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Price/Quality Relationships in the Malting Barley Market

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Foreword

The relationship between prices and quality variables is an important area of research particularly for the more specialized commodities. Price quality relationships are analyzed in this study in the case of malting barley. This research was conducted under Regional Project NC-160, "Performance of the U.S. Grain Marketing System in a Changing Policy and Economic Environment," and under HATCH Project No. 1368, "Economics of Grain Marketing."

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Highlights

An important characteristic of the market for malting barley is the multitude of quality variables which affect the value of particular shipments. In any given day large price differentials may exist for relatively small variations in quality. Indeed, one of the more frustrating problems for malting barley producers, as well as processors, is the perceived randomness of prices across shipments. The objectives of this study are to analyze the relationships among various quality factors and malting barley prices, and to develop a statistical model for measuring the implicit prices for selected quality factors. The implicit price of a quality attribute is an economic concept similar to premiums and discounts commonly used in the grain trade. In economic terms implicit prices indicate the market-determined value of a quality attribute such as protein or plumpness. As such, these results should be useful to producers in making production decisions, to breeders making decisions on varietal improvement and to merchandisers in evaluating price variations across samples.

Data were collected for four years on price and quality characteristics of malting barley samples. An econometric model was used to analyze factors affecting the variability in malting barley prices, and to estimate implicit prices for plumpness and protein. The results indicate that a change may be evolving in the process of price determination for malting barley. In particular, the feed grains sector has had increasingly less effect on malting barley prices in recent years. In addition, the unexplained variability in malting barley prices has increased in each year. Implicit prices for plumpness and protein were derived and analyzed throughout the time period of the study.

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Introduction

The major domestic use for barley is for livestock and poultry feed. However, since 1970 there has been a decreasing trend for this use. In 1964, 251 million bushels were used for feed and has since decreased to 190 million bushels in 1981. Feed use is becoming secondary in importance to malt utilization. In 1980 over 50 percent of the barley supply was used for nonfeed uses (food, alcohol, and seed) which are largely dominated by malt. Barley production is concentrated in the Upper Midwest. North Dakota has consistently been the largest producer followed by Montana, Idaho, and Minnesota. A large proportion of the barley grown in North Dakota is for malting purposes and this proportion has been increasing over the past eight years (Table 1). In 1981, 93.4 percent of barley acres were planted with malting types. Larker was the industry standard and the most popular variety in North Dakota until 1980. In recent years, two new varieties, Morex and Glenn, surpassed Larker in importance and now are treated as industry standards. These two varieties in 1981 accounted for 35.2 percent and 37.7 percent of total acres, respectively. Barley production in Minnesota is nearly all devoted to malting varieties.

Many factors affect the acceptability and value of particular samples of barley for malting purposes. Variety, protein content, moisture level, test weight, color, percent plumpness, percent skinned and broken kernels, and thin barley all influence buyers' decisions on the suitability of a sample of barley for malting.

TABLE 1. PERCENT OF ACREAGE PLANTED BY VARIETIES IN NORTH DAKOTA, 1974-1981 AND PLANTED ACREAGE, 1981

Variety	1974	1975	1976	1977	1978	1979	1980	1981	Acres Planted (1981)
	Percent								Thousand
Morex*	--	--	--	--	0.3	7.6	38.2	35.2	792.0
Glenn*	--	--	--	--	0.4	8.0	22.5	37.7	848.2
Larker*	39.7	35.1	35.3	37.9	35.3	36.7	18.7	13.5	303.7
Beacon*	17.0	30.9	40.3	38.3	37.7	28.2	9.3	3.9	87.7
Other Malting Varieties*	9.3	7.4	5.1	6.7	5.5	4.1	2.2	3.1	69.9
Total Malting Varieties	66.0	73.4	80.7	82.9	80.2	84.6	90.9	93.4	2101.5
Total Feed Varieties	34.0	26.6	19.3	17.1	19.8	15.4	9.1	6.6	148.5

*Six-rowed varieties.

SOURCE: North Dakota Crop and Livestock Reporting Service, North Dakota Agricultural Statistics, selected issues, United States Department of Agriculture, Statistical Reporting Service, Fargo, North Dakota.

Many of these factors are contained in the U.S. Grade Standards for malting barley which is based on numerical values of a set of factors which reflect quality. The numerical grade is determined by the lowest quality of any of the factors. For example, in six-rowed malting barley and six-rowed blue malting barley, there are nine factors (Table 2): test weight, suitable malting type, sound barley, damaged kernels, foreign material, other grain, skinned and broken kernels, thin barley, and black barley. All of these factors affect the numerical grade. If a sample of six-rowed malting barley is Number 1 on all factors except damaged kernels, then damaged kernels would determine the grade.

TABLE 2. OFFICIAL GRADE REQUIREMENTS FOR SIX-ROWED MALTING BARLEY AND SIX-ROWED BLUE MALTING BARLEY, 1978

	Minimum Limits of			Maximum Limits of					
Grade[1]	Test Weight Per Bushel	Suitable Malting Type	Sound Barley	Damaged Kernels[2]	Foreign Material	Other Grain	Skinned and Broken Kernels	Thin Barley	Black Barley
	Pounds	-----Percent-----							
No. 1	47.0	95.0	97.0	2.0	1.0	2.0	4.0	7.0	0.5
No. 2	45.0	95.0	94.0	3.0	2.0	3.0	6.0	10.0	1.0
No. 3	43.0	95.0	90.0	4.0	3.0	5.0	8.0	15.0	2.0

[1]Six-rowed malting barley and six-rowed blue malting barley may contain a maximum of 1.9 percent of frost-damaged kernels of which not more than 0.4 percent may be frost-damaged (major), may contain a maximum of 0.2 percent of heat-damaged kernels of which not more than 0.1 percent may be heat-damaged (major), and may contain unlimited amounts of mold-damaged kernels (minor); however, mold-damaged kernels (major) shall function as "damaged kernels" and against "sound barley."

[2]Frost-damaged kernels (minor) and mold-damaged kernels (minor) shall not be damaged kernels or scored against sound barley.

SOURCE: United States Department of Agriculture, Federal Grain Inspection Service, The Official United States Standards for Grain, Washington, D.C., January 1978, p. 3.7.

Within the malting barley market, prices vary across grades and varieties and in response to kernel plumpness and the level of protein. Official grades partially reflect the quality of malting barley. In addition, a minimum level of protein is important in malting barley because it acts as a source of nitrogen for yeast metabolism and growth during fermentation and provides the enzymes necessary to convert starch to fermentable sugars. Barley with a high level of protein, however, is undesirable because it produces a beer with unstable clarity. Consequently, maltsters generally try to avoid barley over 14 percent protein (Heid and Leath) and pay premiums for lower levels. Kernel plumpness affects the evenness of germination and the amount of extract which can be produced from a bushel of barley. At least 96 percent of the kernels must germinate to be classed as good quality malting barley (Briggs). Kernel plumpness is associated with a higher rate of germination, and consequently, premiums are paid for high levels of plumpness.

