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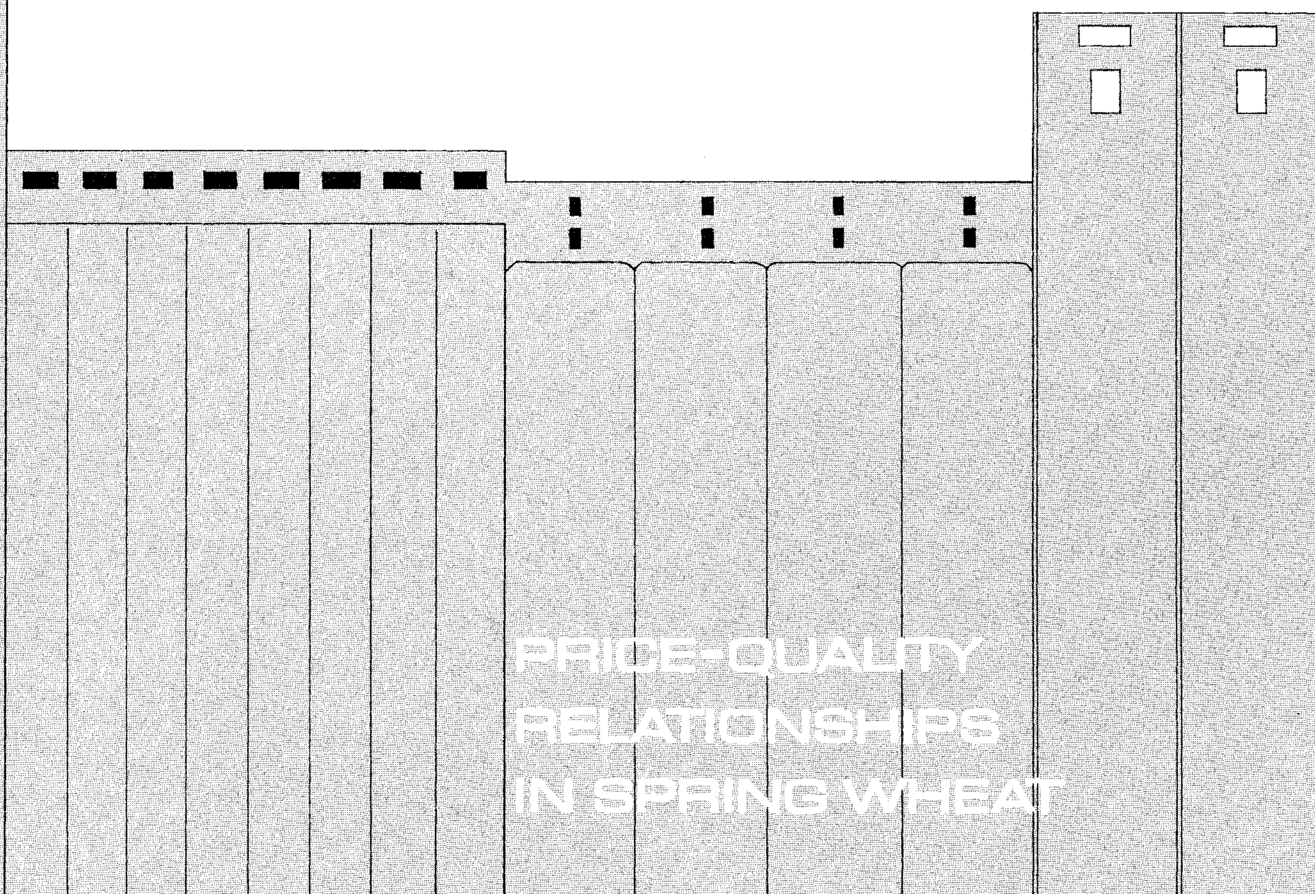
JOHN D. HYSLOP



PRICE-QUALITY RELATIONSHIPS IN SPRING WHEAT

AGRICULTURAL EXPERIMENT STATION - UNIVERSITY OF MINNESOTA

Contents

PRICE-QUALITY RELATIONSHIPS IN SPRING WHEAT

JOHN D. HYSLOP*

INSPECTION AND GRADING

The primary economic function of grades and standards is, basically, to improve the efficiency of the marketing system. The classification of units of a commodity according to well-defined and accepted quality standards aids the user in allocating expenditures to his best advantage. Producers, insofar as they can control quality, are similarly aided.

The technical efficiency of the marketing system is increased through the use of well-defined grades and standards. Merchandising and warehousing of large volumes of grain would be much more costly and inefficient without grades. Grading permits the commingling of grains owned by different persons. Each individual's share in the stock of grain is represented by a warehouse receipt which specifies the quantity and grade.

Inspection and grading of grain in the United States are, in some form, as old as the grain trade itself. The first formal set of grade standards for grain was instituted by the Chicago Board of Trade in 1857[1]. These standards grew out of the necessity for efficient bulk handling of large volumes of grain. During that time Chicago became the nation's leading grain market center.

During the latter part of the nineteenth century other cities became important grain market centers, and they developed their own sets of grain standards. Confusion resulting from the multiplicity of grain grades was of concern to the grain trade. Largely as a result of agitation by trade groups, Congress passed the United States Grain Standards Act of 1916. The Act authorizes the Secretary of Agriculture to "fix and establish standards of quality and condition for corn, wheat, rye, oats, barley, flaxseed, soybeans, and such other grains as the usage of the trade may warrant and permit."[2] The Act required that all grain which was sold by grade, shipped in interstate or foreign commerce, and shipped from or to a place where a licensed inspector is located had to be inspected.[3] In 1968 the Act was amended to require inspection and grading only for grain to be exported.

The Grain Standards Act has brought about uniformity in grades and inspection procedures. Most wheat produced in the United States is transported between various states and thus falls within the mandatory provisions of the Act. The federal grades have received such wide acceptance that they are incorporated in state statutes, which in turn bring mandatory inspection and grading to the country elevator level.

Quality Indicators in Grades

Nationwide standards for wheat were first promulgated by the Secretary of Agriculture in 1917. These standards were based on quality characteristics that had always been desired by the grain trade: plumpness of kernel, soundness, cleanliness, dryness, purity of type, and the general condition of the grain. Today, these characteristics still comprise the set of criteria for assigning grades to wheat.

To reflect these characteristics, the official grades require determination of the following quality factors: (1) test weight per bushel; (2) percent of damaged kernels; (3) percent of foreign material; (4) percent of shrunken and broken kernels; and (5) percent of wheat of other classes.

Grade standards specify for each grade a minimum test weight and maximum percentage by weight of the other factors. Any wheat with moisture content exceeding 13.5 percent receives the special grade designation "Tough." The special grade designation "Heavy," in the case of Hard Red Spring wheat, is applied if the test weight of wheat grading Number 1, 2, or 3 is at least 60 pounds per bushel. Wheat in the lower grades cannot be graded "Heavy" regardless of test weight. Other special grade designations are used to denote wheat that contains specified amounts of particularly objectionable foreign material such as garlic, weevils, smut, or ergot.

Other Quality Indicators

The official grades do not reflect all the factors that affect wheat quality. Milling firms devote considerable effort to discovery of milling and baking quality information that is not provided when wheat is officially graded. Quality tests employed by these firms are not part of the mandatory wheat inspection process. One reason for this is that the tests are not sufficiently standardized to communicate information on quality effectively. Another reason is that the amount of time required to perform these quality tests is too great for transactions at the country elevator level or for sales of country-shipped wheat at terminal markets.

Lacking results of complete milling and baking tests, the grain trade has come to rely on protein content as the market index of the bread-making quality of the hard wheats, Hard Red Spring and Hard Red Winter.

Wheat contains the two proteins glutenin and gliadin. When wheat flour is mixed with water, these two proteins combine to form the elastic substance known as gluten. Gluten traps the gases produced by the leavening agent, causing the dough to rise. This property, when gluten is present in large quantities, enables flour to yield loaves of large volume, absorb large amounts of water, and resist physical breakdown under mechanical stress.

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[1] Henry H. Bakken, *Theory of Markets and Marketing*, Madison, Wisconsin: Mimir Press, 1953, p. 231.

[2] Allan E. Korpela, *Federal Farm Law Manual*, Oxford, New Hampshire: Equity Publishing Corp., 1956, p. 313.

[3] *Ibid.*, pp. 313, 314.

Hard Red Spring and Hard Red Winter wheat are excellent bread wheats because of their high protein content. The protein content of Hard Red Winter wheat generally falls in the 10.5-12.5 percent range. Hard Red Spring wheat averages between 13 and 15 percent. Other flour-producing wheats contain much less protein.

Although the test measures the total quantity of protein in wheat, it does not measure the quality of the protein (wheat contains other proteins in addition to gluten.) However, it is accepted as a useful index of both, particularly in Hard Red Spring wheat. All receipts of hard wheat at terminal markets are subjected to the protein test, and it is widely used at the country elevator level.

Premiums paid for hard wheats with high protein content are independent of the premiums and discounts paid on the quality factors that make up official grades. Protein premiums will vary depending on the current distribution of protein in the available supply of wheat and the market demand for protein.

OBJECTIVES

This study had two principal objectives:

1. To analyze the role that the system of official grades plays in the discovery of price-quality relationships in wheat and the effectiveness of this system in differentiating among wheats.

   The approach to this objective involves answers to the following questions:

   a. Does the system of official grades adequately describe spring wheat in terms of its value-differentiating characteristics?

   b. How important to the value of spring wheat are the quality factors that are measured in official, mandatory inspection?

   c. Is there an alternative to the present system of official grades? That is, how might the present system of numerical grades be improved to aid in the discovery of price-quality relationships?

2. To analyze the demand for hard wheat protein. Protein premiums are an important source of revenue to hard wheat producers. Protein is the quality factor unique to bread wheats and the most important and readily available indicator of baking quality. An analysis of the demand for protein can have implications for the efficient operation of the wheat market. It can also have implications for decisions concerning the development and release of high protein wheat varieties.

Analysis of the Official Grades

The Problem

With respect to quality, there are two basic types of transactions in wheat. The first type is made essentially on a sample basis. Traders are presented with a detailed inspection report on the wheat sample. The report identifies the wheat as to its class, subclass, and grade. It lists the measured values of all grading factors; it gives the sample's protein content; and names the country station from which the wheat originated. Cash wheat trades on the floor of an exchange are of this nature. To traders at these market places numerical grade designations are of little interest. The traders already possess more information on quality (presented in the form of the values of the grading factors themselves) than is given by the numerical grade.

In the second type of transaction, numerical grade designation is all-important. These transactions are consummated through the purchase and sale of warehouse receipts. The warehouse receipt contains only the market class, subclass, numerical grade, special grade designation, and protein content of the wheat. Examples of this type of transaction are sales by exporters to foreign buyers, deliveries to the Commodity Credit Corporation of wheat it has stored in public elevators, and deliveries on futures contracts.

Traders involved in this type of transaction do not have access to the detailed quality information possessed by those dealing on a sample basis. They must rely on the numerical grade itself for information concerning wheat quality.

Criteria for Effective Grades

Ideally, grading is done on the basis of objectively measured factors that are capable of being rapidly and simply determined. The factors must be those that are widely recognized by users as being important to the use for which the product is intended.

For most commodities, grades are intended to indicate ranking. In wheat, for example, the assignment of Grade Number 2 to a sample of wheat means that the wheat should be more desirable for milling into flour than wheat which is graded Number 3, but it should be less desirable than wheat graded Number 1. The desirability is measured in terms of the quantity of flour obtained per unit of wheat or of the quality of the flour obtained.

If the grades are well-defined such that, when grade standards are applied, ranking is achieved, then this fact will be reflected by market prices. That is, wheat graded Number 2 will be priced higher than that graded Number 3, but lower than that graded Number 1.

The three criteria may be summarized as follows: (1) objectivity; (2) relevance; and (3) rank-ordering (if it is intended). In this study the last two criteria formed the standard against which the present official grades were judged. There is no question that the first criterion is met by the official inspection process. Grading factors are measured in terms of pounds and percentages by weight. The competence and honesty of licensed inspectors insure that objectivity is attained. A fourth criterion, completeness of quality information, is not met by the present official grades. As noted earlier, protein content is not a part of the official grades yet it is the most important market index of bread-making quality. The desirability of including protein content in the grade standards will be discussed later.

GRADES AND GRADE FACTORS IN HARD RED SPRING WHEAT

The present official grade standards for Hard Red Spring wheat are shown in table 1. These are essentially unchanged from those first promulgated in 1917.

The grading factor "Total Defects" is defined as the sum of damaged kernels, foreign material, and shrunken and broken kernels. It was added to the standards in 1964. Previously there was no definite limit on the sum of these defects except the sum of the limits for each. Before it was added to the standards, astute merchandisers could profit by blending low grade wheat with, for example, Number 1 wheat up to the limit for each factor and deliver Number 1 wheat.

Test Weight per Bushel

The bushel is commonly regarded as a volume measure.[4] However, the practice of marketing grain by weight, rather than by volume, has become so widespread that the wheat bushel has been legally defined as a 60-pound unit. Test weight per bushel is thus a measure of density. It is regarded as an important indicator of the pounds of flour that may be milled from a legal bushel of wheat. Generally, higher flour yields are obtained from wheat of high test weight.

Damaged Kernels

"The different kinds of damaged wheat kernels affect the milling and baking quality of wheat in different ways.

"Frosted wheat, when the entire seed coat is badly affected, produces a flour of poor dough quality and is unsatisfactory for the production of good bread.

"Heat damage in wheat is perhaps more objectionable than any other, because wheat so injured produces a flour poor in color and of unsatisfactory bread-making properties. Bread from such flour is small in volume, the crumb is discolored, the texture is very poor, and the bread has an offensive odor and normally tastes bad.

"Heat damage in its early stages affects, among other things, the bran or the pericarp protective covering of the kernels. Such damaged kernels are commonly referred to as skin-brunt and possess unsatisfactory milling and baking properties. Similarly, stack stain or header damage, caused from stacking grain that is not fully ripened and consequently is high in moisture content, produces flour of inferior bread-making qualities.

