smyth and Phillips, 2002; Hobbs, 2004; Kennett et al., 1998).

Hard wheat is generally marketed on a grade and protein basis. Specifications are a part of the purchase contract and affect price. Grain factors certified on export cargoes are numerical grade, class, moisture, protein, and dockage—and contract terms define minimum acceptable levels. Other specifications can be included, but in the United States would not be assured as part of the official inspection system. These include specifying varieties, targeted locations, or functional characteristics. Each of these involves more elaborate contractual specifications and non-official evaluation. Certification of additional quality factors can be specified in a contract and be performed and certified by the USDA's Federal Grain Inspection Service or a private inspection company (U.S. Wheat Associates, 2001). Some U.S. end-users have begun the process of contracting the production of selected wheat varieties (Willis, 2001). Variety-specific procurement strategies help end-users meet both economic and functional quality requirements which they are unable to achieve through conventional commodity market channels.

Most major wheat exporting countries have been analyzing institutions impacting exports and quality.[1] The EU changed its intervention policy to encourage adoption of varieties with higher end-use characteristics. Debate in Canada has focused on topics related to kernel visual distinguishability (KVD), where varieties are classed using visual techniques. This system has been challenged due to its high cost and because it

[1] See Canada Grains Council (2005) for a set of presentations on this subject.

inhibits productivity. Recent studies have analyzed the costs (Furtan, Burden, and Scott, 2003) and benefits (Oleson, 2003) of alternatives.

A 1995 report prepared for the Grains Council of Australia concluded that a large portion of the variability in prices received by the Australian Wheat Board (AWB) was due to variability in quality characteristics. More recently, Australia has been evolving toward emphasis on niche marketing whereby varieties and production regions are being matched to customer needs. The AWB "Golden Rewards Varietal Systems" publication (ProFarmer Australia, 2004) provides a clear indication of this escalation in varietal marketing with an emphasis on protein. Argentina has studied its system with respect to differences among varieties and the inability to classify them according to functional differences (Cuniberti and Otamendi, 2004), and changes have now been implemented to class varieties by functional traits.

Lack of consistency in end-use requirements has important implications for buyers. These include risks of not conforming to product contract specifications, greater costs associated with higher quality purchases, and/or the effects of increased operating costs associated with likely stock-out costs due to nonconformance. It is essential to consider these costs and risks for buyers to evaluate among alternative specifications. The risk premiums derived in our analysis can be used by buyers in assessing the value of different strategies. Wheat quality characteristics (e.g., protein and test weight) that are easily measurable in a timely manner are typically used for contracting. Functional characteristics (e.g., stability and peak time) are not easily measurable, but statistical relationships exist between wheat quality and functional characteristics. Though it has not been conventional to use functional characteristics in contracting for wheat procurement, buyers and end-users are ultimately concerned with these characteristics, and some of the more sophisticated buyers are stipulating functional specifications. In support of this tendency, Stiegert and Blanc (1997) found important non-contracted relationships between protein value and the intrinsic protein quality. They estimated marginal values of wheat protein in Japan using interactive effects of non-contracted dough/flour characteristics which are typically proxied by protein. Protein values were linked positively to farinograph stability, a prime factor in blending different flours.

Empirical Model

Stochastic simulation was used to simulate costs and risks of alternative procurement strategies. Strategies analyzed include purchases based on wheat protein levels, varieties, locations, and functional characteristics. Procurement costs and risks were estimated and used to determine the probability that shipments meet end-user requirements for alternative strategies. Statistical relationships between wheat and functional characteristics were estimated and utilized to derive probability distributions for meeting functional conformance for each strategy. Stochastic variables include basis and functional characteristics. Costs for procuring wheat were estimated inclusive of commodity price, shipping, and tests required for each strategy. Then, simulated distributions of costs and risks for alternative strategies were compared using stochastic efficiency with respect to a function (SERF) to identify risk-efficient purchase strategies and to examine effects of risk aversion on preferences.

There are three analytical steps in our methodology. First, we estimate relationships for functional characteristics for each purchase strategy. Second, stochastic simulation is used to iterate 5,000 outcomes of costs/risks for each alternative. Results from these simulations are used to define distributions for each choice. Third, stochastic efficiency techniques (described below) are employed to estimate certainty equivalents and risk premiums across the range of Arrow-Pratt absolute risk-aversion coefficients. The order and size of certainty equivalents yield information on decision-maker preferences and the degree of preference across risk attitudes. The data and distributions are described first, followed by an explanation of the stochastic methodology.

Data Sources and Distributions

Twenty locations defined as Crop Reporting Districts (CRDs) throughout the HRS wheat-producing region were used in this study. Prices at each were determined through inter-market competition among three markets: Minneapolis (Mpls), the Pacific Northwest (PNW), and the U.S. Gulf (Gulf). Basis differentials and freight rate relationships cause purchasing costs to vary geographically. Average costs and probabilities of conforming to requirements were determined for supplying the PNW market from each CRD.

