Agribusiness & Applied Economics Report No. 473 December 2001

Valuation of New Spring Wheat Varieties: Tradeoffs for Growers and End-users

Bruce L. Dahl
William W. Wilson
D. Demcey Johnson
William Nganje

Department of Agribusiness and Applied Economics
Agricultural Experiment Station
North Dakota State University
Fargo, ND 58105-5636

ACKNOWLEDGMENTS

Comments on earlier versions of this paper were obtained from Professors David Lambert and George Flaskerud, though errors and omissions are the responsibility of the authors. We would like to acknowledge the help of Dr. Robert Stack, who provided data and understanding on the relations among varieties and head scores (hs). This research was conducted under the National Research Initiative projects titled *Quality Consistency and Variety Development Strategies in Wheat* (NRI Project No. 98-35400-6111) and *Demand and Marketing for Crops with Improved Quality Consistency* (NRI Project No. 2001-01785).

We would be happy to provide a single copy of this publication free of charge. You can address your inquiry to: Carol Jensen, Department of Agribusiness and Applied Economics, North Dakota State University, P.O. Box 5636, Fargo, ND, 58105-5636, Ph. 701-231-7441, Fax 701-231-7400, e-mail cjensen@ndsuext.nodak.edu . This publication is also available electronically at this web site: http://agecon.lib.umn.edu/.

Information on other titles in this series may be obtained from: Department of Agribusiness and Applied Economics, North Dakota State University, P.O. Box 5636, Fargo, ND 58105. Telephone: 701-231-7441, Fax: 701-231-7400, or e-mail: cjensen@ndsuext.nodak.edu.

TABLE OF CONTENTS

LIST OF TABLES ii

LIST OF FIGURES iv

LIST OF APPENDIX TABLES v

ABSTRACT vi

HIGHLIGHTS vii
- Need for Further Study viii

INTRODUCTION 1

BACKGROUND AND PREVIOUS STUDIES 3
- Evolution of Studies on Grain Quality 3
- Economic Studies on Variety Development 4

MODEL DEVELOPMENT 7
- End-user Value Model 7
- Grower Value Model 9

DATA 10
- Agronomic and Quality Data 10
- Prices, Premiums, and Discounts 16
- Vomitoxin 17

RESULTS: END-USE AND GROWER MODELS 19
- End-user Model: Base Case 19
- Grower Model: Base Case 21
- Sensitivities 24
- Comparison of Grower and End-use Values 24
- Sensitivity of Valuation for Individual Characteristics 26
- Alternate End-use Valuation 27
- Effect of Protein Premiums 29
- Effect of the LDP Program 30

STOCHASTIC DOMINANCE COMPARISON OF VARIETY VALUE 32
- Traditional Stochastic Dominance of Grower and End-use Value of Varieties 33
- Significance Tests of Stochastic Dominance 39
- Comparison of Variety as Portfolio of Characteristics of Grower and End-user Values 45

SUMMARY AND CONCLUSIONS 49
- Need for Further Study 50

REFERENCES 51

APPENDIX 57

LIST OF TABLES

Table		Page
1	Estimated Value of Selected Breeding Characteristics of Wheat	5
2	Means and Standard Deviations for Quality Characteristics, by Variety, 1989-1997 (Base Incumbent Varieties).	11
3	Means and Standard Deviations for Quality Characteristics, by Variety, 1989-1997 (Newer and Hypothetical Varieties)	13
4	Agronomic Characteristics, 1989-1997	15
5	Distributions for Prices, Premiums and Discounts for Farmer Value Model	17
6	Estimated Certainty Equivalent Income, by Variety, Base Case	22
7	Sensitivity of Grower Certainty Equivalent Income to Protein Premiums, by Variety	29
8	Sensitivity of Grower Certainty Equivalent Income to Reduced Variability of Protein Premiums, by Variety	30
9	Results of Estimated First Degree Stochastic Dominance for Paired Comparisons of Varieties from Traditional Step Function Methods for Grower Value	35
10	Results of Estimated First Degree Stochastic Dominance for Paired Comparisons of Varieties from Traditional Step Function Methods for End-use Value	36
11	Results of Estimated Second Degree Stochastic Dominance for Paired Comparisons of Varieties from Traditional Step Function Methods for Grower Value	37
12	Results of Estimated Second Degree Stochastic Dominance for Paired Comparisons of Varieties from Traditional Step Function Methods for End-use Value	38
13	Results of Hypothesis Tests for First Degree Stochastic Dominance for Grower Values, by Variety	41
14	Results of Hypothesis Tests for First Degree Stochastic Dominance for End-use Values, by Variety	42

LIST OF TABLES (continued)

15 Results of Hypothesis Tests for Second Degree Stochastic Dominance for Grower Values, by Variety 43

16 Results of Hypothesis Tests for Second Degree Stochastic Dominance for End-use Values, by Variety 44

17 Portfolio (Mean, Variance) and Risk Adjusted Value, by Variety (Base Case, Weight = .5, Risk Aversion Parameter = 1.5) 47

LIST OF FIGURES

Figure | Page

1 Comparison of Value of New Variety with Frontier Derived from Blends of Existing Varieties 8

2 Distribution of Yields by Variety 16

3 Distribution of Estimated HS, 1989-2000, and Fitted Beta General Distribution 18

4 Mean End-use Value Over/Under Best of Incumbent Varieties 20

5 Distribution of End-use Value Over/Under Best of Incumbents for Newer/Hypothetical Varieties 20

6 Comparison of the Composition of Best Blend of Incumbents by Variety Tested, End-use Model: Base Case 21

7 Certainty Equivalent Income/Acre, by Variety, Base Case 23

8 Probability that Utility of Income for New/Hypothetical Varieties Exceed that of Incumbent Varieties 23

9 Sensitivity of Certainty Equivalent Income by Variety to the Relative Risk Aversion Coefficient 24

10 Relationship of Grower Value to Mean End-user Value 25

11 Relationship of Grower Value to Range (+-2 Standard Deviation Units) of End-user Values 26

12 Sensitivity of Grower/End-use Value to Changes in Individual Wheat/Quality Characteristics 27

13 Relationship of Mean Alternative End-use Value (Protein and Test Weight Only) with Grower Certainty Equivalent Incomes 28

14 Relationship of Range of Alternative End-use Values (Protein and Test Weight Only) with Grower Certainty Equivalent Incomes 28

15 Comparison of Grower Value under Base Case and LDPs, by Variety 31

16 Relationship of Mean End-use Value with Grower Certainty Equivalent Incomes: Effect of LDPs 32

LIST OF FIGURES (continued)

17 Sensitivity of Risk Adjusted Portfolio Value to End-use Weights, by Variety 46

18 Sensitivity of Risk Adjusted Portfolio Value to Risk Parameter, by Variety 48

LIST OF APPENDIX TABLES

Table Page

1a Parameter Δ_1^i, for Traditional Step Function Estimation of First Degree Stochastic Dominance Test of Grower Value 58

1b Parameter Δ_1^s, for Traditional Step Function Estimation of First Degree Stochastic Dominance Test of Grower Value 59

2a Parameter Δ_2^i, for Traditional Step Function Estimation of Second Degree Stochastic Dominance Test of Grower Value 60

2b Parameter Δ_1^s, for Traditional Step Function Estimation of Second Degree Stochastic Dominance Test of Grower Value 61

3a Parameter Δ_1^i, for Traditional Step Function Estimation of First Degree Stochastic Dominance Test of End-use Value 62

3b Parameter Δ_1^s, for Traditional Step Function Estimation of First Degree Stochastic Dominance Test of End-use Value 63

4a Parameter Δ_2^i, for Traditional Step Function Estimation of Second Degree Stochastic Dominance Test of End-use Value 64

4b Parameter Δ_2^s, for Traditional Step Function Estimation of Second Degree Stochastic Dominance Test of End-use Value 65

ABSTRACT

Variety release decisions involve a number of tradeoffs, usually between grower and end-user characteristics as well as significant uncertainties about agronomic, quality, and economic variables. In this study, methodologies were developed to value tradeoffs for grower and end-user characteristics for wheat. The models capture effects of variability in agronomic, quality, and economic variables. The models were applied for three experimental varieties which have since been released and for two hypothetical varieties. Results indicate two of the experimental varieties provide improvements in grower and end-use value over most of the incumbents. Comparison of a risk adjusted portfolio model consisting of characteristics of end-use and grower values with traditional stochastic dominance techniques (tested for level of significance) indicate similar results. However, the portfolio model incorporates aspects of correlation between grower and end-use values simultaneously.

Key Words: Variety Development, Grower Value, End-user Value, North Dakota, Tradeoffs, Stochastic Dominance, Portfolio Value

HIGHLIGHTS

A methodology to value tradeoffs for growers and end-users when evaluating new wheat varieties was developed. Models were developed to place a value on new varieties for growers and end-users and to make comparisons of tradeoffs. These models were applied for three experimental varieties (ND 678 - Keene, ND 694 - Parshall, and ND 695 - Reeder) which have since been released and for two hypothetical varieties (Hypothetical High Quality and Hypothetical High Yield) which were added to supplement the range of potential grower/end-user value comparisons.

Some important findings were:

- Grower values for experimental varieties where higher than for incumbent varieties. End-use value of experimental varieties varied.

- Grower and end-user values exhibited tradeoffs across varieties.

- Grower's risk preferences affected values for a few varieties. Less risk averse growers would prefer ND 678 over 2375 and Amidon over Butte 86, while more risk averse growers' preferences were reversed.

- The sensitivity of grower and end-user values were affected differently by changes in variety characteristics. Grower values increased most for a one percent change in protein ($2.92/A) and yields ($2.17/A). End-use values increased most for a one percent change in absorption (+ 4 cents/bu) and flour extraction rates (+3 cents/bu).

- Doubling the value of protein premiums (from 40 cents/bu for each percent over 14 percent protein and doubling discounts from an average of 14 cents/bu for each percent under 14 percent protein) was to increase grower value of higher protein varieties by as much as $10-$15/A. The effect on lower protein varieties was smaller and, in fact, a Hypothetical High Yield variety actually declined in grower value.

- Reducing variability in protein premiums was to increase the grower value for varieties with lower and more variable wheat protein relative to varieties with moderate to higher levels that were more stable.

- The Loan Deficiency Payment (LDP) program had the effect of increasing grower value of high yielding, low quality varieties relative to high quality, lower yielding varieties by less than $2/A. This is opposite of the effect of higher protein premiums.

- Risk adjusted portfolio values for varieties, which consider characteristics of value to both end-users and growers, suggest rankings of varieties in order of preference. Initial results indicate a ranking order (best to worst) of Gunner, Hypothetical. High Quality, ND 694 (Parshall), Gus, ND 695 (Reeder), Grandin, Butte 86, Oxen, 2375, Stoa, Amidon, McNeal, ND 678 (Keene), Russ, 2398, and Hypothetical High Yield. These rankings varied by the weight applied to characteristics of grower and end-user value in the portfolio and to a lesser extent the risk aversion parameter.

Need for Further Study

There are five areas that are particularly important for future study and/or extensions of this research. One would be detailed analysis of the geographic scope of variety development decisions. A very important fact is that in the United States varieties of hard red spring (HRS) wheat are developed to perform well in specific geographic regions. In contrast, varieties in Canada are developed for broader geographic regions. This has very important implications for end-use consistency and productivity. Further development on the value of variety releases should consider adaptation for specific regions when determining farmer and end-use values. This is especially important in the case of vomitoxin where infestation levels have been affected both by location (environment) and cultivar, but is also important in that specific varieties are better adapted to specific locations.

A second area would be the strategic practicality of breeding for specific market needs or requirements (i.e., niches). Brennan (1988, 1997) suggested that in many cases this may not be practical due to the transitory nature of niches and the time lag in breeding decisions. Yet, with market maturity there seems to be escalated interest in breeding to meet niche market requirements. As examples, General Mills recently has found extensive efficiency gains in processing by using some specifically bred varieties for manufacture of breakfast cereals; and there have been notable gains in breeding for the specific needs of the frozen dough and tortilla industries.

A third area of importance would be how Fusarium Head Blight (FHB) is incorporated in the analysis. This was incorporated in this study using available data. However, that could be enhanced substantially by accounting for more geographic specificity in the incidence of vomitoxin.

Fourth, an important area for consideration in the case of HRS wheat would be to explore the strategic implications of developing varieties that are distinctly higher yielding, perhaps with some other type of measurable characteristic to allow them to be distinguished in the market place. Results for this analysis suggest that the yield-quality frontier from incumbent varieties is particularly constricted and only very marginal improvements could be assessed.

Finally, an important aspect of variety valuation that should be considered is the diversity of quality desired by end-users. Not all end-users desire the highest quality (highest protein, test weight, etc.) for their products, nor the specific requirements used in this study. Therefore, not all end-users may value a specific new release similarly. For example, McNeal is a variety with very high mix tolerance (stability). This is a characteristic that is desired by some end-users of HRS wheats. McNeal has a higher mix tolerance than Gunner, the highest end-use variety from our base case. This suggests that end-use values where mix tolerance is an important attribute might value McNeal over Gunner. However, inclusion of mix tolerance as an element of end-use value is complicated by uncertainty about end-users' valuation of an additional unit of mix tolerance.

Valuation of New Spring Wheat Varieties: Tradeoffs for Growers and End-users

Bruce L. Dahl, William W. Wilson, D. Demcey Johnson, and William Nganje*

INTRODUCTION

During the past decade there has been heightened interest in grain quality among domestic processors and producers of hard wheat. A contributing factor has been the increasingly important role of grain quality in international competition. These interests have come to be focused on two fundamental issues, quality consistency and end-use performance. These issues have important implications for many functions of the grain marketing systems including plant breeding strategies and variety release decisions.

There are fundamental tradeoffs in variety development decisions. These typically involve yields, disease resistance, and quality. Gains in one area often involve losses in another. Growers want greater yields and disease resistence, without foregoing returns due to quality shortfalls. End-users have demands for functional characteristics that are typically proxied by measurable wheat characteristics (e.g., protein). Finally, changes in the regulation and release of new cultivars with specific characteristics not contained in grades are influencing the choice of wheat by end-users (Evers). Ultimately, decision makers must confront these tradeoffs in making breeding and variety release decisions.

Breeders confront not only tradeoffs, but also numerous sources of uncertainty. These include a high degree of randomness in agronomic, quality, and economic variables.[1] Agronomic variables include yield, disease resistance, and climatic conditions. Quality variables include both measurable wheat characteristics such as protein and test weight and functional characteristics (absorption, stability, gluten strength, and varying other measures) that are typically not measured in grain transactions and do not have explicit premiums/discounts attached to them. Finally, correlations among these variables increase the complexity of breeding decisions.

The value of a variety and its post-release success/adoption depends on the valuations of growers and end-users. These groups routinely value new varieties differently based on performance and quality. A new variety with high levels of desired end-use characteristics may not provide competitive yields relative to incumbent varieties or may have more variable yields.

---

*Dahl is Research Scientist, Wilson is Professor, and Nganje is Assistant Professor, all in the Department of Agribusiness and Applied Economics, North Dakota State University, Fargo; and Johnson is Director for the Small Grains Division at the U.S. Department of Agriculture, Economic Research Service.

[1]Smith described the effects of tradeoffs between price, yields, profit, and risk in the context of variety development and adoption. He discusses selected quality characteristics and their effect on quality and examines tradeoffs affecting the adoption of varieties by farmers and their impact on new variety development. He suggested there has been significant variability in prices, premiums, yields, etc., which results in substantial risks to farmers. He concludes that the effects of tradeoffs (especially risk and price) can have significant implications for new variety adoption.

In either case, the growers' value of this variety may actually be lower than for incumbent varieties. Similarly, growers may value a new high yielding variety greater than incumbents; however, if it produces lower quality characteristics, its value to end-users may be lower.

Similar issues related to quality improvement have been confronting most of the major wheat exporting countries. In the United States, quality problems in hard red spring (HRS) wheat have concerned dockage (Wilson and Dahl 2001), consistency (Wilson and Dahl 1999), and end-use performance. More recently, one of the primary problems has been the emergence of a devastating disease called Fusarium Head Blight (FHB). The latter has spread throughout the HRS wheat areas since 1993 and resulted in yield and quality losses (Johnson et al.; Johnson and Nganje; Nganje et al.). In Australia, the concerns have been about the longer term decreases in protein (Peterson; Fraser). In France, there have been concerns about reduced exports due to the wheat crop being comprised mostly of lower protein soft varieties. These have led to development and adoption of medium hard wheats with higher protein levels.

Unlike other countries, the United States does not have formal regulations of variety release at the national level (these decisions involve breeders and their institutions and are subject to market pressures). In addition, unlike other countries, variety is not a criterion in determining wheat class. Instead the varieties are marketed by class, grade, and specification of measurable characteristics (e.g., test weight and protein) which are correlated in some cases with end-use characteristics (e.g., farinograph measures, loaf volume, etc.).

The purpose of this study is to develop a methodology to determine the *ex ante* value of new varieties to end-users and growers. The analytical model is applied to both experimental and hypothetical varieties and comparisons are made relative to a set of incumbent varieties. Extensive agronomic and quality panel data were used to derive distributions and correlations among characteristics and varieties. These agronomic and quality relationships are combined with distributions of economic variables to estimate distributions of the value of varieties for end-users and growers. The results were evaluated using stochastic dominance to determine the extent that one variety is superior to others. The results illustrate tradeoffs in the value of a variety for end-users and growers.

The methods used extend the current literature on the economics of variety development in a number of dimensions. First, we explicitly account for valuations of individual varieties by both end-users and growers. Second, the analysis is conducted in a stochastic framework, allowing for uncertainties and correlations among some key variables. Third, the impact of disease (or value of disease resistance) is incorporated directly, while accounting for its randomness and impact on crop value. Finally, the extension of traditional stochastic dominance methods to portfolios comprised of characteristics of end-user and grower values distinguishes this analysis from previous research on variety development strategies.

This report is organized as follows. First, background and previous studies on variety development are discussed. The next sections present the empirical model and data. Results are then presented for each of the analytical models. These are combined to illustrate the tradeoffs in variety values between end-users and growers. Also, a number of simulations are conducted to illustrate impacts of individual quality and economic parameters on the value of varieties. Then, alternative methods for determining dominance are evaluated for end-use and grower values separately and for a portfolio of characteristics representing both grower and end-use values. The final section provides a conclusion and makes suggestions for further study.

BACKGROUND AND PREVIOUS STUDIES

There is extensive and growing economic literature on topics related to grain quality and variety development. The topics on grain quality are summarized in the first section below. Following that, the studies that have been specifically related to the economics of variety development are summarized.

Evolution of Studies on Grain Quality

Over the past decade there has been heightened interest in the role of grain quality in international competition (U.S. Congress, Office of Technology Assessment, and U.S. Department of Agriculture/Economic Research Service studies, Mercier among these). Much early attention was devoted to issues of cleanliness. Some of the problems with grain cleanliness have been resolved commercially through improved contract specifications (Wilson, Johnson, and Dahl; Johnson and Wilson 1993; Wilson and Dahl 2001). Focus has now shifted to end-use performance and quality consistency (Wilson and Dahl 1999; Dahl and Wilson 1998). Foreign buyers have raised concerns about the inconsistent quality of U.S. grain shipments compared to competitor countries. Concerns have also been raised about the apparent deterioration over time in end-use performance both internationally and domestically. These problems are particularly acute in U.S. hard wheats (which normally command a price premium) because of the intensity of international competition in these classes.

A study conducted for the Minnesota Association of Wheat Growers and the Minnesota Wheat Research and Promotion Council indicated that domestic end-users have reduced their use of HRS wheats over the years, in part because of consistency problems and changes in end-use performance. Domestic millers of HRS wheat indicated a noticeable reduction in gluten strength that would eventually (adversely) affect market penetration and/or premiums for this class of wheat (North Dakota Wheat Commission). In a recent study, Janzen, Mattson, and Wilson found that the most important aspect of quality was consistency and the attribute of greatest importance was water absorption. A survey conducted by U.S. Wheat Associates indicated there has been a drop in protein quality over the last five years and that CWRS has better quality than DNS (Prairie Grains).

There is no doubt that a primary driving force is the intensity of international competition. One of the fundamental issues in competitor countries, notably Canada and Australia, is the economics of regulations governing varietal development and release. Dahl and Wilson (1997) indicated that between 1974 and 1996 in the United States and Canada, 70 and 30 varieties of HRS wheat were adopted, respectively. The important point is that far more wheat varieties are grown in comparable U.S. producing regions.

Partly in response to these concerns, there have been numerous economic studies in the case of wheat quality. Wilson (1989) used the Hufbauer index to show that wheat has become increasingly heterogeneous over time. In cases of commodities with various characteristics, hedonic models are useful for valuing the individual characteristics. Academic and government researchers have made extensive use of hedonic analysis[2] for evaluating wheat quality problems. Numerous studies have been conducted in the case of wheat. Those estimating hedonic values using regression models include Wilson (1989), Veeman, Larue, and Uri and Hyberg. Valuation of characteristics can also be done with optimization models (Ladd and Martin; Ladd and Gibson). In addition to hedonic studies, several studies have modeled demand for wheat differentiated by quality and country of origin (e.g., Hill; Wilson 1994; Wilson and Gallagher; Wilson and Preszler 1993a,b).[3] In all these cases, the results provide estimates of the marginal implicit value of measurable characteristics. These provide preliminary evidence of characteristic values, but do not allow the comprehensive valuation of wheat varieties, because numerous wheat characteristics are not measured within the marketing system.

Economic Studies on Variety Development

Concurrent with the above literature has been a strain of studies focusing on the economics of variety development. Many of these are by Brennan and are described first.

The process of varietal release is complicated, time consuming, and involves trade-offs between conflicting objectives in terms of the attributes of the released varieties. A number of competing aims need to be taken into consideration in determining the breeders' and ultimately the growers' response to wheat quality improvement. Brennan (1988 and 1997) provides a comprehensive summary of the issues and reviews alternative procedures, with particular emphasis on the role the market should play in variety development. The importance of market incentives for growers in inducing breeders to bring about quality improvement is highlighted. He identifies the need for and conditions under which breeders must respond to meet the needs of "niche" markets. Examples of such "niche" markets are wheat for biscuits, noodles, flat breads, etc. There are two issues in using breeding as a tool to address this opportunity: 1) whether the problem is capable of being addressed by breeding, given the genetic materials available; and 2) whether breeding is the appropriate solution, given the stability and robustness of the market niche and any associated price premium. Since breeding varieties to serve niche markets is a long-run process, breeding is unlikely to be appropriate if the market provides only a short-term opportunity.

---

[2]See Ladd and Martin for early contributions to the agricultural economics literature.