"Moldy wheat is often caused by storing damp wheat under unfavorable conditions. Such wheat usually develops a musty odor that will ultimately be transmitted to the products made from the flour."[5]

Table 1. Official grades for Hard Red Spring wheat, 1968

Grade	Test weight	Heat damage	Total damage	Foreign material	Shrunken and broken kernels	Total defects	Wheat of other classes: Contrasting classes	Wheat of other classes: Total other classes
	min. lb/bu.	max. percent	max. percent	max. percent	max. percent	max. percent	max. percent	max. percent
1	58.0	0.1	2.0	0.5	3.0	3.0	1.0	3.0
2	57.0	0.2	4.0	1.0	5.0	5.0	2.0	5.0
3	55.0	0.5	7.0	2.0	8.0	8.0	3.0	10.0
4	53.0	1.0	10.0	3.0	12.0	12.0	10.0	10.0
5	50.0	3.0	15.0	5.0	20.0	20.0	10.0	10.0

Sample grade: Sample grade shall be wheat which does not meet the requirements for any of the grades from No. 1 to No. 5, inclusive; or which contains more than two crotalaria seeds (*crotalaria* spp.) in 1,000 grams of grain, or contains castor beans (*Ricinus communis*), stones, broken glass, animal filth, an unknown foreign substance(s), or a recognized harmful or toxic substance(s); or which is musty, sour, or heating; or which has any commercially objectionable foreign odor except of smut or garlic; or which contains a quantity of smut so great that any one or more of the grade requirements cannot be applied accurately; or which is otherwise of distinctly low quality.

Source: *The Federal Register*, Vol. 33, No. 139. July 18, 1968, p. 10284.

[4] These descriptions of grading factors are largely taken from *Grain Grading Primer*, Miscellaneous Publication No. 740, U.S. Department of Agriculture, Washington: September 1957, pp. 26-50.

[5] "*Grain Grading Primer*," op. cit., p. 26.

Foreign Material

Any material in the lot which is not wheat, other than that considered dockage, is termed foreign material. It differs from dockage in that it must be purchased as wheat. Dockage, on the other hand, is deducted in determining the quantity of wheat in the lot. Much of the foreign material is removed in the cleaning process before milling and thus represents a loss of millable material, possessing value only as feed.

Shrunken and Broken Kernels

They are pieces of the wheat kernels broken during handling and immature whole kernels in which the endosperm (the flour portion) did not fully develop before growth halted. It is technically defined for grading purposes as wheat which will pass through a 0.064″ × 0.375″ oblong hole sieve. Although the miller attempts to recover them, most shrunken and broken kernels are removed in the pre-milling cleaning process and sold as feed.

Wheat of Other Classes

This factor is objectionable because the milling and baking characteristics of the other class wheat will be different from those generally expected in wheat undergoing grade determination.

Application of the Standards in the Assignment of Grades

The inspection process yields information for traders dealing on a sample basis that is less than complete. The licensed inspector is required to report only those percentages of a defect (i.e., damaged kernels, foreign material or shrunken and broken kernels) that lie outside the Number 1 range. For example, as shown in table 1, if the percentage of damaged kernels in the sample is less than 2 percent, the inspector need not report on damaged kernels on the inspection ticket. However, test weight is an exception to this rule: Its value is always reported.

A significant modification of the rule has been made at the request of Minneapolis Grain Exchange members for wheat traded in Minneapolis. Whenever total defects exceed 3 percent (i.e., lie below the Number 1 range), inspectors must record the percentage of each of the component defects.

The effect of the requirement is that in the vast majority of cases, the inspection report for Number 1 wheat will show the percentages of defects at zero. The trader, who examines the sample displayed on the trading floor, guesses the approximate value of each of the defects.

In applying the standards, the inspector assigns the lowest grade permitted by any of the sample's measured grading factors. In order for the sample to receive any of the Grades 1 through 5, the value of all grading factors must lie within that grade's range or within the range of a higher grade. For example, if a sample's foreign material percentage is within the Number 3 range (greater than 1 percent and not over 2 percent), and the values of all other factors are in the ranges of higher grades, the sample will be graded Number 3.

The Grade Standards and the Milling Process

The miller is interested in large yields of high quality flour from each unit of wheat. Thus, he is willing to pay premiums for wheat that is high in test weight and low in defects.

To insure that unsound wheat and foreign material do not lower the quality of his flour, he subjects the wheat to a fairly elaborate cleaning process before milling.

In this cleaning process much of the foreign material is removed by mechanical devices employing differences in size, shape, and specific gravity. Foreign material that is removed, the cleanout, is recleaned to recover as many shrunken and broken kernels as possible.

After tempering (the addition of water to bring the wheat to about 16 percent moisture), as many damaged kernels as possible are removed by an impact machine, which breaks them for removal by screening. After this step, shrunken and broken kernels, recovered from the cleanout, are introduced into the wheat stream for milling into flour.

One would expect that the wheat market would reflect the loss of material in the cleaning process. He would expect that wheat prices would show discounts for each of the defects: damaged kernels, foreign material, and shrunken and broken kernels. He would also expect that the price differentials due to assigned numerical grades would be consistent with the premiums and discounts resulting from the grading factors.

EMPIRICAL ANALYSIS OF THE OFFICIAL GRADES

The Sample

This analysis was based on a survey of all cash transactions in Hard Red Spring wheat at the Minneapolis Grain Exchange on Monday, January 16, 1967. Data were obtained from firms that sell wheat from day-to-day by displaying a sample on the trading floor. All but three were commission firms that act as traders for country wheat shippers. The exceptions were three line elevator companies.

Cash grain sold on the Exchange floor is displayed in sample pans by the selling firms. Most samples represent shipments of grain from country elevators. Only rarely will a sample represent wheat from a terminal elevator in the Twin Cities area. Accompanying each sample is a "pan ticket" on which results of the official inspection and other information pertinent to the sale are recorded. This information is shown in table 2.

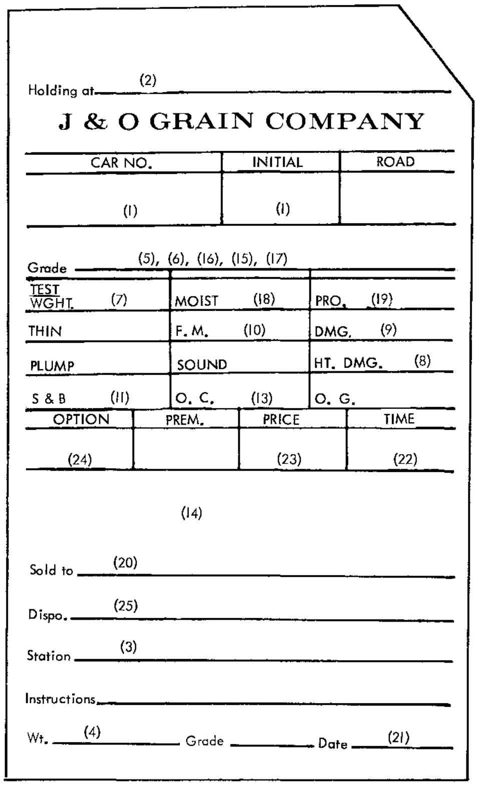
An example of a pan ticket is shown in figure 1. Because the ticket is used for all grains traded at Minneapolis, some of the boxes to be filled in on the ticket do not apply to wheat.

This information (see figure 1) was requested from the firms interviewed. The survey yielded data on 121 sales of Hard Red Spring wheat. Analysis of the data was designed to show the effect that grades, grading factors, nongrade quality factors, and other nonquality factors had on wheat prices. The results of the analysis show how well the present system of grades and standards measures up to the two criteria of relevance and rank ordering.

The Resultant Data

Data were obtained on 102 carlot sales and 19 truck sales of Hard Red Spring wheat. Several firms declined to identify the buyers of wheat they sold, reasoning that this might betray the implied trust between buyer and seller.

The general characteristics of the values of the variables are shown in table 3. All sales were spring wheat in the subclass Dark Northern Spring. Very little wheat of the subclass Northern Spring was seen from the 1966 crop. Wheat of the subclass Red Spring has been extremely rare in recent years. The moisture content of one carload was sufficiently high



Holding at (2)

J & O GRAIN COMPANY

CAR NO.	INITIAL	ROAD
(1)	(1)	

Grade (5), (6), (16), (15), (17)

TEST WGHT. (7)	MOIST (18)	PRO. (19)
THIN	F. M. (10)	DMG. (9)
PLUMP	SOUND	HT. DMG. (8)
S & B (11)	O. C. (13)	O. G.

OPTION	PREM.	PRICE	TIME
(24)		(23)	(22)

(14)

Sold to (20)

Dispo. (25)

Station (3)

Instructions

Wt. (4) Grade Date (21)

Figure 1. Example of pan ticket used in the trading of cash grain (Courtesy J & O Grain Co., Minneapolis)

(13.8 percent) to receive the special grade designation "Tough."

Variables that are not explicit indicators of quality require further discussion:

Area of origin

The area of origin of the wheat is included because buyers tend to discriminate among wheats on this basis. Geographic differences in weather or soils can impart differences in the baking quality of wheat. Spring wheat from South Dakota, area 6 on the map (figure 2) has the reputation of being somewhat lower in quality than spring wheat from North Dakota and Montana.

Location of Car or Truck When Sampled

This recognizes two methods of offering country shipped grain for sale by sample. Diversion point sales represent wheat that is in a position to be shipped either to Minneapolis or Duluth. Samples are drawn from the car at the diversion or holding point, which may be the shipper's station or one of the recognized holding points somewhere between the station and the terminal market place. One sample is sent to Duluth and the other to Minneapolis. The car is then sold on the basis of the sample to the highest bidder and is sent to the city in which the buyer is located. A small number of cars are sent directly to Minneapolis and sampled there. These are sales designated as local.

Analytical Technique

The effect that each quality indicator has on wheat prices was estimated using the statistical technique of multiple linear

Table 2. Information relevant to this study contained on ticket that accompanies each sample of cash grain

	Grain description		
General information	Official grade	Nongrade	Sale information
(1)* Boxcar or truck identification number	(5) Grade	(15) Kind of grain	(20) Name of buyer
(2) Location of car or truck when sampled	(6) Heavy or not heavy	(16) Market class and subclass	(21) Date of sale
(3) Country origin of grain	(7) Test weight per bushel, pounds	(17) Dockage, percent	(22) Time of day
(4) Quantity of grain in car or truck, pounds	(8) Heat damaged kernels, percent	(18) Moisture, percent	(23) Price
	(9) Total damage, percent	(19) Protein, percent	(24) Price of nearby future
	(10) Foreign material, percent		(25) Destination of grain
	(11) Shrunken and broken kernels, percent		
	(12) Total defects, percent		
	(13) Wheat of other classes, percent		
	(14) Special grade factors (smut, garlic, tough, etc.)		

* Numbers in parentheses correspond to numbered boxes in figure 1 to show where information is recorded.

regression.[6] The analysis yielded estimates of the premiums and discounts resulting from differences in the values of the grading factors. From this, the relevance of each of the grading factors to the official grades was assessed. A second analysis, similarly performed, gave estimates of price differences among wheats due to differences in grade. This analysis showed how well rank-ordering was achieved in the market place by the official grades.

In the trading of cash grains, bids and offers are made in terms of the "basis," so many cents or fractions of cents above or below the price of the nearby future. If the basis is positive, the price of cash wheat is greater than that of the future. The cash price at which the sale takes place is the price of the future plus the basis.

[6] A detailed explanation of the technique is given in the Appendix.

Estimates of premiums or discounts due to quality were made in terms of the basis. This was done to take into account any changes in the overall price level during the day. As shown in table 3, the price of the nearby (March) future ranged from $1.80¼ to $1.83¾.

Analysis I: Premiums and Discounts From Grade Factors

The estimated price differences due to differences in the values of the grading factors are shown in table 4. A table that shows the premiums and discounts associated with all factors employed in Analysis I is presented in the appendix. Only the grading factor premiums and discounts are presented here so that attention may be focused on them. Only five grading factors appeared in the survey. These were: test

Table 3. General characteristics of data used in the analysis of the official grades

Numerical grade		Area of origin*		Location of car or truck when sampled		Destination of car or truck		Transportation mode		Special grades	
Grade	Number of sales	Area	Number of sales	Location	Number of sales	Destination	Number of sales	Mode	Number of sales	Grade	Number of sales
A. Variables with discrete values											
1	48	1	42	Local	47	Minneapolis	67	Rail	102	Heavy	17
2	35	2	19	Diversion point	74	Duluth	54	Truck	19	Not heavy	104
3	28	3	8								121
4	8	4	9								
5	1	5	14								
Sample	1	6	22							Tough	1
		7	7							Not tough	120
Total	121		121		121		121		121		121

Variable	Range: Minimum value	Range: Maximum value	Average
B. Variables which are measured on a continuous scale			
Price per bushel, cents per bushel (nearest ⅛)	165½	195¼	187⅞
Price of nearby (March) future, cents per bushel (nearest ⅛)	180¼	183¾	181¾
Basis, cents per bushel†	—15	12	6⅛
Dockage, percent‡	0.0	3.5	0.5
Protein, percent	12.7	17.0	15.2
Moisture, percent	10.0	13.8	11.7
Test weight per bushel, pounds	53.5	61.2	58.1
Damaged kernels, percent	0.0	18.6	1.3
Foreign material, percent	0.0	1.7	0.3
Shrunken and broken, percent	0.0	5.3	1.3
Total defects, percent§	0.0	20.9	1.3

* See map, figure 2.

† Difference between cash and futures prices. Basis > 0 if cash > futures.

‡ Dockage is measured in whole and half percents. Fractions greater than whole or half percent are ignored. For example, dockage from 0.0 to 0.4 percent is entered on the inspection ticket as 0.0; dockage from 0.5 to 0.9 is entered as 0.5; and dockage from 1.0 to 1.4 is entered as 1.0. This practice was followed in preparing this table. All other percentage determinations are recorded to the nearest one-tenth of one percent. Test weight is to the nearest one-tenth of a pound.

§ Total defects is determined as the sum of damaged kernels, foreign material, and shrunken and broken kernels.