There are certain varieties of barley that are recommended for malting and brewing purposes. In North Dakota, Morex, Glenn, Larker, and Beacon are six-rowed malting barley varieties approved by the Malting Barley Improvement Association. During the period 1978-1981, Larker had 3 percent more kernel plumpness than did Morex (Foster). However, Morex had 0.5 percent less protein and 2 percent more extract. Glenn was characterized by earlier uniform maturity. The quantity of these quality characteristics can change through time. Table 3 shows that percent plumpness declined from 74.4 percent in 1977 to 65.7 percent in 1980. The protein content declined the first three years, but rose 0.3 percentage points in 1980. Test weight increased in 1980 while moisture levels remained fairly constant over the period except for a higher level in 1979. Production practices and weather conditions influence

TABLE 3. QUALITY LEVELS FROM SAMPLES OF SIX-ROWED MALTING BARLEY IN NORTH DAKOTA, SOUTH DAKOTA, AND MINNESOTA, 1977-1980

Year	Number of Samples	Protein Content	Moisture Level	Test Weight	Kernel Plumpness
		Percent	Percent	Pounds Per Bushel	Percent
1977	803	13.6	11.8	46.5	74.4
1978	871	13.0	11.6	44.5	68.1
1979	731	12.9	12.2	43.6	69.6
1980	412	13.2	11.7	44.8	65.7

SOURCE: Pyler, R. E., "The Quality of the 1980 Six-Rowed Malting Barley Crop," proceedings, Red River Valley Barley Days, Grand Forks, North Dakota, sponsored by the Malting Barley Improvement Association, Milwaukee, Wisconsin, January 8, 1981, p. 12.

the variation in quantity of these quality characteristics. For example, the moderate increase in protein level in 1980 was mainly due to dry conditions throughout the Upper Midwest. A major shift from Larker and Beacon to Morex and Glenn, which usually have lower protein, may have been a contributing factor (Pyler).

There are price incentives for producing malting barley varieties even though there may be a sacrifice in yields relative to feed barley varieties. Average prices for malting and feed barley at Minneapolis are shown in Table 4. The price in Minneapolis is the average of the midmonth prices paid for malting barley. The difference between malting and feed barley prices indicates the premium paid for the former which is generally large when barley supplies are small.

There are two objectives to this study. One is to analyze the relationship among various quality factors and malting barley prices. The second is to develop and estimate a statistical model for measuring the

TABLE 4. AVERAGE MALTING AND FEED BARLEY PRICES AT MINNEAPOLIS, 1967-1981

Year	Minneapolis Malting[a]	Minneapolis Feed[b]	Difference
	------------------Dollars Per Bushel------------------		
1967	1.20	1.14	0.06
1968	1.11	1.01	0.10
1969	1.06	.98	0.08
1970	1.18	1.11	0.09
1971	1.13	1.04	0.09
1972	1.44	1.17	0.27
1973	2.64	2.03	0.61
1974	4.03	2.58	1.45
1975	3.34	2.38	0.96
1976	2.97	2.35	0.62
1977	2.17	1.68	0.49
1978	2.28	1.80	0.48
1979	2.68	2.16	0.52
1980	3.40	2.62	0.78
1981	3.37	2.38	0.99

[a]No. 3 or better malting, 60-70 percent plumpness at Minneapolis.
[b]No. 3 or better feed barley at Minneapolis.

SOURCE: United States Department of Agriculture, Agricultural Marketing Service, Grain and Feed Market News, selected issues.

implicit price for selected quality factors. A theoretical model is developed following Ladd and Martin which assigns monetary values for quality characteristics possessed by inputs. The purchase price of an input equals the sum of the money values of the inputs' characteristics. Marginal implicit prices are prices for these characterisitcs and are similar to premiums and discounts used in the grain industry. A set of hypotheses about the behavioral relationship of quality factors on malting barley prices are posed and tested.

Weekly data were collected for four years on carlot sales of malting barley at the Minneapolis Grain Exchange and reported in the Daily Market Record. Data collected included price, level of protein and plumpness, variety, and grade for each sale, as well as other characteristics of the market on that day. Analysis of covariance was used to determine the existence and source of significant differences in malting barley prices. An econometric model was specified and estimated to derive market-determined implicit prices (premiums and discounts) for protein and plumpness.

Empirical Procedures for Estimating Price Relationships

The effects of quality characteristics on malting barley prices are estimated using statistical procedures which are described in this section. An empirical model which is used to estimate marginal implicit prices is specified below and provides the basis for testing hypotheses about the behavior of the parameters. Both cross-section and time series data were used in the statistical analysis. The unit of observation was individual sales of malting barley at the Minneapolis Grain Exchange. Characteristics of each sale include its price, levels of protein and plumpness, grade, and variety.

Classical theory of the firm can be used to derive an equation of the relationship between prices of an input, such as malting barley, and values of quality characteristics. The theoretical derivation of this algebraic relationship is developed in Appendix I. In the malting barley market the important quality characteristics are the levels of protein and plumpness, as well as factors such as grade and variety. Since the data were collected through time, a monthly factor was also included in the empirical specification. The general empirical model corresponding with the malting barley market was specified as:

$$P_{it} = \gamma_0 + \sum_{a=2}^{n} \gamma_a V_a + \sum_{r=2}^{3} \delta_r G_r + \sum_{h=2}^{12} \alpha_h M_h + \beta_1 PRO_{it} + \beta_2 PLU_{it} + e_{it} \qquad (1.1)$$

where: P_{it} is the price of the ith sample of malting barley in time t;

V_a is the intercept shifter for variety, n=2 in 1978/79 and 1979/80 and n=4 in 1980/81 and 1981/82;

G_r is an intercept shifter for grade, r = 1,2,3;

M_h is an intercept shifter for month;

PRO_{it} is the percent protein in sample i;

PLU_{it} is the percent plumpness in sample i; and

e_{it} is the error term.

The parameters to be estimated include: the interept γ_0, the intercept shifters γ_a, δr and α_h, and β_1 and β_2. The empirical model simply states that prices of individual sales of malting barley are affected by the month of sale, variety, grade, and levels of protein and plumpness. Two coefficients of particular importance in this study are β_1 and β_2 which represent the marginal implicit prices for protein and plumpness, respectively. A negative sign is expected for β_1, indicating a negative implicit price for protein. A positive sign is expected for β_2 indicating a positive implicit price for plumpness. Values of these coefficients indicate the extent to which the market price reflects discounts and premiums for these two quality characteristics.

Numerical grade is included as a proxy variable to take into account quality factors listed under the U.S Grade Standards. A variable for variety was also included to account for its effect on the variability in malting barley prices. The inclusion of month is used to account for seasonality in malting barley prices. The variables for grade, variety, and month were all included in Equation 1.1 as intercept shifters.

