# Wheat Quality and Wheat Yields: Trade-Offs among Price, Yield, Profit, and Risk

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S U M M A R Y

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In this report, important wheat quality attributes and their links to varietal differences are identified, and their technical and economic importance to the milling and baking industries is examined. Wheat class and grading systems used in the United States and other countries are described, and the relationships between wheat classes and wheat varieties and between physical and wholesomeness attributes and grades are identified. The per bushel prices received by farmers for their wheat depend on the classes and grades of wheat they produce. However, wheat classes and, to some degree, grades are linked to varietal choices and those choices also affect average per acre yields and year-to-year yield variability. Therefore, this report also examines the role of price premiums and yield differences in farmers' varietal choice decisions. Price premiums, particularly protein price premiums, play a crucial role in those decisions, both in terms of their average levels and their year-to-year volatility. Evidence from the Pacific Northwest on average protein price premiums and protein price premium volatility is presented, and implications for varietal choice are discussed. Finally, the links between wheat product uniformity and price premiums are evaluated and compared with the costs of obtaining product uniformity through additional wheat cleaning and varietal regulation.

Price and yield considerations also have important implications for public and industry-supported research programs. Through federal and state funding for State Agricultural Experiment Stations and federal funding for the USDA Agricultural Research Service, the U.S. government provides substantial support for public research programs to develop new wheat varieties. In many states, these funds are enhanced by additional resources provided by agricultural producers through wheat production levies. How these funds should be allocated across alternative lines of research depends on expected payoffs to both producers and consumers. Private seed companies that operate their own research programs also are concerned about trade-offs between yield and quality in developing new varieties because of potential effects on producer demand for those varieties. These issues are examined in the context of the benefits and costs of public policy and private decisions with respect to quality and yield attributes in varietal R&D programs.

The report's key findings are as follows. Wheat producers plant many different varieties of wheat, and their varietal choice decisions depend crucially on the yields they expect to obtain and the prices they expect to

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receive for the different varieties they consider. In addition, to the extent that producers are risk averse, their varietal decisions are also influenced by differences among varieties with respect to both yield and price volatility. Variations in prices among different classes of wheat largely derive from variety-related differences in intrinsic characteristics such as protein and gluten content and kernel hardness. Variations in prices among different grades of wheat within classes are mainly associated with differences in nonintrinsic characteristics such as cleanliness and the presence of contaminants such as pesticide residues.

The potential availability of premiums for specific attributes such as protein and ash content has been used as an economic justification for research targeted to improve wheat quality rather than wheat yields. In general, for any given attribute, if demand remains relatively stable, then as the quantity of the attribute supplied increases, the price of that attribute in the marketplace declines. This has clearly been the case for wheat protein. One important implication of the observed inverse relationship between protein premiums and the supply of high-protein wheat is that the potential economic benefits to producers of plant-breeding programs focused on quality attributes that currently provide price premiums need to be carefully assessed. Finally, with respect to the issue of shipment uniformity, although increasing product uniformity may enhance prices received from end users, achieving increased uniformity also typically imposes costs on producers and the grain-handling system, which may more than offset any potential gains.

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### Introduction

Wheat is not simply just wheat. Hundreds of different varieties of wheat exist. Each variety has different physical and chemical attributes, and each is better suited for one or several of a wide range of uses. These uses include breadmaking and other baking processes, the production of many different types of traditional pastas and oriental noodles, and feed for animals. In addition, producers incur different production costs in raising different types of wheat, in large part because of differences in average per acre yields. Moreover, variations in production, storage, and other on-farm and off-farm practices mean that wheat shipments also may differ in nonintrinsic characteristics and intrinsic attributes. As a result, different types of wheat typically sell for varying prices in local and world markets. Wheat varieties also differ with respect to year-to-year variations in both yields and prices. Depending on the wheat varieties they select, therefore, producers may experience more or less year-to-year variability in gross and net revenues and face more or less financial risk.