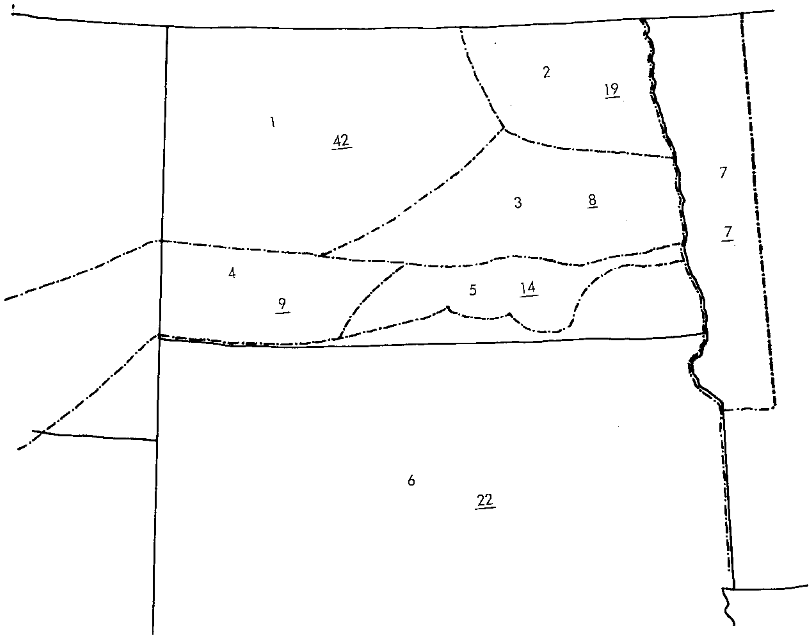


Figure 2. Origins of wheat sold at the Minneapolis Grain Exchange on Monday, January 16, 1967 (the underlined numbers indicate the number of shipments originating in the area)

weight, damaged kernels, foreign material, shrunken and broken kernels, and total defects.

In estimating the premiums and discounts for grading factors, the observed values of each of the grade factors (pounds per bushel for test weight and percent by weight for the other factors) were split into intervals and an average premium in discount was estimated for each. One of the intervals for each of the factors was assumed to be the base (i.e., it received neither a premium nor a discount).

Estimates presented in table 4 are brought out better in figure 3. Here, estimated premiums and discounts are plotted against the measured values of each of the grading factors.

These estimates show that wheat prices tend to increase with higher test weights and decrease as the values of the other factors increase.

Although each of the four factors appears to be relevant to wheat quality, test weight and damaged kernels seem to be more important than foreign material and shrunken and broken kernels. This is very likely to be related to the fact that observed values of test weight and damaged kernels extend over a wider range than observed values of foreign material and shrunken and broken kernels. The values of test weight extend into the Number 5 range, and those of damaged kernels extend into the Sample Grade range. The values of both foreign material and shrunken and broken kernels extend only into the Number 3 Range.

The relevance of grading factors to wheat quality can be seen from premiums and discounts associated with almost the entire range of values for test weight and damaged kernels and those associated with the extreme values of foreign material and shrunken and broken kernels. The market awarded premiums of about 1 cent per bushel for each pound of test weight over 58 pounds. The market extracted discounts of about 2 cents per bushel for each pound of test weight below 58 pounds. No additional discount was extracted for test weights below 55 pounds. Discounts on damaged kernels averaged about 1 cent per bushel for each percent damaged below the Number 1 range. Foreign material of more than 1 percent received a discount of almost 2 cents per bushel. Shrunken and broken kernels over 3 percent was discounted by about ½ cent to more than 2 cents per bushel.

Results of Analysis I point up a criticism of the grading and inspection procedure related to the adequacy of quality information. It was mentioned earlier that the licensed inspector at Minneapolis need only report those values of the discounting factors if total defects exceed 3 percent or if the values of the factors themselves lie outside the Number 1 range. Thus, for example, the trader on the floor of the Grain Exchange would know the value of shrunken and broken kernels in a wheat sample only if it contained more than 3 percent shrunken and broken kernels or if total defects ex-

Table 4. Estimated premiums and discounts paid on the grading factors for Hard Red Spring wheat, January 16, 1967

Test weight*		Damaged kernels*		Foreign material*		Shrunken and broken kernels*	
Range of values	Premium (+) or discount (−)	Range of values	Premium (+) or discount (−)	Range of values	Premium (+) or discount (−)	Range of values	Premium (+) or discount (−)
(lbs./bu.)	(cents/bu.)	(percent)	(cents/bu.)	(percent)	(cents/bu.)	(percent)	(cents/bu.)
61.0—61.2	+2.87†	0.0	0.00	0.0	0.00	0.0	0.00
60.0—60.7	+2.16†	0.2— 0.3	−1.03§	0.1—0.3	+0.70	0.9—1.6	−0.35
59.0—59.6	+0.80†	0.4— 0.5	−1.87‡	0.4	+0.82	1.7—1.9	−0.33
58.0—58.9	0.00†	0.6— 0.7	−2.07‡	0.5	+3.11†	2.0	−1.74
57.5—57.7	−0.14†	0.8— 1.0	−0.42	0.6 & 0.7	+1.46	2.1—2.3	−0.01
57.0—57.3	−1.88†	1.3— 1.7	−3.05‡	0.9 & 1.0	+1.63	2.4	−1.06
56.5—56.8	−3.80†	1.9— 2.0	−2.66†	1.2—1.7	−1.93‡	2.5	−0.86
56.0—56.3	−3.91†	2.4— 3.0	−3.35†			2.6—2.9	−1.20
55.0—55.7	−6.03†	3.4— 4.3	−4.61†			3.1—3.9	−0.66
53.5—54.4	−5.32†	5.0— 7.0	−6.65†			4.0—5.3	−2.27‡
		7.3—18.6	−11.32†				

* Values above the line in each column are in the Number I Grade for each factor. Values below the line are in lower grades.

† Indicates that with the statistical procedure used, a premium (or discount) this large or larger could have occurred by chance alone with a probability of only 1 percent.

‡ Indicates a chance occurrence of a premium (or discount) this large of only 5 percent.

§ The absence of a single or double dagger following a premium or discount indicates an occurrence that large or larger by chance alone of greater than 5 percent.

ceeded 3 percent. Otherwise, the precentage would be unreported or reported as zero percent.

The resulting uncertainty as to the actual defect content of the sample is shown in figure 3 as extreme variability of price differentials for small values of the defects. This is particularly true for foreign material, shrunken and broken kernels, and for values of damaged kernels less than 2 percent.

The grading factors, then, may be judged to meet the criterion of relevance. However, they may be criticized for failing to yield as much quality information as present standards would permit.

Analysis II: Price Differences Due to Grade

The estimated price differences due to differences in assigned grades are shown in table 5. A table that shows the premiums and discounts associated with all factors employed in Analysis II is presented in the appendix. Only grade discounts are presented here so that attention may be focused on them.

In general, average prices exhibited the desired property of lower prices for lower grades of wheat. One exception to this is the average price paid for Number 5 wheat. It is about one-quarter of a cent greater than that paid for Number 4.

Given the general downward progression in prices for lower grades of wheat, the higher price paid for lower grade wheat provides a basis for criticizing the system of official grades. Failure to achieve the rank-ordering intended by grade standards indicates that the official grades do not differentiate among wheats as well as might be expected. Although the standards imply that Number 5 wheat is not as good as Number 4, the market, in this particular case, rates Number 5 wheat above Number 4.

Table 5. Hard Red Spring wheat at Minneapolis: average prices for wheats by official grade

Grade	Average price	Discounts from No. 1
	(cents/bu.)	(cents/bu.)
1	188.76	. .
2	186.98	−1.78
3	183.84	−4.92
4	178.52	−10.24
5	178.77	−9.99
Sample grade	165.06	−23.70

Failure of official grades to meet the criterion of rank-ordering is closely related to the grading requirement that inspectors assign the lowest grade permitted by any one of the sample's measured grading factors. Thus, for example, a wheat sample graded Number 3 on the basis of a single factor, but whose other factors are in the Number 1 range, could be considered to be of higher quality on the market than wheat with all factors in the Number 2 range.

Most often such a "market inversion" occurs between adjacent numerical grades, and even grade Number 1 can be affected. This occurs because grade standards for test weight are not bounded on the top. For example, Number 1 wheat having a test weight of 58 pounds per bushel could be considered less valuable than extremely heavy Number 2.

It would seem that the frequency and quantitive importance of such "market inversions" would tend to be greatest in years in which one single grading factor caused most of the downgrading of wheat shipments. For example, adverse

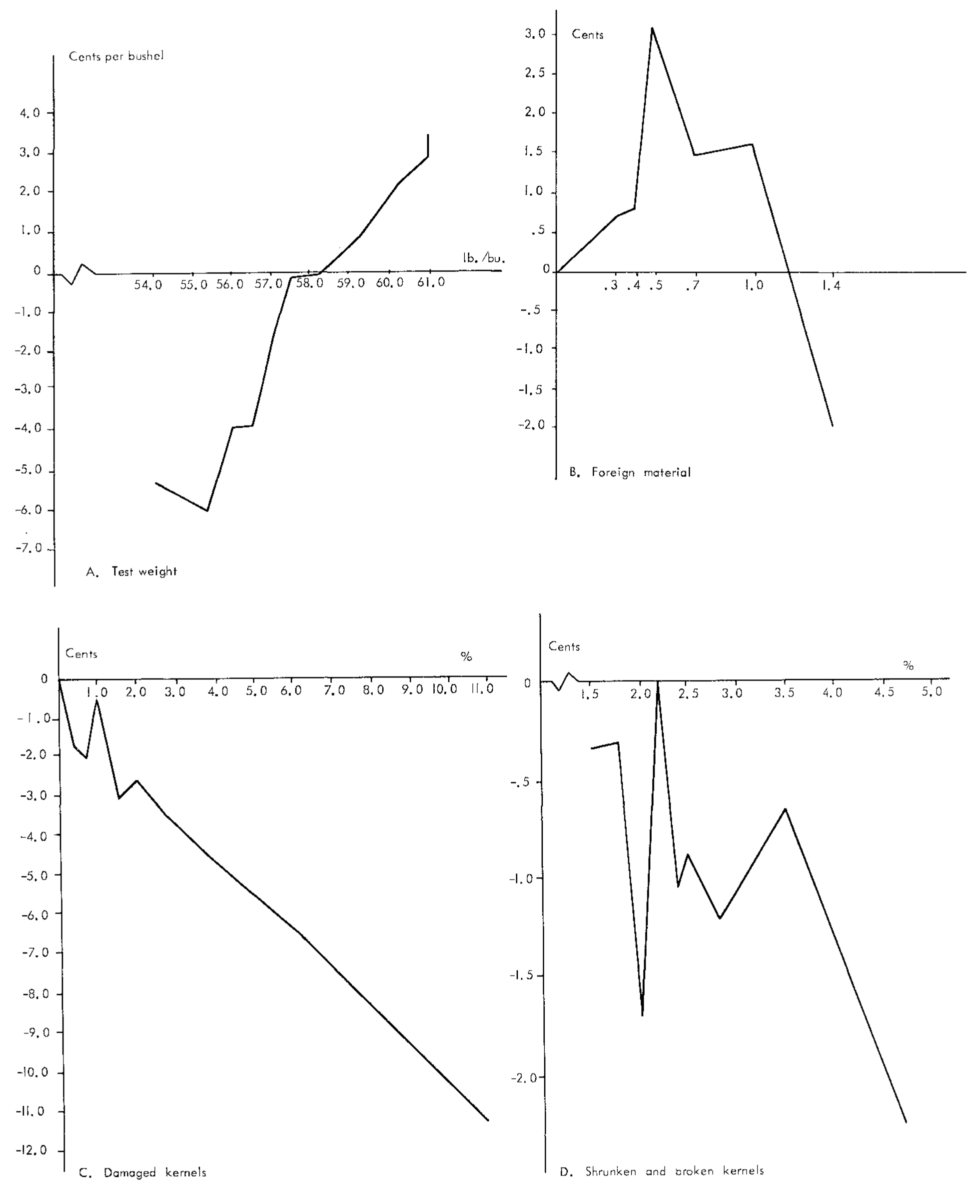


Figure 3. Price differentials for grade factors estimated in Analysis I

weather at harvest time may result in a large amount of wheat being graded Number 3 due solely to damaged kernels. Other shipments grading Number 2 on the basis of damaged kernels and one or more other factors would likely receive a lower price.

Of the 121 sales at the Minneapolis Grain Exchange on a single day the grade other than Number 1 was determined by a single factor in 37 cases. Of these only 15 had all other factors in the Number 1 range. For the most part, several factors in each sale were significant in causing wheat to receive a grade other than Number 1.

Composite Grades: Suggested Modification of Official Grades

The nature of the grading factors that most frequently appear suggests a modification of the present grades that will increase the likelihood of attaining rank ordering. These grading factors serve primarily to divide wheat into its feed and flour portions. Test weight per bushel is regarded by traders as an important index of flour yield because higher test weight wheats generally yield more flour per bushel than lighter wheats. In the cleaning process prior to milling, foreign materials and damaged kernels are removed, and much of the shrunken and broken kernels cannot be recovered, but is sold as feed.

This consideration suggests that existing official grades could be improved by making the overall grade of the wheat sample a composite. This composite grade would be an average of the grades for each factor in the sample. In the Canadian system of grades for wheat the factors of maturity, frost, shrunken kernels, and other types of damage are "composited" in determining soundness.

Grading wheat according to this system would increase the likelihood of attaining proper rank-ordering in the market place. Composite grades differentiate among wheat samples according to the relative quantities of feed and flour that can be obtained. So long as the market values feed and flour dif-

Table 6. Composite grades for Hard Red Spring wheat

Grade for each factor*	Minimum test weight per bushel	Maximum limits of: Damaged kernels	Foreign material	Shrunken and broken kernels	Composite grade†
	(pounds)	(percent)	(percent)	(percent)	
1	58.0	2.0	0.5	3.0	1
2	57.0	4.0	1.0	5.0	5
3	55.0	7.0	2.0	8.0	9
4	53.0	10.0	3.0	12.0	13
5	50.0	15.0	5.0	20.0	17
6					21

* A factor will be graded Number 6 if its value lies outside the limit for Number 5.