[3] The hedonic analysis by Melton, et al. is focused on characteristics of livestock; they propose a methodology for estimating the value of genetic characteristics of varieties which may only be available in non-separable bundles. McVey extended the model by Melton, Colette, and Willham to include logistical aspects of grain quality. He examined valuation of characteristics of corn and soybean varieties including additional logistical costs for identity preserved (IP) shipments of specific varieties. McVey developed an optimization model of a grain handling system (farmer to end-user) with the objective of minimizing costs. In the model, farmers were given the opportunity to grow three different corn and soybean varieties. Varieties for each included a generic variety with characteristics appropriate to different end-uses and varieties specifically having higher quality for one of the defined end-uses (processing or livestock feed). Alternative logistical costs of handling were incorporated based on whether generic or specific varieties were grown and shipped to targeted uses. Results of the optimization problem were then utilized to estimate values for specific end-use characteristics. McVey and Melton, Colette, and Willham advance this type of methodology as an alternative to traditional input characteristic models (ICM) and blending ICM methodologies, which can suffer from data problems. In reality, varieties come as a packet of characteristics, some beneficial, some not.

Yield, quality, and disease-resistance are three broad attributes that breeders have to consider while developing new varieties for cultivation. Brennan (1988) evaluated wheat breeding programs using a dynamic deterministic model and observed a general tendency to release high yielding varieties in Australia. Brennan (1990, 1997) developed a "quality index" based on a combination of hedonic studies, implicit market valuations, and payments made for quality in different countries to estimate the implicit value of breeding characteristics of wheat. He concluded that increasing yield by 1 percent has the same value as: a) increasing flour extraction by 0.31 percentage points; b) increasing protein content by 0.36 percentage points; c) increasing test weight by 1.28 kg/hl; d) increasing falling number by 9.9 seconds; e) increasing water absorption by 0.42 percentage points; or f) increasing bake score by 0.32 index points.

Brennan (1988) described practices in a number of countries that have either advanced methods for paying producers for quality characteristics other than protein or offered premiums/discounts for specific qualities. In New Zealand, a Bread Quality Index is utilized when determining payments for farmers. This index is determined by variety (bake score, absorption, and flour extraction) and baking characteristics (base score, kernel weight, screening percentage, moisture, and incidence of black point).

Brennan examined a range of end-use characteristics, using estimates from the processing sector where those could be established. These included flour extraction rate, grain protein content, grain soundness (sprout damage), moisture, and unmillable material. These were later refined and estimated for test weight, bake score, and a quality index (Brennan 1990, 1997).

Table 1. Estimated Value of Selected Breeding Characteristics of Wheat (U.S. Dollars per MT, 1986 Dollars)[a]

Characteristic	Unit Estimated	Estimated Value	
		$US/MT	cents/bu
Yield	1%	0.74	2.0
Quality			
Flour extraction rate	1 percentage point	2.37	6.5
Protein content	1 percentage point	2.01	5.5
Test weight	1 kg/hl	0.58	1.6
Amylase activity	Falling number 10 sec.	0.73	2.0
Water absorption	1 percentage point	1.75	4.8
Bake score	1 index point	2.33	6.3
-Quality Index	1 index unit (base = 100)	0.72	2.0

[a] Based on wheat price of $A174 per MT FOB, converted to $US at average 1986 exchange rate of $A1.00=$US0.67.

Source: Brennan 1997.

An important area of research has been the value of disease resistance. Brennan and Murray (1988) evaluated the importance of specific diseases in Australia. Their analysis utilized prior estimates of incidence of diseases and incorporated yield and quality (price) impacts to estimate the cost of a disease (value of resistance). The impact of diseases on yields was estimated in two stages. First, the level of incidence of specific diseases was ranked on a 6 point ordinal scale (the scale represented both the number of years and the range of area for which the disease would be a problem). Then severity of disease was also ranked on a 6 point scale (representing the range of yield loss associated with the disease). Combining these two scales resulted in an estimate of average yield losses for each disease. Quality impacts were evaluated by evaluating changes in grade designations that would occur with specific levels of disease severity and then applying the discount associated with the grade change. The impact of diseases was then measured as the combined effect of quality and price, which allowed specific disease controls to be valued.

Other recent studies have analyzed various aspects of variety development strategies. Bana e Costa, Ensslin, and Costa.utilized multicriteria structuring to evaluate the value of rice varieties in South Brazil. Their methodology focused on a categorical analysis of attributes. To quantify the attractiveness of varieties for each attribute, a cardinal value function was constructed for each descriptor, and scaling constants were assessed. Both partial value scales and scaling constants were defined based on qualitative value judgements of experts.[4] This methodology was applied for a set of 14 varieties. They found that because this method relies heavily on value judgements of the expert, results are influenced by biases contained within value judgements.

A major problem in Australia has been a longer term trend toward reduced protein levels. Robinson developed a stochastic crop growth simulation model as a decision aid for analyzing the value of specific varieties and nitrogen application for Australian farmers. This model relies heavily on biological relationships between environment and crop growth and is based on the CERES wheat crop growth simulation model. The focus of this methodology is on the value of a variety to growers. It was utilized to assess the prospective distribution of gross margins among specific varieties for alternative levels of nitrogen fertilization application. Prospective gross margins reflect risks due to environmental variability from a given growth stage to physiological maturity of the crop.

Fraser examined the effect of protein premiums on income streams for growers (and land values). A model of certainty equivalent profits of growers was developed to capture the effects of yield and price variability, as well as yield-protein tradeoffs. This model was solved analytically. Introduction of protein payment schemes reduced the expected level and variability of income; however, effects varied depending on the level of yield variability across regions. Petersen expanded on Fraser's model incorporating increased segregations for protein levels, which allowed for a better representation of the effect of alternative protein levels, and protein

[4]Attributes included 1) adequacy of variety to existing soil conditions, 2) adequacy of variety to irrigation process, 3) sensitivity to fertilizers, 4) resistance to illnesses, 5) tolerance to non-biological aspects, 6) duration of biological cycle, 7) agricultural productivity, 8) loss of grain, 9) industrial productivity, 10) grain quality, and 11) grower resistance or risk associated with changing from established varieties.

premiums and discounts, on growers income streams. The model was of grower certainty equivalent profits and was solved numerically and evaluated over a range of risk attitudes.

Unnevehr utilized the consumer goods characteristics model developed by Ladd and Suvannunt to estimate implicit prices of grain quality characteristics. These estimates were utilized to examine whether consumer preferences correspond to measures of quality used to screen material in breeding programs, to examine if consumer preferences were consistent across geographical regions, and to estimate the returns to quality improvement. Returns to quality improvement were developed by estimating the change in consumer surplus after addition of a new variety and comparing this to the cost of developing the new variety.

MODEL DEVELOPMENT

The value of a new variety is typically different for growers and end-users. Growers may be indifferent between the choice of planting existing varieties and a new variety that has similar agronomic characteristics (yields, disease resistance, etc.), but higher end-use characteristics (higher gluten strength, absorption, flour extraction, etc.). In contrast, end-users may find no value in improved agronomic characteristics (additional yield, straw strength, etc.) while growers may perceive these as substantial. Since the development, release, and adoption of a new variety relies on its value to these groups, two models were developed. The first estimates the value of a new variety to end-users; the second estimates the value of a new variety to growers. Results from these two models are compared and contrasted to evaluate tradeoffs among varieties.

End-user Value Model

A theoretical model was developed to estimate the value of a new variety with specific end-use characteristics to end-users. An end-user evaluating a new variety can compare its value to that of incumbent varieties or to values obtained from blending existing varieties. Consider an example in which there are two end-use characteristics of interest to buyers. A range of varieties are available, each with end-use characteristics. Varieties can also be blended to meet the needs of buyers. Blending opportunities expand the range of alternatives available to buyers. Graphically, this may be shown as a 'frontier,' as in Figure 1. A new variety with levels of end-use characteristics A_1 and B_1 lies outside the frontier of existing varieties. The extent of improvement in each characteristic is gauged by comparison with a particular point on the frontier, representing a blend of existing varieties.

A weighted goal-programming model is utilized in the end-user value model (Zeleny). This allows for incorporation of multiple objectives which may conflict.[5] The model evaluates differences between selected end-use characteristics for a new variety and that available from the best blend of incumbent varieties. Deviations of end-use characteristics between a new variety and optimal blend are assessed costs, which can vary by marketing year. The objective is to minimize the net cost of such deviations. The solution technique utilizes linear programming to

[5] The weighted goal programming model allows multiple end-use characteristics that may be negatively correlated with other end-use characteristics to be evaluated. Therefore, the goal of increasing quality for one characteristic can conflict with increasing quality in another. For further description of goal programming see Zeleny and recent texts by Render and Stair; and Bonini, Hausman and Bierman among others.

identify the best blend, given relevant price and quality parameters for a given year. Stochastic simulation is then used to estimate the expected end-use value of the new variety, relative to the best blend of incumbent varieties, given variation in price and quality parameters.

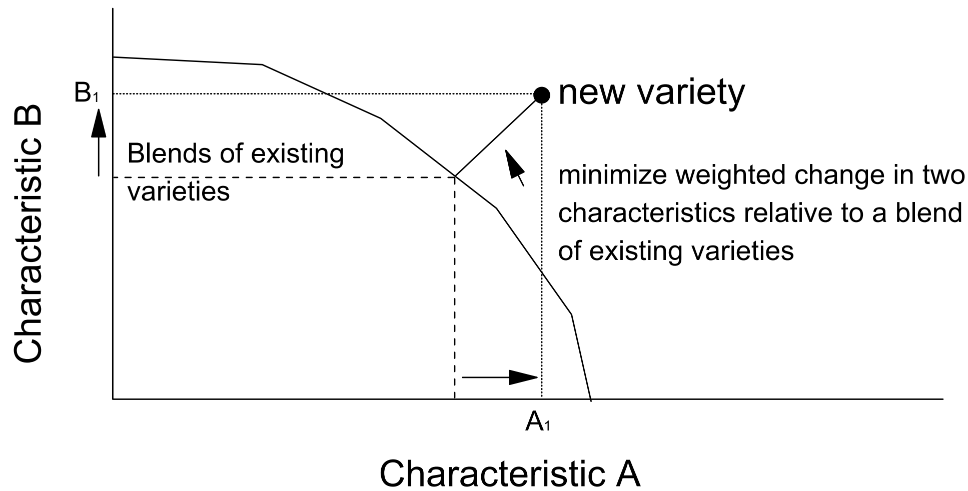

Figure 1. Comparison of Value of New Variety with Frontier Derived from Blends of Existing Varieties.

The end-user model is defined as:

$$\min_{x_{i=1}\ldots x_n} Z_k = \sum_j (K_{j,k} \times P_{j,k}) + (L_{j,k} \times N_{j,k})$$

Subject to:

$$\sum_{i=1}^{n} G_{i,j,k} * X_{i,k} - P_{j,k} + N_{j,k} = Y_{j,k} \qquad \text{j =, 1,.., m characteristics}$$

$$\sum_{i=1}^{n} X_{i,k} = 1$$

and the expected value of a new variety is

$V^u = E(Z_k)$

where

V^u is the expected value to the end-user of a new variety,
Z_k is the implicit value of a new variety, given k,
j is the index for characteristics (1 to m),
i is index for variety 1 to n,
k is the index for quality distribution (year),
G_{ijk} is the level of characteristic j for variety i, given k,
Y_{ik} is the level of characteristic j in the new variety, given k,
K_{jk} is an array of marginal values for positive deviations of characteristic j, given k,

L_{jk} is an array of marginal values for negative deviations of characteristic j, given k,
X_{ik} is share of variety i in a blend of current varieties, given k,
P_{jk} is positive deviation for characteristic j, given k, and
N_{jk} is negative deviation for characteristic j, given k.

Grower Value Model

The values of individual varieties to growers were derived by estimating the certainty equivalent of utility of income for each variety using stochastic simulation. Income was defined as:

$$I = [P - T - H + P^P*(C) - D^P*(C) - D^T*TW - D^{FN}*FN - D^{Vom}*VS] * Y$$

where

- I is income in dollars per acre
- P^w is base price Mpls. (random)
- T is transportation cost from ND to Mpls.
- H is local handling
- P^P is premium for protein > 14 percent (random)
- D^P is discount for protein < 14 percent (random)
- C is protein content (correlated with yield)
- D^T is test weight discount (random)
- TW is max(58-Test weight,0) amount test weight is below 58 lbs/bu
- D^{FN} is falling number discount (random)
- FN is binary indicating falling number is lower than limit (300 minutes)
- D^{Vom} is vomitoxin discount (random)
- VS is binary indicating vomitoxin exceeds critical limit (2ppm), and
- Y is yield (includes variability due to disease, etc.).

A constant relative risk aversion functional form was assumed for the growers utility of income (Keeney and Raiffa). This utility function was used by Fraser, and Pope and Justice provide empirical evidence that supports this specification. Utility of income is defined as:

$$U(I) = [I^{1-\lambda} / 1-\lambda]$$

where

- $U(I)$ is utility of income, and
- λ is constant relative risk aversion coefficient.

These were determined with a stochastic simulation to capture effects of inherent variability in yields, prices, premiums/discounts, and correlations for each variety. From these results, the expected utility was derived for each variety. The certainty equivalent of income was defined as:

$$U(\hat{I}) = EU(I) = E\,[\,\hat{I}^{1-\lambda} / 1-\lambda\,]$$

where $\hat{I}$ is the certainty equivalent, and EU(I) is the expected utility of income. This was estimated for a range of risk aversion parameters for the purposes of sensitivity analysis.

DATA

Agronomic and Quality Data

Data for each of the models were obtained from a number of sources. Variety yields, protein content, and other wheat, flour, and end-use characteristics are from results of North Dakota variety trials (Department of Cereal Science and Food Technology). Means, standard deviations, and correlations were estimated by variety for the years 1989-1997. For the end-user model, values for wheat and end-use characteristics were estimated for two groups of varieties.

A group of eight varieties with observations throughout the sample period were utilized as the base for comparison with newer varieties (with limited observations), experimental varieties, and hypothetical varieties (Table 2). For this first group of varieties, means, standard deviations, and correlations among varieties and characteristics were estimated by variety and characteristic.[6] Then values for a second group was estimated consisting of five newer varieties with limited observations (2398, Gunner, McNeal, Oxen, and Russ), three experimental varieties that have been released, and two hypothetical varieties that were developed to supplement the range of end-user/grower tradeoffs (Table 3). For the hypothetical varieties, one is a higher-yielding, lower end-use quality variety, and the other is a higher end-use quality, average-yielding variety. For this second group, the correlation between the tested variety and an existing variety (V_1) for a characteristic was assumed to be represented by the average of correlations of remaining existing varieties ($V_2..V_N$) with V_1 for a given characteristic.

For the grower model, values were estimated for a set of varieties that were more popular in the late 1990s; these included the five newer varieties and six of the eight base incumbent varieties. Data included distributions and correlations for yields, protein, falling number, test weights, and the resistance rating for Head Scab (Table 4, and Figure 2).

---

[6] Only means and standard deviations are presented here. Correlations are not presented here due to the volume of results.

Table 2. Means and Standard Deviations for Quality Characteristics, by Variety, 1989-1997 (Base Incumbent Varieties)

Variety	Wheat Protein	Test Weight	Vitreous Kernels	Falling Number	Flour Protein	Flour Extraction	Ash	Wet Gluten	Absorption	Peak Time
Mean										
2375	15.2	60.6	76	438	13.9	69.0	0.43	40.4	65.4	11.5
Amidon	15.3	60.2	88	417	14.2	69.1	0.42	42.6	64.8	9.5
Butte 86	15.6	60.1	83	422	14.4	68.2	0.42	42.6	67.1	10.6
Grandin	15.7	60.2	82	411	14.5	69.6	0.43	40.5	66.5	14.4
Gus	16.4	59.2	86	401	15.3	68.9	0.45	45.1	66.0	13.3
Len	16.0	59.6	87	413	14.9	69.3	0.44	40.8	65.4	16.4
Marshall	14.7	59.2	83	411	13.7	70.4	0.41	38.7	61.7	11.3
Stoa	15.7	59.4	83	420	14.6	68.7	0.41	41.4	64.5	16.9
Standard Deviation										
2375	0.9	1.5	18.3	28	0.9	1.9	0.04	3.3	1.9	4.8
Amidon	1.1	1.4	14.1	31	1.1	1.5	0.03	4.0	2.0	3.5
Butte 86	0.9	1.8	16.2	30	0.9	1.4	0.04	3.7	1.8	4.2
Grandin	0.9	2.0	16.0	30	1.0	1.6	0.04	3.3	2.2	6.8
Gus	1.0	2.0	15.6	47	1.0	1.7	0.04	4.0	1.9	5.1
Len	0.9	2.3	10.4	22	0.9	1.8	0.04	3.1	2.0	7.8
Marshall	1.1	2.8	9.0	46	1.1	2.1	0.04	3.9	2.0	6.2
Stoa	1.0	1.9	14.7	32	1.0	1.8	0.04	3.7	2.1	7.5

Table 2. (Continued) Means and Standard Deviations for Quality Characteristics, by Variety, 1989-1997 (Base Incumbent Varieties)

Variety	Mix Tolerance	MTI	Mix Time	DO	Loaf Volume	Granularity	Crumb Color	Crust Color	Symmetry
Mean									
2375	16.6	23.7	2.1	9.8	932	7.9	8.4	10.0	9.8
Amidon	13.9	26.6	2.1	9.9	948	8.0	8.3	10.0	9.8
Butte 86	13.6	24.2	2.0	9.9	954	8.2	8.4	10.0	9.8
Grandin	19.9	18.7	2.6	9.8	972	8.1	8.2	10.0	9.8
Gus	17.2	21.9	2.2	9.7	991	7.9	8.1	10.0	9.7
Len	23.3	15.7	2.9	10.0	1,032	8.0	7.7	10.0	9.9
Marshall	16.3	27.2	1.8	9.8	862	8.1	8.2	10.0	9.8
Stoa	21.8	18.5	2.6	9.9	980	8.0	8.4	10.0	9.8
Standard Deviation									
2375	6.0	10.4	0.28	0.46	48	0.40	0.34	0	0.24
Amidon	5.0	10.8	0.27	0.23	52	0.45	0.32	0	0.21
Butte 86	5.9	13.5	0.26	0.27	57	0.40	0.27	0	0.34
Grandin	7.8	7.6	0.39	0.37	59	0.42	0.37	0	0.37
Gus	6.8	12.2	0.27	0.50	57	0.52	0.51	0	0.32
Len	8.0	6.2	0.54	0.05	60	0.49	0.41	0	0.26
Marshall	5.3	9.3	0.31	0.24	61	0.50	0.47	0	0.38
Stoa	6.6	8.9	0.27	0.19	67	0.36	0.37	0	0.21

Table 3. Means and Standard Deviations for Quality Characteristics, by Variety, 1989-1997 (Newer and Hypothetical Varieties)

Variety	Wheat Protein	Test Weight	Vitreous Kernels	Falling Number	Flour Protein	Flour Extraction	Ash	Wet Gluten	Absorption	Peak Time
Mean										
2398	14.4	58.4	55.9	378	13.5	70.4	.52	37.2	62.2	12.7
Gunner	16.7	61.5	66.2	447	15.5	70.3	.49	45.2	65.4	9.0
McNeal	15.2	59.7	81.5	450	14.1	66.9	.45	37.1	66.5	32.7
Oxen	15.4	59.7	59.3	401	14.0	70.1	.41	38.3	63.5	10.8
Russ	14.8	59.8	68.1	393	13.6	69.0	.46	38.3	64.5	11.4
ND 678	14.9	61.3	91.6	373	13.5	67.2	.39	40.2	66.5	12.0
ND 694	16.2	61.6	73.3	393	15.0	70.0	.45	40.8	64.4	11.5
ND 695	15.8	60.5	51.9	414	14.6	68.9	.42	41.7	63.5	9.6
H. High Q.	16.0	61.0	75.0	400	14.7	71.0	.50	40.0	68.0	12.0
H. High Yld.	13.8	59.0	75.0	370	12.5	68.0	.50	25.0	62.0	10.0
Standard Deviation										
2398	1.21	3.1	26.6	47	1.18	1.5	.05	3.6	2.5	8.5
Gunner	1.10	1.3	21.4	31	1.17	1.6	.04	4.1	1.9	5.0
McNeal	1.77	1.6	16.9	20	1.81	2.0	.04	6.4	1.8	13.7
Oxen	.91	2.1	24.5	40	.90	1.5	.03	3.5	2.1	6.9
Russ	.84	1.9	19.9	49	.82	1.8	.04	3.0	1.3	6.4
ND 678	.77	1.8	9.8	89	.72	1.7	.03	2.8	1.7	5.6
ND 694	.95	1.1	23.0	45	1.04	1.6	.03	3.7	1.9	7.0
ND 695	1.06	1.6	26.2	28	1.05	1.9	.03	3.4	1.7	4.5
H. High Q.	.95	2.1	14.2	33	.96	1.7	.04	3.5	2.0	6.8
H. High Yld.	.95	2.1	14.2	33	.96	1.7	.04	3.5	2.0	6.8

Table 3. (Continued) Means and Standard Deviations for Quality Characteristics, by Variety, 1989-1997 (Newer and Hypothetical Varieties)

Variety	Mix Tolerance	MTI	Mix Time	DO	Loaf Volume	Granularity	Crumb Color	Crust Color	Symmetry
Mean									
2398	16.1	23.2	2.8	9.3	1061	7.9	8.4	10.0	9.8
Gunner	16.7	20.2	2.7	9.8	1095	7.8	8.0	10.0	9.9
McNeal	24.1	14.3	4.8	9.4	1089	8.4	8.4	10.0	9.9
Oxen	17.2	20.5	3.0	9.4	1110	8.2	8.4	10.0	10.0
Russ	16.5	21.7	2.8	9.6	1035	8.0	7.8	10.0	9.7
ND 678	16.5	21.8	2.0	9.5	959	8.2	8.8	10.0	9.8
ND 694	16.7	18.9	3.0	9.7	1139	9.1	8.6	10.0	10.0
ND 695	14.6	20.4	2.7	9.6	1084	7.8	8.0	10.0	9.6
H. High Q.	15.0	30.0	3.0	10.0	970	9.0	9.0	10.0	10.0
H. High Yld.	8.0	20.0	3.0	9.0	950	9.0	9.0	10.0	9.5
Standard Deviation									
2398	7.3	13.5	.5	1.0	66	.6	.6	0	.3
Gunner	8.4	5.6	.3	.4	53	.4	.4	0	.2
McNeal	10.4	7.6	1.1	.6	74	.3	.4	0	.3
Oxen	6.2	8.2	.4	.7	69	.4	.4	0	.1
Russ	6.1	10.6	.3	.4	52	.5	.3	0	.3
ND 678	5.2	10.1	.2	1.0	55	.5	.5	0	.5
ND 694	8.5	12.6	.3	.6	55	.5	.3	0	0
ND 695	5.6	7.9	.2	1.0	50	.5	.4	0	.8
H. High Q.	7.3	8.7	.4	.3	61	.5	.4	0	.3
H. High Yld.	7.3	8.7	.4	.3	61	.5	.4	0	.3

Table 4. Agronomic Characteristics, 1989-1997.			
	Yield	Standard Deviation of Yield	Head Scab Resistance Rating*
2375	48.0	13.8	MS
2398	48.4	15.5	VS
Amidon	45.1	15.1	S
Butte 86	43.8	14.2	MS
Grandin	44.9	14.0	S
Gunner	49.2	15.3	M
Gus	43.7	15.5	VS
McNeal	49.1	15.9	VS
Oxen	48.4	14.7	S
Russ	48.4	14.7	S
Stoa	43.8	14.5	MS
ND 678	50.4	15.8	S
ND 694	48.4	14.8	M
ND 695	52.9	16.3	S
H. High Q.	50.0	14.0	MS
H. High Yld.	60.0	14.0	MS

* R = Resistant, MR = Marginally Resistant, M = Medium, MS = Marginally Susceptible, S = Susceptible, and VS = Very Susceptible.