In this report, important wheat quality attributes and their links to varietal differences are identified, and their technical and economic importance to the milling and baking industries is examined. Wheat class and grading systems used in the United States and other countries are described, and the relationships between wheat classes and wheat varieties and between physical and wholesomeness attributes and grades are identified. The per bushel prices received by farmers for their wheat depend on the classes and grades of wheat they produce. However, wheat classes and, to some degree, grades are linked to varietal choices, and those choices also affect average per acre yields and year-to-year yield variability. This report therefore also examines the role of price premiums and yield differences in farmers' decisions about which varieties will be planted. Price premiums, particularly protein price premiums, play a crucial role in those decisions, both in terms of their average levels and their year-to-year volatility. Evidence from the Pacific Northwest on average protein price premiums and protein price premium volatility is presented, and implications for varietal choice are discussed. Finally, the links between wheat product uniformity and price premiums are evaluated and compared with the costs of obtaining product uniformity through additional wheat cleaning and varietal regulation.

**Varietal choices affect average per acre yields and year-to-year yield variability.**

At the farm level, producers' decisions about varietal selections are driven by considerations about the differences across varieties with respect to expected average prices and average yields and year-to-year variability in those prices and yields. Price and yield considerations also have important implications for public and industry-supported research programs. Through federal and state funding for State Agricultural Experiment Stations and federal funding for the USDA Agricultural Research Service, the U.S. government provides substantial support for public research programs to develop new wheat varieties. In many states, these funds are enhanced by additional resources provided by agricultural producers through wheat production levies (Alston, Pardey, and Smith 1998). How these funds should be allocated across alternative lines of research depends on expected payoffs to both producers and consumers. Private seed companies that operate their own research programs also are concerned about trade-offs between yield and quality in developing new varieties because of potential effects on producer demand for those varieties. These issues are examined in the context of the benefits and costs of public policy and private decisions with respect to quality and yield attributes in varietal R&D programs.

**The allocation of research funds should depend on expected payoffs to both producers and consumers from alternative varietal R&D programs.**

### Wheat Quality Attributes

The heterogeneous nature of the wheat delivered to the U.S. grain-handling and processing system arises because of differences across varieties and agronomic environments with respect to a wide array of wheat quality attributes. Wheat quality attributes can usefully be divided into three general categories. These categories include (1) intrinsic characteristics, including the biochemical and structural properties of wheat, such as protein and ash content, (2) physical condition, including test weight, damaged kernels, moisture, and purity, and (3) wholesomeness, including pesticide residues, live insects, insect damage, and noxious weed seeds. A brief summary of major attributes originally developed by Mercier is presented in Table 1. Uniformity within and among wheat shipments is a fourth general attribute important to end users.

**Table 1. Major Wheat Quality Characteristics**

| Physical | Wholesomeness | Intrinsic |
|---|---|---|
| Heat-damaged kernels | Live insects | Protein quality |
| Shrunken and broken kernels | Insect damage | Protein quantity |
| Nonmillables: | Noxious weed seeds | Gluten quality |
| Dockage | Pesticide residues | Wheat hardness |
| Foreign material | | Sprout damage |
| Other wheat classes | | Kernel size |
| Moisture content | | Color |
| Test weight | | Ash content |
| Total defects | | Water absorption |

*Source:* Mercier (1993), Table 1

*Intrinsic Characteristics*

Intrinsic characteristics determine the viability of different wheats for various end uses and generally cannot be identified by simple visual inspection. Important intrinsic characteristics include protein quality and quantity, gluten quality, wheat hardness, kernel size, color, ash content, sprouting, and disease resistance. Several of these attributes are partially related to one another. Grading systems use characteristics that are relatively easy to observe because, to some degree, they are linked to other quality attributes that are less readily identified.

Protein content or quantity is a proxy measure of two groups of proteins in the gluten complex: gliadins and glutenins (Stiegert and Blanc 1997). Gliadins provide cohesiveness to dough, whereas glutenins give dough its ability to resist extension. These proteins are the sources of the viscoelastic properties of dough needed in baking processes. Protein content, both in terms of quality and quantity, is important in determining wheat's end use because it affects the gluten strength of wheat flour dough. High-protein wheats are usually preferred for breadmaking. Products made with soft wheats are often leavened with chemicals and need wheat with low-protein content (Wilson 1989).