† The composite grade is the sum of the factor grades minus a constant whose value is one less than the number of factors included in the composite. Thus, for Composite Grade Number 1, the sum of the factor grades is four. Four factors were included in the composite, so the constant subtracted is three. For Composite Grade 5, the sum of the factor grades is eight. Subtracting the constant, three, gives 5 as the composite grade.

ferently, the difference should be reflected in price differentials among wheats falling into different composite grades.

A simple alternative to the process of averaging factor grades would be that of making the Composite Grade the sum of the factor grades. A constant would then be subtracted from this sum so that the top grade be Number 1.

Composite Grades: An Example Using the Existing Standards

One possible set of composite grades for wheat is shown in table 6. This set was defined using only those factors that appeared in the survey's sample. The grade boundaries for each factor, the factor grades, are those presently employed in the official standards for wheat.

Obtaining a composite grade other than those shown in table 6 can be illustrated by an example. Assume the results of an official inspection were as follows:

Factor	Factor grade
Test weight	2
Damaged kernels	1
Foreign material	3
Shrunken and broken kernels	2
Total	8
Constant to be subtracted	−3
Composite grade	5

The factor grades add up to eight. Four factors were included in the composite, so the constant to be subtracted is three. The resulting composite grade is Number 5.

One apparently disturbing feature is the large number (21) of composite grades permitted under this grading process. In practice, however, the larger numbers would seldom appear. Most wheat samples would continue to fall into Grades 1 and 2.

Distribution of wheat samples from the survey among these composite grades and existing official grades is shown in table 7. Under the present requirements, 83 of the 121 samples lie in Official Grades 1 and 2. Eighty-two of the samples lie in Grades 1 and 2 when the system of composite grade classification is applied.

Table 7. Distribution of 121 wheat samples from the survey among the composite grades and existing official grades

Composite grade	Number of samples in each of the existing grades assigned according to existing requirements: 1	2	3	4	5	Sample grade	Total in composite grade
1	48	2	..	..	..	..	50
2	..	29	3	..	..	..	32
3	..	4	13	..	..	..	17
4	..	..	7	3	..	..	10
5	..	..	5	1	1	..	7
6	..	..	..	3	..	..	3
7	..	..	..	1	..	..	1
8	..	..	..	..	..	1	1
Total in each existing federal grade	48	35	28	8	1	1	121

Analysis III: Price Differences Among Wheats in the Resulting Composite Grades

It was argued that rank-ordering, as displayed by market prices, would be more likely with composite grades than existing official grades. In order to demonstrate this, wheat samples from the survey were classified according to the composite grade system. Price differences due to differences in assigned composite grades were then estimated. These are shown in table 8.

Table 8. Hard Red Spring wheat at Minneapolis: average prices for wheats by composite grade

Composite grade	Average price	Discount from No. 1
	(cents/bu.)	(cents/bu.)
1	189.26	. .
2	187.47	−1.79
3	185.56	−3.73
4	183.55	−5.74
5	180.43	−8.86
6	178.81	−10.48
7	177.94	−11.32
8	165.78	−23.48

Estimated prices for wheats assigned the composite grades display the desired property of rank-ordering. The composite grades, therefore, do a better job of differentiating among wheats on the basis of recognized quality factors.

OTHER FACETS OF THE OFFICIAL GRADES

Subclass Determination

Subclasses of wheat are not part of the system of numerical grades. They are discussed here because they have been purported to be an index of market quality and are defined under the U.S. Official Grade Standards for wheat.[7] This determination is made for all wheat samples during the mandatory inspection.

The market class Hard Red Spring wheat is divided into three subclasses on the basis of the percentage of dark, hard, and vitreous kernels. These subclasses are Dark Northern Spring, Northern Spring, and Red Spring. The market class Hard Red Winter wheat is divided into the subclasses Dark Hard Winter, Hard Winter, and Yellow Hard Winter, also on the basis of its dark, hard, and vitreous kernel content (table 9). Subclasses are a vestige of the early days of grain grading when few other indicators of milling and baking quality were available.

The determination process would seem to be somewhat subjective and time consuming. "Dark, hard, and vitreous" are subjective factors and are not easily measured. For this reason they are not a good index of wheat quality. The experienced inspector, who has his own concept of "dark, hard, and vitreous" well in mind, can usually make the determination at a glance. On occasion, however, he will be presented with a sample containing dark, hard, and vitreous kernel content close to the limits of one of the subclasses. Then the determination must be made by hand-picking the kernels individually from a weighed subsample and weighing them to determine the percentage.

On both these counts, subjectivity and the expenditure of time, the value of subclass determination can be questioned. This is particularly true when there is some indication that subclasses are related to protein content (table 10). Protein determination is invariably made at terminal markets and often at country elevators, and it yields more information about milling and baking quality.

Table 10 was constructed from data presented in *Physical, Chemical, Milling, and Baking Properties of Carlot Receipts of Wheat,* AMS-356, published by the Agricultural Marketing Service, U.S. Department of Agriculture. It provides some basis for assessing the relationship of protein content to subclass. In Hard Red Spring wheat the average protein content of wheat in the subclass Dark Northern Spring is 1.6 percent greater than in the subclass Northern Spring. In Hard Red Winter the subclass Dark Hard Winter has an average protein content 1.6 percent greater than subclass Hard Winter, and the latter has an average protein content 0.9 percent greater than Yellow Hard Winter.

In view of the subjectivity inherent in the present method of determining subclasses, one authority has suggested that protein content should be the basis on which subclass determination is made.[8] The designation "Hard" would be used only on those wheats whose protein contents were at least equal to some established minimum.

Table 9. Official definition of subclasses of Hard Red Spring and Hard Red Winter wheats

Hard Red Spring		Hard Red Winter	
Subclass	Dark, hard, and vitreous kernels	Subclass	Dark, hard, and vitreous kernels
	Percent		Percent
Dark Northern Spring	≧ 75.0	Dark Hard Winter	≧ 75.0
Northern Spring	25.0—74.9	Hard Winter	40.0—74.9
Red Spring	< 25.0	Yellow Hard Winter	< 40.0

Source: *Official Grain Standards of the United States.*

For domestic wheat trade it might be argued that the subclass determination could be eliminated from official grade standards. Subclass determination could be retained for use on a permissive basis by country elevators at which no protein test is available. In terminal markets, traders possess more information about the milling and baking quality of each sample of wheat than that conveyed by the market subclass.[9]

Additional Factors in the Official Grade Standards

It has been argued that the official grades for wheat should include information specific to baking quality. In particular, the standards should include protein content as a factor in determining the official grade.[10] The typical argument for do-

[7] Official Grain Standards of the United States, *op. cit.,* pp. 1.4-1.6.

[8] J. A. Shellenberger, "Are Present Grain Standards Adequate to Merchandise United States Grain in World Markets." Paper presented at Minneapolis Grain Exchange Marketing Seminar, Minneapolis, Minnesota, August 31, 1959.

[9] In an interview, one wheat buyer stated that protein and country origin told him all he could expect to know about the baking quality of country-run wheat.

[10] J. A. Shellenberger. "Protein Grain Standards," *The Northwestern Miller,* Vol. 274, June 1967, p. 10.

Table 10. Mean and dispersion of protein contents within the subclasses of bread wheats: samples from 128,142 cars examined by USDA personnel during the crop years, 1948-52 and 1958-61

Wheat	Mean protein content	Range of protein contents	Number of carlots
	percent	percent	
Hard Red Spring:	14.0	11.4—17.2	25,172
Dark Northern Spring	14.3	11.8—17.2	19,677
Northern Spring	12.7	11.4—14.2	5,495
Red Spring	(No samples of this subclass appeared)		
Hard Red Winter:	11.5	7.8—15.2	102,970
Dark Hard Winter	12.8	10.3—15.2	27,472
Hard Winter	11.2	8.5—13.4	58,057
Yellow Hard Winter	10.3	7.8—12.1	17,441

Source: Agricultural Marketing Service, USDA, *Physical, Chemical, Milling, and Baking Properties of Carlot Receipts of Wheat.* AMS-356, 1949, 1951, 1952, 1953, 1959, 1961, and 1963.

ing so relates to international trade: Wheat could be purchased from the U.S. by foreign buyers on a protein specification basis, but this is normally not done. Canadian wheat is graded partially on a variety identification basis with a high protein variety as the standard. Foreign buyers of Canadian wheat who specify Number 1 or Number 2 have some assurance of the milling quality they will receive. U.S. wheat, graded on the basis of protein, would be more competitive with Canadian wheat.

There are two arguments against making additional quality information available. First, the availability of quality information when transactions take place must be considered. Under present official standards, information on grades and protein content is available within a few hours. Results of complete milling and baking tests, which provide the best information on quality, would probably not be available in 1 day. For example, an interview with an assistant to the director of a wheat evaluation laboratory of one large milling firm revealed that these results are normally available on the third day after the sample has been received. With special effort, results can be made available on the second day. The most time-consuming step in the evaluation process is the tempering of wheat to achieve a desired moisture level. This requires 8 to 12 hours.[11]

This practical consideration is more important at some levels of the marketing process than at others. It is a limiting factor for farmers selling to country elevators and for country elevators that sell at terminal markets. More detailed information can be made available for transactions taking place farther along in the marketing process, because these generally involve wheat that has been in terminal storage for some time.

The second argument relates to the criteria of rank-ordering and is applicable to protein (for which time is not a limiting factor) as well as to other baking quality indicators. Including protein in the grade standards would tend to make rank-ordering more difficult. It is difficult, if not impossible, to compare the importance of protein (an index of flour quality) with that of, for example, foreign material, an indicator of flour quantity. Protein has its own demand schedule, and protein premiums vary independently of the discount schedule for foreign material, which is related to the relative prices of feed and flour. The inclusion of protein increases the likelihood that the price of a lower grade will be pushed above that of a higher grade.

The present system of wheat inspection and grade designations offers the domestic trade fairly good information on wheat quality at the early stages of the marketing process. There seems to be merit in requiring official inspections to reveal additional quality information for those transactions that do not impose time limits. Improved technology may eventually reduce the cost and time involved, and make these determinations available earlier in the marketing process.

But providing quality information for use in transactions is quite different than incorporating that information into a set of grade designations. As the number of quality factors in a grading system is increased, it is less likely that a system will meet the criteria of rank-ordering. Grade designations that include a large number of quality factors, but are not ordinal, may actually convey less information about wheat quality than ordinal designations that contain fewer factors.

OFFICIAL GRADES: SUMMARY AND CONCLUSIONS

Market Day Analysis

The analysis of the market day survey data revealed that the rank-ordering property is not achieved by present grade standards for wheat. It is possible that wheat in a lower grade will be judged more valuable than wheat in a higher grade. It is argued in this study that ordinality could be approached more closely by using composite grades.

[11] A recently reported innovation permits an adequate temper to be achieved in about 20 minutes. Frank J. McNeill, "A Quick Temper for Experimental Milling of Wheat," *Cereal Science Today,* Vol. 9, November 1964, pp. 408-409.

Only brief mention was made of possible problems involved in the use of composite grades. The problem of a large number of possible composite grades was covered. The four factors used in the suggested set of composite grades created 21 possible grades. However, it seems unlikely that more than a small number of these would ever appear. In the market day survey, all six of the existing grades appeared in the sample. These were rearranged into eight composite grades. In both sets of grades, most of the wheat samples were concentrated in Grade Numbers 1 and 2.

Official Grades: Other Considerations

The relationship between protein and wheat subclasses was discussed. It was suggested that they both purport to convey the same sort of information about baking quality. But because protein conveys more information, the practice of dividing hard wheat into subclasses could be eliminated from official standards.

The question of including more information in the official grades was examined. It was argued that doing so may not be desirable because some of the information is not readily available to traders and the inclusion of more information would make the property of rank-ordering harder to achieve.

One recommendation with respect to the present inspection practice is offered. It is concerned with increasing the knowledge of those traders who buy and sell on a sample basis. The present requirement of the inspection system is that percentages of individual defects (damaged kernels, foreign material, and shrunken and broken kernels) must be recorded on the pan ticket only if they lie below the maximum limit for Number 1 or if total defects exceed 3 percent. Requiring the inspector to record all determinations would take little extra effort, and it could contribute significantly to buyers' and sellers' knowledge.

Analysis of the Demand for Hard Wheat Protein

Hard Red Spring and Hard Red Winter are the two principal bread wheats raised in the United States. These two classes of wheat possess the characteristics that are most desired in producing quality bread flour. The primary determinant of this desirability is the protein contained in the wheat berry. Both the quality and quantity of protein are important for baking quality; but the market, for practical purposes, has recognized protein quantity to be an acceptable index of both in the case of Hard Red Spring. The relationship between protein content and bread flour quality is, in general, direct. That is, wheat of higher protein content is more valuable for milling into bread flour than wheat of lower protein content.

"The baker does not usually want the strongest (highest in protein content) flour for bread baking. Therefore, the miller in producing brand flour usually uses a moderately strong wheat or a blend of a strong wheat with a weaker wheat to obtain the strength in his flour the baker desires. Nevertheless, the supply of relatively weaker wheat in the United States and throughout most of the world is greater than the supply of strong wheats. For that reason strong wheat is in great demand (sic.) and usually commands a considerable premium over weaker wheat in the U.S. and world markets."[12]

The protein content of spring wheat will usually lie in the range 11 to 17 percent, with the bulk of it between 13 and 15 percent. Protein content of hard winter wheat will generally be in the 10 to 15 percent range, and most of this will be in the 10.5 to 12.5 percent range. Bakery flours, which represent about 65 percent of all flour consumed,[13] are milled from wheats of 11 to 16 percent protein.[14] Most of this wheat is used in wholesale pan breads, rolls, and continuous-mix breads.[15] This flour is milled from wheat in the 11.3-12 percent protein range.[16] Thus, most bakery flours are blends of spring and hard winter wheats.

Trends in the demand for different wheats affect the demand for hard wheat protein in a fashion that is not entirely one-sided. Higher income and urbanization have undoubtedly been factors behind the long-term trend away from home baking and the relative increase in consumption of commercially-baked breads. Chai has argued that these factors have increased the demand for hard wheats, Hard Red Spring and Hard Red Winter, relative to that for Soft Red Winter.[17] Mechanical mixing devices require wheat of fairly high dough strength, while home-baked breads require weaker doughs that can be easily manipulated by hand. The increase in demand for hard wheats has been accompanied by an increased demand for hard wheat protein.