The empirical model in 1.1 was logically derived from economic relationships. However, it is restricted in several respects because of the lack of a priori knowledge of the behavior of variables. It is restricted in that variety and grade are included as intercept shifters, and the slopes, β_1 and β_2, are constant across these three effects. In other words, Equation 1.1 restricts the value of the implicit prices to be constant across variety and grade. As an alternative it may be appropriate to allow the implicit price to vary across varieties and grades. Rather than restricting the model these restrictions are posed in the form of hypotheses and tested using statistical procedures. The hypotheses posed here are whether the implicit prices for protein and plumpness are homogeneous or whether they vary across variety and grade.

Data Source

This study is based on cash transactions in malting barley at the Minneapolis Grain Exchange, which is the only public market for this grain. Consequently, price discovery at this market plays an important role in establishing prices and policies set by industry and other countries. Malting barley sold on the Exchange floor is displayed in sample pans by commission firms. Most samples represent a railroad car located at country elevators in North Dakota, South Dakota, and Minnesota. Accompanying each sample is a "pan ticket" on which results of the official inspection and other information important to the sale are recorded. The inspection includes data on both grade and nongrade quality factors. The Sampling Department at the Exchange and an official inspection agency located in the state in which the grain originated perform the inspection.

Part of the information recorded on the "pan ticket" is quoted in the Daily Market Record. This source quotes variety type, numerical grade, percent plumpness, protein content, and price for each carlot sold on the Exchange floor. Other quality factors might be included, but protein and plumpness were the only factors that were consistently listed throughout the duration of the study period. This information was collected for every Wednesday for the 1978/79 to 1981/82 crop years. The last crop year, 1981/82, contained only the first six months when this study was undertaken. Over the three-and-one-half crop years, 4,105 carlots of malting barley were examined. In addition to the above information, total barley cars, which included both feed and malting barley handled by the Sampling Department at the Exchange, were recorded from the same source. Minneapolis No. 2 or Better Feed Barley prices were obtained from Grain and Feed Market News. These prices and total barley cars were also posted for every Wednesday in the same period to be consistent with malting barley prices.

Estimation Procedures

Separate equations were estimated for each of the crop years for two reasons. First, fundamental factors affecting supply and demand for both the commodity and the characteristics varied for each year. Estimation of separate equations for each crop year eliminates problems of intercrop year variability in prices. Second, estimating separate equations allows for comparison of implicit prices for each of the crop years.

Standard regression procedures were used to estimate implicit prices from data which were pooled within each crop year. The data consisted of a cross section of observations from the Wednesday of each week. Separate equations could have been estimated for each day, but the large number of parameter estimates which would result would make interpretation and conclusion difficult. There are several problems associated with using pooled data. Of primary importance is the potential for serial correlation and heteroscedasticity in the error terms. It was not possible to test for the existence of serial correlation, or to use recently developed procedures for estimating with pooled data, because of unequal number of observations in each cross section. The models were tested for the constancy of the error term, and in all cases the homogeneity hypothesis could not be rejected.

Empirical Results

The results presented below are reported in three parts. A large amount of very detailed data on the characteristics of carlot sales of malting barley at the Minneapolis Grain Exchange were collected since the 1978/79 crop year. In the first section below, the general characteristics of malting barley sales and prices are presented. In the second section are the results from the regression analysis and hypothesis testing. In the third section the estimates of implicit prices for plumpness and protein are reported and discussed.

Characteristics of Malting Barley Sales at the Minneapolis Grain Exchange

Data were collected from reported carlot sales of malting barley for every Wednesday during the crop years 1978/79 to 1981/82. The distribution of carlots was categorized by variety and by grade. In addition, means of protein content, kernel plumpness, and price were tabulated among varieties.

The distribution of carlots among varieties is presented in Table 5. In the first crop year, 1978/79, sales of Morex and Glenn did not exist since these

TABLE 5. DISTRIBUTION AMONG VARIETIES OF MALTING BARLEY CARLOTS SOLD AT THE MINNEAPOLIS GRAIN EXCHANGE, 1978/79 -1981/82

Crop Year	Variety				Total
	Beacon	Larker	Morex	Glenn	
	Number of Carlots (% in parentheses)				
1978/79	516	605	--	--	1,121
	(46)	(54)			
1979/80	572	665	27	5	1,269
	(45)	(52)	(2)	(1)	
1980/81	249	352	408	42	1,051
	(24)	(33)	(39)	(4)	
1981/82*	118	85	300	161	664
	(18)	(13)	(45)	(24)	

*Includes July through December of 1981 only.

varieties were newly approved by the Malting Barley Improvement Association. A time lag was involved due to the availability of seed and the willingness of producers to try new varieties. Although Larker was the most popular variety in the first two crop years, Beacon and Larker sales decreased substantially in the last two crop years. This decline can be attributed to the popularity of Morex and Glenn. The distribution of carlots among grades in Table 6 reveals the quality of malting barley sold during the designated years. Over 50 percent of the carlots in every crop year were Grade No. 2.

There was very little difference in protein content and kernel plumpness among varieties in any given crop year (Table 7). In 1978/79, the average protein content of Beacon was identical to Larker. However, Larker had the lowest protein content among varieties in the remaining years, except in 1979/80 when Morex was equal to Larker (13.1 percent).

TABLE 6. DISTRIBUTION AMONG GRADES OF MALTING BARLEY CARLOTS SOLD AT THE MINNEAPOLIS GRAIN EXCHANGE, 1978/79-1981/82

Crop Year	Numerical Grades 1	2	3	Total
	----Number of Carlots----			
1978/79	325	569	227	1,121
1979/80	319	680	270	1,269
1980/81	271	588	192	1,051
1981/82*	66	385	213	664

*July through December of 1981 only.

TABLE 7. MEANS AND MEASURES OF DISPERSION OF PLUMPNESS AND PROTEIN CONTENTS AMONG VARIETIES OF MALTING BARLEY, 1978/79-1981/82

Crop Year	Variety	Protein Content Mean	Protein Content Standard Deviation	Protein Content Range	Kernel Plumpness Mean	Kernel Plumpness Standard Deviation	Kernel Plumpness Range
		----------Percent----------					
1978/79	Beacon	13.2	.62	10.0-15.4	72	7.23	47-92
	Larker	13.2	.71	10.7-15.8	71	7.79	41-94
1979/80	Beacon	13.3	.65	11.3-15.2	72	6.93	40-98
	Larker	13.1	.72	10.8-15.7	71	8.15	46-96
	Morex	13.1	.72	11.2-14.5	69	8.41	51-85
	Glenn	13.3	.93	12.0-14.4	73	6.69	67-83
1980/81	Beacon	13.3	.67	10.6-15.0	73	7.78	44-91
	Larker	12.9	.74	11.1-15.9	71	7.67	46-91
	Morex	13.1	.76	10.5-15.1	70	8.05	46-90
	Glenn	13.4	.75	11.0-15.0	78	7.95	55-90
1981/82*	Beacon	13.4	.59	11.0-15.0	74	5.73	56-86
	Larker	13.1	.79	10.7-14.9	72	9.32	50-88
	Morex	13.2	.76	10.5-15.2	68	8.39	42-93
	Glenn	13.4	.69	10.0-15.1	72	7.04	45-88

*Includes July through December of 1981 only.