Prices were defined given inter-market competition. In order for buyers to purchase grain from specific origins, they must effectively bid grain away from competing markets, and local origin prices would reflect the best bid available from all markets. Specifically, the costs of delivering HRS to each market i from each location j were defined as:

$$P_{ij} = F + \text{Max}(B_{1j} - T_{1j}, B_{2j} - T_{2j}, B_{3j} - T_{3j}) + T_{ij} + X_i + RC * (1 - \Pi Y_k), \quad (1)$$

where P_{ij} is the price of HRS wheat at market i (1 = PNW, 2 = Gulf, and 3 = Mpls) from location j (j = 1–20, representing 20 CRDs within the HRS wheat production area); F is the futures price; B_{ij} is the basis for market i from origin j; T_{ij} is the shipping cost to market i from location j; X_i is the testing/verification cost for market i; RC is the rejection cost when lots do not meet joint specifications for the vector **k** of functional characteristics; and ΠY_k is the joint probability of meeting specifications for the vector **k** of functional characteristics.

Since futures prices are constant and affect all strategies similarly, a fixed value was assumed. Basis values at Minneapolis and the export ports, protein premiums and discounts, and the spread between Minneapolis and Kansas City Ordinary were assumed random, drawn from distributions and correlated with one another (table 1). Distributions for basis values and protein premiums and discounts were evaluated over the period August 1991 through July 2002. The distributions for basis values were normal with means (and standard deviations in parentheses) of 61¢/bu. (34¢/bu.) for Mpls, and 106¢/bu. (38¢/bu.) for the export ports. The distributions for protein premiums and discounts were lognormally distributed with means and standard deviations of 40¢/bu. (34¢/bu.) for protein premium 15%–14% and −17¢/bu. (19¢/bu.) for protein discount 13%–14%. Shipping costs were for 52 car rates taken from the Burlington Northern Santa Fe Railroad for each CRD.

Testing costs for location and variety were obtained from CII Laboratories (2002) and functional characteristic testing costs were derived from the Canadian Grain Commission (2002). Costs were $100/sample for a location monitoring test (e.g., auditing), $300/sample for an electrophoresis variety test, $40/sample for a farinograph test, $30/sample for a loaf volume test, and $17/sample for a flour protein test. Each sample

Table 1. Correlations Between Basis Values, Protein Premiums and Discounts, and Mpls 14%-KC Ordinary Protein Spread (August 1991–July 2002)

Description	Mpls Basis	PNW Basis	Gulf Basis	Protein Premium 15%–14%	Protein Discount 13%–14%	Mpls 14%–KC Spread
Mpls Basis		0.93	0.93	0.57	−0.76	0.66
PNW Basis				0.63	−0.69	0.53
Gulf Basis				0.63	−0.69	0.53
Prot. Premium 15%–14%					−0.73	0.43
Prot. Discount 13%–14%						−0.78
Mpls 14%–KC Spread						

Table 2. Wheat and Functional Characteristic Requirements

Wheat and Functional Characteristics	Target Value	Wheat and Functional Characteristics	Target Value
Wheat Characteristics:		**Flour Characteristics:**	
Wheat Protein (%)	14.2	Flour Protein (%)	12.0
Test Weight (lbs./bushel)	60	Extraction (%)	68.0
Moisture (%)	12.5	Ash (% dry basis)	0.47
Falling Number (seconds)	400		
1,000 Kernel Weight (g)	30		
Functional Characteristics:			
Absorption (%)	62.0		
Peak Time (minutes)	7		
Stability (minutes)	14		
Loaf Volume (cc/100g loaf)	1,000		

was assumed representative of every two grain cars (i.e., every 6,600 bushels). If lots did not meet specifications, wheat was considered to be diverted to other markets where it would compete with HRW quality wheats. In those cases, a rejection cost (RC) equivalent to the spread between HRS 14% at Minneapolis and Kansas City Ordinary Protein HRW wheat for 1991–2002 47¢/bu. (42¢/bu.) was added to the procurement cost. This variable was correlated with basis values and protein premiums and discounts as described above. Thus, since there was a non-nil probability of conforming to requirements, an expected rejection cost was included in the expected price.

Wheat Quality Characteristics

Functional characteristic requirements in purchasing were obtained from industry representatives (table 2). These vary across end uses, countries, and processing technologies. Those characteristics listed in table 2 are fairly typical of products produced from HRS wheat (e.g., frozen dough, blends, variety breads).