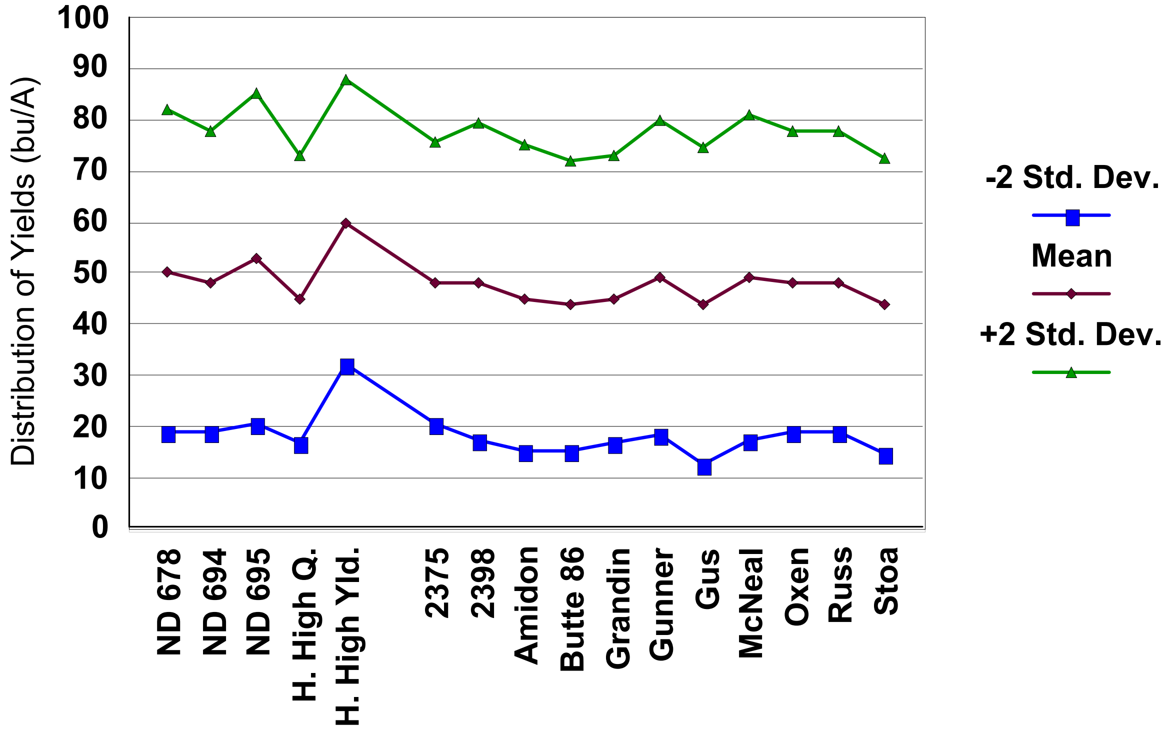

Figure 2. Distribution of Yields by Variety.

Prices, Premiums, and Discounts

Farm prices and protein premiums are average marketing year values, with distributions estimated from daily observations from 1989-1997 (Minneapolis Grain Exchange). Farm prices were estimated as Minneapolis cash prices less transportation costs and local elevator handling charges. Transportation costs were 62 cents/bu, the cost of shipping wheat from Jamestown, ND to Minneapolis (Burlington Northern/Santa Fe). Local elevator handling was assumed to be 10 cents/bu. Premiums and discounts for the farmer value model were assumed to be random and drawn from distributions (Table 5). Protein premiums and discounts reflect average protein premiums/discounts from 14 percent for Minneapolis cash HRS wheat from 1989-1997. Values of discounts for test weight, falling numbers, and vomitoxin were taken from results of a 2001 survey of North Dakota and Montana elevator managers' premiums/discounts for HRS wheat (Wilson and Dahl 2001). Survey results revealed average discounts of 4 cents/bu for test weight of 57 lbs/bu, 26 cents/bu for sprout damage, and 20 cents/bu for vomitoxin. Discounts for sprout damage were applied for falling numbers less than 300 minutes.

The marginal value of flour extraction was estimated using an alternative valuation model proposed by Drynan and utilized by Dahl and Wilson (1999). This model estimates the value of wheat to millers (milling margin) after adjusting for differences in quality characteristics (moisture, foreign material, dockage, and extraction rates). The effect of a higher flour extraction rate from this model was a 5 cents/bu increase in value for a one percentage point increase in flour extraction. This value was utilized in the end-user model.

The marginal value of absorption was estimated assuming that additional absorption values would reduce the amount of flour required to produce a given volume of dough. Using this assumption and a traditional bread formulation, increasing absorption by 1 percent (62 percent to 63 percent absorption) reduces both flour and wheat needs by 0.5 percent. If wheat costs $4.00/bu, then the marginal value of additional absorption is approximately 5 cents/bu which was the value utilized in the end-user model.

An initial value for the constant relative risk aversion parameter of .5 was assumed following Petersen and Fraser. Then a range of constant relative risk aversion parameters around this initial value was examined.

Table 5. Distributions for Prices, Premiums, and Discounts for Farmer Value Model (cents/bu)

	Mean	Std	Correlation	Distribution
MGE Futures Price	436	77		Normal
Protein 15%	40	34	.85 with protein 13%	Normal Truncated at 0
Protein 13%	-14	19	.85 with protein 15%	Normal Truncated at 0
Test Weight	-4	5		Normal Truncated at 0
Falling Number	-26	37		Normal Truncated at 0
Vomitoxin	-20	44		Normal Truncated at 0

Sources: Distributions for prices estimated from Minneapolis Grain Exchange; premiums and discounts for test weight, falling number, and vomitoxin are from Wilson and Dahl (2001).

Vomitoxin

To capture the affect of vomitoxin, VS (a binary variable representing presence/absence of vomitoxin in levels exceeding tolerance) was estimated from a two stage procedure. First, a distribution was estimated for head score values (HS). Head scores are a visual scale used for approximating yield loss due to vomitoxin in field plots developed by Stack and McMullen and represents the percent of yield loss at a location. Johnson et al. and Nganje et al. developed a similar historical measure by crop reporting district (CRD) for North Dakota from 1993-2000 for wheat and barley. These values represent the average wheat loss due to FHB from the hypothetical yield without FHB. This was utilized to derive an average yield loss for locations and using data from 1989 to 2000. Observations were assigned to represent experiment stations based on the CRD in which they lie geographically. Those for years 1989 to 1992 were assigned zero values representing no or minimal vomitoxin levels. A BetaGeneral distribution (which limited observations to positive values) was determined to best fit the data and is used as the distribution for HS within the model (Figure 3). Data from 1989 to 1997 were also utilized along with experiment station data from variety trials for yields, wheat, and end-use characteristics to derive correlations among parameters for each variety.

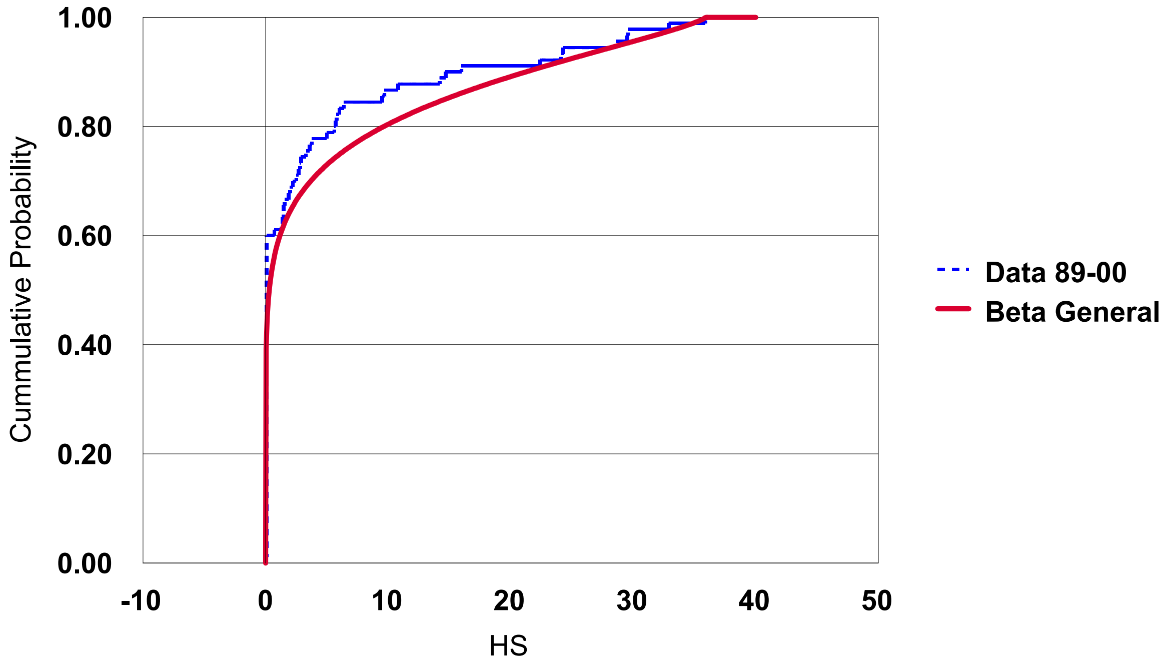

Figure 3. Distribution of Estimated HS, 1989-2000, and Fitted Beta General Distribution.

Correlations for new varieties were assumed to represent the average correlation (across incumbent varieties) for a given parameter. Correlations utilized in the grower model included yields, protein, test weight, falling number, and HS.

In the second step, a relationship was estimated from data by variety for Carrington in 1995 (Stack).[7] This detailed data represented average characteristics for head severity, Deoxynivalenol (DON or more familiarly vomitoxin), yields, test weight, percent tombstone kernels, etc., by variety. Additionally, agronomic descriptions of varieties contain rankings of susceptibility to FHB. These rankings are comprised of a 6 point ordinal scale ranging from Resistant, Marginally Resistant, Medium, Marginally Susceptible, Susceptible, and Very Susceptible. These rankings were assigned values from 0 (Resistant) to 5 (Very Susceptible). From these data, the relationship for DON levels was estimated from (Yield*Test weight)/(Average HS), and the variety susceptibility to FHB score:

$$\underset{(1.92)}{\text{DON} = 16.05} + \underset{(2.68)}{3.27} * \text{Ranking} - \underset{(-3.40)}{7.96} * (\text{Yield*Test Weight/HS})$$

$R^2 = .65$

---

[7] McMullen (2001) indicated preliminary responses of cultivar response indicates some cultivars are known to have more tolerance to head scab than others. For example, “Alsen and Gunner have some infections in the severely impacted fields, but much less than very susceptible cultivars such as McNeal or Amidon.”

Using this relationship, if predicted DON levels equal or exceeded 2 ppm, then the binary variable for vomitoxin levels (VS) was set to 1 and the discount applied. If not, a zero value was assigned to VS and no vomitoxin discount was applied.

RESULTS: END-USE AND GROWER MODELS

Base cases were developed for three North Dakota experimental varieties (ND 678 - Keene; ND 694 - Parshall; and ND 695 - Reeder) that were recently released and two hypothetical varieties. The two hypothetical varieties were constructed to extend the range of potential tradeoffs between value to growers and end-users. One of the hypothetical varieties has higher levels of characteristics for end-use with average yields, while the other is a high-yielding low end-use quality variety. Results were estimated for both the end-user and grower models. Sensitivities were then conducted to evaluate the effects of the constant relative risk aversion coefficient, improving specific wheat and end-use characteristics, protein premiums, alternative end-use value (protein and test weight only), and the effect of the Loan Deficiency Payment (LDP) program..

End-user Model: Base Case

Base case models were developed for each of the varieties. These were compared to the best blend of incumbent varieties for each simulated year. The incumbent varieties were assumed to be the eight varieties grown throughout the time period 1989-1997. Other incumbent varieties (2398, Gunner, McNeal, Oxen, and Russ) were treated as new varieties due to the limited number of observations from which distributions and correlations could be estimated. From the simulation, means and the distribution of end-use values for each of the varieties were collected.

Means for end-use values estimated for the base case range from a high of .01 cents/bu for Gunner to a low of -85.4 cents/bu for the Hypothetical High Yield variety (Figure 4). In this case, all varieties other than Gunner have negative means. This does not mean that end-use quality is less than for incumbent varieties because the new varieties are compared to the best blend of the incumbents within each simulated year, rather than a specific incumbent variety. This represents a valuation comparison where a miller compares quality from a new variety to that which can be obtained by blending incumbents.

Evaluation of the distributions for end-use valuations by variety indicates for the Hypothetical High Quality variety, 50 percent of observations would exceed the value of incumbents (Figure 5). In contrast, 45 percent of observations exceeded the value of the best incumbent for Gunner, 21 percent for ND 694, 7 percent for ND 695, and less than 5 percent for ND 678 and the Hypothetical High Yield variety. Distributions for end-use values are not symmetric across the new varieties. Further, there are distinct differences among the distributions. Both ND 695 and Oxen have a lower probability of having larger negative end-user values in comparison to McNeal; however, McNeal has a higher probability of having more positive end-user values than did either ND 695 or Oxen. It is notable that most of the newer varieties have at least a small probability of having end-use value greater than that of the base incumbent varieties.

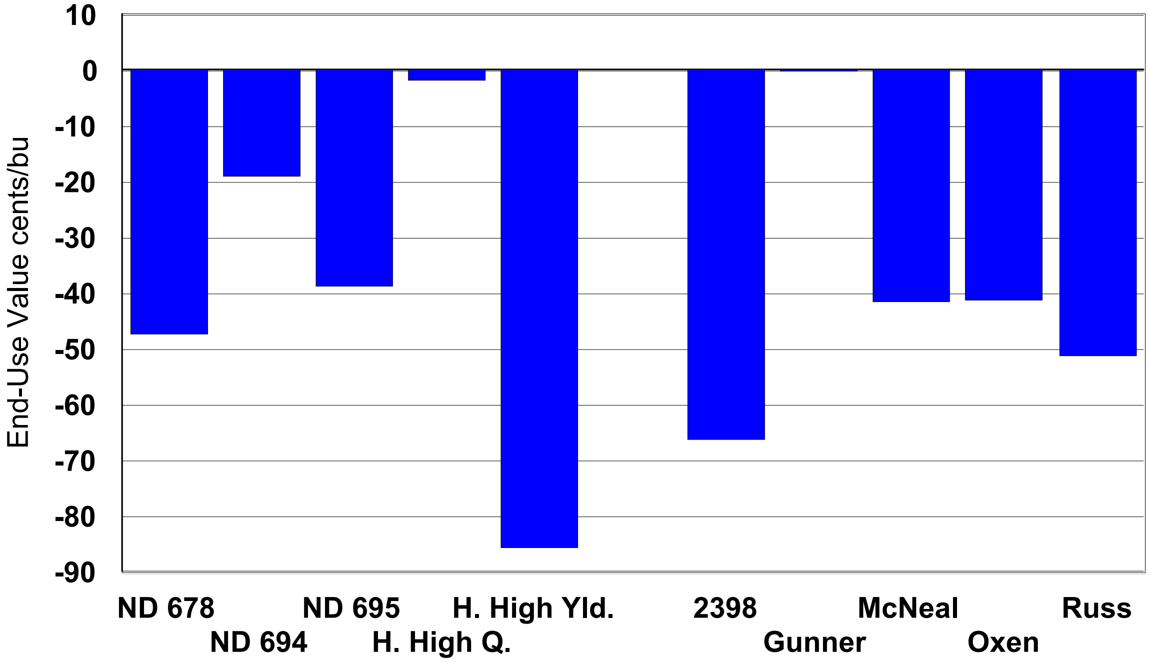

Figure 4. Mean End-use Value Over/Under Best of Incumbent Varieties.

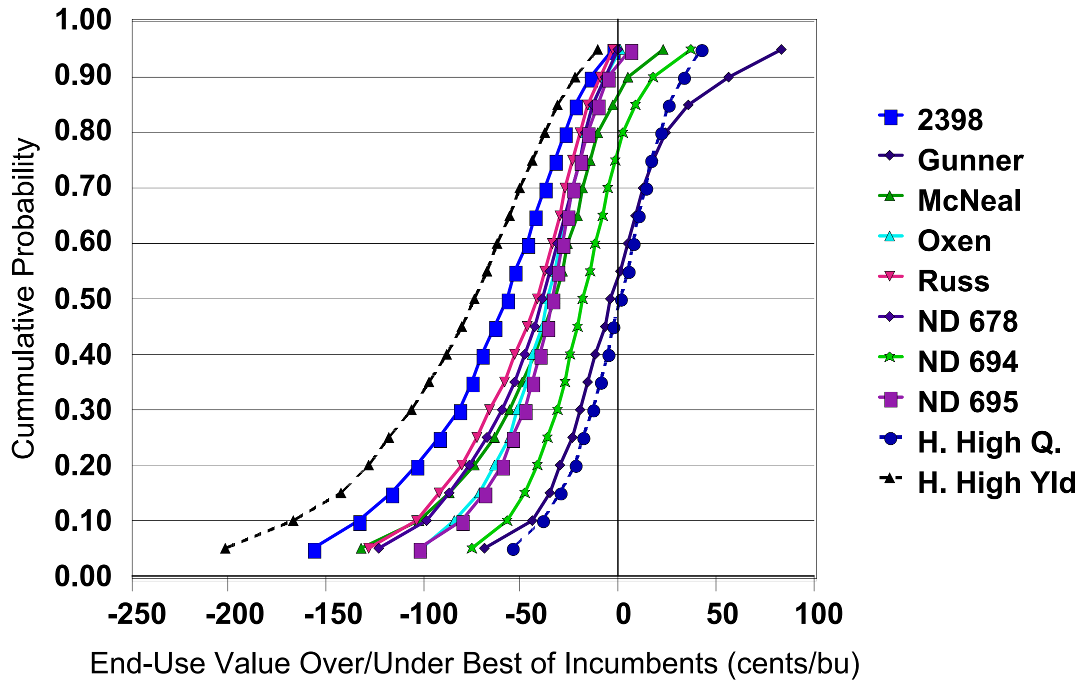

Figure 5. Distribution of End-use Value Over/Under Best of Incumbents for Newer/Hypothetical Varieties.

Comparisons were made to the best blend of incumbent varieties (2375, Amidon, Butte 86, Grandin, Gus, Len, Marshall, and Stoa) in deriving the end-use value of a variety. The model allowed blending of varieties; however, in almost all iterations, the test variety was compared to a single incumbent variety (i.e., a single incumbent variety was the best blend among alternatives). Since tested varieties have different levels of end-use characteristics, they are potentially positioned on different areas on the frontier of best quality available from existing varieties. Therefore, comparisons of the tested variety to the frontier would necessarily be to different groups of incumbent varieties depending on the end-use characteristics of the tested variety. Composition of the best incumbent varieties at the frontier for each variety tested indicate differences which reflect positioning along the frontier (Figure 6). For example, varieties considered higher end-use quality (Gunner, Gus, H. High Q., and ND 694) were most often compared within the simulation to Gus, Grandin, and Len. Those with lower end-use quality (H. High Yld., 2398, and 2375) were compared more frequently to Grandin, Butte 86, and 2375 than were the higher quality varieties. This suggests that these two groups of varieties are positioned on different areas of the frontier, indicating different characteristics or combinations of characteristics may be more important in determining how these groups of varieties relate to incumbents.

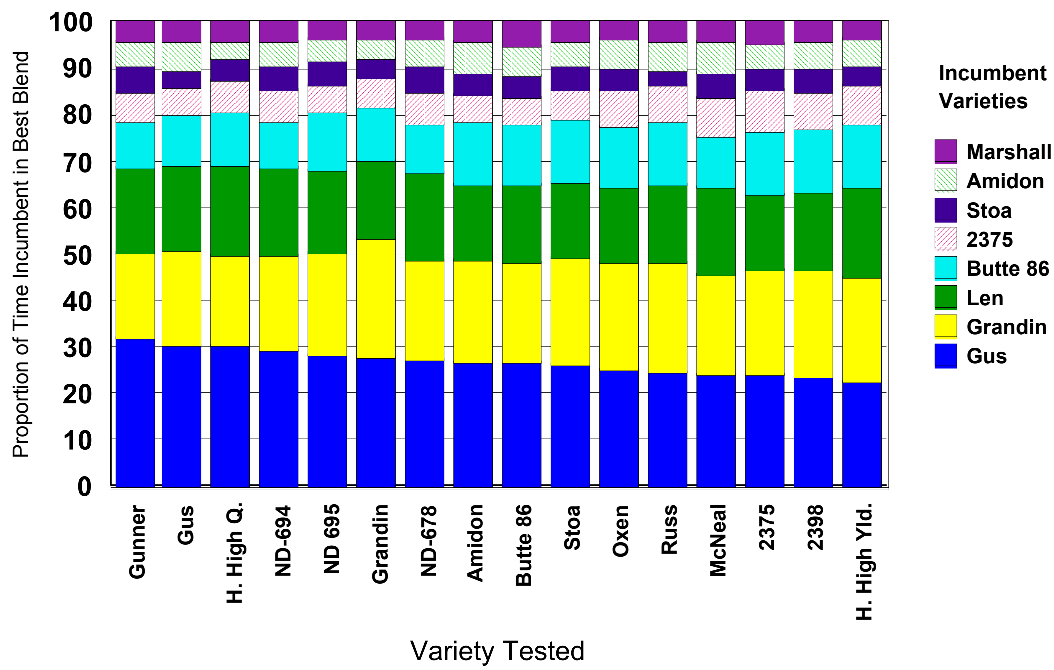

Figure 6. Comparison of the Composition of Best Blend of Incumbents by Variety Tested, End-use Model: Base Case.

Grower Model: Base Case

Models were used to compare grower value to the incumbent varieties for each of the five new varieties. Using simulation values for average utility, certainty equivalents were derived for all incumbent and new varieties being evaluated (Table 6 and Figure 7).

Table 6. Estimated Certainty Equivalent Income, by Variety, Base Case.

New and Hypothetical Varieties		Incumbent Varieties	
Variety	Certainty Equivalent Income	Variety	Certainty Equivalent Income
	Income/A		Income/A
ND 678	184.02	2375	183.47
ND 694	202.28	2398	168.75
ND 695	213.12	Amidon	172.82
H. High Qual.	190.74	Butte 86	173.07
H. High Yld.	209.18	Grandin	177.77
		Gunner	214.43
		Gus	180.42
		McNeal	189.41
		Oxen	186.81
		Russ	178.05
		Stoa	170.36

Estimated certainty equivalent incomes ranged from $169-$190/A. Results for many of the incumbent varieties indicate lower certainty equivalent incomes than for the experimental varieties. Of the incumbent varieties, 2398 had the lowest certainty equivalent of $169/A, while Gunner had the highest value to growers among all incumbents ($214/A). Of the new varieties, all but ND 678 had higher certainty equivalent incomes than the incumbent varieties except for Gunner. ND 678 had a higher grower value than all but Gunner, McNeal, and Oxen.