Glenn exhibited the least variability in protein and plumpness during this period relative to the other varieties. The reason that the mean levels for plumpness and protein were relatively close across varieties is that country elevators blend different lots of malting barley to meet maltsters' specifications. Not all malting barley purchased from producers has the desired levels of protein and plumpness or other grade factors. Country elevators blend different lots of barley together so shipments can be made of the desired levels of quality characteristics. As with variety, plumpness and protein displayed little variability among grades within a given crop year (Table 8). Average protein and plumpness ranged from 13.1 to 13.3 percent and

TABLE 8. MEANS AND MEASURES OF DISPERSION OF PLUMPNESS AND PROTEIN CONTENTS AMONG GRADES OF MALTING BARLEY, 1978/79-1981/82

		Protein Content			Kernel Plumpness		
Crop Year	Grade	Mean	Standard Deviation	Range	Mean	Standard Deviation	Range
		Percent					
1978/79	1	13.3	.63	11.2-15.3	72	6.81	50-94
	2	13.2	.69	10.0-15.8	71	7.45	47-91
	3	13.2	.68	10.7-15.4	72	8.65	41-90
1979/80	1	13.2	.70	11.3-15.1	71	7.44	46-98
	2	13.2	.69	10.9-15.7	71	7.51	40-91
	3	13.3	.69	10.8-15.2	73	8.12	50-96
1980/81	1	13.1	.75	11.1-15.1	71	7.15	46-87
	2	13.1	.73	10.9-15.9	71	7.84	48-91
	3	13.1	.78	10.5-14.8	72	9.61	44-91
1981/82*	1	13.3	.81	11.5-15.2	72	7.27	54-92
	2	13.3	.65	11.0-15.1	71	7.38	50-93
	3	13.3	.83	10.0-15.2	68	9.30	42-89

*Includes July through December of 1981 only.

68 to 73 percent, respectively, in all crop years. Average protein content was identical in all three grades in 1980/81 and the partial crop year of 1981/82.

The highest levels of protein were found in Grade No. 2 during 1978/79 and 1980/81, but some of the lowest protein levels occurred in 1978/79.

Price differences associated with varieties are presented in Table 9. Larker sold at a higher price than Beacon in the first two crop years. The

TABLE 9. MEAN AND STANDARD DEVIATION OF YEARLY PRICES AMONG VARIETIES OF MALTING BARLEY SOLD AT THE MINNEAPOLIS GRAIN EXCHANGE, 1978/79-1981/82

Crop Year	Variety	Mean Price**	Standard Deviation
		------------Cents Per Bushel------------	
1978/79[1]	Larker	244.25	29.04
	Beacon	236.48	21.78
1979/80[2]	Larker	284.78	29.69
	Beacon	272.36	22.26
	Glenn	263.00	23.08
	Morex	276.85	19.27
1980/81[3]	Larker	349.29	33.87
	Beacon	347.97	32.10
	Glenn	358.69	24.62
	Morex	357.99	27.28
1981/82[4]	Larker	290.52	26.82
	Beacon	292.99	27.19
	Glenn	295.55	25.72
	Morex	302.56	25.88

[1]Difference in means across varieties was significant at the 1 percent level where $F_{1,1119} = 2.50$.
[2]Difference in means across varieties was significant at the 1 percent level where $F_{1,1236} = 67.43$.
[3]Differences in means across varieties were significant at the 1 percent level where $F_{3,1047} = 7.99$.
[4]Differences in means across varieties were significant at the 1 percent level where $F_{3,660} = 7.20$.

largest difference occurred in 1979/80 when Larker received a 12-cent/bushel premium over Beacon. In 1980/81, the loss of popularity of Larker and Beacon to Glenn and Morex was reflected by lower prices. Morex and Glenn sold at a 10-cent/bushel premium over Larker and Beacon. A closer examination of

1980/81 indicates less price variability in Morex and Glenn. Standard deviations for these varieties were 25 cents and 27 cents respectively, compared to 32 cents and 34 cents for Beacon and Larker. The differences in the annual average prices across varieties are significant at the 1 percent level.

Estimated Equations and Hypothesis Testing

One of the purposes of the empirical analysis was to describe the process of price determination which establishes price differentials across individual carlots of malting barley. Equation 1.1 provides an empirical specification of a theoretical relationship between the price of barley and quality characteristics. In the initial analysis several other variables and nonlinear relationships were included in that equation. Second and third order polynomials in plumpness and protein were included to allow for nonlinear implicit prices. This simply allows for a premium and discount scale which varies throughout the range of the quality characteristics. The results yielded insignificant second and third order parameters in protein and insignificant third order parameters in plumpness. Experimentation with the inclusion of "car receipts" as an independent variable also was conducted. The results were inconclusive and in most cases insignificant. In the results reported here, the second order parameter in plumpness is included and the effect of "car receipts" is not included.

Tests on the Behavior of Implicit Prices

Several tests on the behavior of the implicit prices were conducted. The purpose of the statistical tests was to evaluate the homogeneity of the implicit prices across varieties and grades. Recall that implicit prices estimated from the theoretical model can be interpreted as premiums and discounts traditionally used in the grade trade. The homogeneity test determines whether the implicit prices estimated from the regression model are constant across varieties and grades. In other words, the question posed is whether the premiums and discounts for plumpness and protein implied in the malting barley market are the same across varieties and grades.

The results, presented in Table 10 for each crop year, are mixed. These results are important both with respect to model specification and because they

TABLE 10. ANALYSIS OF VARIANCE OF IMPLICIT PRICES FOR PROTEIN AND PLUMPNESS: TESTS OF HYPOTHESES OF CONSTANCY OF IMPLICIT PRICES ACROSS VARIETIES AND GRADES[a]

	Crop Year							
	1978/79		1979/80		1980/81		1981/82	
Classification	Protein	Plumpness	Protein	Plumpness	Protein	Plumpness	Protein	Plumpness
Variety	Accept	Reject	Reject	Reject	Accept	Reject	Accept	Accept
Grade	Accept	Accept	Accept	Accept	Accept	Accept	Accept	Accept

[a]Acceptance or rejection was based on the 1 percent level of significance.

reveal the behavior of the market in determining premiums and discounts for plumpness and protein. The results indicate that: premiums and discounts for plumpness and protein implied in the price of malting barley were not significantly different across grades; protein discounts were not significantly different across varieties except in 1979/80; and premiums for plumpness were significantly different across varieties except for 1981/82.