Wheat and functional characteristic data were obtained from a Spring Wheat Baker's (SWB) data set for the 1999 and 2000 harvest years. It includes functional and wheat characteristics representative of the entire HRS wheat-producing region. The data set

Table 3. Distribution Parameters for Wheat and End-Use Characteristics

	Data Statistics		Fitted Distribution and Parameters		
Variable	Mean	Std. Dev.	Distribution	Parameter 1	Parameter 2
Wheat Protein	14.42	0.83	Normal	14.42	0.87
Test Weight	60.25	1.43	Normal	60.21	1.49
Moisture Level	12.32	0.93	Normal	12.35	0.96
Falling Number	437.51	54.73	Normal	437.52	54.72
1,000 Kernel Weight	30.74	2.55	Logistic	30.65	1.36
Absorption	62.89	1.98	Normal	62.83	1.93
Peak Time	8.91	2.11	Ext. Value	8.01	1.62
Stability	17.66	6.21	Normal	17.61	6.29
Extraction	69.39	4.44	Logistic	69.65	1.46
Loaf Volume	11.96	2.88	Logistic	11.71	1.62
Ash	0.51	0.04	Normal	12.71	0.39
Flour Protein	12.71	0.76	Logistic	0.46	0.04

Table 4. Correlations Between Wheat and Functional Characteristics and Prices

Description	Moisture	Falling Number	Test Weight	1,000 Kernel Weight	Absorption	Peak Time	Stability	Loaf Volume
Moisture		−0.16	−0.24	0.15	−0.33	−0.13		−0.17
Falling Number			−0.18		0.13		0.26	0.17
Test Weight					0.26		−0.34	
1,000 Kernel Weight						−0.21	−0.14	−0.23
Absorption						0.26		1.00
Peak Time							−0.21	−0.16
Stability								−0.24
Loaf Volume								

Note: Missing values indicate correlations were not statistically significant at $p = 0.05$.

is comprised of 316 individual samples of HRS from across the producing region. This differs from other quality data sets that normally report composite samples which generally would under-represent the quality variability. Simple statistics and correlations for each variable are reported in tables 3 and 4. Data were fit to distributions for each, with the resulting fitted distributions and shape parameters shown in table 3.

Regression models were estimated for each functional characteristic, and interaction terms for location and variety were included to reflect differences associated with these parameters. The regressions included functional characteristics (e.g., peak time) as dependent variables. The independent variables (e.g., wheat characteristics, location dummy variables, and variety dummy variables) were varied to allow different effects imposed on the functional characteristics.

The base model is specified as:

$$\mathbf{Y}_k = f_1(\mathbf{X}_t) + \varepsilon, \tag{2}$$

where $\mathbf{Y}_k$ is a vector of functional characteristics (i.e., absorption, stability, peak time, loaf volume), $\mathbf{X}_t$ is a vector of wheat characteristics [i.e., wheat protein (%), test weight (lbs./bu.), falling number (seconds), 1,000 kernel weight (g), and moisture level (%)], and ε is the error term. Specifications representing other strategies include:

$$\mathbf{Y}_k = f_2(\mathbf{X}_t, V_{mn}) + \varepsilon, \tag{3}$$

where V_{mn} is variety m in sample n, and

$$\mathbf{Y}_k = f_3(\mathbf{X}_t, L_{ij}) + \varepsilon, \tag{4}$$

where L_{ij} is location j delivered to market i. Significant t-statistics at a 5% level were considered in choosing which characteristics were significant. Insignificant variables were excluded. Base case regressions are reported in table 5. Due to the volume of results, interested readers are referred to Wilson and Dahl (2007) for the other regression results.

The probability of characteristic k conforming to a requirement is defined as:

$$\text{Prob}(\mathbf{Y}_k = 1), \tag{5}$$

and the joint probability for the wheat lot as:

$$\text{Prob}(\Pi \mathbf{Y}_k = 1), \tag{6}$$

where $\mathbf{Y}_k = 1$ if the quality target for the functional characteristic k is satisfied, $\Pi \mathbf{Y}_k = 1$ if the joint probability of quality specifications for all functional characteristics is satisfied, and $k = 1, \ldots, n$, representing absorption, peak time, stability, and loaf volume.

Stochastic Simulation and Efficiency

The stochastic simulation determined the procurement costs from each individual CRD and the probability of meeting individual and joint end-user requirements. The model was simulated using *@Risk* (Palisade Corporation, 1997). Five thousand iterations of each model were run, at which time acceptable stopping criteria were reached. The simulations were conducted with correlations among functional characteristics as well as correlations among values for basis, protein premiums and discounts and the rejection costs, within the model. Root mean squared errors (RMSEs) of the estimated equations were used as measures of uncertainty for each functional characteristic. Rejection costs (RC) were applied to lots not meeting joint specifications for the desired end-use requirements (i.e., this assumes HRS wheat lots not meeting specifications would be resold to alternative wheat markets at a discount, described above).

The base case strategy included specifications for wheat characteristics (e.g., protein and test weight). Other strategies added specifications for varieties, location (represented by CRD—i.e., L1 to L20), and functional requirements. Alternative functional requirements included tests for absorption (%), loaf volume (cc per 100 gram loaf), stability (minutes), and a farinograph test (which assumed jointly meeting specifications for absorption, peak time, and stability).