Protein quantity is more easily measured than protein quality. Higher-protein wheats generally receive higher prices than lower-protein wheats, although protein premiums within given classes of wheats such as hard reds have not been stable over time (Wilson 1989; Espinosa and Goodwin 1991). Protein quality depends in part on the relative proportions of gliadins and glutenins in wheat kernels; these proportions are primarily determined by varietal genetics (Hoseney 1986). Protein quantity, however, is closely linked to growing conditions. As a result, the total supply of wheat protein provided by U.S. and other wheat producers varies from year to year and is an important source of year-to-year fluctuations in protein premiums. Gluten content, which is related to protein content, affects the cohesiveness of wheat flour dough, and optimal gluten content also varies by end use.

Kernel hardness and color are largely determined by variety. Ash content is also linked to variety. It is defined as the inorganic remains, or ash, left after incineration of the wheat and is measured as a percentage of the original weight of the wheat prior to incineration. A lower ash content generally implies that a given quantity of wheat will yield more flour and less bran. One advantage of hard white wheat varieties over hard reds is that hard whites generally have lower ash content. However, currently there is only limited evidence that ash content has any impact on the prices paid for different wheat varieties.

**Grading systems use wheat characteristics that are relatively easy to observe.**

Sprout-induced starch damage occurs when, because of high moisture content, wheat kernels germinate prematurely. The result is that flour thickening is retarded with adverse consequences for baking properties. Sprout damage is measured by the falling number test in which higher numbers indicate higher levels of sprout damage. Some statistical evidence indicates that wheats with higher falling numbers receive lower prices (Espinosa and Goodwin 1991). This finding is consistent with survey results that indicate buyers have strong preferences for wheats with low falling numbers (Mercier 1993; Pick et al. 1994).

Disease and pest resistance is also a potentially important varietal characteristic. Saw fly infestations in the Northern Great Plains, for example, have had adverse effects on wheat yields in recent years. Hence, several plant breeding programs, including programs at North Dakota State University and Montana State University, have attempted to develop wheat varieties that are resistant to such infestations. Similarly, over the past five years, fusarium blight has had adverse effects on yields from many wheat varieties in the Northern Great Plains, although impacts have differed across varieties. In recent years, therefore, plant breeding programs have allocated substantial research resources to identifying and developing varieties that are resistant to this disease.

Milling characteristics are also important and, in large part, intrinsic. Wheat varieties differ with respect to dough stability, mixing time, flour water absorption, and breakdown characteristics, which are all measured by a farinograph. Greater dough stability permits more flexibility with respect to mixing, but very high stability results in dough that is too tough. Mixing time is the time required for dough to reach its maximum consistency, which is achieved when the glutens in the dough are aligned and permit the dough to achieve its optimal elasticity for baking purposes. Mixing time is longer for wheats that produce doughs with stronger viscoelastic mass, which are more suitable for breadmaking. Greater ability to absorb water is desirable in some end uses, including breadmaking, but less desirable in others. A dough's valorimeter value shows the amount of breakdown that occurs twelve minutes after it has reached its maximum consistency. Stronger dough has a higher valorimeter value and is more suited to breadmaking.

### *Physical Condition*

The physical condition of an individual wheat shipment affects its value. Wheat kernels may be damaged by heat, shrunken, or broken. Wheat shipments may also contain nonmillable matter, including dockage—nongrain material that can be removed by approved screening devices—and foreign material. Wheat with higher proportions of heat-damaged, shrunken, and broken kernels and dockage is less valuable than wheat with lower proportions. Prices for U.S. wheat may be lower than for Australian or Canadian wheat because U.S. wheat contains more dockage, foreign matter, and damaged kernels (Mercier 1993; Dahl and Wilson 1998). Some have suggested that the U.S. government should therefore impose tighter standards with respect to these attributes. Whether there would be a net economic benefit to wheat producers is still an open question. Higher prices are likely to be obtained for wheat that has been cleaned to tighter specifications, but those tighter specifications can be attained only if additional cleaning costs are incurred. There is no persuasive evidence that the benefits of additional cleaning unambiguously outweigh the additional costs (Mercier 1993; Carter and Loyns 1996).

**There is no persuasive evidence that the benefits of additional wheat cleaning unambiguously outweigh the additional costs.**

Test weight is the weight per unit volume of wheat. In the United States, test weight is measured in pounds per bushel and is determined by weighing the quantity of grain required to fill a one-quart container. Other things being equal, wheat with a higher test weight generally has denser kernels and provides a higher flour yield. Thus, test weight is widely viewed as an important indicator of wheat quality (Espinosa and Goodwin 1991). However, test weight should be viewed in conjunction with moisture content. Wheat with a higher moisture content has a higher test weight but is more susceptible to moisture damage in storage. Thus, high moisture content can adversely affect wheat prices.