Recent technological developments in milling and baking, Chai argues, tend to increase the demand for Hard Red Winter wheat at the expense of Hard Red Spring.[18] Air classification milling, which permits the production of many flour fractions based on protein content from one wheat, tends to allow Hard Red Winter wheat to serve as the source of several flours of widely varying dough strengths for use in a variety of baked products. The continuous dough mixing process does not require the dough strength that the batch mixing process requires, and therefore, tends to reduce the demand for Hard Red Spring wheat relative to Hard Red Winter. Both these processes are in limited use and their major influence on the demand for hard wheat protein can be expected in the years to come.[19]

[12] Lawrence Zeleny. "Wheat Strength and the Sedimentation Test," AMS 422. Agricultural Marketing Service, USDA. 1960.

[13] Wheat Flour Institute. *From Wheat to Flour.* Chicago, 1965, p. 63.

[14] Derrill B. Pratt, Jr. Manager, Quality Assurance, Industrial Division, The Pillsbury Co., "Competitive Aspects of Wheat by Classes in the Milling Trade." Paper presented at the Grain Exchange Marketing Seminar, Minneapolis, September 8, 1966.

[15] It was estimated that in 1965, commercial bakeries supplied about 95 percent of the bread consumed in the United States. Tom Quick. "Data for Millers." *The Northwestern Miller,* Vol. 272, January 1965. p. 19.

[16] Pratt, *op. cit.*

[17] Ju Chun Chai. *An Economic Analysis of the Demand and Price Structure of Wheat for Food by Classes in the United States.* Unpublished Ph.D. Thesis, University of Minnesota, Minneapolis, 1967, pp. 45-48 and 71, 72.

[18] Ibid., pp. 49-51 and 72, 73.

[19] Air classification milling accounted for about six percent of the U.S. milling capacity in 1965, and about 25 percent of the white pan bread was produced by the continuous mix process in 1966. Chai, op. cit., pp. 49 and 73.

The wheat protein test (for quantity) is employed as a pricing factor in addition to the normal characteristics of test weight, moisture content, damaged kernels, etc., which go into determining numerical grades. Premiums are paid on Hard Spring wheat that tests out at over 11 percent protein, and these premiums can amount to more than 10 percent of the per bushel price.[20]

Spring wheat receipts at Minneapolis and Duluth, the average protein content of spring wheat receipts at Minneapolis, the weighted average protein premium, and total dollar outlay for protein at Minnesota's terminal markets are shown in table 11 for each year from 1950-1963. The receipts and protein data in table 11 were computed from data published in *The Daily Market Record.* Protein premiums used in estimating the averages were taken from the *Annual Report* of the Minneapolis Grain Exchange. The weighted average protein premium paid ranged from 25 cents per bushel in 1956-57 down to 4.8 cents in 1957-58. Extremes in dollar value of protein premiums were also seen in those 2 years: $58.4 million in 1956-57, and $10.2 million the following year.

STATISTICAL ESTIMATION OF THE DEMAND FOR HARD WHEAT PROTEIN

The demand for hard wheat protein was considered to be of the form:

$$Y = A + BQ_s + CQ_w + DZ + u$$

when Y is a measure of the protein premium; A, B, C, and D are the parameters to be estimated. Q_s and Q_w are measures of the quantity of protein in spring and winter wheat supplies. Z is a shift variable that attempts to account for changes in the demand for hard wheat relative to soft wheat; and u is the random disturbance.

This form is a compromise of a more complex model of the demand for hard wheat protein. The compromise is necessitated primarily by data limitations. In estimating the demand for protein, the protein premium was regarded as being determined by the values of parameters A, B, C, and D, and of the Q's and Z. The statistical technique of multiple regression was used to estimate the values of A, B, C, and D from the current values of Y, the Q's, and Z.

Table 11. Total Hard Red Spring wheat receipts at Minneapolis and Duluth; average protein content of receipts at Minneapolis; average protein premium paid at Minneapolis; and total outlay for spring wheat protein at Minneapolis and Duluth

Year beginning July 1	Hard Red Spring wheat receipts at Mpls. and Duluth	Average protein content of receipts at Mpls.	Weighted average protein premium paid at Mpls.	Protein premiums paid at Mpls. and Duluth
	(1,000 bu.)	(percent)	(cents per bu.)	(1,000 dol.)
1949	188,838	13.8	8.2	15,485
1950	287,440	13.2	8.3	23,858
1951	252,985	13.7	6.0	15,179
1952	203,165	13.7	7.9	16,050
1953	199,483	13.4	19.0	37,902
1954	208,379	13.8	17.7	38,883
1955	198,879	14.4	8.9	17,700
1956	233,723	13.9	25.0	58,431
1957	213,095	14.4	4.8	10,229
1958	216,725	14.1	12.2	26,440
1959	177,997	14.8	7.4	13,172
1960	220,093	14.6	6.2	13,646
1961	183,829	14.8	8.0	14,706
1962	202,167	14.1	10.4	21,025

Source: *The Daily Market Record* and the *Annual Report* of the Minneapolis Grain Exchange.

[20] The weighted average protein premium, from table 11, during 1956 was 25 cents per bushel. The average price for Number 1, Dark Northern Spring at Minneapolis that year, from *Agricultural Statistics*, 1965 was $2.42 per bushel.

Sample Period

The sample period covers the 14 years from July 1949 through June 1962. This period was selected for practical reasons. It is the longest continuous period for which complete data for all the variables used are available.

Variables Used and Data Sources

Estimates of four protein premiums were obtained from the analysis. They were:

- Y_1 Premium on 16 percent protein spring wheat. Defined as the price of 16 percent protein spring less the price of 11 percent protein spring. Deflated by the wholesale price index (1947-49 = 100).
- Y_2 Premium on 15 percent protein spring wheat. Defined as the price of 15 percent protein spring less the price of 11 percent protein spring. Deflated by the wholesale price index (1947-49 = 100).
- Y_3 Premium on 13 percent protein spring wheat. Defined as the price of 13 percent protein spring less the price of 11 percent protein spring. Deflated by the wholesale price index (1947-49 = 100).
- Y_4 Premium on 13 percent protein hard winter wheat. Defined as the price of 13 percent protein winter less the price of ordinary protein winter. Deflated by the wholesale price index (1947-49 = 100).

Weighted average protein premiums on spring wheat were obtained from data published in the *Annual Report* of the Minneapolis Grain Exchange and the *Daily Market Record.* The *Annual Report* publishes daily closing cash prices for wheat at six protein levels: 11, 12, 13, 14, 15, and 16 percent. Price observations were taken on the last trading day of each week over the entire sample period. Eleven percent protein wheat was considered to have received no premium. Premiums for the other protein levels were obtained by subtracting the price of 11 protein wheats from the prices of each of the higher protein wheats. Each of these was weighted by the volume of reported receipts at Minneapolis that fell into each of the protein content categories — less than 11.6 percent, 11.6-12.5, 12.6-13.5, 13.6-14.5, 14.5-15.5 percent, and over 15.5 percent protein. These volume data were obtained by observation of all spring wheat transactions occurring on the last trading day of each week over the sample period. These are published in the *Daily Market Record.* Six weighted average protein premiums were thus obtained by adding the premium-protein category products over all weeks in each year and dividing by the total number of bushels in the protein category. Each of the average protein premiums can be expressed by the formula:

$$\frac{\sum_{i=1}^{52} P_{ij} \; Q_{ij}}{\sum_{i=1}^{52} Q_{ij}} \quad (j = 11, \ldots, 16)$$

P_{ij} is the premium paid for the jth protein category in the ith week, and Q_{ij} is the quantity of spring wheat in the jth protein category in the ith week.

Data on the premium paid for 13 percent protein winter wheat in Kansas City were obtained from *Grain Market News,* published weekly by the Grain Division, Agricultural Marketing Service, USDA. The *Grain Market News* reports simple, monthly averages of cash winter wheat prices for 13 percent protein and for ordinary protein. The difference between these was considered to be the premium. These monthly averages were weighted by total wheat receipts for each month, obtained from the Kansas City Board of Trade *Annual Statistical Report,* to derive an annual weighted average protein premium for Hard Red Winter wheat.

The premium paid for winter wheat protein is less precisely measured than that for spring wheat protein because ordinary protein winter wheat is defined as wheat of the lowest protein content currently coming into the market place. For winter wheat this could be 8 to 10 percent protein winter wheat.

Independent variables used in the analysis are shown in table 12. Variables X_1 through X_6 are designed to measure the available supply of hard wheat protein.

For both Hard Red Spring and Hard Red Winter, the size of the current crop and its average protein content are probably the best indicators of the supply of hard wheat protein which is readily available to the milling industry.

Table 12. Independent variables used in the analysis of the demand for hard wheat protein

X_1	Hard Red Spring Wheat, average protein content of current year's crop, percent.
X_2	Hard Red Spring Wheat, production, 10 million bushels.
X_3	Hard Red Spring Wheat, carry-in stocks, 10 million bushels.
X_4	Hard Red Winter Wheat, average protein content of current year's crop, percent.
X_5	Hard Red Winter Wheat, production, 10 million bushels.
X_6	Hard Red Winter Wheat, carry-in stocks, 10 million bushels.
X_7	Domestic consumption of Hard Red Winter and Hard Red Spring Wheats as a percent of the consumption of all wheat less Durum, constant prices.

The average protein content of spring wheat was computed from sales of spring wheat at the Minneapolis Grain Exchange, which were reported in *The Daily Market Record.* The average was based on all carlot sales that occurred on the last trading day of each week throughout the sample period.

The average protein content of the winter wheat crop was computed from data appearing in *Physical, Chemical, Milling and Baking Properties of Carlot Receipts of Wheat,* AMS-356, published by the Agricultural Marketing Service, USDA. The 1961 crop was the last one covered by this series. The average protein content of the 1962 Hard Red Winter wheat crop was obtained from data in the *Grain Market News.*

Annual production of both Hard Red Spring and Hard Red Winter were obtained from various issues of *Wheat Situation,* published four times a year by the Economic Research Service, USDA.

"Carry-in" stocks of both wheats represent additional sources of supply of hard wheat protein. These are less readily available to the milling industry because they are composed primarily of wheat owned by the Commodity Credit Corporation. No information was available throughout the sample period on the protein content of carry-in stocks.

The July 1 carry-in for both hard wheats is published in *Wheat Situation.*

Variable X_7 is selected as an indicator of the shift in the demand for hard wheat relative to that for soft wheat. Chai examined the demands for hard and soft wheats in terms of the quantity consumed of each wheat, the price of each and consumer income.[21] In order to abstract from the effect of changes in wheat prices, consumption of each of the four wheats, as estimated in his analysis with prices held constant at their average values, was used in constructing variable X_7.

The values of each of the variables employed in this analysis are shown in appendix table 5A.

Results of the Analysis of the Demand for Hard Wheat Protein

Results of the demand analysis are shown in table 13. The numbers in the main body of the table are the computed coefficients which correspond to the parameters of the demand equation on page 16. The numbers in parentheses below each row of coefficients are the standard errors. The numbers in the last column on the right of table 13 are the values of the Durbin-Watson test statistic for serial correlation. The double dagger indicates that the test is inconclusive in each case.

The demand coefficients may be interpreted for the 16 percent HRS protein premium as follows:

Column	*Coefficients*
Constant term	If the values of all the explanatory (independent) variables (X_1 through X_7) were zero, then the 16 percent HRS protein premium would be 1810.46 cents per bushel. This is of minor interest since the values of all these are never zero.
X_7	The value −41.67 indicates that if the average protein content of the Hard Red Spring wheat crop increases by one percentage point (e.g., from 13.0 percent to 14.0 percent), the premium paid on 16 percent protein HRS will fall by 41.67 cents per bushel.
X_2	The value −0.39 indicates that if the size of the Hard Red Spring wheat crop increases by 10 million bushels, the premium on 16 percent protein HRS will fall by 0.39 cent per bushel.
X_3	The value 1.59 indicates that if carry-in stocks of Hard Red Spring wheat increase by 10 million bushels, the premium on 16 percent protein HRS will increase by 1.59 cents per bushel.
X_4	The value −11.05 indicates that if the average protein content of the Hard Red Winter wheat crop increases by one percentage point (e.g., from 10.0 to 11.0 percent), the premium on 16 percent protein HRS will fall by 11.05 cents per bushel.
X_5	The value −0.22 indicates that if the size of the Hard Red Winter wheat crop increases by 10 million bushels, the premium on 16 percent HRS will fall by 0.22 cent per bushel.
X_6	The value 0.15 indicates that if the size of the Hard Red Winter wheat carry-in increases by 10 million bushels, the premium on 16 percent protein HRS will increase by 0.15 cent per bushel.
X_7	The value −14.56 indicates that if the percentage of total U.S. wheat consumption, which is Hard Red Spring and Hard Red Winter, increases by one percentage point (e.g., from 74 to 75 percent), the premium on 16 percent protein HRS will fall by 14.56 cents per bushel.

Coefficients for the remaining three protein premiums are interpreted the same way.

[21] Chai, op cit., footnotes 17, 18, 19.

Table 13. Results of the statistical analysis of the demand for hard wheat protein

Protein premium Y	Constant term	X_1 (¢/bu)	X_2 (¢/bu)	X_3 (¢/bu)	X_4 (¢/bu)	X_5 (¢/bu)	X_6 (¢/bu)	X_7 (¢/bu)	R^2 (pct.)	d
16% HRS	1810.46	−41.67*	−0.39	1.59	−11.05	−0.22	0.15	−14.56	0.85	2.21‡
		(8.73)	(0.65)	(0.93)	(8.00)	(0.18)	(0.13)	(21.84)		
15% HRS	2040.60	−29.71*	−0.25	1.38	−7.78	−0.15	0.11	−20.50	0.83	2.53‡
		(6.38)	(0.50)	(0.72)	(6.17)	(0.14)	(0.10)	(16.85)		
13% HRS	916.44	−9.61†	−0.02	0.76	−3.24	−0.04	0.00	−9.99	0.65	2.16‡
		(3.67)	(0.27)	(0.39)	(3.36)	(0.08)	(0.05)	(9.18)		
13% HRW	561.03	−10.67†	0.14	1.08†	−11.12†	−0.18	0.04	−3.79	0.73	1.84‡
		(4.83)	(0.36)	(0.52)	(4.43)	(0.10)	(0.07)	(12.09)		

* Indicates that with the statistical procedure used, a value of the coefficient this large or larger could have occurred by chance alone with a probability of only 1 percent.