Table 5. Functional Relationships for Protein-Only Procurement Strategy

Description	Absorption	Extraction	Peak Time	Stability	Loaf Volume	Ash	Flour Protein
Intercept	34.27	59.34	14.66	102.15	5.55	0.1929	5.24
Wheat Protein	0.9297	−0.2983			0.6160	0.0104	0.5970
Moisture	−0.4406					0.0095	−0.0888
Falling Number		−0.0074		0.0327	0.0074		
Test Weight	0.2698	0.2329		−1.6398			
1,000 Kernel Weight	0.1431	0.1223	−0.1870		−0.1840		
R^2	0.31	0.12	0.04	0.20	0.10	0.07	0.55
RMSE	1.57	2.02	2.09	5.64	2.72	0.04	0.49

Distributions of procurement costs and probability of meeting specifications for individual purchase strategies were derived from the stochastic simulation results. The distributions for costs were inverted by subtracting all procurement costs from 1,000. This effectively inverts rankings of strategies so that highest costs are least preferred, which is equivalent to adding a fixed value to negative cost values to obtain positive values. These inverted cost distributions were compared using SERF, a method of ranking which uses the certainty equivalents of distributions.

Stochastic efficiency was used to determine and rank risk-efficient decisions among purchase strategies. It allows behavioral assumptions by decision makers to be explicitly accounted for and provides a theoretically sound comparison of the risky alternatives. Stochastic efficiency allows for calculation of certainty equivalents and subsequent rankings of choices across the range of absolute risk-aversion coefficients (Hardaker et al., 2004), rather than computing rankings just at the endpoints for risk-aversion coefficients, as in stochastic dominance with respect to a function (SDRF). The estimated certainty equivalents indicate the ranking of choices for a given risk attitude as well as the level of risk attitude when the order of risk preferences changes. Risk premiums can be derived from the SERF results. These indicate the value of preference for each procurement strategy relative to the base distribution (here, protein-only) as risk aversions change. Risk premiums are the amounts required for the decision maker to be indifferent between a choice and purchase by protein-only. The premium indicates the change that would have to occur in the certainty equivalent of net payoffs in order to induce a change in preferences. Positive premiums indicate the alternative is preferred to the protein-only strategy, while negative premiums indicate the protein-only strategy is preferred.

Simetar was used in this analysis, which estimates certainty equivalents and risk premiums across the range of absolute risk-aversion coefficients (ARACs) (Hardaker et al., 2004; Richardson, Schumann, and Feldman, 2005). Certainty equivalents were computed assuming a negative exponential utility function which assumes constant absolute risk aversion (CARA) following Ribera, Hons, and Richardson (2004); Sangtaek, Mitchell, and Leatham (2005); Babcock and Hennessy (1996); Kaylen, Loehman, and Preckel (1989); and Lambert and McCarl (1985). The ARAC range utilized was from 0 to 0.108, where the upper bound was estimated using the methods developed by McCarl and Bessler (1989). This upper bound is similar to that estimated with methods advanced by Babcock, Choi, and Feinerman (1993).

Results and Sensitivities

Effects of Protein Specifications

The base case assumes quality representative of that produced in the HRS wheat growing region and buyers specify a minimum protein of 14.2%. This strategy utilizes functional relationships between protein and other wheat characteristics to estimate end-use characteristic values and procurement costs. The strategy was simulated to determine the probability that each functional requirement is met. Sensitivities were conducted to evaluate alternative minimum protein purchase strategies (tables 6–7).

For the base case (protein = 14.2%), the average procurement cost was 542¢/bu., and the joint probability of meeting all specifications was only 0.28. Sensitivities on the protein level specified were conducted with values ranging from 13% to 15% (tables 6–7). As the level of protein specified increases, the likelihood of conforming to requirements increases. Procurement costs also increase due to the effects of higher protein premiums. It is notable that the probability of meeting specifications for peak time and stability are unchanged with increases in protein levels, with respective values remaining at 0.80 and 0.70 across the 13%–15% protein levels. This is a result of the estimated regression models which did not infer a significant relationship between protein levels and either peak time or stability and is likely a consequence of these characteristics being evaluated with a larger number of observations over a relatively short time frame. More generally, a positive relationship is commonly found between these variables when evaluating this relationship with cross-sectional data. The low probabilities of meeting specifications for absorption reflect the low levels of absorption occurring over the period of the data.

Stochastic efficiency analysis revealed that 13% protein was the most preferred set across ARACs (table 8). The second most preferred set included purchase of 13.5% protein, followed by 14%, base case (14.2%), 14.5%, and 15%. The risk premium of 13% protein over the 14.2% base case decreased from 19.23¢/bu. for the risk-neutral buyers to 17.63¢/bu. for slightly risk averse (ARAC = 0.018), and increased to 19.33¢/bu. for highly risk-averse buyers (ARAC = 0.108). Thus, risk-neutral to slightly risk-averse decision makers should prefer the 13% protein level buying strategy over the base case by as much as 19.33¢/bu. These results suggest the higher protein premiums outweigh the effects of reductions in rejection costs due to higher conformance. Consequently, buyers would prefer to purchase lower protein wheats due to lower protein premiums and take the risk that lots will not meet specifications.