*Wholesomeness*

Wheat that is infested with live insects, contains substantial insect damage or noxious weed seeds, or is contaminated with pesticide residues is less desirable than wheat that does not contain such impurities. Careful storage and cleaning reduce insect infestation and damage and the presence of noxious weed seeds, for which there may be low or zero tolerance in some markets. Controlling pesticide residues requires adjustments in production practices.

**Among comparable grades of Canadian and U.S. wheat, uniformity and consistency are quite similar.**

*Uniformity*

A final quality concern for many wheat purchasers is the uniformity of wheat both within any given shipment and across shipments to end users. Private-sector buyers in both the United States and foreign markets appear to have strong preferences for uniformity (Mercier 1993; Mercier and Hyberg 1995), although the extent of their willingness to pay premiums for such uniformity is unclear. Uniformity is a multidimensional attribute, involving uniformity with respect to many of the individual attributes discussed above, including both physical and intrinsic attributes such as dockage, protein content, falling numbers, damaged, shrunken, and broken kernels, and so on. Higher grades of wheat are generally more uniform in both Canada and the United States than lower grades of wheat, but among comparable grades of Canadian and U.S. wheat, uniformity and consistency are quite similar (Dahl and Wilson 1998).

## U.S. Wheat Classes and Grades

Hundreds of wheat varieties are grown in the United States, each of which has different intrinsic quality attributes that affect the wheat's optimal end use and market price. Many varieties, however, have quite similar characteristics such as color, kernel hardness, and protein quality. Each variety of wheat, therefore, is allocated to a class of wheat within which the varieties have relatively similar intrinsic properties. In the United States, each wheat variety is allocated to one of eight different classes: hard red winter, hard red spring, hard white, soft red winter, soft white wheat, durum, unclassed, and mixed.

Generally, wheat classes are determined by the time of year when varieties are planted (spring versus winter) and by hardness, color, and kernel shape. Hard red winter wheat generally has good milling and baking characteristics and is used to produce bread, noodles, some sweet goods, and some all-purpose flour. Hard red spring wheat generally has the highest protein content and, with superior baking and milling characteristics, is widely viewed as an excellent wheat for breadmaking. Hard white wheat is a newly created class of wheat closely related to hard red wheats with similar baking characteristics but a milder, sweeter flavor and lower ash content. Soft red winter wheat tends to be high yielding but low in protein content and is used for flat breads, cakes, pastries, and crackers. Soft white wheat is used in much the same way as soft red wheat, tends to be low in protein content, and has high yields. Durum wheat is the hardest wheat and is used to produce semolina flour from which pasta products are made. Unclassed wheat is a catchall class that includes any wheat varieties that cannot be classified under other criteria and includes any wheat that is neither red nor white in color. Mixed wheat is wheat that consists of less than 90 percent of one class of wheat and more than 10 percent of another class of wheat. Many wheat classes are further divided into subclasses. For example, durum wheat is divided into three subclasses; hard amber durum wheat, amber durum wheat, and durum wheat.

**Producer's varietal choices are largely determined by expected yields and prices and the potential for unpredictable variations in these yields and prices.**

Individual shipments are graded by their physical characteristics and wholesomeness. Both the class and grade are important in determining a shipment's value. Each grade has minimum test weight limits, maximum percent limits for foreign material, broken, heat-damaged, and shrunken kernels, wheat of other classes, stones, and maximum count limits for other material (including animal filth, castor beans, crotalaria seeds, insect-damaged kernels, and unknown foreign substances). The standards are most stringent for grade 1 wheat and least stringent for grade 5 wheat. Wheat that does not meet grade 5 standards is classified as sample wheat. Sample wheat also includes wheat that is either heating, or simply of obvious low quality, or that emits an objectionable odor. Sample wheat is usually used as animal feed.

Other countries allocate wheats to different classes and, within classes, to different grades. In Canada, for example, among other classes, the Canadian Wheat Board distinguishes between Canadian western red spring, Canadian western red winter, and Canadian amber durum classes of wheat and, within those classes, allocates wheat to different grades. Similar classification and grading practices are also used in Australia although the range of classes is smaller because Australia produces mainly low-protein soft wheats.