Estimated Equations of Malting Barley Prices

The estimated equations for each crop year are presented in Tables 11-14. Three models are presented in each case. Model One, the simplest model, is linear in both protein and plumpness and does not include the price of feed barley as an explanatory variable. In this case the effect of variability in the price of feed barley on malting barley prices is reflected in the intercept. Model Two includes a second-order term in plumpness and the effect of feed barley prices. These effects are reflected in Model Three as well as in the inclusion of dummy variables for grades. Restrictions were placed on the values of the coefficients associated with plumpness and protein in the different years as a result of the tests for homogeneity (see Table 10). These restrictions can be stated in terms of the reformulated empirical model as follows:

$$P_{it} = \gamma_0 + \sum_{a=2}^{n} \gamma_a V_a + \sum_{v=2}^{3} \delta_r GR + \sum_{h=2}^{12} \alpha_h M_h + \theta FDBAR_t$$

$$+ \sum_{a=2}^{n} \beta_{1a}\, PRO_{it} + \sum_{a=2}^{n} \beta_{2a}\, PLU_{it} + \sum_{a=2}^{n} \beta_{3a}\, PLU_{it}^2 + e_{it} \quad (2.1)$$

where the variables are as previously defined except for $FDBAR_t$ which is the price of No. 2 feed barley at Minneapolis during time period t. Model One assumes $\beta_{3a} = 0$, $\delta_r = 0$, and $\theta = 0$. Model Two relaxes two of these assumptions allowing for $\beta_{3a} \neq 0$ and $\theta \neq 0$, but $\delta_r = 0$. In Model Three all of these restrictions are relaxed. The restrictions placed on the empirical model regarding the homogeneity of the implicit prices vary across the years following the results in Table 10.[1]

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[1]These restrictions are:

1978/79 $\beta_{11} = \beta_{12}$, $\beta_{21} \neq \beta_{22}$, $\beta_{31} \neq \beta_{32}$

1979/80 $\beta_{11} \neq \beta_{12}$, $\beta_{21} \neq \beta_{22}$, $\beta_{31} \neq \beta_{32}$

1980/81 $\beta_{11} = \beta_{12} = \beta_{13} = \beta_{14}$, $\beta_{21} \neq \beta_{22} \neq \beta_{23} \neq \beta_{24}$, $\beta_{31} \neq \beta_{32} \neq \beta_{33} \neq \beta_{34}$

1981/82 $\beta_{11} = \beta_{12} = \beta_{13} = \beta_{14}$, $\beta_{21} = \beta_{22} = \beta_{23} = \beta_{24}$, $\beta_{31} = \beta_{32} = \beta_{33} = \beta_{34}$.

TABLE 11. ESTIMATED COEFFICIENTS OF EQUATIONS DESCRIBING MALTING BARLEY PRICES, 1978/79[1]

Variables	Model One	Model Two	Model Three
Month[2]			
August	0.15	0.15	0.15
	(8.67)	(11.29)	(11.31)
September	0.19	0.14	0.14
	(10.29)	(9.70)	(9.82)
October	0.17	0.08	0.08
	(6.05)	(3.65)	(3.68)
November	0.35	0.15	0.15
	(16.36)	(8.42)	(8.44)
December	0.26	0.17	0.17
	(13.01)	(10.83)	(10.77)
January	0.20	0.20	0.20
	(9.53)	(12.27)	(12.27)
February	0.29	0.29	0.30
	(11.07)	(14.66)	(14.81)
March	0.40	0.23	0.23
	(17.16)	(11.91)	(11.99)
April	0.49	0.30	0.30
	(24.72)	(17.51)	(17.55)
May	0.64	0.34	0.33
	(37.33)	(17.68)	(19.67)
June	0.66	0.15	0.15
	(35.65)	(6.42)	(6.35)
Variety[3]			
Larker	-0.02	-0.16	-0.21
	(0.29)	(0.44)	(0.56)
Plumpness			
Beacon	0.003	0.04	0.04
	(3.60)	(4.83)	(4.72)
Larker	0.005	0.05	0.05
	(7.38)	(6.61)	(6.64)
Plumpness Squared			
Beacon		-0.0003	-0.0003
		(6.04)	(6.08)
Larker		-0.0003	-0.0002
		(4.48)	(4.38)
Protein	-0.067	-0.072	-0.073
	(10.40)	(4.49)	(14.60)
Grade[4]			
No. 2			-0.02
			(2.52)
No. 3			-0.005
			(0.55)
Feed Barley		1.13	1.13
		(26.18)	(26.34)
Constant	2.65	-0.44	-0.40
	(26.32)	(1.48)	(1.36)
R^2	0.72	0.83)	0.83

[1]Different coefficients for plumpness were estimated for each variety but the coefficient for protein was restricted to be equal across varieties (see Table 10).

[2]The month classification has a significant impact on price at the 5 percent level. The calculated $F_{11,1101}$ = 244.98 for Model Two.

[3]The variety classification has an insignificant impact on price at the 5 percent level. The calculated $F_{1,1101}$ = 0.19 for Model Two.

[4]The grade classification has an insignificant impact on price at the 5 percent level. The calculated $F_{2,1100}$ = 0.79 for Model Three.

TABLE 12. ESTIMATED COEFFICIENTS OF EQUATIONS DESCRIBING MALTING BARLEY PRICES, 1979/80[1]

Variables	Model One	Model Two	Model Three
Month[2]			
August	-0.14	-0.07	-0.07
	(5.15)	(2.48)	(2.41)
September	0.24	0.28	0.28
	(8.62)	(10.12)	(10.11)
October	0.29	0.28	0.28
	(10.52)	(10.59)	(10.60)
November	0.08	0.14	0.14
	(2.76)	(4.82)	(4.75)
December	-0.09	-0.02	-0.02
	(3.12)	(0.90)	(0.86)
January	-0.19	-0.10	-0.10
	(6.49)	(3.32)	(3.20)
February	-0.14	-0.05	-0.04
	(4.51)	(1.47)	(1.41)
March	-0.22	-0.14	-0.13
	(7.90)	(4.73)	(4.66)
April	-0.12	-0.04	-0.04
	(4.68)	(1.52)	(1.58)
May	-0.02	0.07	0.069
	(0.55)	(2.24)	(2.27)
June	0.10	0.16	0.16
	(4.05)	(6.24)	(6.22)
Variety[3]			
Larker	0.58	0.89	0.92
	(2.39)	(1.33)	(1.38)
Plumpness			
Beacon	0.005	0.06	0.06
	(3.94)	(4.40)	(4.43)
Larker	0.008	0.05	0.05
	(8.59)	(4.98)	(4.91)
Plumpness Squared			
Beacon	-0.06	-0.00032	-0.0003
	(4.88)	(4.18)	(4.08)
Larker	-0.117	-0.0004	-0.0004
	(11.01)	(4.06)	(4.11)
Protein			
Beacon		-0.06	-0.06
		(4.90)	(4.84)
Larker		-0.11	-0.11
		(11.10)	(11.07)
Grade[4]			
No. 2			0.03
			(2.22)
No. 3			0.008
			(0.51)
Feed Barley		0.31	0.32
		(7.50)	(7.52)
Constant	3.23	0.50	0.46
	(17.70)	(0.95)	(0.88)
R^2	.49	.53	.53

[1]Different coefficients were estimated for each variety for both the plumpness and protein variables (see Table 10).
[2]The month classification has a significant impact on price at the 5 percent level. The calculated $F_{11,1218} = 51.11$ for Model Two.
[3]The variety classification has an insignificant impact on price at the 5 percent level. The calculated $F_{1,1218} = 1.78$ for Model Two.
[4]The grade classification has an insignificant impact on price at the 5 percent level. The calculated $F_{2,1217} = 0.45$ for Model Three.