Variety Specifications

The second strategy included a variety specification. This was defined as specifying one of eight of the more common varieties in recent years, along with a minimum protein level. These models used the estimated relationships between functional characteristics and binary variables for variety, along with wheat characteristics to simulate functional characteristics and the probability of meeting requirements. A testing cost of $300/sample for an electrophoresis test was added to the procurement cost to allow for targeting varieties.

Table 6. Probability of Meeting Requirements (protein specified only)

	Protein Level					
Functional Characteristic	Base Case 14.2%	13%	13.5%	14%	14.5%	15%
	— Probability of Meeting Requirements —					
Absorption	0.64	0.41	0.50	0.60	0.69	0.77
Peak Time	0.80	0.80	0.80	0.80	0.80	0.80
Stability	0.70	0.70	0.70	0.70	0.70	0.70
Loaf Volume	0.74	0.65	0.70	0.73	0.76	0.79
Joint Probability	0.28	0.15	0.21	0.26	0.31	0.36
Effective Procurement Cost (¢/bu.)	542	523	529	535	553	570

Table 7. Comparison of Strategies

Strategy	Probability of Conformance (joint)	Effective Procurement Cost at PNW (¢/bu.)
Base Case	0.28	542
Wheat & Protein 13%	0.15	523
Wheat & Protein 14%	0.26	535
Wheat & Protein 15%	0.36	570
Variety:		
V1	0.17	552
V2	0.38	542
V3	0.18	552
V4	0.14	553
V5	0.20	551
V6	0.59	532
V7	0.26	548
V8	0.31	546
Location (CRDs 1–20):		
L1	0.28	579
L2	0.28	583
L3	0.33	542
L4	0.45	545
L5	0.33	544
L6	0.28	544
Location (cont'd.)		
L7	0.28	545
L8	0.28	551
L9	0.28	558
L10	0.43	562
L11	0.21	580
L12	0.39	561
L13	0.11	581
L14	0.23	582
L15	0.28	561
L16	0.28	570
L17	0.28	580
L18	0.33	567
L19	0.13	582
L20	0.28	578
Functional Tests:		
Absorption	0.52	531
Stability	0.37	538
Loaf Volume	0.32	538
Farinograph	0.68	524

As reported in table 7, the variety V6 had the least cost delivered at the PNW market ($5.32/bu.) and the highest probability of meeting all functional requirements (0.59), followed by V2 with a cost of $5.42/bu. and probability of meeting specifications of 0.38. Varieties V4, V1, and V3 had the lowest probabilities of meeting all functional requirements (0.14 to 0.18) and were the highest cost ($5.52/bu. to $5.53/bu.).

Dominance of varieties varied by ARAC (table 8). V6 was preferred to the base case protein-only strategy for risk-neutral to slightly risk-averse decision makers. Variety V2 was the second preferred variety and also preferred to protein-only for risk-neutral to

Table 8. Risk Premiums (¢/bushel) for Purchase by Protein Level, Variety, Functional Trait, and Location, by ARAC

	Protein Level						Variety			
ARAC	Base Case 14.2%	13%	13.5%	14%	14.5%	15%	V1	V2	V3	V4
0	—	19.23	12.88	7.03	−10.57	−28.13	−9.48	0.40	−9.25	−11.02
0.009	—	17.81	12.38	7.02	−11.53	−34.65	−9.33	0.79	−8.82	−10.68
0.018	—	17.63	12.85	7.98	−12.96	−49.18	−6.33	−1.75	−5.86	−6.79
0.027	—	18.57	13.76	8.92	−13.58	−49.21	−4.63	−4.26	−4.57	−4.65
0.036	—	18.98	14.03	9.06	−13.67	−45.53	−4.55	−4.52	−4.54	−4.55
0.045	—	19.16	14.13	9.09	−13.67	−42.85	−4.55	−4.54	−4.55	−4.55
0.054	—	19.25	14.18	9.10	−13.67	−41.00	−4.55	−4.54	−4.55	−4.55
0.063	—	19.29	14.20	9.11	−13.67	−39.73	−4.55	−4.55	−4.55	−4.55
0.072	—	19.31	14.21	9.11	−13.68	−38.84	−4.55	−4.55	−4.55	−4.55
0.081	—	19.32	14.22	9.12	−13.68	−38.21	−4.55	−4.55	−4.55	−4.55
0.090	—	19.33	14.22	9.12	−13.68	−37.76	−4.55	−4.55	−4.55	−4.55
0.099	—	19.33	14.23	9.12	−13.68	−37.43	−4.55	−4.55	−4.55	−4.55
0.108	—	19.33	14.23	9.12	−13.68	−37.19	−4.55	−4.55	−4.55	−4.55