The probability that the utility of income for new/hypothetical varieties exceeded that of incumbent varieties was derived through simulation (Figure 8). ND 695 was most likely to have higher utility of income than incumbent varieties. The probability that ND 695 had higher utility of income than incumbents was .21. This was followed by the Hypothetical High Quality (.186), the Hypothetical High Yield (.178), ND 694 (.150), and ND 678 (.099) varieties.

These probabilities indicate the proportion of simulated years where utility would be greater for the newer variety than that of any of the incumbent varieties. Since Gunner (an incumbent variety) has the greatest certainty equivalent income, it is expected that the proportion of time that new varieties exceed that of incumbents would be less.

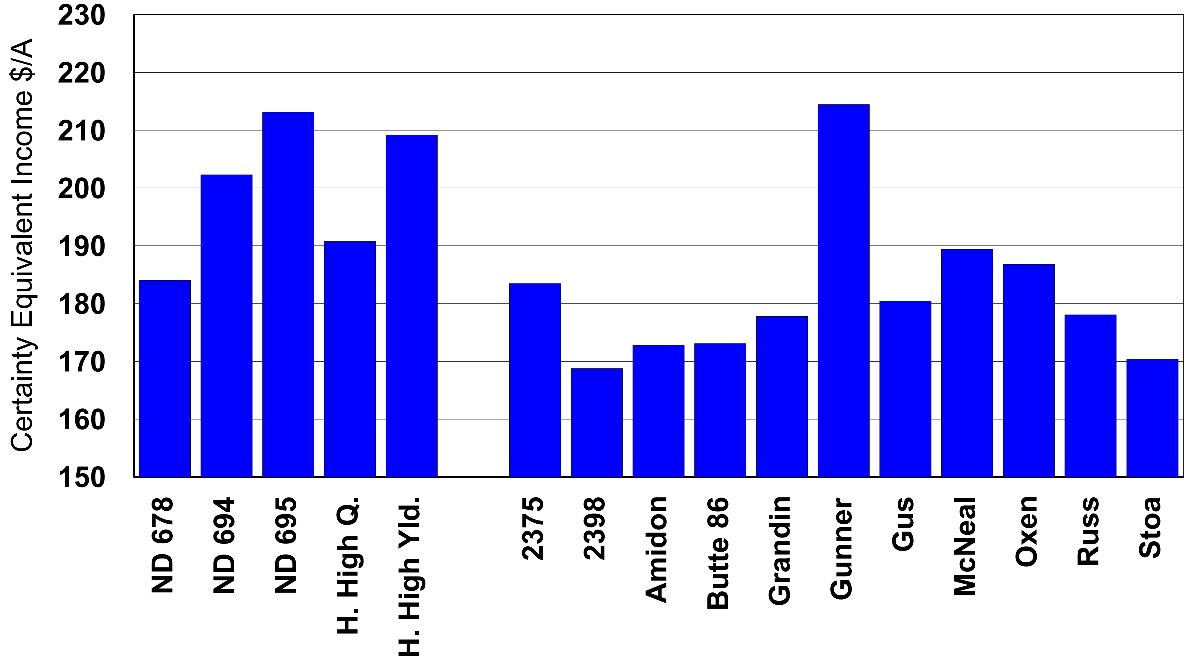

Figure 7. Certainty Equivalent Income/Acre, by Variety, Base Case.

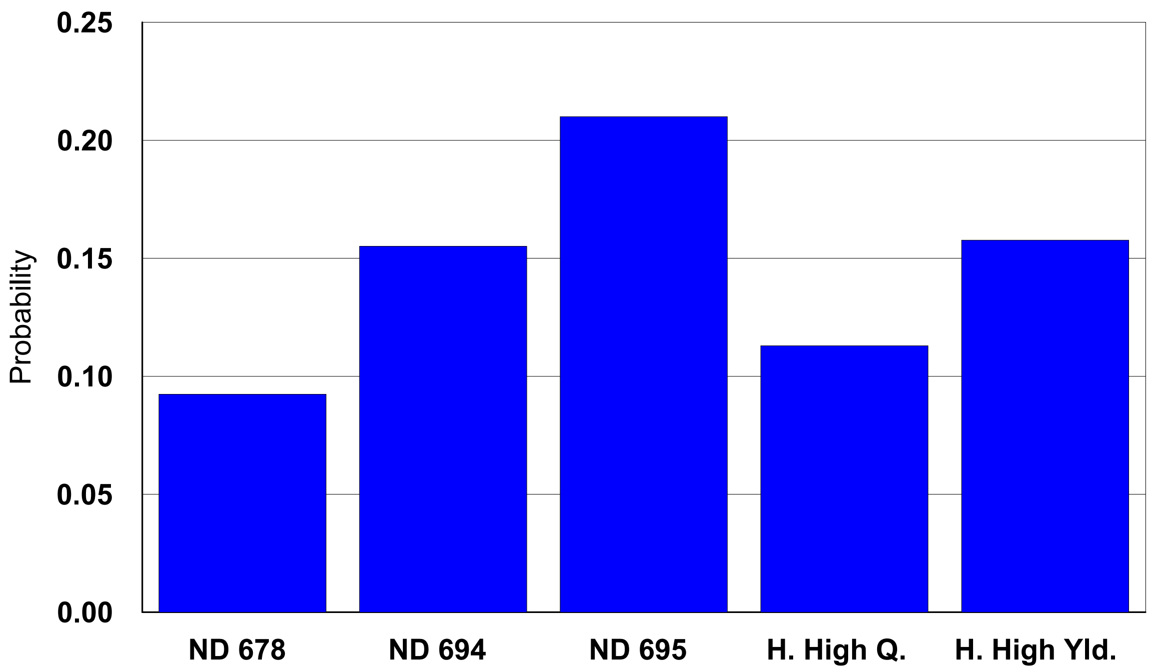

Figure 8. Probability that Utility of Income for New/Hypothetical Varieties Exceed that of Incumbent Varieties.

Sensitivities

A constant relative risk aversion coefficient of .5 was assumed in the base case grower model. Since the value of relative risk aversion coefficients varies by grower, the grower valuations were examined over a range of relative risk aversions, ranging from .1 to .9.

Certainty equivalent incomes suggest growers may respond differently depending on their level of risk aversion when evaluating both new and incumbent varieties (Figure 9). For example, less risk averse growers (lower relative risk aversion coefficients) would prefer ND 678 over 2375, McNeal over the Hypothetical High Quality variety, and Amidon over Butte 86. More risk averse growers (higher relative risk aversion coefficients) would prefer 2375 over ND 678, the Hypothetical High Quality variety over McNeal, and Butte 86 over Amidon. Similarly, the more risk averse growers would view the difference between ND 695 and the Hypothetical High Yield variety as smaller than would the less risk averse growers.

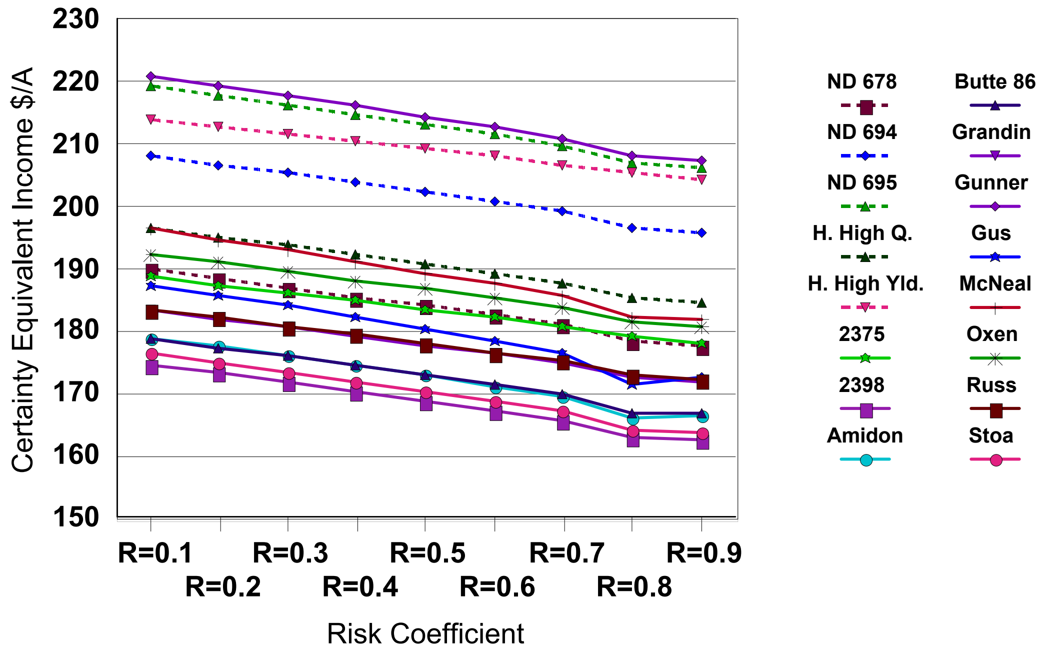

Figure 9. **Sensitivity of Certainty Equivalent Income by Variety to the Relative Risk Aversion Coefficient.**

Comparison of Grower and End-use Values

Results from both grower and end-user models were combined to demonstrate potential tradeoffs among varieties. This provides insight into how new varieties are valued in relation to existing varieties. Two figures are presented. The first shows mean values for end-users against the certainty equivalent income of growers for each variety (Figure 10). The second, shows the range of end-use value (± 2 standard deviation units from mean) (Figure 11). This provides insight into the prospective range of end-use values and how they compare to incumbents.

Comparison of mean end-use values and grower certainty equivalent incomes indicate that many of the newer and hypothetical varieties provide greater grower income than incumbents (Figure 10). Most notable of these are ND 695, ND 694, Gunner, and the Hypothetical High Yield variety. All of these varieties have grower values that are $10-$25/A greater than other varieties. Similarly, Gunner, ND 694, and the Hypothetical High Quality variety dominate end-use value of incumbents (are rightward of incumbents). Other comparisons can also be derived from these relationships. For example, ND 694 is worth 20 cents/bu more to end-users than is ND 695, but growers would prefer the latter because of its $10/A higher certainty equivalent income.

Comparison of grower values to the prospective range of end-use values reveals additional information. The varieties Gunner, ND 694, and the Hypothetical High Quality variety would provide end-use value greater than that of the best of the base incumbent varieties a high proportion of the time (Figure 11). ND 695, McNeal, and Oxen also are able to exceed quality of
the best of the incumbent varieties, but for a lesser proportion of the time. All of these varieties reflect a technical improvement in end-use quality.

This methodology for comparing variety value is somewhat limited due to the complexity of incorporating risk preferences. Further, there is a need for either a sensitivity analysis or risk based models that provide comparisons for higher moments of the distribution other than the mean.

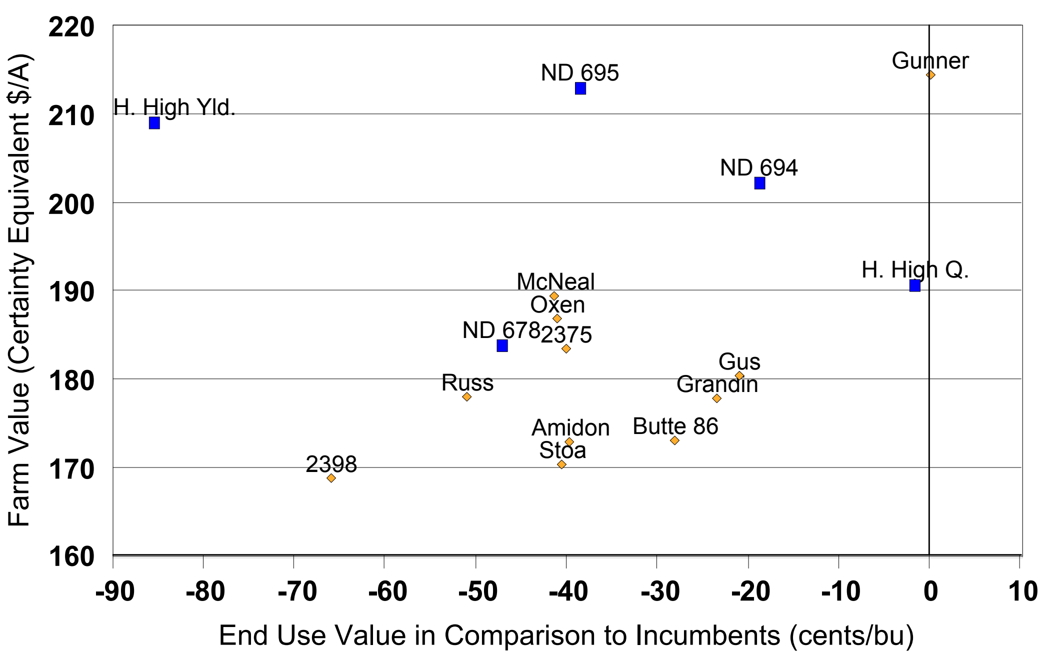

Figure 10. Relationship of Grower Value to Mean End-user Value.

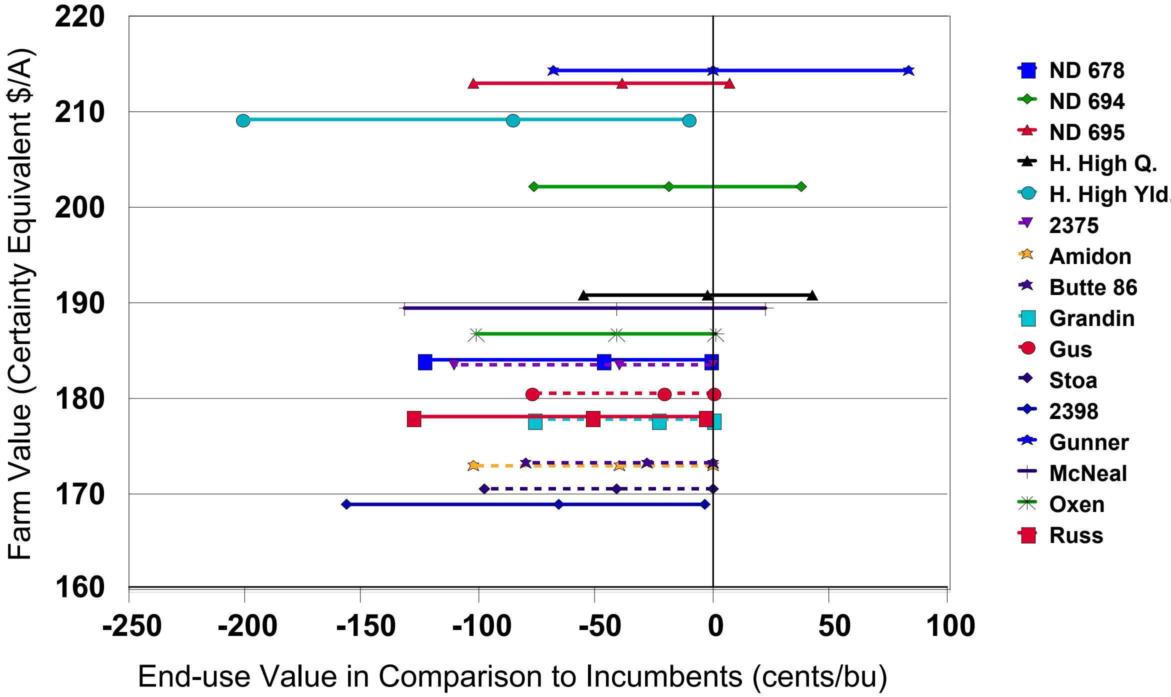

Figure 11. Relationship of Grower Value to Range (+-2 Standard Deviation Units) of End-use Values.

Sensitivity of Valuation for Individual Characteristics

A sensitivity analysis was used to evaluate how different levels of characteristics affect the value of a new variety. This was done by examining values for a new variety which was similar to ND 694 except for a higher level of a specific characteristic. This was replicated for several individual characteristics utilizing one percent changes in characteristic levels. One exception to this was the head scab resistance rating for which a new variety was examined that was one rating category more resistant to head scab than ND 694.

Grower and end-user values were affected differently depending on the characteristic (Figure 12). For example, one percent changes in protein and yield had the largest impacts on grower value. A one percent higher wheat protein increased grower value by $2.92/A, while one percent higher yields increased grower value by $2.17/A. Yields had no affect on end-use value and the effect of protein on end-use value was less than that of either extraction or absorption. The effect of a one percent change in absorption had the highest effect on end-use value (+4 cents/bu), followed by flour extraction which increased grower value by 3 cents/bu. The effect of a one unit change in head scab rating increased grower value by 27 cents/A. This result should be interpreted with caution in that it represents value throughout the state. The value to growers in specific areas where vomitoxin is more likely to occur could be higher.

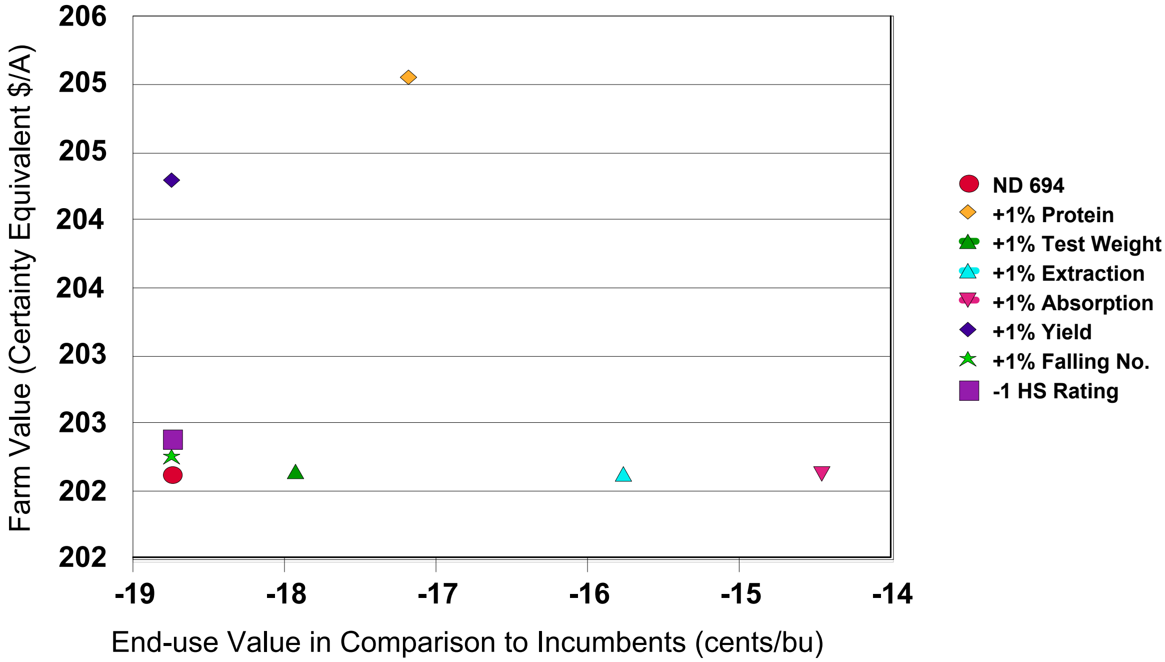

Figure 12. Sensitivity of Grower/End-use Value to Changes in Individual Wheat/Quality Characteristics.

Alternate End-use Valuation

An alternative model was estimated where varieties were valued only on protein and test weight (marginal values for other characteristics set to zero value). These are the characteristics normally measured in the market and where premiums and discounts are explicitly applied. Results of this end-use model were compared to certainty equivalent incomes of the base case grower model. Comparison of the tradeoffs for the alternative end-use values with those in the base case indicate some differences (Figures 13-14). First, average end-use values for many of the varieties were higher (less negative) than in the base case. For example, ND 694 increased in value from -19 cents/bu to -15 cents/bu, while ND 695 increased from -39 cents/bu to -23 cents/bu. Gunner actually declined in end-use value, moving from a slightly positive to a slightly negative value. The Hypothetical High Quality variety also decreased significantly in value. It declined from having just a slightly negative value to an average mean value of near -20 cents/bu. This indicates that this potential variety is getting a significant portion of end-use value from higher extraction and absorption rates.

Examination of changes in the range of end-use values are less dramatic, except for the two hypothetical varieties. Values for the higher quality variety had a smaller range and were more negative, on average, than in the base case. This suggests that this potential variety would have lower end-use value than if we consider contributions of extraction and absorption rates. In contrast, the higher yielding variety increased end-use value with a portion of the potential range of end-use values exceeding that of incumbents. This is dramatically higher than that in the base case where none of the range for the higher yielding variety exceeded the value of incumbents.

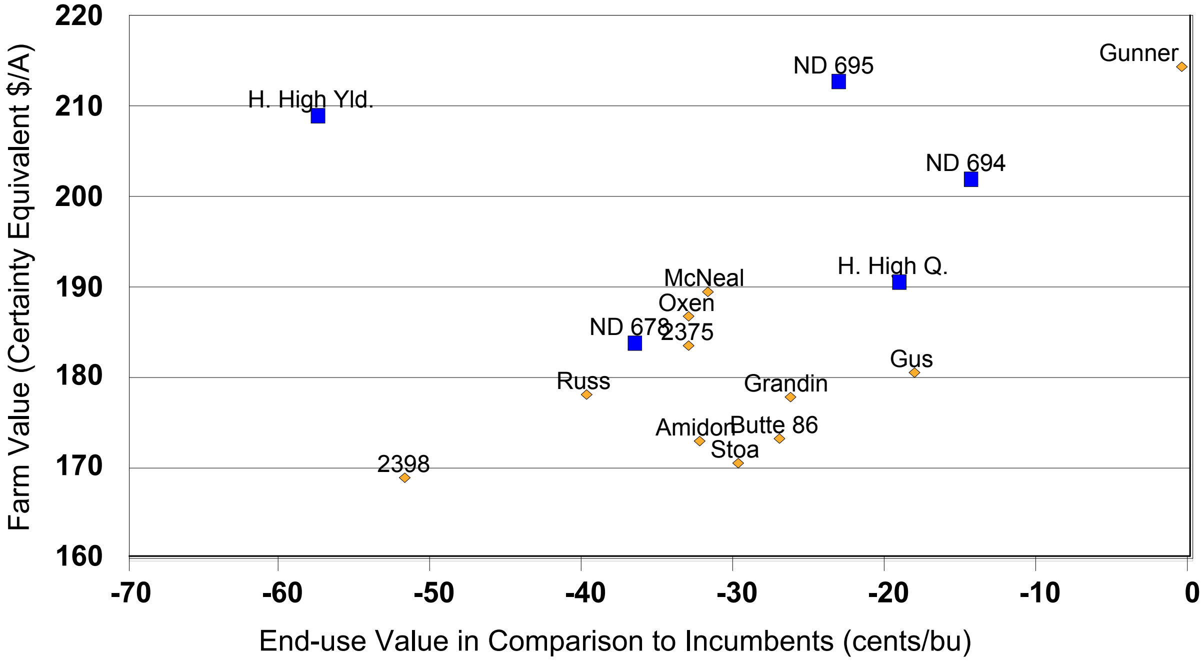

Figure 13. Relationship of Mean Alternative End-use Value (Protein and Test Weight Only) with Grower Certainty Equivalent Incomes.