† Indicates a chance occurrence of a coefficient this large or larger of only 5 percent.

‡ Indicates that the Durbin-Watson test for serial correlation is inconclusive.

Discussion of the Results

Generally, the coefficients associated with variables that measured hard wheat protein supplies from current production were in accord with expectations: the protein premiums declined as supplies increased.

The coefficients of the variables measuring carry-in stocks of hard wheat were positive. It was expected that these would be negative — that premiums would decline as these stocks increased. The fact that the protein contents of these stocks were not known and, therefore, could not be taken into account may have had some influence on the effect which these stocks had on the protein premiums. The most interesting variables in the demand for hard wheat protein are the average protein contents of Hard Red Spring and Hard Red Winter wheats. These appear to be the most important in determining the protein premium, as judged by the size of the coefficients relative to their standard errors.

The actual values of each of the four protein premiums and the values computed from the results of the analysis are shown in figures 4 through 7. In comparing figures 4 and 5 with figures 6 and 7, note that the vertical scales of the latter two are larger.

Protein premiums exhibit considerable variation over the entire sample period. Extremely high values for the 15 and 16 percent protein premiums in 1950 and 1953 were associated with spring wheat crops of low average protein content (13.2 percent in 1950 and 13.4 percent in 1953). The average protein content of the 14 spring wheat crops in the sample was 14 percent. The low spring wheat premiums paid in 1959, 1960, and 1961 were associated with average protein contents of 14.6-14.8 percent.

Premium Flexibilities

A useful concept associated with the demand for hard wheat protein is that of flexibility. It is defined as the percent by which premiums decline when the supply of the commodity increases by 1 percent.

The relevance of the flexibility concept lies in the fact that it indicates what will happen to total premium receipts if supplies increase. A flexibility greater than 1 percent indicates that if the quantity of protein supplied increases, the premium will decline by a proportionately greater amount, and, therefore, total premium receipts will fall. A flexibility less than one, indicates that the decline in the premium will be proportionately less than the increase in quantity, and, therefore, total premium receipts will increase.

The premium flexibilities associated with changes in the average protein content of the Hard Red Spring and Hard Red Winter wheat crops are shown in table 14. The percent change in the average protein content of wheat, on which the flexibility concept is based, must not be confused with a percentage change. The latter would be a change from, say 13 to 14 percent protein. A 1 percent change from 13 percent protein, as used in the flexibility concept, is quite different and considerably smaller in magnitude. A 1 percent (as in flexibility) increase from 13 percent protein would be an increase to just over 13.1 percent protein.[22]

[22] $13.0 \times 0.01 = 0.13$
$13.0 + 0.13 = 13.13$ percent protein.

Table 14. Premium flexibilities with respect to the average protein content of the Hard Red Spring and Hard Red Winter wheat crops

Protein premium	Premium flexibility with respect to HRS average protein content	Premium flexibility with respect to HRW average protein content
16 percent HRS	28.59	6.34
15 percent HRS	31.52	6.89
13 percent HRS	28.02	7.90
13 percent HRW	14.79	12.88

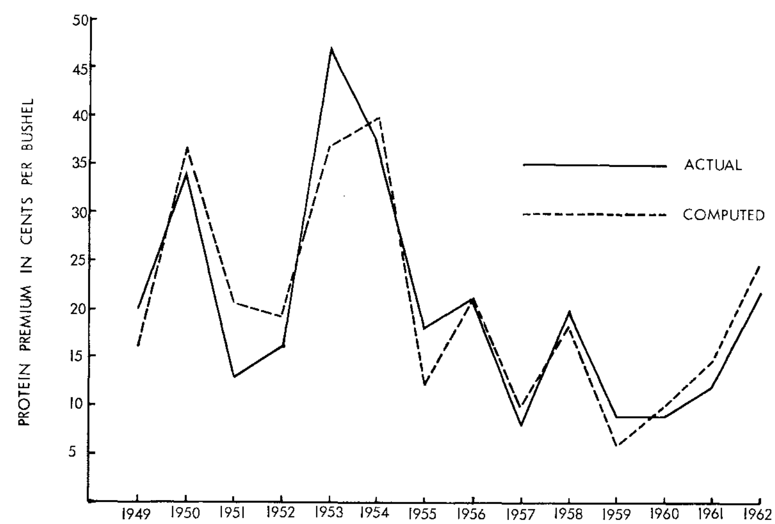


Figure 4. Actual and computed protein premiums for 16 percent protein Hard Red Spring

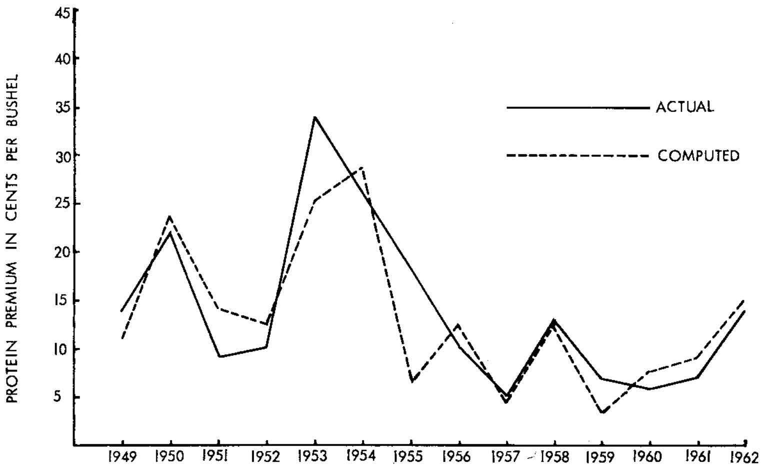


Figure 5. Actual and computed protein premiums for 15 percent protein Hard Red Spring

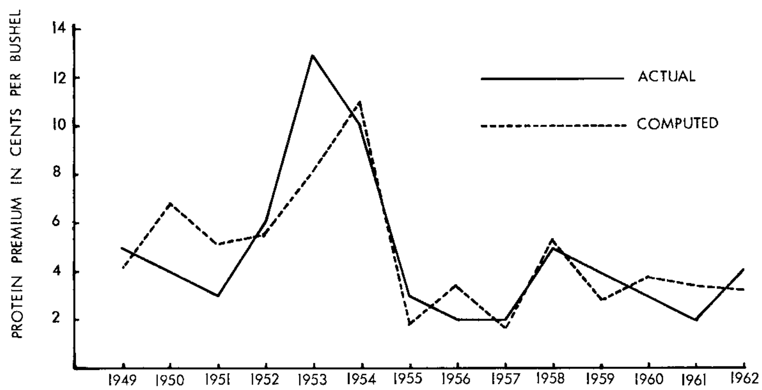


Figure 6. Actual and computed protein premiums for 13 percent protein Hard Red Spring

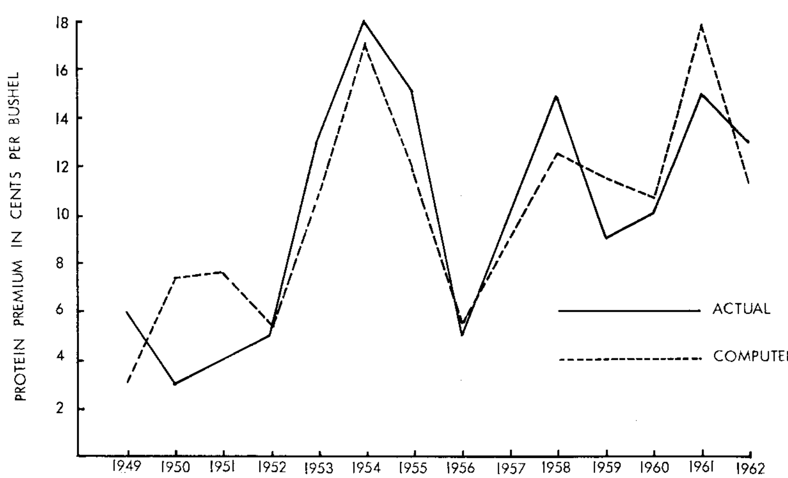


Figure 7. Actual and computed protein premiums for 13 percent protein Hard Red Winter

Estimated flexibilities shown in table 14 are very high. A one percent (not percentage) change in the average protein content of the spring wheat crop was estimated to be associated with declines in spring wheat protein premiums of over 28 percent and of more than 14 percent in the winter wheat protein premium. A one percent increase in the average protein content of the winter wheat crop was estimated to be associated with declines of over 6 percent in the premium paid for spring wheat protein and more than 12 percent in the winter wheat premium. These results indicate that total protein premium receipts to sellers will fall quite sharply whenever the average protein content of either the Hard Red Spring or Hard Red Winter wheat crops increases.

An implication for wheat breeding research

Extremely high premium flexibilities with respect to average protein content raise questions concerning the development of higher protein wheat varieties. There appears to be a conflict of interest between producers and the grain trade.

On one hand, the grain trade is interested in hard wheats of good milling and baking quality. This, in general, implies hard wheats of high protein content. Their interest is manifested in such organizations as the Crop Quality Council, an organization that is active in promoting development and adoption of wheat varieties with good milling characteristics. On the other hand, producers, as a group, are penalized by lower total premium revenue when adoption of higher protein wheat varieties becomes widespread.

SEASONALITY IN SPRING WHEAT PROTEIN MARKETING

Monthly data on protein premiums paid in Minneapolis and on the average protein content of spring wheat receipts at Minneapolis were examined for the existence of discernible seasonality in premiums and in protein content. Analysis of the premiums paid on 16 percent protein wheat was felt to be sufficient for determining seasonality.[23] The sample period for this analysis was the 11 years from August 1952 through July 1963.

There seems to be a regular seasonal pattern in the average protein content of receipts, but there does not appear to be one in premiums paid.[24]

The 11-year average protein content of receipts for each month is plotted in figure 8. Protein content rises from a low of 14 percent in August, when the spring wheat harvest is underway, to a high of 14.4 percent in October. From its October high, it declines irregularly over the remainder of the season.

This behavior is consistent with the hypothesis that country elevator operators in the spring wheat area attempt to market their high protein wheat as soon as possible after the harvest rush. Delay until October might be associated with the jamming of elevator facilities in late August and September and the resulting inability to segregate wheats by protein content. Operators are usually unable to sort out their stocks (and their smaller volume of purchases from farmers) according to protein content until October.

Anderson has suggested that elevator operators possess a fairly strong motive for selling their high protein wheat as soon as possible.[25] He reported that country elevator operators doubted the effectiveness of hedging high protein wheat with Minneapolis futures. Elevator operators feared the risk of loss if the premium on high protein wheat should narrow, relative to that on 13.5 percent wheat (the contract wheat), over the life of the hedge.

Anderson attempted to assess this risk by placing hypothetical hedges on 15 percent and 17 percent wheat for 30-, 60-, and 90-day periods from June 1964 to May 1966. Portions of his summary tables are reproduced in table 15.

Data in table 15 show that, on the average, a 30-day hedge will result in a gain of about ½ cent per bushel on wheat of 15 percent protein or more, but that hedges held for longer periods will, on the average, result in very little gain or even losses (an average of 1.6 cents per bushel on 17 percent wheat hedged for 90 days).

Table 15. Gains and losses from hypothetical hedges placed on 15 and 17 percent spring wheat in Minneapolis, June 1964-May 1965

Length of hedge (days)	Average gain (+) or loss (−) (cents/bu.)	Maximum loss (cents/bu.)	Maximum gain (cents/bu.)
15% protein wheat			
30	+0.4	16	17
60	−0.6	14	20
90	−1.2	14	16
17% protein wheat			
30	+0.7	15	16
60	+0.1	21	16
90	−1.6	28	23

These averages and the wide differences between the maximum gain and maximum loss for each hedge suggest that the elevator operators' doubts are not without merit.

The risk of loss may be related to the absence of premiums paid for the delivery of high protein wheat on Minneapolis futures contracts. Wheat deliverable on Minneapolis futures at the contract price is Number 2 northern spring, 13.5 percent or higher protein. Wheat of protein content 13-13.4 percent is deliverable at a 3-cent per bushel discount. In other words, there is no premium for delivering wheat of protein content greater than 13.5 percent, but there is a fixed discount for wheat under 13.5 percent. These fixed differentials, zero for higher protein and minus 3 cents for lower, are rarely changed from year-to-year to reflect the market's current estimate of the value of protein.

[23] The correlation between annual average premiums paid on 16 percent and 15 percent protein wheat over the 1959-62 sample period was 0.98. The correlation between 16 percent and 13 percent protein wheat was 0.85.

[24] Analysis of Variance was used to test for seasonality in each case. The F ratios were 1.53 for premiums and 2.97 for average protein content. The degrees of freedom were 11 for the numerator and 110 for the denominator in each case. The critical value of $F(11, 110)$ at the 95 percent level of probability is 1.88.

[25] Donald E. Anderson. "Hedging High Protein Wheat in the Minneapolis Market." Paper presented at Minneapolis Grain Exchange Marketing Seminar, September 8, 1966.

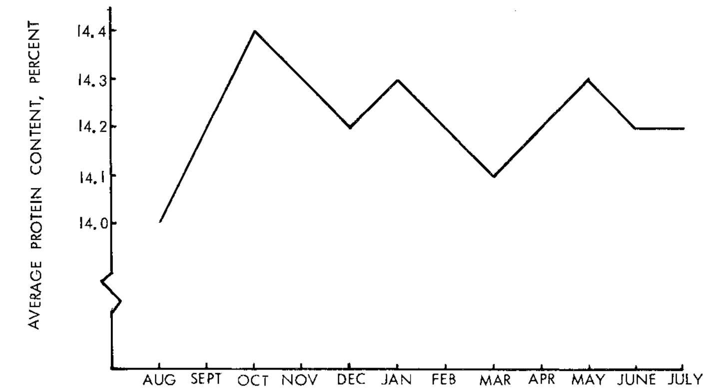


Figure 8. Eleven-year average protein content of spring wheat receipts at Minneapolis, by months

Delivery for the purpose of satisfying a futures contract is at the seller's option. That is, the trader who is short a futures contract has an active role in deciding whether a delivery will be made. The trader who is long, plays a passive role, accepting delivery or liquidating his long position by selling before the delivery month.