TABLE 13. ESTIMATED COEFFICIENTS OF EQUATION DESCRIBING MALTING BARLEY PRICES, 1980/81[1]

Variables	Model One	Model Two	Model Three
Month[2]			
August	-0.18	-0.17	-0.17
	(6.08)	(5.97)	(5.94)
September	0.18	0.18	0.18
	(5.81)	(6.10)	(6.08)
October	0.37	0.22	0.22
	(14.68)	(6.70)	(6.72)
November	0.45	0.16	0.16
	(16.57)	(3.70)	(3.70)
December	0.23	0.07	0.07
	(6.41)	(1.90)	(1.94)
January	0.22	0.03	0.03
	(4.69)	(0.62)	(0.60)
February	0.37	0.15	0.15
	(11.95)	(3.81)	(3.80)
March	0.24	0.16	0.16
	(9.75)	(5.00)	(5.04)
April	0.31	0.28	0.28
	(9.05)	(8.19)	(8.77)
May	0.28	0.33	0.34
	(8.73)	(10.98)	(10.98)
June	0.07	0.25	0.25
	(2.32)	(7.37)	(7.39)
Variety[3]			
Larker	-0.62	-1.15	-1.19
	(3.47)	(1.21)	(1.26)
Morex	-0.01	-0.21	-0.24
	(0.08)	(0.23)	(0.27)
Glenn	0.005	0.86	0.81
	(0.02)	(0.38)	(10.36)
Plumpness			
Beacon	0.007	0.10	0.09
	(3.87)	(4.73)	(4.81)
Larker	0.015	0.12	0.12
	(9.93)	(6.53)	(6.49)
Morex	0.009	0.11	0.10
	(5.31)	(6.49)	(6.36)
Glenn	0.007	0.07	0.07
	(1.70)	(1.23)	(1.23)
Plumpness Squared			
Beacon		-0.0006	-0.0006
		(4.59)	(4.47)
Larker		-0.0007	-0.0007
		(5.71)	(5.66)
Morex		-0.0007	-0.0007
		(6.06)	(5.94)
Glenn		-0.0004	-0.0004
		(1.13)	(1.13)
Protein	-0.117	-0.1105	-0.105
	(11.91)	(11.40)	(11.41)
Grade[4]			
No. 2			0.01
			(0.63)
No. 3			-0.009
			(0.46)
Feed Barley		0.49	0.49
		(8.41)	(8.42)
Constant	4.34	-0.16	(-0.09)
	(23.46)	(0.22)	(0.13)
R^2	.47	.54	.54

[1]Different coefficients for plumpness wrre estimated for each variety but the coefficient for protein was restricted to be equal across varieties (see Table 10).

[2]The month classification has a significant impact on price at the 5 percent level. The calculated $F_{11,1032}$ = 33.05 for Model Two.

[3]The variety classification has an insignificant impact on price at the 5 percent level. The calculated $F_{3,1032}$ = 0.90 for Model Two.

[4]The grade classification has an insignificant impact on price at the 5 percent level. The calculated $F_{2,1031}$ = 0.01 for Model Three.

TABLE 14. ESTIMATED COEFFICIENTS DESCRIBING MALTING BARLEY PRICES, 1981/82[1]

Variables	Model One	Model Two	Model Three
Month[2,3]			
August	0.22 (9.34)	0.20 (8.11)	0.21 (8.26)
September	0.19 (5.95)	0.18 (5.57)	0.18 (5.67)
October	0.10 (2.53)	0.09 (2.27)	0.09 (2.31)
November	0.16 (4.91)	0.15 (4.91)	0.15 (4.95)
December	0.07 (2.21)	0.07 (2.06)	0.07 (1.94)
Variety[4]			
Larker	-0.05 (1.60)	-0.03 (1.04)	-0.04 (1.16)
Morex	0.10 (4.31)	0.12 (4.71)	0.11 (4.54)
Glenn	0.04 (1.31)	0.04 (1.36)	0.04 (1.37)
Plumpness	0.007 (6.24)	0.055 (4.33)	0.052 (4.03)
Plumpness Squared		-0.0003 (3.79)	-0.0003 (3.54)
Protein	-0.144 (12.02)	-0.133 (10.69)	0.133 (10.77)
Grade[5]			
No. 2			-0.03 (1.07)
No. 3			-0.05 (1.63)
Feed Barley		0.11 (1.05)	0.09 (0.89)
Constant	4.21 (22.74)	2.18 (3.77)	2.38 (4.04)
R^2	.33	.34	.34

[1]Coefficients for plumpness and protein were restricted to be equal across varieties (see Table 10).
[2]Only the first six months of the crop year were included in the sample.
[3]The month classification has a significant impact on price at the 5 percent level. The calcualted $F_{6,649}$ = 15.16 for Model Two.
[4]The variety classification has a significant impact on price at the 5 percent level. The calculated $F_{3,649}$ = 14.38 for Model Two.
[5]The grade classification has an insignificant impact on price at the 5 percent level. The calculated $F_{2,648}$ = 2.77 for Model Three.

Several observations can be made of the results prior to discussing the estimates of the implicit prices. The effects of month, variety, and grade were classification variables included in the estimated equations as binary intercept variables. Hypotheses were posed to determine if these effects had a statistically significant effect on prices. Analysis of variance with covariance was used to test these hypotheses. The results indicated that the effect of month, or seasonal effect, was significant in all years. The effect of variety was insignificant in all years except 1981/82. Grade was also included as an effect and was insignificant in all years. These results indicate that given the other variables which affect the price of malting barley, its grade does not have a significant effect on price. However, the month of the year and, in 1981/82, the variety have significant effects on the price of malting barley.

There are several differences in the specification and results for Models One and Two. The estimated coefficients are similar in the two models except for those associated with month. In Model Two these coefficients are closer to zero relative to Model One, but are still significant. Essentially, the seasonality in malting barley price is reflected in feed barley prices in Model Two. The significance of the monthly variables in Model Two represents the inherent seasonality in malting barely prices relative to feed barley prices. Generally malting barley prices increase throughout the crop year after the harvest period lows. The values of the monthly coefficients in Model One indicate the increase in malting barley prices relative to July, throughout the remainder of the crop year. These were positive in all crop years except for the latter half of 1979/80 in which they decreased. These results are confirmed in another study by Wilson.