	Location									
ARAC	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
0	−36.38	−41.07	0.20	−2.95	−1.33	−1.45	−2.69	−8.37	−15.92	−19.74
0.009	−35.18	−39.89	0.17	−1.62	−0.82	−1.46	−2.64	−8.02	−15.46	−17.33
0.018	−25.14	−28.23	−0.99	−0.52	−1.47	−1.42	−2.47	−7.07	−13.70	−10.03
0.027	−12.88	−13.94	−1.65	−2.07	−2.38	−1.50	−2.14	−5.00	−9.60	−6.18
0.036	−8.33	−8.90	−1.62	−2.46	−2.11	−1.51	−1.87	−3.56	−6.66	−5.08
0.045	−5.83	−6.22	−1.57	−2.31	−1.85	−1.51	−1.70	−2.68	−4.74	−4.11
0.054	−4.27	−4.56	−1.54	−2.08	−1.69	−1.52	−1.62	−2.17	−3.51	−3.33
0.063	−3.27	−3.50	−1.53	−1.89	−1.61	−1.52	−1.57	−1.88	−2.75	−2.76
0.072	−2.64	−2.81	−1.52	−1.75	−1.57	−1.52	−1.54	−1.72	−2.28	−2.35
0.081	−2.24	−2.37	−1.52	−1.66	−1.54	−1.52	−1.53	−1.63	−1.99	−2.08
0.090	−1.98	−2.08	−1.52	−1.60	−1.53	−1.52	−1.52	−1.58	−1.81	−1.89
0.099	−1.82	−1.89	−1.52	−1.57	−1.52	−1.52	−1.52	−1.55	−1.70	−1.77
0.108	−1.71	−1.76	−1.52	−1.55	−1.52	−1.52	−1.52	−1.54	−1.63	−1.68

(extended →)

slightly less risk-averse buyers. The risk premium over the protein-only strategy for V6 increased from 10.18¢/bu. for risk-neutral buyers to a high of 13.13¢/bu., then declining for highly risk-averse buyers. The risk premium for V2 ranged from 0.40¢/bu. for risk-neutral buyers to 0.79¢/bu. before declining to a low of −4.55¢/bu. for the most risk-averse buyers. All other varieties were dominated by the protein-only strategy across the range of risk attitudes.

Location Specifications

The effect of buying based on location in addition to wheat characteristics was evaluated. Wheat was assumed purchased by location. A location verification test cost of $100/sample was added for monitoring IP at each location. This test is envisioned as a cost of auditing, which is common in IP transactions.

Table 8. Extended

	Variety (cont'd.)				Functional Trait			
ARAC	V5	V6	V7	V8	Absorption	Stability	Loaf Volume	Farinograph
0	-8.20	10.18	-5.40	-3.15	11.08	4.28	1.69	18.79
0.009	-7.72	13.13	-5.22	-2.93	13.24	7.63	2.87	23.95
0.018	-5.24	10.35	-4.45	-3.56	6.12	17.42	1.35	31.86
0.027	-4.51	-0.26	-4.48	-4.44	-1.60	10.19	-1.89	28.52
0.036	-4.54	-3.18	-4.54	-4.54	-1.44	4.98	-1.34	28.75
0.045	-4.54	-4.06	-4.54	-4.54	-0.56	2.97	-0.42	30.36
0.054	-4.55	-4.36	-4.55	-4.55	0.14	2.16	0.29	31.99
0.063	-4.55	-4.47	-4.55	-4.55	0.63	1.82	0.78	33.38
0.072	-4.55	-4.52	-4.55	-4.55	0.96	1.67	1.11	34.50
0.081	-4.55	-4.53	-4.55	-4.55	1.17	1.60	1.32	35.41
0.090	-4.55	-4.54	-4.55	-4.55	1.30	1.57	1.46	36.13
0.099	-4.55	-4.54	-4.55	-4.55	1.39	1.56	1.54	36.72
0.108	-4.55	-4.54	-4.55	-4.55	1.45	1.55	1.60	37.21

	Location (cont'd.)									
ARAC	L11	L12	L13	L14	L15	L16	L17	L18	L19	L20
0	-37.82	-18.88	-39.15	-39.80	-18.30	-27.44	-38.08	-24.66	-39.92	-35.31
0.009	-36.87	-16.98	-37.99	-38.51	-17.43	-26.39	-36.88	-23.67	-38.61	-34.20
0.018	-26.76	-10.11	-27.26	-26.82	-13.57	-20.22	-26.15	-18.99	-27.89	-26.64
0.027	-13.43	-6.16	-13.46	-13.11	-8.36	-12.04	-13.08	-11.93	-15.40	-17.00
0.036	-8.48	-5.06	-8.47	-8.36	-5.67	-8.16	-8.37	-8.15	-10.89	-12.84
0.045	-5.87	-4.11	-5.86	-5.83	-4.04	-5.79	-5.84	-5.79	-8.39	-10.38
0.054	-4.28	-3.33	-4.28	-4.27	-3.04	-4.26	-4.27	-4.26	-6.81	-8.81
0.063	-3.28	-2.76	-3.28	-3.28	-2.43	-3.27	-3.28	-3.27	-5.80	-7.80
0.072	-2.64	-2.35	-2.64	-2.64	-2.06	-2.64	-2.64	-2.64	-5.15	-7.15
0.081	-2.24	-2.08	-2.24	-2.24	-1.84	-2.24	-2.24	-2.24	-4.73	-6.73
0.090	-1.98	-1.89	-1.98	-1.98	-1.71	-1.98	-1.98	-1.98	-4.47	-6.47
0.099	-1.82	-1.77	-1.82	-1.82	-1.63	-1.82	-1.82	-1.82	-4.30	-6.30
0.108	-1.71	-1.68	-1.71	-1.71	-1.59	-1.71	-1.71	-1.71	-4.19	-6.19