### Yield versus Quality: The Wheat Producer's Varietal Choice Decision

Each year, wheat producers in the United States have to make important decisions about the varieties they will plant, and as has been shown above, they have a large number of varieties from which to choose. Agricultural producers are generally concerned with maximizing the profitability of their operations while avoiding exposure to excessive financial risks. Their decisions about which crops they raise and, for any given crop, which varieties they plant are largely determined by these concerns. On an area or per acre basis, within any given class of wheat and across some wheat classes, production costs for any given producer are generally very similar. To a large extent, therefore, a producer's varietal choice decision at the time of planting is determined by expected yields and prices for each variety at the time of marketing and the potential for unpredictable variations in those yields and prices.

A producer's per acre gross revenue, R, from a given variety is simply the price received for the variety, P, multiplied by its yield, Y; that is, R = P x Y. If two varieties, A and B, involve identical per acre production costs, C, then the producer's per acre net revenues from growing varieties A and B are $R_A - C$ and $R_B - C$. If the producer is reasonably certain about the prices he will receive and the yields he will obtain from each variety, his varietal choice problem is relatively straightforward. The producer will select variety A over variety B if $R_A > R_B$ or, equivalently, $P_AY_A > P_BY_B$ ; the producer will select variety B over variety A if $R_B > R_A$ or, equivalently, $P_BY_B > P_AY_A$.

In some situations, the producer's varietal choice is quite straightforward. If variety A enjoys both a price premium and a yield advantage over variety B ($P_A > P_B$ and $Y_A > Y_B$), then the producer will choose variety A (and vice versa). In other situations, the choice between the two varieties is less obvious. Variety A, for example, may provide a price premium ($P_A > P_B$), and variety B may enjoy a yield advantage ($Y_B > Y_A$). In these circumstances, an alternative and useful way of looking at the decision rule is as follows. If the gross revenue from variety A is greater than the gross revenue from variety B — that is, if $P_AY_A > P_BY_B$ — and variety A is preferred to variety B, then $P_A/P_B > Y_B/Y_A$. This version of the varietal choice decision rule has a simple commonsense interpretation. For variety A to be chosen, its proportional or percentage price advantage must exceed any proportional or percentage yield advantage enjoyed by variety B. If, for example, A's price advantage over B is only 5 percent (that is, $P_A/P_B$ = 1.05), then A will be preferred to B only if B's yield advantage is less than 5 percent (that is, $Y_B/Y_A < 1.05$). If A's percentage price premium exactly equals B's percentage yield premium, then the producer will see no advantage of one variety over the other, at least in terms of price and yield. If, in contrast, B enjoys a yield premium that is greater than A's price premium, then variety B will be chosen.

The following example usefully illustrates the point. Suppose that on a dryland operation, variety A's expected yield is 35 bushels per acre and its expected price is $4 per bushel, while variety B's expected yield is 39 bushels per acre and its expected price is $3.50. Variety A therefore enjoys a price premium of 14.3 percent ($P_A/P_B = 1.143$), while variety B enjoys a yield premium of 11.4 percent ($Y_B/Y_A = 1.114$). Given that variety A's percentage price premium exceeds variety B's yield premium ($P_A/P_B > Y_B/Y_A$), the producer will choose to plant variety A. This conclusion is confirmed by a simple comparison of expected per acre gross revenues. The expected gross revenue for variety A ($P_AY_A$ = $4 x 35 bushels) is $140 per acre, and the expected gross revenue for variety B ($P_BY_B$ = $3.50 x 39 bushels) is $136.50. It should be noted that a per acre gross revenue difference of $3.50 per acre may not seem a great deal, but on a relatively typical dryland family farm operation in which 1,500 acres of wheat are likely to be planted, selecting variety A will increase the farm family's net income by $5,250. Thus, other things being equal, fairly small differences between yield and price premiums are likely to be important in determining varietal choices.