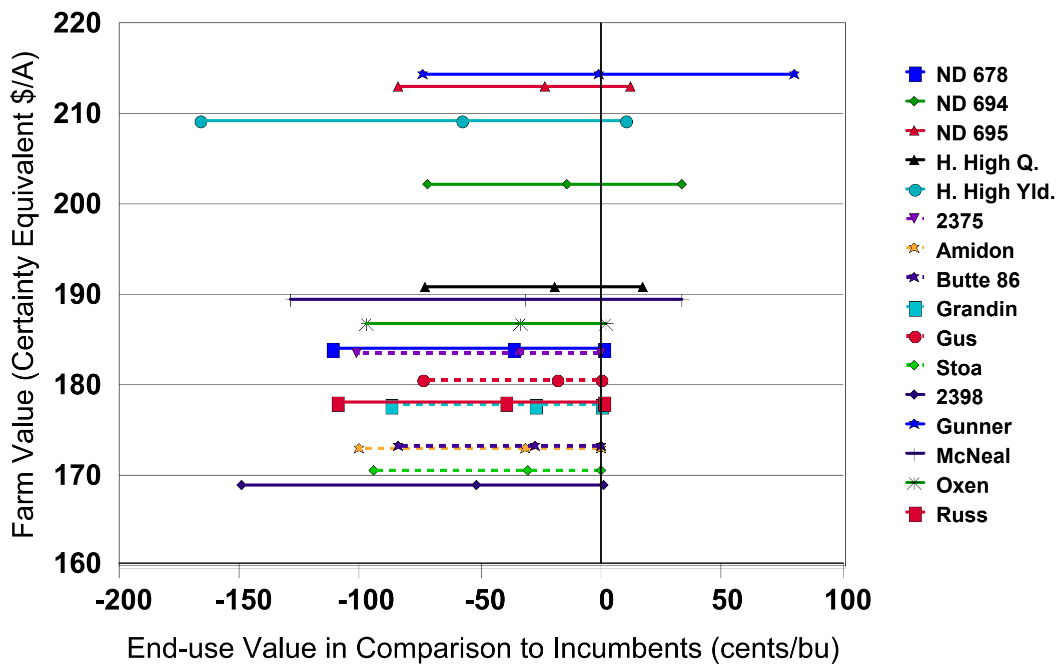

Figure 14. Relationship of Range of Alternative End-use Values (Protein and Test Weight Only) with Grower Certainty Equivalent Incomes.

Under this alternative valuation for end-use, the experimental varieties have a higher valuation than they did under the base case. This indicates that under this alternative valuation, the experimental varieties are closer to the frontier than they are in the base case. These results differ from the base case in that they reflect currently applied market premiums and discounts. In contrast, the base case also incorporates implicit premiums and discounts for higher/lower extraction and absorption rates which are not reflected in current industry practices.

Effect of Protein Premiums

The effect of changes in the distribution of protein premiums was also examined. Mean protein premiums and discounts in the base case were doubled (i.e., premiums for protein > 14 percent were raised to 80 cents/bu/percentage point while discounts for protein less than 14 percent were increased to 28 cents/bu/percentage point). Then, the variability of protein premiums was reduced (i.e., premiums and discounts were assumed fixed at mean values).

Doubling protein premiums increased the grower value of higher protein varieties more than that for lower protein varieties (Table 7). Gunner, the highest protein variety, increased in grower value from \$214/A to \$230/A, an increase of \$15/A. In contrast, the variety 2398 increased in grower value by only \$1/A and the Hypothetical High Yield variety actually declined in grower value.

Table 7. Sensitivity of Grower Certainty Equivalent Income to Protein Premiums, by Variety.

New and Hypothetical Varieties				Incumbent Varieties			
Variety	Certainty Equivalent Income		Change	Variety	Certainty Equivalent Income		Change
	Base Case	Protein Premium Double			Base Case	Protein Premium Double	
ND 678	184.02	188.51	4.49	2375	183.47	189.12	5.65
ND 694	202.28	214.01	11.73	2398	168.75	169.93	1.18
ND 695	213.12	222.98	9.86	Amidon	172.82	178.77	5.95
H. High Qual.	190.74	202.70	11.96	Butte 86	173.07	180.58	7.51
H. High Yld.	209.18	208.29	-0.89	Grandin	177.77	185.67	7.90
				Gunner	214.43	229.79	15.36
				Gus	180.42	191.75	11.34
				McNeal	189.41	195.33	5.92
				Oxen	186.81	193.40	6.59
				Russ	178.05	181.58	3.53
				Stoa	170.36	177.10	6.74

Reducing the variability of protein premiums increased grower values of all varieties. Increased grower values ranged from a low of $0.30/A for Oxen to a high of $2.36/A for the Hypothetical High Yield variety (Table 8). Of the varieties that increased in value the most, some were lower protein varieties (Hypothetical High Yield variety and 2398) while others like McNeal had a larger standard deviation for wheat protein. This suggests that reducing variability of protein premiums increased grower values of varieties with lower and more variable wheat protein relative to those with more stable, moderate to higher levels of protein.

Table 8. Sensitivity of Grower Certainty Equivalent Income to Reduced Variability of Protein Premiums, by Variety.

New and Hypothetical Varieties				Incumbent Varieties			
Variety	Certainty Equivalent Income		Change	Variety	Certainty Equivalent Income		Change
	Base Case	Protein Premium Reduced Variability			Base Case	Protein Premium Reduced Variability	
ND 678	184.02	184.79	0.77	2375	183.47	184.70	1.23
ND 694	202.28	202.76	0.48	2398	168.75	170.74	1.99
ND 695	213.12	213.62	0.50	Amidon	172.82	173.82	1.00
H. High Qual.	190.74	191.33	0.59	Butte 86	173.07	173.58	0.52
H. High Yld.	209.18	211.54	2.36	Grandin	177.77	178.42	0.65
				Gunner	214.43	215.17	0.74
				Gus	180.42	181.13	0.71
				McNeal	189.41	191.09	1.68
				Oxen	186.81	187.11	0.30
				Russ	178.05	178.90	0.85
				Stoa	170.36	171.10	0.74

Effect of the LDP Program

During the 1980s, the development and adoption of varieties that were higher yielding, but of lower quality, were reinforced by the mechanics of the deficiency payment program. Under previous farmer legislation, deficiency payments were based on proven yields, and payments were in the range of 15 to 198 cents/bu. Though deficiency payments as they were defined in the 1980s have been discontinued, a surrogate program emerged in the 1996 farm bill called the Loan Deficiency Payment (LDP) program or marketing loan. The effect of the LDP program on grower value was examined by modifying the base case grower model to include payments for the LDP program. This was accomplished by adding revenue of 30 cents/bu[8] when the base wheat price was in the lowest 1/3 of the price distribution. This was utilized to reflect the historical occurrence of LDPs .[9]

Grower values for each of the varieties examined increased on average $4/A to $6/A (Figures 15-16). Butte 86 was affected least by the addition of the LDP program (value increased $4.39/A), while the Hypothetical High Yield variety increased in value $6.32/A. The difference in value over the base case for these two varieties is $1.93/A. Therefore, the addition of the LDP program had the effect of widening the advantage of higher yielding varieties over varieties with higher end-use quality. The increase in advantage of higher yielding varieties over lower yielding high quality varieties due to the LDP program was less than $2.00/A.

The sensitivity analysis provides perspective on effects of specific factors on value. However, to select varieties based on sensitivity analysis would require estimation of all sensitivity factors which may be unrealistic to simulate by breeders. Alternative risk based methods like stochastic dominance would be preferred for ranking varieties.

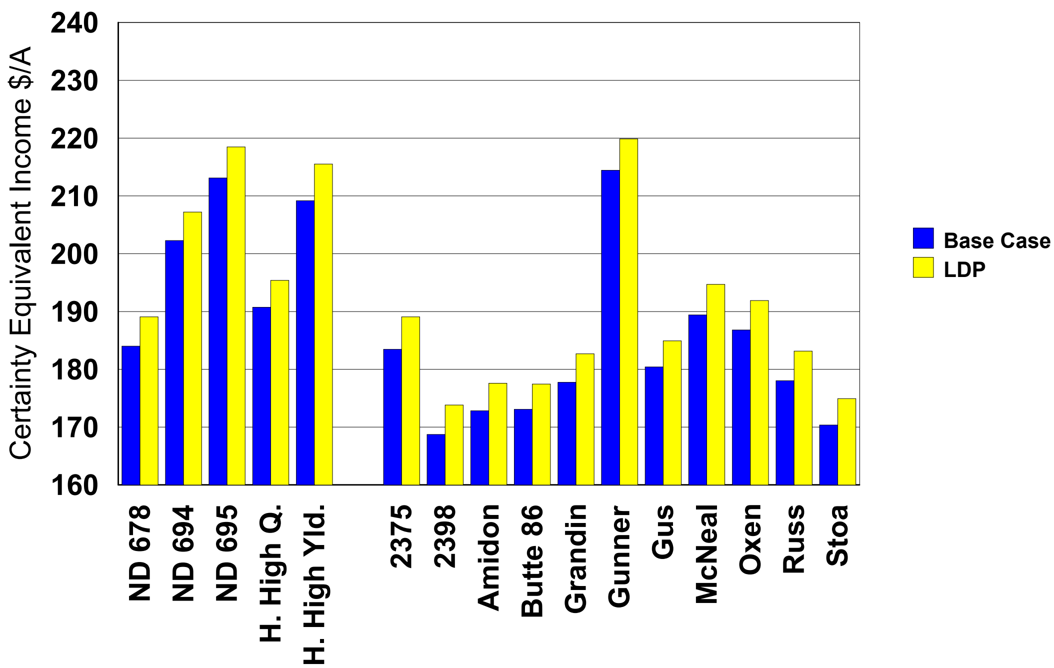

Figure 15. Comparison of Grower Value under Base Case and LDPs, by Variety.

---

[8] A rate of 30 cents/bu for LDPs was utilized and is similar to the rate applied by Westcott and Price when examining the effect of LDP provisions.

[9] LDPs for wheat occurred in 1998, 1999, and 2000. The potential for LDPs was assumed to be three years out of nine.

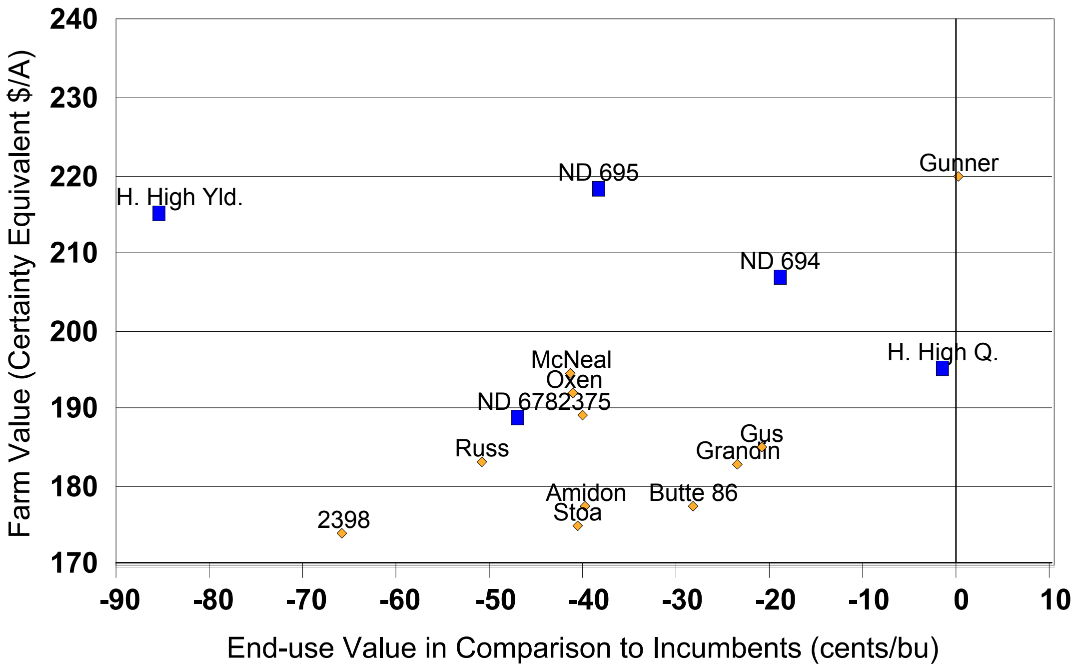

Figure 16. Relationship of Mean End-use Value with Grower Certainty Equivalent Incomes: Effect of LDPs.

STOCHASTIC DOMINANCE COMPARISON OF VARIETY VALUE

Values of varieties to end-users and growers can be compared to determine if specific varieties dominate or are preferred to another. Traditional stochastic dominance methods are one procedure for determining preferences (Hadar and Russell). However, these methods only determine dominance, not statistical significance and would be applied separately to end-user and grower values, thus not accounting for correlations or tradeoffs between end-users and growers. Several different methods have recently been advanced for assessment of the statistical significance of stochastic dominance (Tse and Zhang). These methods allow estimation of statistical significance of preferences, but also would be applied separately for grower and end-use values. McCarl et al. developed a portfolio method for ranking choices where two or more goals are involved. This procedure allows for simultaneous consideration of the multiple goals of end-users and growers when ranking varieties and considers correlations between values for the two groups.

In the next section, three separate analyses were conducted to evaluate the dominance of varieties over others. First, a traditional first and second order stochastic dominance analysis was conducted for end-use and grower values. Second, a statistical test for stochastic dominance was applied to determine if preferences identified in the traditional analysis for varieties were statistically significant. Third, a portfolio was constructed for each variety consisting of characteristics that provide value to both growers and end-users. This portfolio value was then compared to determine dominance of varieties.

For this analysis, grower values were determined by estimating the income for each variety relative to incumbent varieties. This definition of grower value is more comparable to the end-use value. Grower values were defined as:

$$GV_i = (I_i - Target_{b-n}) / Target_{b-n}$$

where:

GV_i	is grower value for variety i,
I_i	is income for variety i, and
$Target_{b-n}$	is average income for variety b-n where b-n are all incumbent varieties.

End-use values were estimated as before. However, to capture the effects of correlations between grower and end-use values that would be present in the portfolio model, a joint model was developed to estimate grower and end-use values for varieties simultaneously. This joint model utilized the same random draws for quality and agronomic characteristics of varieties to determine both end-use and grower values which were then used to estimate the value of the portfolio.

Traditional Stochastic Dominance of Grower and End-use Value of Varieties

Traditional methods for determining dominance include first and second degree stochastic dominance. In this section, the distributions of grower and end-use values for varieties were evaluated to determine which varieties dominate others. First and second degree stochastic dominance was tested through pairwise comparisons of varieties.

Following Hadar and Russell and Moss, the decision maker has a utility function U(x), defined on the outcomes of a random variable, x and chooses between two actions. For growers, this is the choice of producing either varieties a_1 or a_2 and x is per acre income. The returns for growing a variety are defined by the probability density function f(x) for variety a_1 and g(x) for variety a_2. First degree stochastic dominance (FDD) implies variety a_1 is preferred to a_2 if it is always expected to yield income at least equal to a_2, with a greater probability of earning income higher than a_2 for at least one income level. That is, variety a_1 dominates variety a_2 in the first degree if:

$$\widetilde{\Delta}_1 = G(x) - F(x) \geq 0 \;\; \forall \;\; x$$

with at least one strict inequality where G and F are cumulative distribution functions. FDD is a fairly weak criterion and tends to eliminate few alternatives.

Second degree stochastic dominance (SDD) is more discriminating because it includes higher moments of the distribution of returns and considers risk preferences of decision makers. SDD implies that the area under the cumulative density functions for *f* are always less than for *g*. Variety a_1 dominates variety a_2 in the second degree if:

$$\widetilde{\Delta}_2 = \int_a^x [G(z) - F(z)]dz \geq 0 \;\; \forall \;\; x$$

with at least one strict inequality.

Determination of FDD involves elimination of varieties that are dominated by others. This involves solving a sequence of binary comparisons:

$$\widetilde{\Delta}_1^i = \inf_x \; G(x) - F(x)$$

$$\widetilde{\Delta}_1^s = \sup_x \; G(x) - F(x)$$

where if the signs of inf and sup are positive, then *f* dominates *g*, if they are negative, then *g* dominates *f*, and if opposite signs, then there is no FDD.

For SDD, the binary comparisons are:

$$\widetilde{\Delta}_1^i = \inf_x \int_a^x [G(z) - F(z)]dz$$

$$\widetilde{\Delta}_1^s = \sup_x \int_a^x [G(z) - F(z)]dz$$

where the same rules apply.

A standard approach by Goh et al. is to assume a stepwise cumulative probability density function where:

$$F(x) = \frac{N^*[y \le x]}{N}$$

where F(x) is the cumulative density function, $N^*[y \le x]$ is the number of observations less than or equal to the index value, and N is the sample size. A similar distribution is estimated for G(x) which allows comparisons of the two alternatives.

The Goh et al. procedure was utilized to compute inf and sup statistics for pairwise comparisons of varieties. These are shown in Appendix Tables 1a-2b for grower value and Appendix Tables 3a-4b for end-use value. Comparison of these inf and sup statistics, reveals varieties that FDD dominate others for grower values (Table 9) and end-use values (Table 10) and SDD dominate others for grower values (Table 11) and end-use values (Table 12).

Comparing FDD for varieties for grower values indicates many varieties are dominated. For example, 2375, a variety which is somewhat tolerant to vomitoxin, dominates many varieties that have higher end-use quality such as Amidon, Grandin, Gus, Stoa, etc. The grower value for 2375 is dominated by most of the experimental and hypothetical varieties.

Many comparisons indicate there is no dominance using FDD of varieties for end-use value. Further, for those varieties that dominated others for grower value, many of these switched dominance. Specifically, 2375 dominates both Butte 86 and Grandin for grower value, but, both Butte 86 and Grandin dominate 2375 for end-use value. Results for SDD for grower value largely show varieties are dominated by or dominate others. The only variety not exhibiting dominance is Gus. Gus does not dominate or is not dominated by many of the current varieties (Amidon, Butte 86, Grandin, Stoa, 2398, and Russ). For end-use value, the number of variety comparisons having dominance for SDD increased dramatically over those identified using FDD for end-use values.

The switching of dominance, depending on whether grower and end-user value are utilized, indicates the tradeoffs between groups for selected varieties. Further, it highlights the need for simultaneous evaluation of value across growers and end-users.

Table 9. Results of Estimated First Degree Stochastic Dominance for Paired Comparisons of Varieties from Traditional Step Function Methods for Grower Value.

Variety Y	Variety Z															
	2375	Amidon	Butte 86	Grandin	Gus	Stoa	2398	Gunner	McNeal	Oxen	Russ	ND 678	ND 694	ND 695	H. High Q.	H. High Yld
2375		1	1	1	1	1	1	3	3	3	1	3	2	2	2	2
Amidon	2		1	2	3	1	1	2	2	2	2	2	2	2	2	2
Butte 86	2	2		2	3	1	1	2	2	2	2	2	2	2	2	2
Grandin	2	1	1		3	1	1	2	2	2	2	2	2	2	2	2
Gus	2	3	3	3		3	3	2	2	2	3	2	2	2	2	2
Stoa	2	2	2	2	3		1	2	2	2	2	2	2	2	2	2
2398	2	2	2	2	3	2		2	2	2	2	2	2	2	2	2
Gunner	3	1	1	1	1	1	1		1	1	3	1	3	3	3	3
McNeal	3	1	1	1	1	1	1	2		1	3	1	2	2	2	2
Oxen	3	1	1	1	1	1	1	2	2		3	1	2	2	2	2
Russ	2	1	1	1	3	1	1	3	3	3		3	2	2	2	2
ND 678	3	1	1	1	1	1	1	2	2	2	3		2	2	2	2
ND 694	1	1	1	1	1	1	1	3	1	1	1	1		2	1	2
ND 695	1	1	1	1	1	1	1	3	1	1	1	1	1		1	1
H. High Q.	1	1	1	1	1	1	1	3	1	1	1	1	2	2		2
H. High Yld	1	1	1	1	1	1	1	3	1	1	1	1	1	2	1	

1 = Variety Y Dominates Z
2 = Variety Z Dominates Y
3 = No Dominance Identified

Table 10. Results of Estimated First Degree Stochastic Dominance for Paired Comparisons of Varieties from Traditional Step Function Methods for End-use Value.

Variety Y	Variety Z															
	2375	Amidon	Butte 86	Grandin	Gus	Stoa	2398	Gunner	McNeal	Oxen	Russ	ND 678	ND 694	ND 695	H. High Q.	H. High Yld
2375		3	2	2	3	3	3	3	3	3	3	3	2	3	2	3
Amidon	3		3	2	3	3	3	3	3	3	3	3	3	3	3	3
Butte 86	1	3		2	3	3	3	3	3	3	3	3	2	3	2	3
Grandin	1	1	1		3	1	3	3	3	3	3	3	3	3	3	3
Gus	3	3	3	3		3	3	3	3	3	3	3	3	3	2	3
Stoa	3	3	3	2	3		3	3	3	3	3	3	3	3	3	3
2398	3	3	3	3	3	3		3	3	3	3	3	2	2	2	1
Gunner	3	3	3	3	3	3	3		3	3	3	3	3	3	3	1
McNeal	3	3	3	3	3	3	3	3		3	3	3	3	3	3	1
Oxen	3	3	3	3	3	3	3	3	3		3	1	2	3	2	1
Russ	3	3	3	3	3	3	3	3	3	3		3	2	3	2	3
ND 678	3	3	3	3	3	3	3	3	3	2	3		2	3	2	3
ND 694	1	3	1	3	3	3	1	3	3	1	1	1		3	3	1
ND 695	3	3	3	3	3	3	1	3	3	3	3	3	3		3	1
H. High Q.	1	3	1	3	1	3	1	3	3	1	1	1	3	3		1
H. High Yld.	3	3	3	3	3	3	2	2	2	2	3	3	2	2	2	

1 = Variety Y Dominates Z
2 = Variety Z Dominates Y
3 = No Dominance Identified

Table 11. Results of Estimated Second Degree Stochastic Dominance for Paired Comparisons of Varieties from Traditional Step Function Methods for Grower Value.