Clearly, if cash market premiums for high protein wheat are positive, shorts will attempt to avoid delivering wheat of protein content greater than 13.5 percent. Avoiding delivery will tend to lower the premiums on the cash market. If traders who are short hold higher protein wheat, they will sell it in the cash market and either buy 13.5 percent wheat for delivery, or they will cover their short futures positions by buying back their contracts.

The option of delivery provides the basis of conformity between cash and futures markets. It prevents prices in the cash and futures markets from moving independently of one another. Delivery differentials that approximate premiums in the cash market would tend to increase the total quantity of wheat delivered; to make the distribution of protein within this quantity more nearly the same as that of the current wheat crop; and to prevent the distortion of cash wheat protein premiums in the delivery month.

Analysis of the demand for protein may provide a basis for the setting of delivery differentials on a year-to-year basis. The general quality of crops is usually known some time before it moves into terminal markets. This advanced knowledge and estimates of the parameters of the hard wheat protein demand relation might be used in predicting the level of premiums that will prevail in the market during the coming year, and delivery differentials could be set accordingly.

Delivery premiums set at the beginning of the year that approximate expected cash premiums could reduce the risk of loss from hedging high protein wheat. The Minneapolis market would become more effective for hedging high protein wheat.

Summary and Conclusions

This study analyzed the relationship between price and quality in spring wheat. The study was divided into two parts: The *first* was devoted to an analysis of the official grades for wheat and the measured quality factors that determine them. The *second* was the analysis of the demand for hard wheat protein, the factor which the market regards as the most important indicator of bread-making quality.

OFFICIAL GRADES

Information on wheat quality, as conveyed by the official grade designation or by the sample's inspection report, is less detailed than desired by milling firms. These firms subject wheat to detailed analyses to discover its milling and baking properties. Yet official inspection results, which include protein content, form the only explicit information on quality available to traders in their day-to-day activities of buying and selling country-shipped wheat.

In addition to these transactions, which are essentially made on a sample basis, there are other classes of transactions conducted solely on the basis of grade designation, without the benefit of detailed inspection reports. Included here are sales for export, deliveries on warehouse receipts held by the Commodity Credit Corporation, and deliveries on futures contracts.

For the first set of traders, those buying and selling on a sample basis, no grade designations are required. The detailed inspection report bears more quality information than grade designations convey. For the second type of transaction, grade designations should properly differentiate among lots of wheat according to their relative milling values.

The analysis dealt with how the system of numerical grades is used to discover price-quality relationships and how effective the system is in differentiating among wheats.

Specific Questions

The following questions were believed to be pertinent to this analysis:

1. Does the system of official grades adequately describe spring wheat in terms of its value-differentiating characteristics?
2. How important to the value of spring wheat are the quality factors which are measured in the official, mandatory inspection?

3. Is there an alternative to the present system of grades? That is, how might the present system of wheat grades be improved to aid in the discovery of price-quality relationship?

Analysis of the Official Grades: Market Day Sample

The Data

A sample of all trades in spring wheat at the Minneapolis Grain Exchange on January 16, 1967, was taken. Resulting data included the price at which each sale took place; the current price of the nearby (March) future; assigned numerical and special grades; values of measured quality factors, including protein; and other, nonquality sources of price dispersion.

Analytical Technique

Intra-day movements in the price level were removed by subtracting the price of the March future from the price of cash wheat. The difference between them (the basis) was then analyzed as being determined by the quality variables and by the other, nonquality, sources of price dispersion.

The analytical technique was linear regression, with all the employed sources of price dispersion expressed as dummy variables. Two analyses were performed initially. Analysis I analyzed the basis in terms of measured quality factors. Analysis II analyzed the basis in terms of the assigned numerical grades.

Results of Analysis I

Analysis I yielded estimates of the premiums or discounts attributable to the different values of each grading factor. On the whole, the grading factors met the test of relevance to wheat quality.

Of the grading factors, test weight per bushel and damaged kernels were the major sources of price dispersion. Foreign material and shrunken and broken kernels contributed less than test weight and damage. This was due to the fact that the ranges of values taken on by the former two were much greater than the ranges of the latter two. Test weight took on values that extended from the Number 4 range (53-54 lb./bu.) up into the special grade — heavy — category (over 59.9 lb./bu.). Damaged kernel values extended from the Number 1 range down into the Sample Grade range (greater than 15 percent). The values of foreign material and shrunken and broken kernels fell only as low as the Number 3 range (1.1-2 percent for foreign material and 5.1-8 percent for shrunken and broken kernels).

Estimates of the discounts for values of factors (other than test weight) that were in the Number 1 range were believed to be unreliable. Grain inspectors need not report the values of these factors unless they are outside the Number 1 range or Total Defects exceeds 3 percent. More than one-third (48 out of 121) of the wheat samples sold that day graded Number 1, and, therefore, the values of these factors were not reported. A value of zero was assumed.

Results of Analysis II

Analysis II showed that the present system of official grades accounts reasonably well for price differences among wheats. Discounts for lower grades exhibited, with one exception, the desired property of increasing from Number 2 through Sample Grade. The exception was Number 5, which was estimated to receive a higher price than Number 4. Thus the present official grades do not consistently meet the criterion of rank-ordering.

The likelihood that lower grade wheat will be priced above that of a higher grade is fairly great under the present grading system requirements. The values of a number of quality factors are determined in the assignment of the grade to a sample. But these values are not weighted or averaged in the assignment of grade. Any one of the factors is sufficient to lower the grade of the sample, regardless of how high it might grade on the basis of the remaining factors.

Composite Grades

A set of grades more likely to meet the criterion of rank-ordering can be devised by, in effect, averaging the factor grades. Analysis of the relationship between wheat prices and the resulting composite grades showed that, in this sample, rank-ordering was achieved.

Analysis of the Official Grades: Additional Considerations

Subclass determination

Although the official grades are independent of market subclasses, licensed inspectors determine subclasses, which are defined according to the subjective criterion of the percentage of "dark, hard, and vitreous kernels" in the sample. Determinating this percentage can be laborious and time-consuming.

Data on the protein content of hard wheat subclasses show that the subclass is related to the protein content of wheat. Since both determinations are regarded as conveying the same type of information about milling and baking quality, and since protein content conveys more of this information than any knowledge of the subclass, it may be recommended that subclass determination be eliminated from the inspection.

Additional Quality Information Within the Federal Grades

Incorporating additional quality information into the system of grades and standards has been advocated. Such proposals face at least two difficulties.

One, the results of complete milling and baking tests are typically not available soon enough to be of use to traders dealing at the country elevator level or dealing with country-shipped wheat at the terminal markets. This difficulty may not be important for transactions in which the wheat has been stored in terminal warehouses for some time. Information of the type yielded by milling and baking tests, in the latter instances, could be valuable and might be made a part of the inspection process.

Second, there is the difficulty of communicating, through a single grade designation, quality information borne by a number of factors of diverse types. Protein content yields information of a type essentially different from that borne by the factors included in the official grades. Protein premiums respond to a different set of supply and demand forces than the present grading factors. Incorporating protein analysis into the grades would tend to reduce the system's ability to meet the rank-ordering criterion.

Analysis of the Official Grades: Conclusion

The present system of grades and standards plays a role in differentiating wheats by quality. This was shown in Analysis II and, more clearly, in the premiums and discounts discussed in Analysis I.

The effectiveness of the official grade system in describing wheat quality could be improved by employing a system of composite grades. Such a system, in which each grading factor is averaged to arrive at a composite grade, would aid in giving grades the desired property of rank-ordering.

Grading factors, themselves, could be improved and would provide more information for wheat traders by requiring inspectors to report all determined values of the factors, even if those values lie in the Number 1 range.

It is not at all clear whether additional quality information should be incorporated into the system of numerical grades. As much quality information as can be made available, within the time limits imposed, should be offered to traders. However, the attempt to make the system of numerical grades convey this information will make rank-ordering harder to achieve. The system may, in this case, actually carry less information rather than more.

HARD WHEAT PROTEIN DEMAND

Protein is unique among the quality factors in hard wheat. As opposed to the grading factors, it alone purports to be an index of milling and baking quality, and nothing else. As opposed to other individual quality factors that affect milling and baking quality, it alone makes itself felt in the market place through the schedule of protein premiums. For this reason an analysis of the demand for protein was felt to be worthwhile for its own sake and for the practical information yielded by such an analysis.

In addition, the market for hard wheat protein was believed to be well-defined in terms of the important cause and effect variables. Also, data on many of these variables were known to be in existence. For these reasons a modest attempt at a quantitative demand analysis was believed possible.

The demand analysis regarded protein premium as being determined by the average protein content of the Hard Red Spring and Hard Red Winter wheat crops; the production of HRS and HRW; carry-in stocks of HRS and HRW; and the ratio of HRS and HRW consumption to the consumption of all wheat other than Durum.

The analysis was used to estimate four different protein premiums: 16 percent protein HRS, 15 percent protein HRS, 13 percent protein HRS, and 13 percent protein HRW. Estimations were based on a 14-year sample period, July 1949-June 1963.

Protein Demand: Results of the Analysis

The signs of the regression coefficients of the variables used to measure protein content in current production were, in general, in accord with expectations. Signs of the coefficients on variables measuring stocks and on the wheat consumption ratio were not.

Premium flexibilities with respect to the average protein content of the spring and winter wheat crops were computed. Each of the premiums was found to be quite flexible with respect to average protein content.

Protein: Intrayear Variation

Protein premiums paid in Minneapolis and the average protein content of HRS receipts at Minneapolis were tested for seasonality using analysis of variance. The basic data were the average protein content of receipts and the average premium on 16 percent protein HRS for each month from August 1952 through July 1963.

No significant seasonality was displayed by protein premiums. On the other hand, a significant difference among months in average protein content was found. The average tends to rise from August to October and then declines, irregularly, through the remainder of the season.

Country elevator firms appear to market their high protein wheat as soon after harvest as possible. Evidence suggests that this behavior is due to the risk of loss from hedging wheat of over 13.5 percent protein in Minneapolis futures.

Protein: Conclusions

The high flexibility of protein premiums with respect to average protein content implies that total premium revenue to growers, as a group, will fall whenever the average protein content of the crop increases. The interests of producers, in terms of total premium income, conflicts with that of the grain trade, which is interested in the production of larger quantities of high protein wheat.

The risk of loss from hedging high protein spring wheat at Minneapolis may be related to the fact that delivery differentials, based on protein, are small and seldom altered from year to year to conform to protein premiums prevailing in the cash market. The estimated demand relation for hard wheat protein may provide a basis for setting delivery differentials at the start of the season to improve the conformity of the futures with the cash market. The effectiveness of Minneapolis futures for hedging high protein wheat might, thereby, be improved.

Appendix

STATISTICAL TECHNIQUE EMPLOYED IN ANALYSIS OF OFFICIAL GRADES

The statistical technique employed for the major analysis of the official grades was multiple linear regression. Three analyses were performed. In each analysis the price at which each sale took place was "explained" by quality determinants and other nonquality sources of price "dispersion."[26]

In cash grain trading, bids and offers are made in terms of the "basis," so many cents or fractions of cents above or below the price of the nearby future. The cash price at which the sale takes place is, thus, the algebraic sum of the price of the future and the basis. It is the basis that the statistical models attempted to estimate.

Analysis I employed the values of each of the factors that, in combination, determine grade. Analysis II employed the numerical grade designations and the special grade designation "heavy" as major determinants of quality differences among wheats in the sample. Analysis III used the proposed composite grades as the sources of market day price dispersion.

All analyses employed the technique of expressing the regressors (the independent variables) as sets of "dummy" variables.[27] A very simple model will illustrate the technique.

Assuming that only two factors, numerical grade and protein, exert measurable influence on price, the simple model may be shown as:

$$(1)\quad Y_k = m\,X_{ok} + \sum_{i=1}^{s} p_i\,X_{ik} + \sum_{j=1}^{t} g_j\,X_{jk} + e_k$$

$$(k = 1, 2, \ldots, 121)$$

where: Y_k is the basis; m is a basis parameter common to all the wheats and may be interpreted as the constant term in the equation; p_i is a basis parameter common to all wheats in the protein category i; and g_j is a basis parameter common to all wheats in grade j. The error terms, e_k, are assumed to be normally distributed random variables with zero mean and equal, finite variances. The observations lie in s protein categories and t grade categories.

(2) $X_{ok} = 1$ for all values of k

X_{ik} and X_{jk} define the protein category and grade, respectively, into which each wheat in the sample of 121 lies.

(3)

$$X_{ik} \begin{cases} = 1 \text{ if the wheat is in the ith protein category} \\ = 0 \text{ if the wheat is not in the ith protein category.} \end{cases}$$

$$X_{jk} \begin{cases} = 1 \text{ if the wheat is in the jth grade} \\ = 0 \text{ if the wheat is not in the jth grade.} \end{cases}$$

The model assumes that the effects of protein and of grade are additive. That is, there is no interaction between the two. Protein premiums are determined in the market independently of price differentials due to grade.

The parameters, p_i and g_j, are estimated using ordinary least squares,[28] but they cannot be estimated directly for equation (1). In equation (1) there is perfect linear dependency between the sum of the values of the X_{ik} and X_{ok}. Perfect linear dependency also exists between the sum of the values of the X_{jk} and X_{ok}.[29] From the definitional equation (3) it is seen that for each observation (each value of k) only one of the X_i's has the value one and the remaining X_i's have the value zero. Therefore,

$$\sum_{i=1}^{s} X_{ik} = 1 = X_{ok}$$

Similarily, in each observation only one of the X_j's has the value one and the remaining X_j's have the value zero, and

$$\sum_{j=1}^{t} X_{jk} = 1 = X_{ok}$$

The result of attempting to estimate the p_i and g_j directly is the same as that which obtains when there is perfect intercorrelation between two independent variables in any multiple regression problem. The inverse of the matrix of sums of squares and cross products does not exist, and no determinant solutions for the normal equations can be obtained.