**Other things being equal, fairly small differences between yield and price premiums are likely to be important in determining varietal choices.**

However, other things may not be equal. Most producers certainly focus on maximizing the profitability of their operations, but many of those same producers also want to avoid exposing themselves to substantial financial risks. Costs incurred in crop production are generally relatively stable from one year to the next, especially in periods of low or no general inflation. Crop revenues are much less stable both because of year-to-year variability in yields and farm-gate prices. If, for the moment, we assume that prices of different varieties move in the same direction and that price premiums remain relatively stable, then risk averse producers will be mainly concerned about differences in the relative stability of the yields associated with different varieties when they make their varietal choice decisions.

Suppose, for example, that varieties A and B have identical average price and yield premiums and, therefore, identical expected gross revenues per acre. However, suppose also that under similar growing conditions, experimental test plot data indicate that variety A yields are less volatile than variety B yields. In these circumstances, many producers who are risk averse will choose variety A instead of variety B because the revenue stream associated with variety A is less volatile. Moreover, even if variety A's price premium is a little smaller than variety B's yield premium (and expected per acre gross revenue for B is greater than for A), many producers may continue to prefer A over B because they are willing to trade off some potential revenue gains for reduced revenue variability and reduced financial risk.

The above discussion is relevant not only in the context of a producer's farm-level decisions about varietal choice but also for decisions about investments in public and private plant breeding research programs. Hard white wheats, for example, are widely viewed as having milling qualities preferable to those of hard red wheats. Thus, there may be a potential for price premiums for hard white varieties over hard red varieties. This possibility has led some to argue that substantial proportions of research and development resources should be allocated to hard white wheat plant-breeding programs. However, if the price premium for hard whites is relatively small and hard reds have more substantial yield premiums, then hard white varieties will not be adopted on a voluntary basis by producers. Moreover, even if expected hard white and hard red wheat yields are similar, and hard white wheats command modest price premiums, if hard white wheat yields are more volatile, then hard white varieties may be not be selected because of producer concerns about increased financial risk. Economic benefits to producers from varietal innovations are linked not only to price premiums. Yields and yield variability are also important, and the potential for improvements in these areas should to be taken into account, along with any potential for price premiums, in allocating research resources among alternative plant-breeding programs.

**Economic benefits to producers from varietal innovations are linked not only to price premiums. Yields and yield variability are also important.**

### Quality-Related Price Premiums

Another significant factor in the farmer's varietal choice decision is the degree to which wheat class and protein price premiums vary over time. This instability represents a potentially important source of financial risk to producers. To illustrate the issue, Table 2 presents data on average annual prices and percentage protein premiums for dark northern spring

**Table 2. Pacific Northwest Dark Northern Spring Prices and Protein Premiums**

| | DNS 13% Protein | DNS 14% Protein | DNS 15% Protein | Premium for 14% over 13% DNS | Premium for 15% over 13% DNS |
|---|---|---|---|---|---|
| | ------------- $ per bushel ------------- | | | --------------- percent --------------- | |
| 1981 | 5.08 | 5.24 | 5.38 | 3.08 | 5.78 |
| 1982 | 5.07 | 5.23 | 5.40 | 3.22 | 6.53 |
| 1983 | 4.60 | 4.73 | 4.84 | 2.76 | 5.22 |
| 1984 | 4.61 | 4.74 | 4.81 | 2.92 | 4.33 |
| 1985 | 4.61 | 4.73 | 4.80 | 2.76 | 4.14 |
| 1986 | 4.28 | 4.44 | 4.53 | 3.86 | 5.97 |
| 1987 | 3.60 | 3.88 | 4.11 | 7.84 | 14.26 |
| 1988 | 2.99 | 3.50 | 3.88 | 17.00 | 29.70 |
| 1989 | 4.34 | 4.51 | 4.60 | 3.98 | 6.02 |
| 1990 | 4.82 | 4.85 | 4.85 | 0.56 | 0.68 |
| 1991 | 3.90 | 3.94 | 3.94 | 0.87 | 1.01 |
| 1992 | 3.71 | 3.78 | 3.81 | 2.10 | 2.79 |
| 1993 | 4.34 | 4.59 | 4.75 | 5.80 | 9.32 |
| 1994 | 4.27 | 4.97 | 5.46 | 16.35 | 27.77 |
| 1995 | 4.50 | 5.19 | 5.56 | 15.21 | 23.46 |
| 1996 | 5.07 | 5.36 | 5.57 | 5.63 | 9.79 |
| 1997 | 5.79 | 6.02 | 6.19 | 4.01 | 6.93 |
| Average | | | | 5.76 | 9.63 |
| Maximum value | | | | 17.00 | 29.70 |
| Minimum value | | | | 0.56 | 0.68 |
| Sample standard deviation | | | | 5.28 | 8.95 |