The variety dummy variable represents the inherent value of a variety relative to Beacon given the other factors in the equation (i.e., protein, plumpness, etc.). In the first three years of the study the statistical results indicated that this classification was insignificant. In other words, there was not a significant inherent varietal premium which was not accounted for by differences in protein or plumpness.[2] In 1981/82, however, the varieties had statistically significant differences in their inherent value. The values of the coefficients indicate that the inherent value of Morex was 12¢/bushel greater than Beacon, but those for Larker and Glenn were not significantly different than Beacon.

One final observation is that a change likely is occurring in the determination of prices in the malting barley market. Throughout the time period of this study the coefficient associated with feed barley has decreased and in 1981/82 was not significantly different than zero. This means that in the first three years, fundamentals in the feed grains sector, as represented by feed barley prices, had a significant effect on malting barley prices. In 1978/79 for example, there was nearly a one-to-one relationship between changes in feed barley prices and malting barley prices. Since then this has decreased and in 1981/82 changes in feed barley prices did not have a significant impact on malting barley prices. In addition, the R^2 which measures the extent that variability in malting barley prices is explained by the empirical equation, has decreased in recent years. In 1978/79 about 83 percent of the variability in malting barley prices was explained by the fundamental variables. Since then the value of R^2 has decreased and in 1981/82 only 34 percent of the variability in the price of malting barley was

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[2]The significant differences in prices Table 9 must be accounted for by differences in the levels of plumpness and protein and their implicit prices.

explained. These two observations indicate that changes have likely been occurring in the price determination mechanism in the Minneapolis malting barley market. In general, the change has been towards less influence from the feed grains sector, and greater unexplained variability or randomness in malting barley prices.

Estimates of Marginal Implicit Prices for Plumpness and Protein

The estimated equations in Tables 11-14 can be used to describe the pricing structure for malting barley and to derive estimates of marginal implicit prices for plumpness and protein. A distinction should be made which illustrates the interpretation of marginal implicit prices. The price of malting barley reflects the variety, month, and levels of plumpness and protein in particular samples. Implicit in the observed price is a premium for plumpness and a discount for protein which are referred to as marginal implicit prices. They are the additional value implied in the price of malting barley attributed to a one unit change in the quantity of plumpness or protein. The overall price level varies from year to year as well as with respect to variety and the level of feed barley prices. These variables are referred to as shifters because they change the level of the overall price structure, but the implicit prices for plumpness and protein vary only between crop years. An example which illustrates the price structure for malting barley in August 1980 is shown in Table 15. Protein has a negative impact on the price structure. Given a particular level of plumpness and overall price level as determined by the shifters, the results indicate that increases in protein are associated with lower prices. A 1 percentage point change in protein results in an 11¢/bushel change in price. Plumpness, on the other hand, has a positive effect on prices of malting barley. However, this effect

TABLE 15. ESTIMATED PRICES FOR MOREX MALTING BARLEY IN AUGUST 1980 FOR VARIOUS LEVELS OF PLUMPNESS AND PROTEIN[1]

	Protein (%)			
Plumpness (%)	11	12	13	14
	$/Bushel			
50	3.16	3.05	2.94	2.83
60	3.49	3.38	3.27	3.16
70	3.68	3.57	3.46	3.35
80	3.73	3.62	3.51	3.40

[1]Estimated from Model Two in Table 13 assuming the average price for Feed Barley of $2.395/bushel.

is not constant across all levels of plumpness. Prices increase at a decreasing rate with increases in plumpness. For a given level of protein, prices increase by 33¢/bushel for changes in plumpness between 50 and 60 percent, by 19¢/bushel for changes in plumpness between 60 and 70 percent, and by 5¢/bushel for changes in plumpness between 70 and 80 percent.

The price structure for malting barley is illustrated in Figure 1 below for different levels of protein and plumpness. The overall price level in this figure is for Morex in August 1980. The overall level of prices changes but the relationships with respect to protein and plumpness are constant within a crop year. The interpretation of a constant marginal implicit price for protein means that prices decrease at a constant rate with increases in protein. The shape of the price curve with respect to plumpness means that prices increase with additional units of that characteristic but decrease after reaching a peak at some point.

The pricing structure for malting barley can be stated in equation form as:

$$P = K + \beta_{1a} \, PRO + \beta_{2a} \, PLU + \beta_{3a} \, PLU^2 \qquad (3.1)$$