The greatest probabilities of meeting all functional requirements are found for the L4, L10, and L12 CRDs, respectively (table 7). The lowest probabilities of meeting functional requirements are found in the L13, L19, and L11 CRDs. Low probabilities were affected by stability and loaf volume in L13 and by stability in L11, while low absorption affected L19. In fact, L19 had a higher probability of meeting loaf volume than did any other location. The minimum cost strategy, while meeting all requirements with a probability of at least 0.4, would be to buy from CRDs L4 or L10.

The only location having risk premiums greater than the protein-only strategy for any ARAC was L3 (table 8). This was the preferred location for risk-neutral decision makers over protein-only by 0.2¢/bu. However, as decision makers become more risk averse, the preference for L3 declines, and L3 becomes less preferred to the protein-only strategy. All other locations had lower risk premiums than protein-only and generally tended to become less negative as decision makers shifted from risk neutral to highly risk averse.

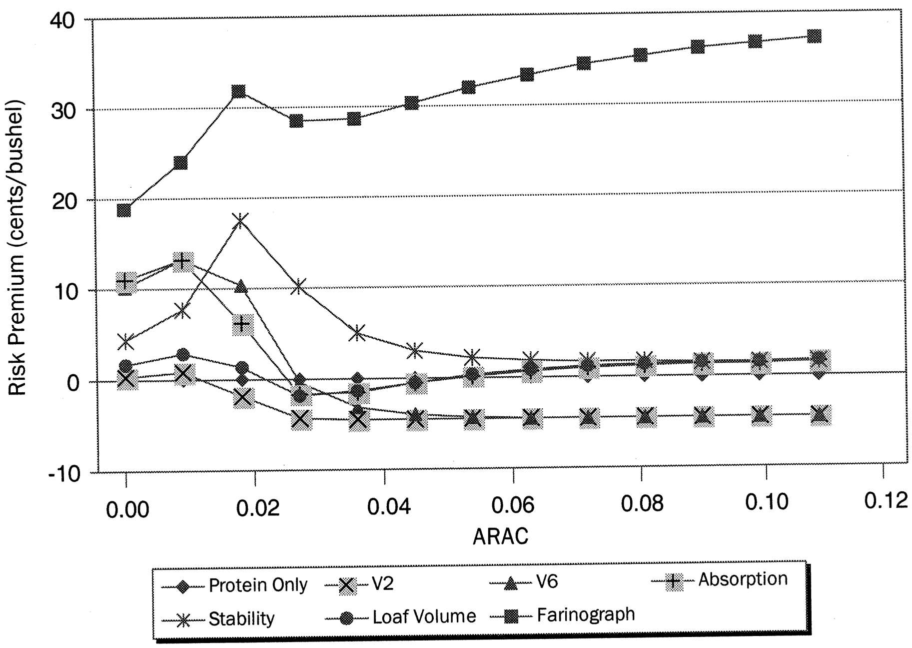

Figure 2. Relationship between risk premiums and risk-aversion coefficients for selected purchase strategies

Functional Characteristics

We also analyzed the effect of specifying functional requirements as a purchasing strategy. Tests were conducted at costs of $40/sample for a farinograph test and $30/sample for a loaf volume test. All tests are 95% accurate. The farinograph and loaf volume tests were incorporated using a hypogeometric function at a 95% accuracy level to derive individual and joint probabilities. If the characteristic is not met with the test, it is rejected. Models were analyzed for separate functional characteristics for absorption, stability, and loaf volume; then an additional model was analyzed that included tests for absorption, peak time, and stability using a farinograph test.

The probability of meeting functional tests for absorption was 0.52 and resulted in an effective procurement cost of 11¢/bu. lower than the base case (table 7). For stability and loaf volume, the respective probability of meeting specifications was 0.37 and 0.32, and both strategies resulted in procurement costs 4¢/bu. lower than the base case. The joint probability of meeting requirements was 0.68 when the farinograph test was conducted. The farinograph test resulted in the lowest procurement cost, which was 18¢/bu. lower than the base case. The probability of meeting requirements increased considerably when functional characteristic tests were performed, and effective procurement costs were lowered compared to the base case.