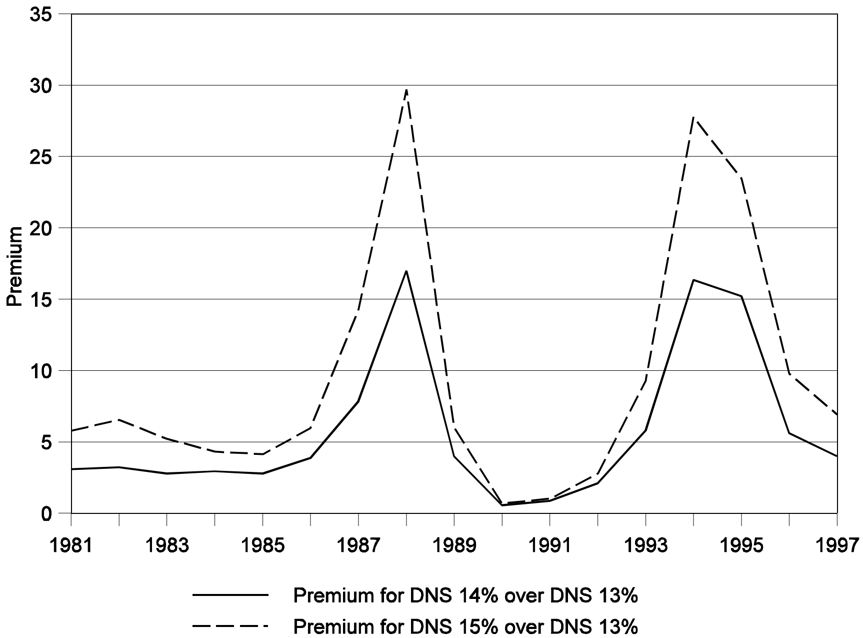
*Source:* Data on Pacific Northwest prices were provided by the Montana Wheat and Barley Commission.

(DNS) wheat sold at Pacific Northwest ports over the period 1981 to 1997. Percentage premiums for DNS (14 percent protein compared to 13 percent, and 15 percent over 13 percent) are shown in columns 5 and 6. The average premiums for 14 percent DNS over 13 percent and for 15 percent over 13 percent were respectively 5.76 percent and 9.63 percent between 1981 and 1997. The premium for 14 percent DNS over 13 percent DNS ranged from a low of 0.56 percent in 1990 to a high of 17 percent in 1988 and the coefficient of variation for the premium (the ratio of the standard error to the mean measured in percentage terms) was 91 percent. The range for 15 percent DNS over 13 percent DNS premiums was also wide with a low of 0.68 percent in 1990 and a high of 29.7 percent in 1988, and year-to-year changes in those premiums were also volatile as indicated by a coefficient of variation for the period of 92.9 percent. Simple plots for both sets of premiums (Figure 1) also show that protein premiums exhibit considerable volatility from year to year.

**If premiums for wheat attributes and different varieties of wheat are highly volatile, producers may be reluctant to trade off yield benefits for price benefits.**

If premiums for wheat attributes and different varieties of wheat are highly volatile, producers may be reluctant to trade off yield benefits for price benefits, although opportunities to hedge price risks in futures markets could mitigate these concerns. It should be recognized, moreover, that premiums associated with wheat attributes are closely linked to market supplies of those attributes. Protein premiums, for example, increased

**Figure 1. Pacific Northwest Dark Northern Spring Protein Premiums, 1981–1997**




*Source:* Table 2

sharply in 1988 when, because of severe drought in western Canada and the Northern Great Plains, production of high-protein wheats was severely curtailed. When, in 1990, supplies of high-protein wheats were plentiful because of well above average production levels in those regions, premiums for high-protein wheats almost disappeared. An important lesson from these supply-related shifts in protein premiums is that the introduction of new varieties that systematically increase the market supply of specific attributes may reduce or even remove the premiums for those attributes. Focusing plant-breeding programs exclusively on quality improvements may, therefore, not be an optimal research strategy, at least from an economic perspective.