There are several methods of circumventing this difficulty; each requires that a restriction be placed on the values of the parameters p_i and g_j or on m.[30] The most convenient restriction in the present case is to let one of the p_i and one of the g_j equal zero. For example, let

$$p_1 = g_1 = 0$$

With this restriction, the equation to be estimated is

$$(4)\quad Y_k = m'\,X_{ok} + \sum_{i=2}^{s} p_i\,X_{ik} + \sum_{j=2}^{t} g_j\,X_{jk} + e_k$$

The constant term, m′, is now interpreted as the basis paid on wheat in the first $(i = 1)$ protein content category and of the first $(j = 1)$ grade. The estimates of p_i and g_j are interpreted as deviations from m′ due to the wheat's being in the ith protein content category and jth grade.

A numerical example will illustrate these interpretations. Protein content categories and grades are defined as shown in table 1A. Hypothetical estimates of p_i, g_j, and m′ are also shown.

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[26] In effect the analysis seeks to account for differences in spring wheat prices due to the quality and nonquality variables. The statistical technique and the term "dispersion" were suggested by John K. Hanes of the Marketing Economics Division, Economic Research Service, U.S. Department of Agriculture. Hanes had been using them in some of his own market analysis work. Price dispersion was suggested to denote price differences within a single market-day. The term price "variation" or price "variability" is commonly used to denote price differences which occur over time.

[27] D. B. Suits. "Use of Dummy Variables in Regression." *Journal of the American Statistical Association*, Vol. 52, December 1957, pp. 548-551; Oscar Kempthorne, The Design and Analysis of Experiments, John Wiley & Sons, New York. 1952; T. P. Hill, "An Analysis of the Distribution of Wages and Salaries in Great Britain." *Econometrica*, Vol. 27, July 1959, pp. 355-363.

[28] Kempthorne, op. cit., pp. 91-94.

[29] William G. Tomek. "Using Zero-One Variables with Time Series Data in Regression Equations." *Journal of Farm Economics*, Vol. 54, November 1963, pp. 818-821.

[30] Tomek, op. cit., pp. 820, 821.

Table 1A. Hypothetical protein content categories, grades and estimates of p_i, g_j and m' for Dark Northern Spring wheat

Protein category	i	p_i	Grade	j	g_j	m'
(percent)		(cents/bu.)			(cents/bu.)	
≤ 13.9	1		1	1		9
14.0– 14.9	2	1	2	2	−2	
15.0– 15.9	3	2	3	3	−3	
≥ 16.0	4	2	4	4	−5	
			5	5	−10	
			Sample grade	6	−18	

In the example the protein category set has four categories ($i = 1, \ldots, 4$), which are defined in the first column of the table. The grade category set has six categories ($j = 1, \ldots, 6$), which are defined in the fourth column of the table.

Since the *a priori* restrictions on the p_i and g_i were

$$p_1 = g_1 = 0$$

the constant term (m′) in the equation is an estimate of the basis paid for wheat in the first protein category. (≤ 13.9 percent) and the first grade category (Number 1). That basis is in the last column in the table. Number 1 wheat of not more than 13.9 percent protein is traded at a price that is 9 cents over the nearby future.

Bases on other wheats can be read from the table. Number 1 Dark Northern of over 16 percent protein is traded at 11 cents (9 + 2) over the nearby. Number 4 Dark Northern in the protein range 15-15.9 percent is worth 6 cents (9 −5 + 2) more than the nearby future.

Table 1A also illustrates the rationale of using dummy variables even in the case of a continuous variable such as protein content. The effect of protein on the basis is apparently nonlinear. Estimating a single parameter for the effect of protein content or for any other continuous variable such as test weight or damaged kernels will give biased results if the effect of any of these on the basis is nonlinear.[31]

[31] Suits, op. cit., p. 551.

Table 2A. Summary of the estimation of the premiums and discounts of Analysis I: price differences due to grading factors

Independent variable: Mean value	Independent variable: Range of values	Estimate of the parameter b	Standard error s_b	
		(cents/bu.)	(cents)	
Dockage (%):				
0.5	0.5	−0.141	0.272	Constant term:
1.0	1.0	−0.235	0.338	7.472 cents
1.5	1.5	−0.235	0.494	per bushel‡
2.0	2.0 & 2.5	−0.338	0.451	
3.0	3.0 & 3.5	−0.221	0.476	$R^2 = 0.973$
				$S^2 = 0.843$
Protein content (%):				
14.5	14.0—14.9	1.600*	0.424	S = 0.918
15.4	15.0—15.9	1.219*	0.412	
16.5	16.0—17.0	1.297*	0.459	
				121 observations
Test weight (lb/bu):				50 independent
54.0	53.5—54.4	−5.315*	0.842	categories
55.4	55.0—55.7	−6.027*	0.660	70 degrees of
56.1	56.0—56.3	−3.907*	0.553	freedom
56.6	56.5—56.8	−3.799*	0.528	
57.1	57.0—57.3	−1.878*	0.364	
57.5	57.5—57.7	−0.138*	0.528	
59.2	59.0—59.6	0.802*	0.284	
60.2	60.0—60.7	2.165*	0.387	
61.0	61.0—61.2	2.869*	0.544	
Damaged kernels (%):				
0.3	0.2 & 0.3	−1.027	0.657	
0.5	0.4 & 0.5	−1.867†	0.891	
0.7	0.6 & 0.7	−2.068†	0.947	(continued)

Table 2A. Summary of the estimation of the premiums and discounts of Analysis I: price differences due to grading factors (continued)

Independent variable: Mean value	Range of values	Estimate of the parameter b	Standard error s_b
Damaged kernels (%):		(cents/bu.)	(cents)
0.9	0.8— 1.0	−0.422	0.905
1.6	1.3— 1.7	−3.050†	1.021
2.0	1.9 & 2.0	−2.663*	0.982
2.7	2.4— 3.0	−3.354*	0.949
3.8	3.4— 4.3	−4.609*	1.008
6.2	5.0— 7.0	−6.652*	1.041
10.8	7.3—18.6	−11.315*	1.038
Foreign material (%):			
0.3	0.1— 0.3	0.703	1.018
0.4	0.4	0.820	1.033
0.5	0.5	3.113*	1.056
0.7	0.6 & 0.7	1.455	1.065
1.0	0.9 & 1.0	1.633	1.000
1.4	1.2— 1.7	−1.932†	0.838
Shrunken and broken (%):			
1.5	0.9— 1.6	−0.352	0.855
1.8	1.7— 1.9	−0.330	0.943
2.0	2.0	−1.737	0.969
2.2	2.1— 2.3	−0.007	0.923
2.4	2.4	−1.064	0.962
2.5	2.5	−0.858	0.865
2.8	2.6— 2.9	−1.203	0.942
3.5	3.1— 3.9	−0.663	0.645
4.7	4.0— 5.3	−2.273†	1.032
Area of origin:			
1		0.242	0.355
2		0.887†	0.387
3		0.124	0.510
4		0.882†	0.482
5		0.501	0.441
7		0.367	0.526
Destination:			
Duluth		−0.164	0.246
Transport mode:			
Truck		−4.012*	0.354

* Significantly different from zero at the 99 percent level of probability.

† Significantly different from zero at the 95 percent level of probability.

‡ The constant term represents Dark Northern Spring wheat with the following characteristics:

Dockage:	0.0 percent	Shrunken & broken:	0.0 percent
Protein:	13.5 percent	Origin:	Area 6 (South Dakota)
Test weight:	58.3 lbs./bu.	Destination:	Minneapolis
Damaged kernels:	0.0 percent	Transport mode:	Rail
Foreign material:	0.0 percent		

In terms of the day's closing quotation for the March future ($1.80-⅜), the price of this wheat would be $1.87857 per bushel, or, to the nearest ⅛ of a cent, $1.87-⅞.

Table 3A. Summary of the estimation of the premiums and discounts of Analysis II: price differences due to official grades

Independent variable		Estimate of the parameter b	Standard error s_b	Difference between prices of adjacent grades	
Numerical grade:		(cents/bu.)	(cents)	(cents)	
2		−1.775*	0.354	1.775	Constant term:
3		−4.918*	0.445	3.143	8.382 cents
4		−10.236*	0.666	5.318	per bushel‡
5		−9.986*	1.546	−0.250	$R^2 = 0.904$
Sample grade		−23.696*	1.662	13.710	$S^2 = 2.096$
Special grade:					
"heavy"		1.868*	0.456		$S = 1.448$
Dockage:					121 observations
Mean value	Range of values				
0.5	0.5	−0.083	0.369		22 independent categories
1.0	1.0	0.423	0.467		
1.5	1.5	−0.553	0.651		
2.0	2.0 & 2.5	0.456	0.560		98 degrees of freedom
3.0	3.0 & 3.5	0.117	0.684		
Protein content:					
Mean value	Range of values				
14.5	14.0—14.9	−0.313	0.589		
15.4	15.0—15.9	0.198	0.583		
16.5	16.0—17.0	0.083	0.633		
Area of origin:					
1		1.248†	0.492		
2		1.125†	0.524		
3		1.572*	0.641		
4		0.773†	0.650		
5		0.334†	0.556		
7		0.920†	0.712		
Destination: Duluth		−0.523†	0.319		
Transport mode: Truck		−3.492*	0.426		

* Significantly different from zero at the 99 percent level of probability.
† Significantly different from zero at the 95 percent level of probability.
‡ The constant term represents Dark Northern Spring wheat with the following characteristics:

Grade:	Number 1
Dockage:	0.0 percent
Protein:	13.5 percent
Test weight:	60 lbs./bu.
Origin:	Area 6 (South Dakota)
Destination:	Minneapolis
Transport mode:	Rail

In terms of the day's closing quotation for the March future ($1.80-3/8), the price of this wheat would be $1.88757 per bushel, or, to the nearest 1/8 of a cent, $1.88-3/4.

Table 4A. Summary of the estimation of the premiums and discounts due to composite grades

Independent variable		Estimate of the parameter b	Standard error s_b	Difference between prices for adjacent grades	
Numerical grades:		(cents/bu.)	(cents)	(cents)	
2		−1.792*	0.339	1.792	Constant term:
3		−3.728*	0.454	1.936	8.889 cents
4		−5.741*	0.597	2.013	per bushel†
5		−8.861*	0.610	3.120	
6		−10.480*	0.913	1.619	$R^2 = 0.916$
7		−11.325*	1.503	0.845	$S^2 = 1.882$
8		−23.482*	1.576	12.157	$S = 1.372$
Special grade:					121 observations
"heavy"		1.875*	0.431		
Dockage:					24 independent
Mean value	Range of values				categories
0.5	0.5	0.336	0.357		96 degrees of
1.0	1.0	0.197	0.447		freedom
1.5	1.5	−0.704	0.621		
2.0	2.0 & 2.5	0.152	0.526		
3.0	3.0 & 3.5	0.325	0.649		
Protein content:					
Mean value	Range of values				
14.5	14.0—14.9	−0.378	0.562		
15.4	15.0—15.9	−0.198	0.548		
16.5	16.0—17.0	−0.160	0.595		
Area of origin:					
1		0.747	0.474		
2		0.500	0.500		
3		0.711	0.641		
4		0.932	0.622		
5		−0.777	0.549		
7		−0.339	0.686		
Destination:					
Duluth		−0.404	0.303		
Transport mode:					
Truck		−3.537*	0.403		

* Significantly different from zero at the 99 percent level of probability.

† In terms of the day's closing quotation for the March future ($1.80-⅜), the price of the base wheat would be $1.89264 per bushel, or, to the nearest ⅛ of a cent, $1.89¼.

Table 5A. Data for the variables used in the analysis of the demand for hard wheat protein

Year beginning July 1	Protein premium 16% HRS Y_1*	15% HRS Y_2*	13% HRS Y_3*	13% HRW Y_4†	HRS ave. protein content X_1‡	HRS production X_2§	HRS carry-in stocks X_3§	HRW ave. protein content X_4¶	HRW production X_5§	HRW carry-in stocks X_6§	Ratio: Hard wheat to total wheat consumption X_7**
	- - - (cents per bushel) - - -				(pct.)	(10 mil. bu.)	(10 mil. bu.)	(pct.)	(10 mil. bu.)	(10 mil. bu.)	(pct.)
1949	20	14	15	6	13.8	16.9	7.9	11.7	54.1	16.7	74.6
1950	34	22	4	3	13.2	20.7	8.6	12.1	45.9	25.2	74.8
1951	13	9	3	4	13.7	25.6	10.6	12.0	38.2	21.4	74.7
1952	16	10	6	5	13.7	18.1	11.8	11.6	72.3	9.7	74.8
1953	47	34	13	13	13.4	21.7	12.8	12.0	50.4	39.5	74.8
1954	37	26	10	18	13.8	14.5	19.5	11.7	48.9	56.0	74.8
1955	8	18	3	15	14.4	18.4	17.2	11.5	41.5	67.7	75.0
1956	21	10	2	5	13.9	17.8	18.5	12.6	44.6	69.1	75.1
1957	8	5	2	10	14.4	16.9	19.6	11.9	42.9	64.8	75.1
1958	20	13	5	15	14.1	23.3	20.3	11.4	83.6	61.1	75.0
1959	9	7	4	9	14.8	15.1	25.1	11.6	62.0	93.6	75.1
1960	9	6	3	10	14.6	18.8	21.8	11.4	79.4	100.2	74.9
1961	12	7	2	15	14.8	11.6	23.7	10.7	75.4	110.4	75.1
1962	22	14	4	13	14.1	17.5	18.7	11.9	53.7	108.5	75.1

* Minneapolis Grain Exchange. *Annual Report.* Annually, 1949-1963, and *Daily Market Record,* various issues. 1949-1963.

† U.S. Department of Agriculture, Grain Division, Agricultural Marketing Service, *Grain Market News,* various issues. 1953-1963 and Kansas City Board of Trade. *Statistical Report,* Annually, 1949-1963.

‡ *The Daily Market Record.*

§ Economic Research Service, U.S.D.A., *Wheat Situation,* various issues, 1949-1964.

¶ Average protein contents of 1949-1961 crops was estimated from data published in Agricultural Marketing Service, U.S.D.A., *Physical, Chemical, Milling and Baking Properties of Carlot Receipts of Wheat.* AMS-356. Annual to 1961. That of the 1962 crop was estimated from data published in the *Grain Market News,* February 8, 1963.

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