Stochastic efficiency for functional tests indicated dominance over protein-only varied by ARAC (figure 2 and table 8). Farinograph tests dominated all of the variety strategies. Absorption dominated all but V6 for less risk-averse buyers, and V2 for moderate to highly risk-averse buyers. For risk-neutral decision makers, the farinograph test was the most preferred to protein-only by 18.79¢/bu., while absorption ranked second (11.08¢/bu.), and stability (4.28¢/bu.) and loaf volume (1.69¢/bu.) were the third and fourth preferred strategies. Risk premiums relative to protein-only exhibited shifting patterns as buyers shifted from risk neutral to risk averse for all of the functional tests. Risk premiums for risk-neutral to highly risk-averse buyers ranged from 18.79¢/bu. to 37.21¢/bu. for farinograph, from 13.24¢/bu. to −1.6¢/bu. for absorption, from 17.42¢/bu. to 1.55¢/bu. for stability, and from 2.87¢/bu. to −1.89¢/bu. for loaf volume.

Comparing stochastic efficiency of functional tests to location strategies indicated farinograph tests were the most preferred functional test and dominated all locational purchase strategies. As noted above, the extent of preference relative to the protein-only strategy (measured by the risk premium) for the best of the alternative strategies (farinograph) ranged from 18.79¢/bu. to 37.21¢/bu. for risk-neutral to highly risk-averse decision makers.

Summary

Consistency of functional characteristics in grain is a major problem confronting the relationship between suppliers and end-users. Changes in varieties planted, along with variable growing conditions, have led to increased conformance uncertainties. Variability in quality for functional characteristics has implications for processors including the risk of not conforming to requirements, greater costs associated with higher quality purchasing, and increased operating costs associated with likely stock-out costs due to nonconformance. A common procurement strategy in wheat designed to alleviate this problem is to base purchases on protein levels. Less common strategies include vertical integration, targeting of origins or varieties, and pre-shipment samples. End-users chose among these procurement strategies to improve quality.

These procurement strategies were modeled using stochastic simulation to estimate procurement costs and risks. Earlier work by Stiegert and Blanc (1997) suggested there was value associated with non-contracted functional characteristics (farinograph stability) proxied by wheat protein. In this paper we measure risks of different purchasing strategies, including purchases by protein, variety, location, and contract requirements for functional characteristics. Purchasing costs and the probabilities of meeting buyer requirements were estimated for each strategy. Statistical relationships and correlations among wheat characteristics and functional characteristics were used to determine probabilities of meeting buyer requirements. Testing costs for varieties and functional characteristics were included in sensitivities involving these requirements.

The results indicate there is substantial risk of not meeting functional trait requirements using conventional contracts. These risks can be mitigated by specifying either higher protein levels, targeted varieties, locations, or functional traits, though at higher costs. Increasing minimum protein levels increases conformance, but due to the added costs were less preferred than the base case or lower protein strategies. Several of the variety and location purchase strategies also increase conformance and are preferred to increasing protein levels. However, use of functional trait specifications in contracts, even at higher costs, is a much more cost-effective means of reducing these risks and is preferred to the other strategies examined. These results suggest risk premiums up to 13¢/bu. for particular varieties and 19¢/bu. to 37¢/bu. for farinograph tests.

Our investigation suggests some limitations. The analysis may be limited because it ignores the potential for blending by buyers and potential use of gluten fortification by some buyers. Implicitly, it assumes the wheat is used as purchased subject to these contractual limits. Of course, the implications of this assumption would be highly idiosyncratic to individual buyers. Second, as in any risk analysis, the results would change if and as the distributions for relevant parameters change. Those used in this study are from a relatively comprehensive data set which is representative of the underlying data.

There are also implications for buyer/seller relationships and the hard wheat markets. Protein premiums are an important feature of this market and have served it well for many years. Protein is used by nearly all buyers and is easily measurable. Our findings show protein is of lesser importance in meeting requirements versus other potential contractual parameters, suggesting that protein premiums are potentially overpriced in contrast to other strategies. It is possible that as a greater portion of buyers use these alternative contractual specifications, the protein premium market could be impacted, but the extent of such a change is beyond the scope of what we could infer from this analysis. Further, with improved testing and contracting, more precise pricing of individual lots will occur, and protein-based pricing may consequently decline in importance.

These results illustrate that wheat suppliers and end-users can utilize contract requirements to improve quality consistency. The wheat protein model, which is used extensively by end-users, involves modest cost increases, and protein premiums and protein levels are easy to measure. More specific strategies, such as location, variety, and/or functional tests, involve greater communication and commitment between suppliers and end-users. Long-term relationships could likely develop to facilitate such contracts. There are three requirements for these alternative strategies to be effectual. One is that buyers must be very assertive and intense in terms of developing an understanding of underlying data distributions and relationships. Second, these results are highly dependent on the requirements for the particular products being produced (as in our table 2). Finally, it would be necessary to create contractual requirements, along with potential for premiums and discounts for deviations from specifications, to provide incentives to suppliers in meeting these requirements.

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