Variety Y	Variety Z															
	2375	Amidon	Butte 86	Grandin	Gus	Stoa	2398	Gunner	McNeal	Oxen	Russ	ND 678	ND 694	ND 695	H. High Q.	H. High Yld
2375		1	1	1	1	1	1	2	2	2	1	2	2	2	2	2
Amidon	2		1	2	3	1	1	2	2	2	2	2	2	2	2	2
Butte 86	2	2		2	3	1	1	2	2	2	2	2	2	2	2	2
Grandin	2	1	1		3	1	1	2	2	2	2	2	2	2	2	2
Gus	2	3	3	3		3	3	2	2	2	3	2	2	2	2	2
Stoa	2	2	2	2	3		1	2	2	2	2	2	2	2	2	2
2398	2	2	2	2	3	2		2	2	2	2	2	2	2	2	2
Gunner	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1
McNeal	1	1	1	1	1	1	1	2		1	1	1	2	2	2	2
Oxen	1	1	1	1	1	1	1	2	2		1	1	2	2	2	2
Russ	2	1	1	1	3	1	1	2	2	2		2	2	2	2	2
ND 678	1	1	1	1	1	1	1	2	2	2	1		2	2	2	2
ND 694	1	1	1	1	1	1	1	2	1	1	1	1		2	1	2
ND 695	1	1	1	1	1	1	1	2	1	1	1	1	1		1	1
H. High Q.	1	1	1	1	1	1	1	2	1	1	1	1	2	2		2
H. High Yld	1	1	1	1	1	1	1	2	1	1	1	1	1	2	1	

1 = Variety Y Dominates Z
2 = Variety Z Dominates Y
3 = No Dominance Identified

Table 12. Results of Estimated Second Degree Stochastic Dominance for Paired Comparisons of Varieties from Traditional Step Function Methods for End-use Value.

Variety Y	Variety Z															
	2375	Amidon	Butte 86	Grandin	Gus	Stoa	2398	Gunner	McNeal	Oxen	Russ	ND 678	ND 694	ND 695	H. High Q.	H. High Yld
2375		2	2	2	3	3	1	3	3	3	3	1	2	3	2	1
Amidon	1		3	2	3	3	1	3	1	1	1	1	3	3	3	1
Butte 86	1	3		2	3	3	1	3	1	1	1	1	2	3	2	1
Grandin	1	1	1		3	1	1	3	1	1	1	1	3	1	3	1
Gus	3	3	3	3		3	3	3	3	3	3	3	3	3	2	1
Stoa	3	3	3	2	3		1	3	1	1	1	1	3	3	3	1
2398	2	2	2	2	3	2		3	2	2	2	2	2	2	2	1
Gunner	3	3	3	3	3	3	3		3	3	3	3	3	3	3	1
McNeal	3	2	2	2	3	2	1	3		3	3	3	2	2	2	1
Oxen	3	2	2	2	3	2	1	3	3		3	1	2	3	2	1
Russ	3	2	2	2	3	2	1	3	3	3		3	2	3	2	1
ND 678	2	2	2	2	3	2	1	3	3	2	3		2	2	2	1
ND 694	1	3	1	3	3	3	1	3	1	1	1	1		1	2	1
ND 695	3	3	3	2	3	3	1	3	1	3	3	1	2		2	1
H. High Q.	1	3	1	3	1	3	1	3	1	1	1	1	1	1		1
H. High Yld.	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	

1 = Variety Y Dominates Z
2 = Variety Z Dominates Y
3 = No Dominance Identified

Significance Tests of Stochastic Dominance

The second procedure for comparing dominance of varieties is a statistical test developed to assess the significance of dominance. This evaluates the stochastic dominance identified in the prior analysis and determines whether the observed stochastic dominance of variety a_1 over variety a_2 is statistically significant. Tse and Zhang examined a number of methods that assess the statistical significance of dominance and compared them. They identified the Davidson Duclos test as most appropriate based on the power of the test. This test was utilized to evaluate first and second degree dominance for both grower and end-use values.

Davidson and Duclos considered the following sample statistics for alternatives Y and Z:

$$\hat{D}_Y^s(x) = \frac{1}{N(s-1)!}\sum_{i=1}^{N}(x-y_i)_+^{s-1},$$

$$\hat{D}_Z^s(x) = \frac{1}{N(s-1)!}\sum_{i=1}^{N}(x-z_i)_+^{s-1},$$

$$\hat{V}_Y^s(x) = \frac{1}{N}\left[\frac{1}{((s-1)!)^2}\frac{1}{N}\sum_{i=1}^{N}(x-y_i)_+^{2(s-1)} - \hat{D}_Y^s(x)^2\right],$$

$$\hat{V}_Z^s(x) = \frac{1}{N}\left[\frac{1}{((s-1)!)^2}\frac{1}{N}\sum_{i=1}^{N}(x-z_i)_+^{2(s-1)} - \hat{D}_Z^s(x)^2\right],$$

$$\hat{V}_{Y,Z}^s(x) = \frac{1}{N}\left[\frac{1}{((s-1)!)^2}\frac{1}{N}\sum_{i=1}^{N}(x-y_i)_+^{(s-1)}(x-z_i)_+^{(s-1)} - \hat{D}_Y^s(x)\hat{D}_Z^s(x)\right]$$

where s = degree of dominance test, N is number of samples,

They proposed the following normalized statistic:

$$T^s(x) = \frac{\hat{D}_Y^s(x) - \hat{D}_Z^s(x)}{\sqrt{\hat{V}^s(x)}}$$

where

$$\hat{V}^s(x) = \hat{V}_Y^s(x) + \hat{V}_Z^s(x) - 2\hat{V}_{Y,Z}^s(x)$$

However, if we assume that observations from the two distributions being compared are independent, then: $\hat{V}^s(x) = \hat{V}_Y^s(x) + \hat{V}_Z^s(x)$ and the normality results still holds.

Using these estimated statistics, Tse and Zhang indicate the following hypotheses to test for significance:

1. $H_O: \hat{D}_Y^s(x_i) = \hat{D}_Z^s(x_i)$ for all x_i,
2. $H_A: \hat{D}_Y^s(x_i) \neq \hat{D}_Z^s(x_i)$ for some x_i,
3. $H_{A1}: Y \succ_s Z$,
4. $H_{A2}: Z \succ_s Y$.

Then they advance the following decision rules to assess each of the hypothesis:

1. If $\left|T^s(x_i)\right| < M_{\infty,\alpha}^K$ for i=1,...,K accept H_O.
2. If $-T^s(x_i) > M_{\infty,\alpha}^K$ for some i and $T^s(x_i) < M_{\infty,\alpha}^K$ for all i, accept H_{A1}.
3. If $T^s(x_i) > M_{\infty,\alpha}^K$ for some i and $-T^s(x_i) < M_{\infty,\alpha}^K$ for all i, accept H_{A2}.
4. If $T^s(x_i) > M_{\infty,\alpha}^K$ for some i and $-T^s(x_i) > M_{\infty,\alpha}^K$ for all i, accept H_A.

Where $M_{\infty,\alpha}^K$ is the studentized maximum modulus statistic with K and infinite degrees of freedom.

Test statistics were generated for each *i* and results of the hypothesis tests are shown in Tables 13-16. Results of tests of hypotheses for grower value indicate that for FDD, a number of variety comparisons were not statistically significant where dominance had been identified using the traditional step function analysis. For example, grower value of 2375 was indicated to dominate Butte 86, Grandin, Amidon, and Russ among others and the Hypothetical High Quality variety dominated 2375. However, these varieties were not statistically different from 2375. Further, for some pairwise comparisons where the traditional step function indicated no dominance, the significance tests indicated a FDD for grower value. For example, grower value of Gunner was identified as statistically dominating 2375 and Gus was identified as being dominated by Amidon, Butte 86, and Grandin, yet the traditional step function indicated no FDD.

Results for FDD of end-use values indicate more varieties dominate others than from the traditional analysis. For example, Amidon Stoa, and ND 695 dominate 2375, while the traditional FDD did not identify any of these as dominant. Further, a number of comparisons indicated that distributions were different but dominance was not identified.

Table 13. Results of Hypothesis Tests for First Degree Stochastic Dominance for Grower Values, by Variety.

Variety Y	Variety Z															
	2375	Amidon	Butte 86	Grandin	Gus	Stoa	2398	Gunner	McNeal	Oxen	Russ	ND 678	ND 694	ND 695	H. High Q.	H. High Yld
2375		3	3	3	1	1	1	2	3	3	3	3	2	2	3	2
Amidon	3		3	3	1	3	3	2	2	2	3	3	2	2	2	2
Butte 86	3	3		3	1	3	3	2	2	2	3	3	2	2	2	2
Grandin	3	3	3		1	3	3	2	3	3	3	3	2	2	3	2
Gus	2	2	2	2		2	2	2	2	2	2	2	2	2	2	2
Stoa	2	3	3	3	1		3	2	2	2	3	2	2	2	2	2
2398	2	3	3	3	1	3		2	2	2	3	2	2	2	2	2
Gunner	1	1	1	1	1	1	1		1	1	1	1	1	3	1	3
McNeal	3	1	1	3	1	1	1	2		3	3	3	3	2	3	2
Oxen	3	1	1	3	1	1	1	2	3		3	3	2	2	3	2
Russ	3	3	3	3	1	3	3	2	3	3		3	2	2	3	2
ND 678	3	3	3	3	1	1	1	2	3	3	3		2	2	3	2
ND 694	1	1	1	1	1	1	1	2	3	1	1	1		3	3	3
ND 695	1	1	1	1	1	1	1	3	1	1	1	1	3		1	3
H. High Q.	3	1	1	3	1	1	1	2	3	3	3	3	3	2		2
H. High Yld	1	1	1	1	1	1	1	3	1	1	1	1	3	3	1	

1 = Variety Y Statistically Dominates Z at P=.05.
2 = Variety Z Statistically Dominates Y at P=.05
3 = No Significant Statistical Difference Between Variety Y and Z at p=.05.
4 = Variety Y is Statistically Different From Z at P=.05, however Z does not dominate Y and Y does not dominate Z at P=.05.

Table 14. Results of Hypothesis Tests for First Degree Stochastic Dominance for End-use Values, by Variety.

Variety Y	Variety Z															
	2375	Amidon	Butte 86	Grandin	Gus	Stoa	2398	Gunner	McNeal	Oxen	Russ	ND 678	ND 694	ND 695	H. High Q.	H. High Yld
2375		2	2	2	4	2	1	4	4	4	4	4	2	2	2	1
Amidon	1		4	2	4	1	1	4	1	4	1	1	4	1	4	1
Butte 86	1	4		2	4	4	1	4	1	4	1	1	2	4	2	1
Grandin	1	1	1		1	1	1	4	1	1	1	1	4	1	4	1
Gus	4	4	4	2		4	4	4	4	4	4	4	4	4	2	1
Stoa	1	2	4	2	4		1	4	1	4	1	1	4	1	4	1
2398	2	2	2	2	4	2		4	2	2	2	2	2	2	2	1
Gunner	4	4	4	4	4	4	4		4	4	4	4	4	4	2	1
McNeal	4	2	2	2	4	2	1	4		4	2	4	2	2	2	1
Oxen	4	4	4	2	4	4	1	4	4		4	1	2	4	2	1
Russ	4	2	2	2	4	2	1	4	1	4		4	2	4	2	1
ND 678	4	2	2	2	4	2	1	4	4	2	4		2	2	2	1
ND 694	1	4	1	4	4	4	1	4	1	1	1	1		1	2	1
ND 695	1	2	4	2	4	2	1	4	1	4	4	1	2		2	1
H. High Q.	1	4	1	4	1	4	1	1	1	1	1	1	1	1		1
H. High Yld.	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	

1 = Variety Y Statistically Dominates Z at P=.05.
2 = Variety Z Statistically Dominates Y at P=.05
3 = No Significant Statistical Difference Between Variety Y and Z at p=.05.
4 = Variety Y is Statistically Different From Z at P=.05, however Z does not dominate Y and Y does not dominate Z at P=.05.

Table 15. Results of Hypothesis Tests for Second Degree Stochastic Dominance for Grower Values, by Variety.

Variety Y	Variety Z															
	2375	Amidon	Butte 86	Grandin	Gus	Stoa	2398	Gunner	McNeal	Oxen	Russ	ND 678	ND 694	ND 695	H. High Q.	H. High Yld
2375		3	3	3	1	1	1	2	3	3	3	3	2	2	3	2
Amidon	3		3	3	1	3	3	2	2	2	3	2	2	2	2	2
Butte 86	3	3		3	1	3	3	2	2	2	3	2	2	2	2	2
Grandin	3	3	3		1	3	3	2	2	3	3	3	2	2	2	2
Gus	2	2	2	2		4	4	2	2	2	2	2	2	2	2	2
Stoa	2	3	3	3	4		3	2	2	2	3	2	2	2	2	2
2398	2	3	3	3	4	3		2	2	2	3	2	2	2	2	2
Gunner	1	1	1	1	1	1	1		1	1	1	1	1	3	1	3
McNeal	3	1	1	1	1	1	1	2		3	1	3	2	2	3	2
Oxen	3	1	1	3	1	1	1	2	3		3	3	2	2	3	2
Russ	3	3	3	3	1	3	3	2	2	3		3	2	2	2	2
ND 678	3	3	3	3	1	1	1	2	3	3	3		2	2	3	2
ND 694	1	1	1	1	1	1	1	2	1	1	1	1		2	1	2
ND 695	1	1	1	1	1	1	1	3	1	1	1	1	1		1	3
H. High Q.	3	1	1	1	1	1	1	2	3	3	1	3	2	2		2
H. High Yld	1	1	1	1	1	1	1	3	1	1	1	1	1	3	1	

1 = Variety Y Statistically Dominates Z at P=.05.
2 = Variety Z Statistically Dominates Y at P=.05
3 = No Significant Statistical Difference Between Variety Y and Z at p=.05.
4 = Variety Y is Statistically Different From Z at P=.05, however Z does not dominate Y and Y does not dominate Z at P=.05.

Table 16. Results of Hypothesis Tests for Second Degree Stochastic Dominance for End-use Values, by Variety.

Variety Y	Variety Z															
	2375	Amidon	Butte 86	Grandin	Gus	Stoa	2398	Gunner	McNeal	Oxen	Russ	ND 678	ND 694	ND 695	H. High Q.	H. High Yld
2375		2	2	2	4	2	1	4	4	4	4	4	2	2	2	1
Amidon	1		4	2	4	4	1	4	1	4	1	1	4	1	4	1
Butte 86	1	4		2	4	4	1	4	1	4	1	1	2	4	2	1
Grandin	1	1	1		4	1	1	4	1	1	1	1	4	1	4	1
Gus	4	4	4	4		4	4	4	4	4	4	4	4	4	2	1
Stoa	4	4	4	2	4		1	4	1	4	1	1	4	4	4	1
2398	2	2	2	2	4	2		4	4	2	2	2	2	2	2	1
Gunner	4	4	4	4	4	4	4		4	4	4	4	4	4	2	1
McNeal	4	2	2	2	4	2	4	4		4	2	4	2	2	2	1
Oxen	4	4	4	2	4	4	1	4	4		4	1	2	4	2	1
Russ	4	2	2	2	4	2	1	4	4	4		4	2	4	2	1
ND 678	4	2	2	2	4	2	1	4	4	2	4		2	2	2	1
ND 694	1	4	1	4	4	4	1	4	1	1	1	1		1	2	1
ND 695	1	2	4	2	4	4	1	4	1	4	4	1	2		2	1
H. High Q.	1	4	1	4	1	4	1	1	1	1	1	1	1	1		1
H. High Yld.	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	

1 = Variety Y Statistically Dominates Z at P=.05.
2 = Variety Z Statistically Dominates Y at P=.05
3 = No Significant Statistical Difference Between Variety Y and Z at p=.05.
4 = Variety Y is Statistically Different From Z at P=.05, however Z does not dominate Y and Y does not dominate Z at P=.05.

Analysis of variety dominance using the SDD significance test for grower value indicated no statistical difference for a number of variety comparisons where the traditional SDD had indicated there was SDD. For end-use value, a few variety comparisons indicated significant dominance where none were present in the traditional SDD (Gunner dominated H. High Q. and ND 695 dominated 2375 and Amidon). Also, a number of varieties where dominance was indicated in the traditional analysis were indicated to be not significant, or the distributions were different but no dominance identified.

Comparisons of statistically significant dominance for end-users and growers again indicates differences in dominance as in the traditional stochastic dominance analysis. The statistical tests indicate that the Hypothetical High Quality variety is dominated by ND 694 and ND 695 for grower value, yet it dominates these same varieties for end-use value. These results are repeated for ND 678, which is preferred over Amidon and Butte 86 for grower value, but is dominated by these varieties for end-use value. In contrast, other varieties are ranked similarly on either value. For example, the Hypothetical High Yield variety is one of the more preferred varieties for both grower and end-use values. Again, these differences suggest the need for simultaneous evaluation of value to both growers and end-users as rankings change based on the user value utilized and the covariance of end-use and grower values is not constant across varieties.

Comparison of Variety as Portfolio of Characteristics of Grower and End-user Values

The joint value of varieties to both end-users and growers was also evaluated simultaneously using a portfolio approach following McCarl et al. This approach considers goals of growers and end-users simultaneously and accounts for covariance. A portfolio was developed combining characteristics of end-use and grower values. The portfolio value of a variety (VV_i) was estimated as the weighted sum of end-use and grower values. An initial weight (W) of .5 was assumed for each implying equal weighting of grower and end-user values for the portfolio value of a variety.

$$VV_i = W*GV_i + (1-W)*EV_i$$

These portfolio values were simulated using stochastic simulation and means and variances for each variety portfolio were collected.

Values of portfolios were then compared using the procedure developed by McCarl et al. to determine preferences for varieties. For this, a variety (A) was considered to be preferred over an alternative variety (B) if:

$$u_A - \theta / 2\sigma_A^2 \geq u_B - \theta / 2\sigma_B^2$$

where

u = Mean portfolio value of weighted income for a variety,
θ = Pratt risk aversion parameter,
σ^2 = Variance of weighted income of a variety, and
A and B represent the prospective varieties compared.

A risk aversion parameter of 1.5 was assumed initially (McCarl et al.). Sensitivities were conducted to examine the effect of alternative weights for end-use and grower value and risk attitude parameters on preferences for varieties.

Mean portfolio values and variances were collected from the simulations for each of the varieties (Table 17). These were used to estimate the risk adjusted portfolio value for each variety. These risk adjusted portfolio values, (Table 17) were utilized to compare and rank varieties. Risk adjusted values ranged from a high of 0.0292 $/bu for Gunner to a low of -0.5240 $/bu for the Hypothetical High Yield variety. Higher risk adjusted portfolio values indicate that a variety is preferred to another variety with lower values. Gunner would be preferred to all other varieties tested (Table 17). Butte 86 would be preferred over Stoa, but not over either ND 695 or Grandin.

Since the initial assumption on weights was arbitrary, sensitivities were conducted for alternative weights for end-use and grower values. End-use weights were varied from 0 to1 and grower weights were simply 1 minus end-use weight. A weight of 0 for end-use value represents the special case where value is only based on grower values, and a weight of 1 represents only end-use values. Estimated risk adjusted portfolio values for varieties indicate that as weights change, the ordering of preference for varieties changes (Figure 17). For example, when end-use weights are less than .5, the Hypothetical High Yield variety increases in rank. As end-use weights approach 0, this variety is one of the more preferred varieties. Similarly, as end-use weights are lower, ND 695 is preferred over Butte 86, Grandin, and Gus. As end-use weights increase, Gus, Grandin, and Butte 86 become preferred over ND 695.

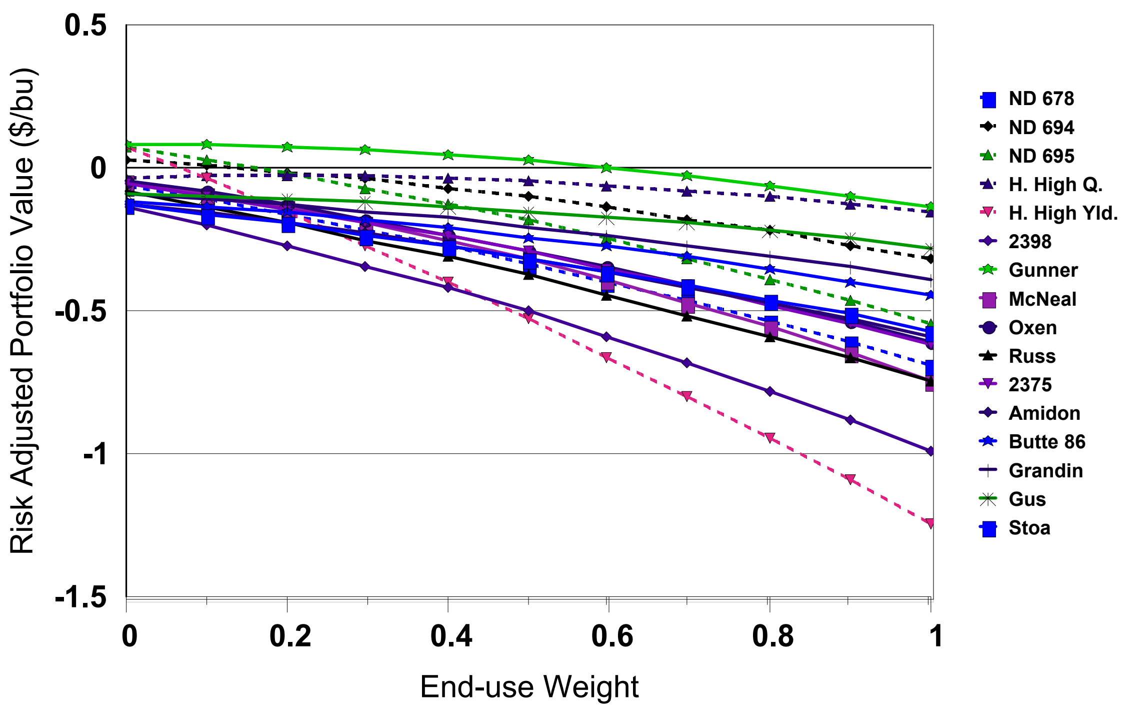

Figure 17. Sensitivity of Risk Adjusted Portfolio Value to End-use Weights, by Variety.

Table 17. Portfolio (Mean, Variance) and Risk Adjusted Value, by Variety (Base Case, Weight = .5, Risk Aversion Parameter = 1.5).			
Variety	Mean Portfolio Value	Portfolio Variance	Risk Adjusted Value of Portfolio
	-------------------$/bu-------------------		
Gunner	0.087	0.077	0.0292
H. High Q.	0.001	0.059	-0.0431
ND 694	-0.051	0.061	-0.0966
Gus	-0.114	0.044	-0.1472
ND 695	-0.128	0.070	-0.1799
Grandin	-0.167	0.044	-0.2001
Butte 86	-0.202	0.047	-0.2375
Oxen	-0.243	0.054	-0.2833
2375	-0.249	0.055	-0.2901
Stoa	-0.270	0.053	-0.3098
Amidon	-0.266	0.059	-0.3101
McNeal	-0.237	0.105	-0.3157
ND 678	-0.278	0.068	-0.3288
Russ	-0.325	0.063	-0.3720
2398	-0.440	0.079	-0.4990
H. High Yld.	-0.446	0.104	-0.5240

Changes in θ, the risk aversion parameter, affect the estimated value of the risk adjusted portfolio for individual varieties, but had little impact on rankings of varieties (Figure 18). As θ increased (become more risk averse), risk adjusted portfolio values for varieties decreased. However, the varieties that did change rankings included ND 678, McNeal, and Stoa, where McNeal was preferred to Stoa and ND 678 for lower values for θ and Stoa and ND 678 were preferred to McNeal for higher values for θ.

Results of the portfolio analysis are similar to those identified by the traditional stochastic dominance analysis and indicated as statistically significant. For example, the Hypothetical High Yield variety dominated the other varieties using the statistical test for SDD for grower values, yet was dominated by all varieties for SDD for end-use values. Results from the portfolio when weights were 0 and 1 (implying all grower value and all end-use value, respectively), indicate similar results.