### Product Uniformity, Cleaning, and Varietal Control

Another potential source of price premiums is uniformity within and among wheat shipments. Uniformity has been identified as an important characteristic by end users in both the domestic and commercial export markets for U.S. wheat. One explanation for some price premiums paid for wheat exports from other countries, such as Canada, over prices received for U.S. exports has been that shipments from those other countries are more uniform with respect to quality. Dahl and Wilson (1998) have recently provided evidence that, in fact, among comparable classes and grades, Canadian and U.S. wheat shipments are quite similar with respect to the uniformity of important intrinsic and physical attributes. However, lower grades of wheat are generally much less uniform that higher grades of wheat. Given that U.S. wheat exports usually include a greater proportion of lower-grade wheats than do Canadian exports, U.S. wheat exports may on average be less uniform.

**Focusing plant-breeding programs exclusively on quality improvements may not be an optimal research strategy.**

A greater degree of uniformity within and among shipments may result in price premiums. However, increases in uniformity are not achieved without effort. Two important strategies for improving uniformity are more intensive cleaning and varietal regulation or control. More intensive cleaning removes a larger proportion of total defects and results in shipments with more uniform physical characteristics. Regulations that restrict producers' varietal choices can also increase uniformity of intrinsic and physical characteristics.

Both strategies have been implemented in western Canada, where wheat is extensively cleaned and farmers are limited to choices between a relatively small number of varieties within any given class of wheat. Increased cleaning imposes higher costs on the grain-handling system and correspondingly reduces farm-gate prices. If, for example, cleaning costs rise by $5 per ton, then farm-gate prices generally fall by that amount unless the cleaning increases the end use market value of the wheat. For a $5 per ton increase in cleaning costs to be of any benefit to wheat producers, the cleaner wheat's end-use value would have to rise by more than $5 per ton. As noted earlier, there is no compelling evidence that, on balance, very much is to be gained by U.S. wheat producers from increased cleaning.

Varietal regulation also imposes costs on at least some producers, although these costs tend to be hidden. Limitations on varietal choice prevent some producers from selecting varieties that maximize per acre revenues, most often because the restricted varieties provide lower yields. Carter, Loyns, and Ahmadi-Esfahani (1986) estimated that in the early 1980s, wheat producers in western Canada experienced substantial yield losses because of such varietal controls. Such losses from varietal restrictions are not unique to wheat, nor are they necessarily small. Constantine, Alston, and Smith (1994) estimated that in the 1970s and early 1980s, cotton producers in the San Joaquin Valley in California could have increased their annual net incomes by as much as 20 percent per year had a varietal control law targeted to guaranteeing product uniformity not been imposed. Ulrich, Furtan, and Schmitz (1987) reported similar estimates of yield and income losses because of malt barley varietal restrictions in western Canada. It seems unlikely that the benefits of uniformity within and among wheat shipments would exceed varietal-control-related costs of these magnitudes.

**Varietal regulation also imposes costs on at least some producers, although these costs tend to be hidden.**

## Conclusion

Wheat producers plant many different varieties of wheat, and their varietal choice decisions depend crucially on the yields they expect to obtain and the prices they expect to receive for the different varieties they consider. In addition, to the extent that producers are risk averse, their varietal decisions are also influenced by differences among varieties with respect to both yield and price volatility. Variations in prices among different classes of wheat largely derive from variety-related differences in intrinsic characteristics such as protein and gluten content and kernel hardness. Variations in prices among different grades of wheat within classes are mainly associated with differences in nonintrinsic characteristics such as cleanliness and the presence of contaminants such as pesticide residues.

The potential availability of premiums for specific attributes such as protein and ash content has been used as an economic justification for research targeted to improve wheat quality rather than wheat yields. In general, for any given attribute, if demand remains relatively stable, then as the quantity of the attribute supplied increases, the price of that attribute in the marketplace declines. This has clearly been the case for wheat protein. One important implication of the observed inverse relationship between protein premiums and the supply of high-protein wheat is that the potential economic benefits to producers of plant-breeding programs focused on quality attributes that currently provide price premiums need to be carefully assessed. Finally, the issue of shipment uniformity has been examined. Although increasing product uniformity may enhance prices received from end users, achieving increased uniformity also typically imposes costs on the producers and the grain-handling system, which may more than offset any potential gains.

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