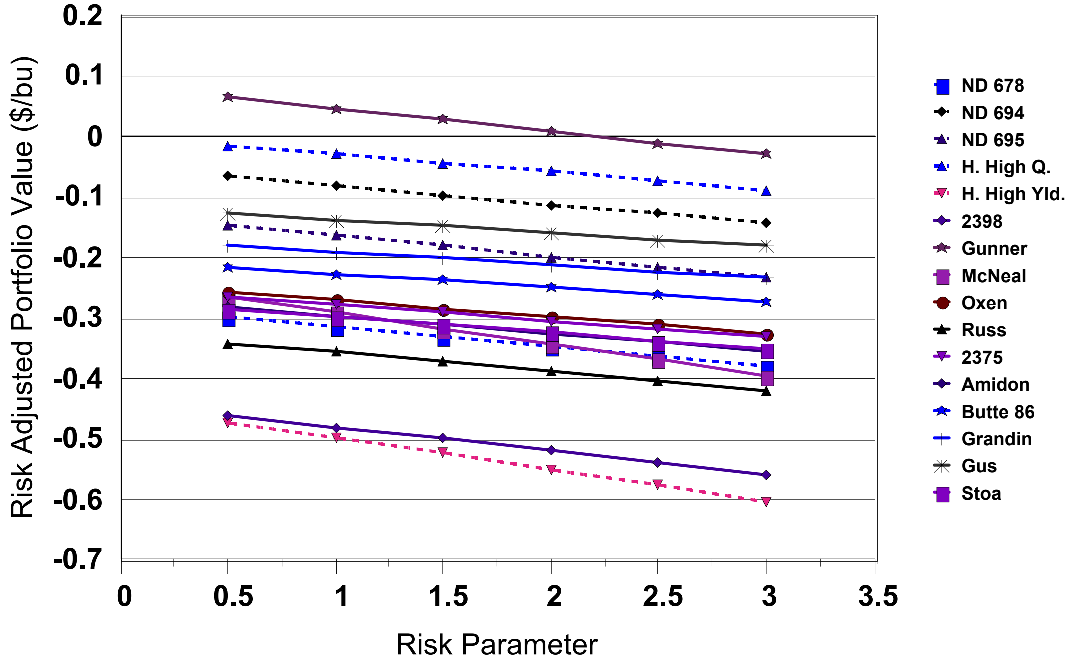

Figure 18. Sensitivity of Risk Adjusted Portfolio Value to Risk Parameter, by Variety.

However, the portfolio analysis allows consideration of both end-use and grower values concurrently. For example, across most of weight values, the portfolio analysis indicates that Gunner is the best variety. However, when examining end-use value alone, the stochastic dominance techniques indicate that the Hypothetical High Quality variety is best for end-use values and are unable to distinguish between Gunner and the Hypothetical High Yield variety for grower values.

For the newer releases, ND 678 provides higher grower income than many of the incumbent varieties except for Gunner, ND 694 and ND 695. For end-use values, ND 678 only dominates 2398 and the Hypothetical High Yield variety. The portfolio method indicates that ND 678 dominates Russ and 2398, and when the end-use weight is less than .3 it also dominates the Hypothetical High Yield variety. Of the other two new releases (ND 694 and ND 695), both were higher ranked varieties. Using SDD, ND 695 was ranked higher for grower value, while ND 694 was ranked higher for end-use values. Using the portfolio analysis, both ND 694 and ND 695 rank higher than most of the incumbent varieties across a wide range of end-use weights. However, as end-use weights increased to higher levels, Gus and Grandin become competitive. Both ND 694 and ND 695 have lesser value than Gunner. Of the two newer releases, ND 694 consistently ranks higher than ND 695 unless end-use weights are less than .2.

SUMMARY AND CONCLUSIONS

A methodology to value tradeoffs for growers and end-users when evaluating new varieties of hard wheat was developed. Models were developed to place a value on new varieties for growers and end-users and to make comparisons of tradeoffs. These models were applied for three experimental varieties (ND 678 - Keene, ND 694 - Parshall, and ND 695 Reeder) which have since been released and for two hypothetical varieties (Hypothetical High Quality and Hypothetical High Yield) which were added to supplement the range of potential grower/end-user value comparisons.

Some important findings were:

- Grower values for experimental varieties were higher than for incumbent varieties. End-use value of experimental varieties varied.

- Grower and end-user values exhibited tradeoffs across varieties.

- Grower's risk preferences affected values for a few varieties. Less risk averse growers would prefer ND 678 over 2375 and Amidon over Butte 86, while more risk averse growers' preferences were reversed.

- The sensitivity of grower and end-user values were affected differently by changes in variety characteristics. Grower values increased most for a one percent change in protein ($2.92/A) and yields ($2.17/A). End-use values increased most for a one percent change in absorption (+ 4 cents/bu) and flour extraction rates (+3 cents/bu).

- Doubling the value of protein premiums (from 40 cents/bu for each percent over 14 percent protein and doubling discounts from an average of 14 cents/bu for each percent under 14 percent protein) was to increase grower value of higher protein varieties by as much as $10-15/A. The effect on lower protein varieties was lesser and in fact a Hypothetical High Yield variety actually declined in grower value.

- Reducing variability in protein premiums was to increase the grower value for varieties with lower and more variable wheat protein relative to varieties with moderate to higher levels that were more stable.

- The LDP program had the effect of increasing grower value of high yield, low quality varieties relative to high quality, lower yield varieties by less than $2/A. This was opposite the effect of higher protein premiums.

- Risk adjusted portfolio values for varieties comprised of characteristics of value to both end-users and growers suggest rankings of varieties in order of preference. Initial results indicate a ranking order (best to worst) of Gunner, Hypothetical High Quality, ND 694 (Parshall), Gus, ND 695 (Reeder), Grandin, Butte 86, Oxen, 2375, Stoa, Amidon, McNeal, ND 678 (Keene), Russ, 2398, and Hypothetical High Yield. These rankings varied by the weight applied to characteristics of grower and end-user value in the portfolio and to a lesser extent the risk aversion parameter.

Need for Further Study

There are five areas that are particularly important for future study and/or extensions of this research. One would be detailed analysis of the geographic scope of variety development decisions. A very important fact is that in the United States varieties of HRS are developed to perform well in specific geographic regions. In contrast, varieties in Canada are developed for broader geographic regions. This has important implications for end-use consistency and productivity. Further development on the value of variety releases should consider adaptation for specific regions when determining farmer and end-use values. This is especially important in the case of vomitoxin where infestation levels have been affected both by location (environment) and cultivar, but is also important in that specific varieties are better adapted to specific locations.

A second area would be the strategic practicality of breeding for specific market needs or requirements (i.e., niches). Brennan (1988 and 1997) suggested that in many cases this may not be practical due to the transitory nature of niches and the time lag in breeding decisions. Yet with market maturity there seems to be more interest in breeding to meet niche market requirements. As examples, General Mills recently has found extensive efficiency gains in processing by using some specifically bred varieties for manufacture of breakfast cereals; and there have been notable gains in breeding for the specific needs of the frozen dough and tortilla industries.

A third area of importance would be how FHB is incorporated in the analysis. This was incorporated in this study using available data. However, the analysis could be enhanced substantially by accounting for more geographic specificity in the incidence and likelihood of vomitoxin.

Fourth, an important area for consideration in the case of HRS wheat would be to explore the strategic implications of developing a strain of varieties that are distinctly higher yielding, perhaps with some other type of measurable characteristic to allow it to be distinguished in the market place. Results from this analysis suggest that the yield-quality frontier from incumbent varieties was particularly constricted and only very marginal improvements could be assessed.

Finally, an important aspect of variety valuation that should be considered is the diversity of quality desired by end-users. Not all end-users desire the highest quality (highest protein, test weight, etc.) for their products, nor the specific requirements used in this study. Therefore, not all end-users may value a specific new release similarly. For example, McNeal is a variety with very high mix tolerance (stability). This is a characteristic that is desired by some end-users of HRS wheats. McNeal has a higher mix tolerance than Gunner, the highest valued end-use variety from our base case. This suggests that end-use values where mix tolerance is an important attribute might value McNeal over Gunner. However, inclusion of mix tolerance as an element of end-use value is complicated by the fact that a specific valuation of an additional unit of mix tolerance is highly elusive.

REFERENCES

Bana e Costa, Carlos A., Leonardo Ensslin, and Alessandro P. Costa. 1998. "Structuring the Process of Choosing Rice Varieties at the South of Brazil." In *Multicritera Analysis for Land-Use Management*. Edited by Euro Beinat and Peter Nijkamp. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Brennan, John P. 1988. *An Economic Investigation of Wheat Breeding Programs*. Agricultural Economics Bulletin No. 35. Department of Agricultural Economics and Business Management, University of New England, Armindale, NSW, Australia.

Brennan, John P. 1997. "Economic Aspects of Quality Issues in Wheat Variety Improvement." in *Proceedings of the International Wheat Quality Conference*, Manhattan, Kansas, pp. 363-376, May 18-22.

Brennan, John P. 1990. *Valuing the Breeding Characteristics of Wheat*. Agricultural Economics Bulletin 7, Agriculture and Fisheries, Sydney, NSW, Australia.

Brennan, John P., and Gordon M. Murray. 1988. "Australian Wheat Diseases: Assessing Their Economic Importance." *Agricultural Science: The Journal of the Australian Institute of Agricultural Science* 1(7):26-35.

Bonini, Charles P., Warren H. Hausman, and Harold Bierman, Jr. 1997. *Quantitative Analysis for Management*, Ninth Edition. Irwin, Chicago, IL.

Booz, Allen and Hamilton. 1995. *Milling Wheat Project: Consultant's Report to the Australian Grains Council*. Canberra, Australia.

Burlington Northern/Santa Fe. 2001. *BNSF Rate Book 4022-K.* Burlington Northern-Santa Fe Railway. http://www.bnsf.com/business/agcom/bnsf4022/bnsf4022.html.

Dahl, Bruce L., and William W. Wilson. 1998. *Consistency of Quality Characteristics in Hard Red Spring Wheats*. Agricultural Economics Report No. 393, Department of Agricultural Economics, North Dakota State University, Fargo, May.

Dahl, Bruce L., and William W. Wilson. 1999. *Effect of Hard Red Spring Wheat Consistency on Milling Value*. Agricultural Economics Report No. 413, Department of Agricultural Economics, North Dakota State University, Fargo, February.

Dahl, Bruce L., and William W. Wilson. 1997. *Factors Affecting the Supply of Quality Characteristics in Spring Wheats: Comparisons Between the United States and Canada.* Agricultural Economics Report No. 374, Department of Agricultural Economics, North Dakota State University, Fargo, April.

Davidson, R. and J.-Y. Duclos. 2000. "Statistical Inference for Stochastic Dominance and for the Measurement of Poverty and Inequality." *Econometrica* Vol. 68:1435-1464.

Department of Cereal Science and Food Technology. Various Years. *Quality Evaluation Program: Hard Red Spring Wheat*. North Dakota State University, Agricultural Experiment Station, Fargo.

Drynan, Robert. 1996. *Economic Elements of Quality in Wheat Buying*. Wheat Marketing Center, Inc., Portland, OR.

Evers, Tony. 2000. "Several Factors Influence the Choice of Wheat for Milling." *World Grain*. 82:32-33, July.

Fraser, R.W. 1997. "Seasonal variability, land values and willingness-to-pay for a forward wheat contract with protein premiums and discounts." *The Australian Journal of Agricultural and Resource Economics* Vol. 41:139-155.

Goh, S., C.C. Shih, M.J. Cochran, and R. Raskin. 1989. "A Generalized Stochastic Dominance Program for the IBM PC." *Southern Journal of Agricultural Economics* Vol. 59:175-182.

Hadar, Josef, and William R. Russell. 1969. "Rules for Ordering Uncertain Prospects." *American Economic Review* Vol. 59:25-34.

Hill, Lowell D. 1990. *Grain Grades and Standards: Historical Issues Shaping the Future*. University of Illinois Press, Urbana.

Janzen, Edward L., Jeremy W. Mattson, and William W. Wilson. 2001. *Wheat Characteristic Demand and Implications for Development of Genetically Modified Grains*. Agribusiness and Applied Economics Report No. 469, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo.

Johnson, D. Demcey, and William N. Nganje. 2000. *Impacts of Don in the Malting Barley Supply Chain: Aggregate Costs and Firm-Level Risks*. Agribusiness & Applied Economics Miscellaneous Report No. 187, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo, April.

Johnson, D., and W. Wilson. 1993. "Wheat Cleaning Decisions at Country Elevators." *Journal of Agriculture and Resource Economics* 18(2):147-158.

Johnson, D. Demcey, George K. Flaskerud, Richard D. Taylor, Vidyashankara Satyanarayana. 1998. *Economic Impacts of Fusarium Head Blight in Wheat*. Agricultural Economics Report No. 396, Department of Agricultural Economics, North Dakota State University, Fargo, June.

Keeney, Ralph L., and Howard Raiffa. 1976. *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*. John Wiley and Sons, New York, NY, pp. 175-179.

Ladd, G.W., and C. Gibson. 1978. "Microeconomics of Technical Change: What's a Better Animal Worth?" *American Journal of Agricultural Economics* 60(2):236-240.

Ladd, G.W., and M.B. Martin. 1976. "Prices and Demands for Input Characteristics." *American Journal of Agricultural Economics* 58:21-30.

Ladd, G.W., and V. Suvannunt. 1976. "A Model of Consumer Goods Characteristics." *American Journal of Agricultural Economics* Vol. 58:504-510.

Larue B. 1991. "Is Wheat a Homogeneous Product?" *Canadian Journal of Agricultural Economics* Vol. 39(1, March):103-117.

McCarl, Bruce A., Thomas O. Knight, James R. Wilson, and James B. Hastie. 1987. "Stochastic Dominance over Potential Portfolios: Caution Regarding Covariance." *American Journal of Agricultural Economics* Vol. 69 (4, November):804-812.

McMullen, Marcia. 2001. Weather Favorable for Wheat Scab in 2001, August 3. http://www.ext.nodak.edu/extnews/newsrelease/2001/current/15weathe.html.

McVey, Marty Jay. 1996. *Valuing Quality Differentiated Grains from A Total Logistics Perspective*. Unpublished Ph.D. Dissertation, Department of Economics, Iowa State University, Ames.

Melton, Bryan E., W. Arden Colette, and Richard L. Willham. 1994. "Imputing Input Characteristic Values from Optimal Commercial Breed or Variety Choice Decision." *American Journal of Agricultural Economics* Vol. 76(August):478-491.

Mercier, S. 1993. *The Role of Quality in Wheat Import Decision Making*. Agricultural Economics Report No. 670, U.S. Department of Agriculture, Commodity Economics Division, Economic Research Service, Washington, DC, December.

Minneapolis Grain Exchange. 1998-1997. *Statistical Annual*. Minneapolis Grain Exchange, Minneapolis, MN.

Minnesota Association of Wheat Growers and Minnesota Wheat Research and Promotion Council. 1994. *Identifying and Defining Key Quality Criteria for Spring Wheat Flour in the Domestic Market*. Submitted by Ag-Nomics Research, Red Lake Falls, MN, September.

Moss, Charles B. 2001. *Implementation of Stochastic Dominance: A Non-parametric Kernel Approach*. Staff Paper SP 01-6, University of Florida, Institute of Food and Agricultural Sciences, Food and Resource Economics Department, Gainesville, FL.

Nganje, William E., D. Demcey Johnson, William W. Wilson, F. Larry Leistritz, Dean A. Bangsund, and Napoleon Tiapo. 2001. *Economic Impacts of Fusarium Head Blight on Wheat and Barley*. Agribusiness and Applied Economics Report No. 464, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo, August.

North Dakota Wheat Commission. 1996. "Millers, Survey Say Crop Quality Improved." *Dakota Gold* 13:1-4.

Petersen, Elizabeth Helen. 2000. *The Impact of Quality Premiums and Discounts in an Uncertain Production Environment: An Application to the Australian Wheat Industry.* Unpublished Ph.D. Thesis, University of Western Australia, Perth.

Pope and Justice. 1991. "On testing the structure of risk preferences in agricultural supply analysis." *American Journal of Agricultural Economics* Vol. 73:743-748.

Prairie Grains. 1997. "What Overseas USW Offices Say about U.S. Spring Wheat Quality." *Prairie Grains* Issue 8, p. 15.

Render, Barry, and Ralph M. Stair. 2000. *Quantitative Analysis for Management*, Sixth Edition. Prentice Hall, Upper Saddle River, New Jersey.

Robinson, Stephen D. 1995. *Selecting Wheat Varieties in a Stochastic Environment*. Paper presented at the 39th Annual Conference of the Australian Agricultural Economics Society, February 14-16, University of Western Australia, Perth.

Smith, Vincent H. 2000. *Wheat Quality and Wheat Yields: Trade-offs among Price, Yield, Profit, and Risk*. Special Report No. 5, Trade Research Center, Montana State University, Bozeman, June.

Stack, Robert. 2001. Personal Data on Vomitoxin by Variety.

Stack, Robert, and Marcia McMullen. 1998. *A Visual Scale to Estimate Severity of Fusarium Head Blight in Wheat*. North Dakota State University, NDSU Extension Service. PP-1095, http://www.ext.nodak.edu/extpubs/plantsci/smgrains/pp1095w.htm.

Tse, Y.K., and X.B. Zhang. 2000. *A Monte Carlo Investigation of Some Tests for Stochastic Dominance*. Department of Economics, National University of Singapore, December.

Unnevehr, Laurian J. 1986. "Consumer Demand for Rice Grain Quality and Returns to Research for Quality Improvement in Southeast Asia." *American Journal of Agricultural Economics* 68(3):634-641.

Uri, Noel D., and Bengt Hyberg. 1996. "The Market Valuation of Wheat Quality Characteristics." *Journal of Economic Studies* 23(3):44-63.

U.S. Congress. 1989. *Grain Quality in International Trade: A Comparison of Major U.S. Competitors*. F-402, Office of Technology Assessment, Washington, DC.

Veeman, M. 1987. "Hedonic Price Function for Wheat in the World Market: Implications for Canadian Wheat Export Strategy." *Canadian Journal of Agricultural Economics* 35(4):535-52, November.

Westcott, Paul C., and J. Michael Price. 2001. *Analysis of the U.S. Commodity Loan Program with Marketing Loan Provisions*. Agricultural Economics Report No. 801, Market and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture, Washington, DC.

Wilson, W. 1994. "Demand for Wheat Classes by Pacific Rim Countries." *Journal of Agricultural and Resource Economics* 19(1):197-209.

Wilson, W. 1989. "Differentiation and Implicit Prices in Export Wheat Markets," *Western Journal of Agricultural Economics* 14:67-77.

Wilson, W., and P. Gallagher. 1990. "Quality Differences and Price Responsiveness of Wheat Class Demands." *Western Journal of Agricultural Economics* 15(2):254-264.

Wilson, William W., and Bruce L. Dahl. 2001. *Evaluation of Changes in Grade Specifications for Dockage in Wheat*. Agribusiness & Applied Economics Report No. 458, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo.

Wilson, William W., and Bruce L. Dahl. 1999. "Quality Uncertainty in International Grain Markets: Analytical and Competitive Issues." *Review of Agricultural Economics* 21(1):209-224.

Wilson, W., and T. Preszler. 1993a. "End-use Performance Uncertainty and Competition in International Wheat." *American Journal of Agricultural Economics* 74(3):556-563.

Wilson, W., and T. Preszler. 1993b. "Quality and Price Competition in the International Wheat Market: A Case Study of the UK Wheat Import Market." *Agribusiness: An International Journal* 9(4):377-389.

Wilson, William W., D. Demcey Johnson, and Bruce L. Dahl. 2000. "The Economics of Grain Cleaning on the Prairies." *Canadian Journal of Agricultural Economics* Vol. 48:279-297.

Zeleny, Milan. 1982. *Multiple Criteria Decision Making*. McGraw-Hill Book Company, New York, NY.

Blank page for duplicating.

APPENDIX

Appendix Table 1a. Parameter Δ_1^i, for Traditional Step Function Estimation of First Degree Stochastic Dominance Test of Grower Value

	2375	Amidon	Butte 86	Grandin	Gus	Stoa	2398	Gunner	McNeal	Oxen	Russ	ND 678	ND 694	ND 695	H. High Q.	H. High Yld.
2375	0.0000	-0.0780	-0.0788	-0.0424	-0.0112	-0.1098	-0.1164	-0.0002	-0.0002	-0.0002	-0.0410	-0.0002	0.0000	0.0000	0.0000	0.0000
Amidon	0.0000	0.0000	-0.0008	0.0000	-0.0002	-0.0318	-0.0384	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Butte 86	0.0000	0.0000	0.0000	0.0000	-0.0002	-0.0310	-0.0376	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Grandin	0.0000	-0.0356	-0.0364	0.0000	-0.0002	-0.0674	-0.0740	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Gus	0.0000	-0.0668	-0.0676	-0.0312	0.0000	-0.0986	-0.1052	0.0000	0.0000	0.0000	-0.0298	0.0000	0.0000	0.0000	0.0000	0.0000
Stoa	0.0000	0.0000	0.0000	0.0000	-0.0002	0.0000	-0.0066	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2398	0.0000	0.0000	0.0000	0.0000	-0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Gunner	-0.2122	-0.2902	-0.2910	-0.2546	-0.2234	-0.3220	-0.3286	0.0000	-0.1630	-0.1822	-0.2532	-0.2070	-0.0884	-0.0296	-0.1618	-0.0344
McNeal	-0.0492	-0.1272	-0.1280	-0.0916	-0.0604	-0.1590	-0.1656	0.0000	0.0000	-0.0192	-0.0902	-0.0440	0.0000	0.0000	0.0000	0.0000
Oxen	-0.0300	-0.1080	-0.1088	-0.0724	-0.0412	-0.1398	-0.1464	0.0000	0.0000	0.0000	-0.0710	-0.0248	0.0000	0.0000	0.0000	0.0000
Russ	0.0000	-0.0370	-0.0378	-0.0014	-0.0002	-0.0688	-0.0754	-0.0002	-0.0002	-0.0002	0.0000	-0.0002	0.0000	0.0000	0.0000	0.0000
ND 678	-0.0052	-0.0832	-0.0840	-0.0476	-0.0164	-0.1150	-0.1216	0.0000	0.0000	0.0000	-0.0462	0.0000	0.0000	0.0000	0.0000	0.0000
ND 694	-0.1238	-0.2018	-0.2026	-0.1662	-0.1350	-0.2336	-0.2402	-0.0002	-0.0746	-0.0938	-0.1648	-0.1186	0.0000	0.0000	-0.0734	0.0000
ND 695	-0.1826	-0.2606	-0.2614	-0.2250	-0.1938	-0.2924	-0.2990	-0.0002	-0.1334	-0.1526	-0.2236	-0.1774	-0.0588	0.0000	-0.1322	-0.0048
H. High Q.	-0.0504	-0.1284	-0.1292	-0.0928	-0.0616	-0.1602	-0.1668	-0.0002	-0.0012	-0.0204	-0.0914	-0.0452	0.0000	0.0000	0.0000	0.0000
H. High Yld.	-0.1778	-0.2558	-0.2566	-0.2202	-0.1890	-0.2876	-0.2942	-0.0002	-0.1286	-0.1478	-0.2188	-0.1726	-0.0540	0.0000	-0.1274	0.0000

Appendix Table 1b. Parameter Δ_1^s, for Traditional Step Function Estimation of First Degree Stochastic Dominance Test of Grower Value

	2375	Amidon	Butte 86	Grandin	Gus	Stoa	2398	Gunner	McNeal	Oxen	Russ	ND 678	ND 694	ND 695	H. High Q.	H. High Yld.
2375	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2122	0.0492	0.0300	0.0000	0.0052	0.1238	0.1826	0.0504	0.1778
Amidon	0.0780	0.0000	0.0000	0.0356	0.0668	0.0000	0.0000	0.2902	0.1272	0.1080	0.0370	0.0832	0.2018	0.2606	0.1284	0.2558
Butte 86	0.0788	0.0008	0.0000	0.0364	0.0676	0.0000	0.0000	0.2910	0.1280	0.1088	0.0378	0.0840	0.2026	0.2614	0.1292	0.2566
Grandin	0.0424	0.0000	0.0000	0.0000	0.0312	0.0000	0.0000	0.2546	0.0916	0.0724	0.0014	0.0476	0.1662	0.2250	0.0928	0.2202
Gus	0.0112	0.0002	0.0002	0.0002	0.0000	0.0002	0.0002	0.2234	0.0604	0.0412	0.0002	0.0164	0.1350	0.1938	0.0616	0.1890
Stoa	0.1098	0.0318	0.0310	0.0674	0.0986	0.0000	0.0000	0.3220	0.1590	0.1398	0.0688	0.1150	0.2336	0.2924	0.1602	0.2876
2398	0.1164	0.0384	0.0376	0.0740	0.1052	0.0066	0.0000	0.3286	0.1656	0.1464	0.0754	0.1216	0.2402	0.2990	0.1668	0.2942
Gunner	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0002	0.0002	0.0002	0.0002
McNeal	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1630	0.0000	0.0000	0.0002	0.0000	0.0746	0.1334	0.0012	0.1286
Oxen	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1822	0.0192	0.0000	0.0002	0.0000	0.0938	0.1526	0.0204	0.1478
Russ	0.0410	0.0000	0.0000	0.0000	0.0298	0.0000	0.0000	0.2532	0.0902	0.0710	0.0000	0.0462	0.1648	0.2236	0.0914	0.2188
ND 678	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2070	0.0440	0.0248	0.0002	0.0000	0.1186	0.1774	0.0452	0.1726
ND 694	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0884	0.0000	0.0000	0.0000	0.0000	0.0000	0.0588	0.0000	0.0540
ND 695	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0296	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H. High Q.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1618	0.0000	0.0000	0.0000	0.0000	0.0734	0.1322	0.0000	0.1274
H. High Yld.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0344	0.0000	0.0000	0.0000	0.0000	0.0000	0.0048	0.0000	0.0000

Appendix Table 2a. Parameter Δ_2^i, for Traditional Step Function Estimation of Second Degree Stochastic Dominance Test of Grower Value

	2375	Amidon	Butte 86	Grandin	Gus	Stoa	2398	Gunner	McNeal	Oxen	Russ	ND 678	ND 694	ND 695	H. High Q.	H. High Yld.
2375	0.0000	-0.0411	-0.0387	-0.0217	-0.0072	-0.0536	-0.0591	0.0000	0.0000	0.0000	-0.0250	0.0000	0.0000	0.0000	0.0000	0.0000
Amidon	0.0000	0.0000	-0.0003	0.0000	-0.0001	-0.0102	-0.0130	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Butte 86	0.0000	0.0000	0.0000	0.0000	-0.0001	-0.0088	-0.0114	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Grandin	0.0000	-0.0121	-0.0111	0.0000	-0.0001	-0.0204	-0.0238	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Gus	0.0000	-0.0300	-0.0279	-0.0134	0.0000	-0.0405	-0.0453	0.0000	0.0000	0.0000	-0.0158	0.0000	0.0000	0.0000	0.0000	0.0000
Stoa	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000	-0.0020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2398	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Gunner	-0.1500	-0.1563	-0.1464	-0.1329	-0.1411	-0.1612	-0.1709	0.0000	-0.1078	-0.1221	-0.1577	-0.1083	-0.0517	-0.0181	-0.0909	-0.0212
McNeal	-0.0319	-0.0611	-0.0570	-0.0425	-0.0347	-0.0703	-0.0765	0.0000	0.0000	-0.0118	-0.0509	-0.0205	0.0000	0.0000	0.0000	0.0000
Oxen	-0.0197	-0.0528	-0.0494	-0.0342	-0.0241	-0.0631	-0.0689	0.0000	0.0000	0.0000	-0.0407	-0.0117	0.0000	0.0000	0.0000	0.0000
Russ	0.0000	-0.0164	-0.0154	-0.0007	-0.0001	-0.0278	-0.0320	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ND 678	-0.0027	-0.0284	-0.0257	-0.0155	-0.0072	-0.0349	-0.0393	0.0000	0.0000	0.0000	-0.0197	0.0000	0.0000	0.0000	0.0000	0.0000
ND 694	-0.0709	-0.0816	-0.0748	-0.0645	-0.0673	-0.0856	-0.0927	0.0000	-0.0394	-0.0504	-0.0805	-0.0462	0.0000	0.0000	-0.0314	0.0000
ND 695	-0.1095	-0.1126	-0.1037	-0.0935	-0.1018	-0.1152	-0.1236	0.0000	-0.0741	-0.0861	-0.1154	-0.0739	-0.0281	0.0000	-0.0602	-0.0024
H. High Q.	-0.0277	-0.0490	-0.0447	-0.0339	-0.0293	-0.0550	-0.0605	0.0000	-0.0007	-0.0106	-0.0425	-0.0166	0.0000	0.0000	0.0000	0.0000
H. High Yld.	-0.1073	-0.1114	-0.1027	-0.0923	-0.1000	-0.1143	-0.1227	0.0000	-0.0719	-0.0839	-0.1137	-0.0725	-0.0260	0.0000	-0.0585	0.0000

Appendix Table 2b. Parameter Δ_2^s, for Traditional Step Function Estimation of Second Degree Stochastic Dominance Test of Grower Value

	2375	Amidon	Butte 86	Grandin	Gus	Stoa	2398	Gunner	McNeal	Oxen	Russ	ND 678	ND 694	ND 695	H. High Q.	H. High Yld.
2375	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1500	0.0319	0.0197	0.0000	0.0027	0.0709	0.1095	0.0277	0.1073
Amidon	0.0411	0.0000	0.0000	0.0121	0.0300	0.0000	0.0000	0.1563	0.0611	0.0528	0.0164	0.0284	0.0816	0.1126	0.0490	0.1114
Butte 86	0.0387	0.0003	0.0000	0.0111	0.0279	0.0000	0.0000	0.1464	0.0570	0.0494	0.0154	0.0257	0.0748	0.1037	0.0447	0.1027
Grandin	0.0217	0.0000	0.0000	0.0000	0.0134	0.0000	0.0000	0.1329	0.0425	0.0342	0.0007	0.0155	0.0645	0.0935	0.0339	0.0923
Gus	0.0072	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001	0.1411	0.0347	0.0241	0.0001	0.0072	0.0673	0.1018	0.0293	0.1000
Stoa	0.0536	0.0102	0.0088	0.0204	0.0405	0.0000	0.0000	0.1612	0.0703	0.0631	0.0278	0.0349	0.0856	0.1152	0.0550	0.1143
2398	0.0591	0.0130	0.0114	0.0238	0.0453	0.0020	0.0000	0.1709	0.0765	0.0689	0.0320	0.0393	0.0927	0.1236	0.0605	0.1227
Gunner	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
McNeal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1078	0.0000	0.0000	0.0000	0.0000	0.0394	0.0741	0.0007	0.0719
Oxen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1221	0.0118	0.0000	0.0000	0.0000	0.0504	0.0861	0.0106	0.0839
Russ	0.0250	0.0000	0.0000	0.0000	0.0158	0.0000	0.0000	0.1577	0.0509	0.0407	0.0000	0.0197	0.0805	0.1154	0.0425	0.1137
ND 678	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1083	0.0205	0.0117	0.0000	0.0000	0.0462	0.0739	0.0166	0.0725
ND 694	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0517	0.0000	0.0000	0.0000	0.0000	0.0000	0.0281	0.0000	0.0260
ND 695	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0181	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H. High Q.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0909	0.0000	0.0000	0.0000	0.0000	0.0314	0.0602	0.0000	0.0585
H. High Yld.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0212	0.0000	0.0000	0.0000	0.0000	0.0000	0.0024	0.0000	0.0000

Appendix Table 3a. Parameter Δ_1^i, for Traditional Step Function Estimation of First Degree Stochastic Dominance Test of End-use Value

	2375	Amidon	Butte 86	Grandin	Gus	Stoa	2398	Gunner	McNeal	Oxen	Russ	ND 678	ND 694	ND 695	H. High Q.	H. High Yld.
2375	0.0000	-0.0541	0.0000	0.0000	-0.0010	-0.1171	-0.2893	-0.0010	-0.0511	-0.0981	-0.1592	-0.1071	0.0000	-0.0871	0.0000	-0.4004
Amidon	-0.0280	0.0000	-0.0020	0.0000	-0.0010	-0.0631	-0.2663	-0.0030	-0.0691	-0.0521	-0.1311	-0.0821	-0.0010	-0.0420	-0.0010	-0.4084
Butte 86	-0.1461	-0.2002	0.0000	0.0000	-0.0010	-0.2633	-0.4264	-0.0030	-0.1892	-0.2442	-0.3053	-0.2513	0.0000	-0.2332	0.0000	-0.5465
Grandin	-0.2392	-0.2663	-0.1061	0.0000	-0.0080	-0.3203	-0.4745	-0.0100	-0.2332	-0.3013	-0.3584	-0.3053	-0.0280	-0.3083	-0.0020	-0.5756
Gus	-0.2953	-0.3193	-0.1642	-0.0661	0.0000	-0.3814	-0.5345	-0.0060	-0.2973	-0.3624	-0.4234	-0.3694	-0.0811	-0.3614	0.0000	-0.6126
Stoa	-0.0430	-0.0260	-0.0010	0.0000	-0.0010	0.0000	-0.2823	-0.0020	-0.0881	-0.0380	-0.1542	-0.1051	-0.0010	-0.0140	-0.0010	-0.4294
2398	-0.0400	-0.0400	-0.0400	-0.0400	-0.0400	-0.0400	0.0000	-0.0010	-0.0020	-0.0010	-0.0090	-0.0060	0.0000	0.0000	0.0000	-0.1552
Gunner	-0.4655	-0.4655	-0.4655	-0.4655	-0.4655	-0.4805	-0.5906	0.0000	-0.3854	-0.4695	-0.5035	-0.4715	-0.2242	-0.4555	-0.0821	-0.6667
McNeal	-0.1281	-0.1281	-0.1281	-0.1281	-0.1281	-0.1281	-0.2462	-0.0010	0.0000	-0.0841	-0.1271	-0.0861	-0.0060	-0.0771	-0.0060	-0.3574
Oxen	-0.0521	-0.0521	-0.0521	-0.0521	-0.0521	-0.0521	-0.2603	-0.0030	-0.0611	0.0000	-0.1241	-0.0761	0.0000	-0.0090	0.0000	-0.4024
Russ	-0.0350	-0.0350	-0.0350	-0.0350	-0.0350	-0.0350	-0.1461	-0.0010	-0.0160	-0.0010	0.0000	-0.0040	0.0000	-0.0010	0.0000	-0.2783
ND 678	-0.0450	-0.0450	-0.0450	-0.0450	-0.0450	-0.0450	-0.1892	-0.0010	-0.0260	0.0000	-0.0571	0.0000	0.0000	-0.0030	0.0000	-0.3263
ND 694	-0.2422	-0.2513	-0.2422	-0.2422	-0.2422	-0.3063	-0.4625	-0.0080	-0.2222	-0.2913	-0.3483	-0.2943	0.0000	-0.2803	-0.0010	-0.5726
ND 695	-0.0711	-0.0711	-0.0711	-0.0711	-0.0711	-0.0711	-0.2743	-0.0010	-0.0791	-0.0400	-0.1421	-0.0931	-0.0010	0.0000	-0.0010	-0.4174
H. High Q.	-0.5265	-0.5265	-0.5265	-0.5265	-0.5265	-0.5576	-0.6416	-0.0891	-0.4695	-0.5465	-0.5796	-0.5526	-0.2923	-0.5325	0.0000	-0.7107
H. High Yld.	-0.0300	-0.0300	-0.0300	-0.0300	-0.0300	-0.0300	0.0000	0.0000	0.0000	0.0000	-0.0020	-0.0030	0.0000	0.0000	0.0000	0.0000

Appendix Table 3b. Parameter Δ_1^s, for Traditional Step Function Estimation of First Degree Stochastic Dominance Test of End-use Value

	2375	Amidon	Butte 86	Grandin	Gus	Stoa	2398	Gunner	McNeal	Oxen	Russ	ND 678	ND 694	ND 695	H. High Q.	H. High Yld.
2375	0.0000	0.0280	0.1461	0.2392	0.2953	0.0430	0.0400	0.4655	0.1281	0.0521	0.0350	0.0450	0.2422	0.0711	0.5265	0.0300
Amidon	0.0541	0.0000	0.2002	0.2663	0.3193	0.0260	0.0400	0.4655	0.1281	0.0521	0.0350	0.0450	0.2513	0.0711	0.5265	0.0300
Butte 86	0.0000	0.0020	0.0000	0.1061	0.1642	0.0010	0.0400	0.4655	0.1281	0.0521	0.0350	0.0450	0.2422	0.0711	0.5265	0.0300
Grandin	0.0000	0.0000	0.0000	0.0000	0.0661	0.0000	0.0400	0.4655	0.1281	0.0521	0.0350	0.0450	0.2422	0.0711	0.5265	0.0300
Gus	0.0010	0.0010	0.0010	0.0080	0.0000	0.0010	0.0400	0.4655	0.1281	0.0521	0.0350	0.0450	0.2422	0.0711	0.5265	0.0300
Stoa	0.1171	0.0631	0.2633	0.3203	0.3814	0.0000	0.0400	0.4805	0.1281	0.0521	0.0350	0.0450	0.3063	0.0711	0.5576	0.0300
2398	0.2893	0.2663	0.4264	0.4745	0.5345	0.2823	0.0000	0.5906	0.2462	0.2603	0.1461	0.1892	0.4625	0.2743	0.6416	0.0000
Gunner	0.0010	0.0030	0.0030	0.0100	0.0060	0.0020	0.0010	0.0000	0.0010	0.0030	0.0010	0.0010	0.0080	0.0010	0.0891	0.0000
McNeal	0.0511	0.0691	0.1892	0.2332	0.2973	0.0881	0.0020	0.3854	0.0000	0.0611	0.0160	0.0260	0.2222	0.0791	0.4695	0.0000
Oxen	0.0981	0.0521	0.2442	0.3013	0.3624	0.0380	0.0010	0.4695	0.0841	0.0000	0.0010	0.0000	0.2913	0.0400	0.5465	0.0000
Russ	0.1592	0.1311	0.3053	0.3584	0.4234	0.1542	0.0090	0.5035	0.1271	0.1241	0.0000	0.0571	0.3483	0.1421	0.5796	0.0020
ND 678	0.1071	0.0821	0.2513	0.3053	0.3694	0.1051	0.0060	0.4715	0.0861	0.0761	0.0040	0.0000	0.2943	0.0931	0.5526	0.0030
ND 694	0.0000	0.0010	0.0000	0.0280	0.0811	0.0010	0.0000	0.2242	0.0060	0.0000	0.0000	0.0000	0.0000	0.0010	0.2923	0.0000
ND 695	0.0871	0.0420	0.2332	0.3083	0.3614	0.0140	0.0000	0.4555	0.0771	0.0090	0.0010	0.0030	0.2803	0.0000	0.5325	0.0000
H. High Q.	0.0000	0.0010	0.0000	0.0020	0.0000	0.0010	0.0000	0.0821	0.0060	0.0000	0.0000	0.0000	0.0010	0.0010	0.0000	0.0000
H. High Yld.	0.4004	0.4084	0.5465	0.5756	0.6126	0.4294	0.1552	0.6667	0.3574	0.4024	0.2783	0.3263	0.5726	0.4174	0.7107	0.0000

Appendix Table 4a. Parameter Δ_2^i, for Traditional Step Function Estimation of Second Degree Stochastic Dominance Test of End-use Value

	2375	Amidon	Butte 86	Grandin	Gus	Stoa	2398	Gunner	McNeal	Oxen	Russ	ND 678	ND 694	ND 695	H. High Q.	H. High Yld.
2375	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0003	-0.0370	-0.0001	-0.0096	-0.0024	-0.0105	-0.0055	0.0000	-0.0006	0.0000	-0.0612
Amidon	-0.0010	0.0000	0.0000	0.0000	-0.0001	-0.0005	-0.0374	-0.0004	-0.0110	-0.0028	-0.0107	-0.0057	0.0000	-0.0011	0.0000	-0.0616
Butte 86	-0.0061	-0.0059	0.0000	0.0000	0.0000	-0.0063	-0.0499	-0.0004	-0.0270	-0.0169	-0.0194	-0.0138	0.0000	-0.0187	0.0000	-0.0718
Grandin	-0.0077	-0.0075	-0.0016	0.0000	-0.0001	-0.0079	-0.0539	-0.0014	-0.0329	-0.0216	-0.0220	-0.0161	-0.0005	-0.0246	-0.0001	-0.0749
Gus	-0.0085	-0.0083	-0.0024	-0.0008	0.0000	-0.0087	-0.0561	-0.0005	-0.0362	-0.0241	-0.0233	-0.0173	-0.0031	-0.0278	0.0000	-0.0765
Stoa	-0.0016	-0.0006	0.0000	0.0000	0.0000	0.0000	-0.0364	-0.0003	-0.0125	-0.0024	-0.0101	-0.0053	0.0000	-0.0015	0.0000	-0.0607
2398	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0412
Gunner	-0.0837	-0.0830	-0.0566	-0.0473	-0.0422	-0.0847	-0.1894	0.0000	-0.1305	-0.1154	-0.1227	-0.1071	-0.0515	-0.1198	-0.0045	-0.2403
McNeal	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000	-0.0605	-0.0001	0.0000	0.0000	-0.0191	-0.0091	0.0000	0.0000	0.0000	-0.1057
Oxen	-0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0531	-0.0003	-0.0138	0.0000	-0.0166	-0.0082	0.0000	-0.0006	0.0000	-0.0919
Russ	-0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0263	-0.0001	-0.0023	0.0000	0.0000	-0.0001	0.0000	0.0000	0.0000	-0.0575
ND 678	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0327	0.0000	-0.0042	0.0000	-0.0056	0.0000	0.0000	0.0000	0.0000	-0.0619
ND 694	-0.0269	-0.0264	-0.0112	-0.0060	-0.0033	-0.0275	-0.0964	-0.0017	-0.0533	-0.0441	-0.0509	-0.0409	0.0000	-0.0450	0.0000	-0.1324
ND 695	-0.0027	-0.0021	0.0000	0.0000	-0.0001	-0.0034	-0.0662	-0.0002	-0.0180	-0.0057	-0.0242	-0.0142	0.0000	0.0000	0.0000	-0.1105
H. High Q.	-0.0477	-0.0472	-0.0307	-0.0250	-0.0220	-0.0483	-0.1302	-0.0121	-0.0921	-0.0775	-0.0771	-0.0656	-0.0325	-0.0834	0.0000	-0.1649
H. High Yld.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix Table 4b. Parameter Δ_2^s, for Traditional Step Function Estimation of Second Degree Stochastic Dominance Test of End-use Value

	2375	Amidon	Butte 86	Grandin	Gus	Stoa	2398	Gunner	McNeal	Oxen	Russ	ND 678	ND 694	ND 695	H. High Q.	H. High Yld.
2375	0.0000	0.0010	0.0061	0.0077	0.0085	0.0016	0.0000	0.0837	0.0000	0.0015	0.0001	0.0000	0.0269	0.0027	0.0477	0.0000
Amidon	0.0000	0.0000	0.0059	0.0075	0.0083	0.0006	0.0000	0.0830	0.0000	0.0000	0.0000	0.0000	0.0264	0.0021	0.0472	0.0000
Butte 86	0.0000	0.0000	0.0000	0.0016	0.0024	0.0000	0.0000	0.0566	0.0000	0.0000	0.0000	0.0000	0.0112	0.0000	0.0307	0.0000
Grandin	0.0000	0.0000	0.0000	0.0000	0.0008	0.0000	0.0000	0.0473	0.0000	0.0000	0.0000	0.0000	0.0060	0.0000	0.0250	0.0000
Gus	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0422	0.0001	0.0000	0.0000	0.0000	0.0033	0.0001	0.0220	0.0000
Stoa	0.0003	0.0005	0.0063	0.0079	0.0087	0.0000	0.0000	0.0847	0.0000	0.0000	0.0000	0.0000	0.0275	0.0034	0.0483	0.0000
2398	0.0370	0.0374	0.0499	0.0539	0.0561	0.0364	0.0000	0.1894	0.0605	0.0531	0.0263	0.0327	0.0964	0.0662	0.1302	0.0000
Gunner	0.0001	0.0004	0.0004	0.0014	0.0005	0.0003	0.0000	0.0000	0.0001	0.0003	0.0001	0.0000	0.0017	0.0002	0.0121	0.0000
McNeal	0.0096	0.0110	0.0270	0.0329	0.0362	0.0125	0.0000	0.1305	0.0000	0.0138	0.0023	0.0042	0.0533	0.0180	0.0921	0.0000
Oxen	0.0024	0.0028	0.0169	0.0216	0.0241	0.0024	0.0000	0.1154	0.0000	0.0000	0.0000	0.0000	0.0441	0.0057	0.0775	0.0000
Russ	0.0105	0.0107	0.0194	0.0220	0.0233	0.0101	0.0000	0.1227	0.0191	0.0166	0.0000	0.0056	0.0509	0.0242	0.0771	0.0000
ND 678	0.0055	0.0057	0.0138	0.0161	0.0173	0.0053	0.0000	0.1071	0.0091	0.0082	0.0001	0.0000	0.0409	0.0142	0.0656	0.0000
ND 694	0.0000	0.0000	0.0000	0.0005	0.0031	0.0000	0.0000	0.0515	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0325	0.0000
ND 695	0.0006	0.0011	0.0187	0.0246	0.0278	0.0015	0.0000	0.1198	0.0000	0.0006	0.0000	0.0000	0.0450	0.0000	0.0834	0.0000
H. High Q.	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0045	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H. High Yld.	0.0612	0.0616	0.0718	0.0749	0.0765	0.0607	0.0412	0.2403	0.1057	0.0919	0.0575	0.0619	0.1324	0.1105	0.1649	0.0000