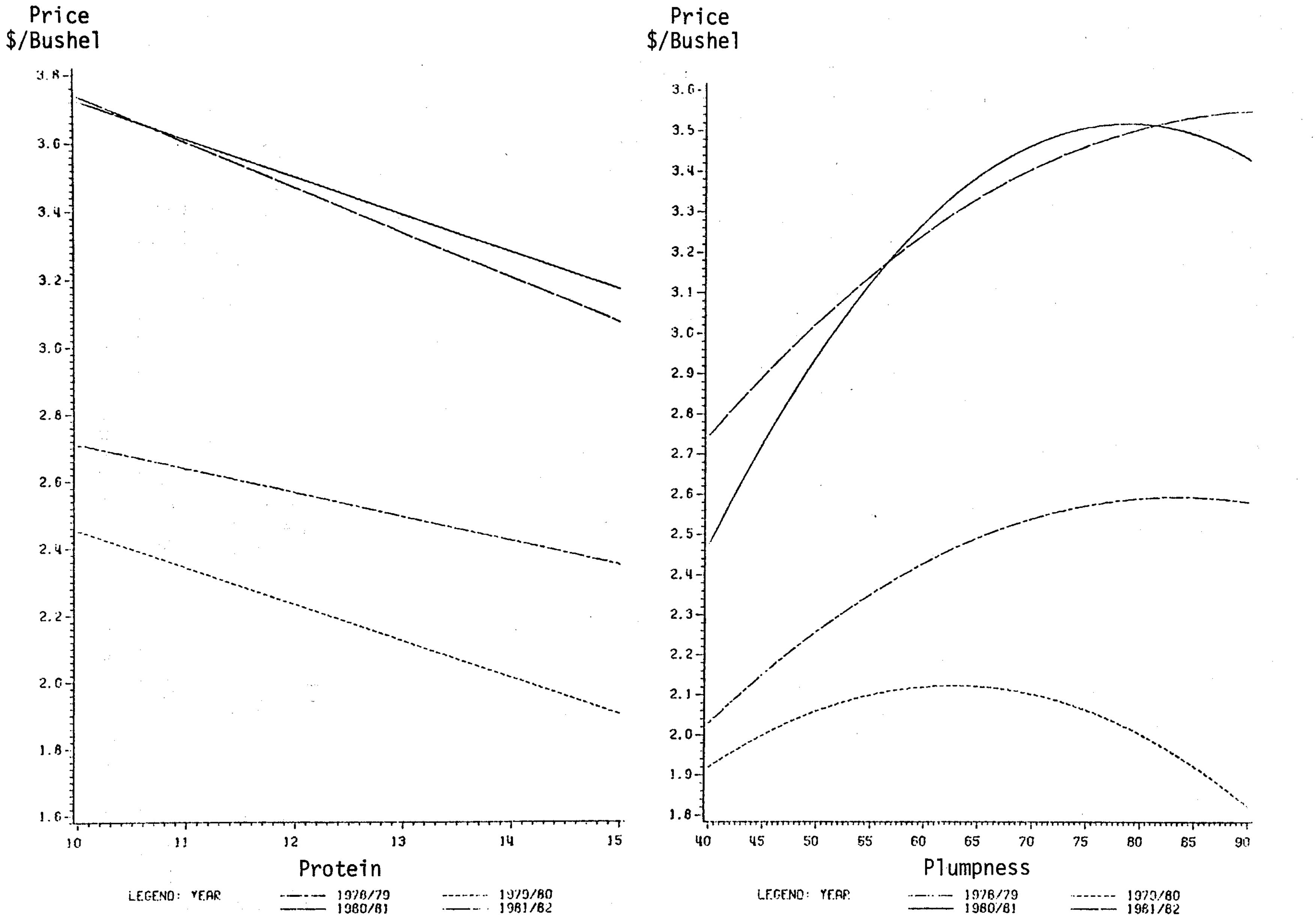

Figure 1. Prices for Morex Malting Barley in August 1980 in Relation to Protein and Plumpness

where P is price, k is some constant and reflects the price of seed barley, month, and variety, and β_{1a}, β_{2a}, and β_{3a} are estimated parameters. Marginal implicit prices are formally defined as the first derivative of equation 3.1 with respect to the quality characteristic:

$$MIP_{PR} = \frac{\partial P}{\partial PRO} = \beta 1a$$

$$MIP_{PL} = \frac{\partial P}{\partial PLU} = \beta 2a + 2\beta 3a \ PLU$$

Equation 3.1 can be maximized with respect to plumpness equal to zero to determine the quantity of plumpness which yields the highest price. This varies by year and with respect to varieties with the exception of 1981/82. Table 16 shows parameters for plumpness and the quantity which yields the

TABLE 16. PARAMETERS FOR PLUMPNESS AND THE QUANTITY OF PLUMPNESS WHICH MAXIMIZES PRICE[1]

Year	$\beta 2$	$\beta 3$	Quantity of Plumpness Which Maximizes Price
			----------Percent----------
1978/79			
Beacon	.04	-.0003	67
Larker	.05	-.0003	83
1979/80			
Beacon	.06	-.00032	94
Larker	.05	-.0004	62
1980/81			
Beacon	.10	-.0006	83
Larker	.12	-.0007	86
Morex	.11	-.0007	79
Glenn	.07	-.0004	87
1981/82			
All Varieties	.055	-.0003	92

[1]Taken from the results from Tables 11-14 in Model Two.

greatest price. The quantity of plumpness which maximizes price should serve as an objective for merchandisers since it can be varied by blending.[3]

Marginal implicit prices for protein and plumpness were calculated from the estimated equations for each year and are shown in Table 17. The marginal

TABLE 17. ESTIMATED MARGINAL IMPLICIT PRICES FOR PLUMPNESS (AT THE 65 PERCENT LEVEL) AND PROTEIN FOR CROP YEARS 1978/79-1981/82[1]

Variety	Marginal Implicit Prices for Plumpness[2]			
	1978/79	1979/80	1980/81	1981/82
	$/Bushel			
Beacon	.004	.024	.028	.019
Larker	.014	.002	.036	.019
Morex	(a)	(a)	.026	.019
Glenn	(a)	(a)	.022	.019
	Marginal Implicit Prices for Protein			
	1978/79	1979/80	1980/81	1981/82
Beacon	-.072	-.06	-.11	-.13
Larker	-.072	-.11	-.11	-.13
Morex	(a)	(a)	-.11	-.13
Glenn	(a)	(a)	-.11	-.13

[a]Not estimated.

[1]Values taken from regression results for Model Two reported in Tables 11-14. Marginal implicit prices are defined as the first derivative of the price function with respect to the characteristics. These are linear in the case of protein or nonlinear in the case of plumpness.

[2]Marginal implicit prices for plumpness were calculated for plumpness equal to 65 percent.

[3]For example, using the equation for Morex in August 1980 with 12 percent protein the price of barley with 70 percent plumpness would be $3.595/bushel; 75 percent plumpness $3.637/bushel; and 80 percent plumpness would be $3.645/bushel. The optimum plumpness was 78.6 percent which would yield a price of $3.646/bushel which slightly exceeds the others.

implicit price for plumpness was calculated at 65 percent plumpness since its value varies throughout its range. The marginal implicit price for plumpness varies by variety except for 1981/82 in which it was constant across varieties. It increased for the first three years of the study but has since decreased. The marginal implicit price for protein was constant across varieties except in 1979/80. An important observation is that the marginal implicit price for protein, or discount, increased in each year of the study. In the first year a one unit, or 1 percentage point, higher protein resulted in discount of 7.2¢/bushel. In 1981/82 this discount increased to 13¢/bushel. This simply indicates that the discounts the market establishes for protein have been increasing, and have nearly doubled, during the study period.

Summary and Conclusions

An important attribute of the market for malting barley is the price differentials which are established for relatively small differences in quality. Price differentials are established first between malting barley and feed barley, which represents fundamentals of the feed grains sector. Price differentials are simultaneously established between different samples of malting barley. One of the purposes of this study was to analyze statistically the relationship among various quality factors and malting barley prices. The second was to develop and estimate a statistical model for measuring the implicit price for selected quality characteristics. The implicit price of a quality attribute is an economic concept similar to premiums and discounts used in the grain trade. In economic terms implicit prices indicate the market-determined value of an additional quality attribute.

Weekly data were collected for four years on price and characteristics of carlot sales of malting barley at the Minneapolis Grain Exchange. Simple analysis of the data demonstrated the decreased importance of the variety Larker, and the increased importance of Morex. In 1981/82 Morex and Larker had similar protein levels which were about .2 percentage points less than Beacon and Glenn. Morex, however, consistently had a lower level of plump kernels. In 1981/82 Morex commanded a 12¢/bushel premium over Larker, a 10¢/bushel premium over Beacon, and a 7¢/bushel premium over Glenn.

An econometric model was specified and estimated to derive market determined implicit prices for protein and plumpness. Several observations were made from the estimated equations. First, malting barley prices have a seasonal effect which is greater than that of feed barley prices. Second, the grade variables do not have a significant effect on the level of malting barley prices, given the other variables, or on the implicit prices for plumpness and protein. Third, in the first three years of the study period there was not a significant varietal premium which was not accounted for by the characteristics. In 1981/82 however, there was a statistically significant varietal premium for Morex. Fourth, there appears to be a change which is evolving in the process of price determination for malting barley. In general, the feed grains sector has had increasingly less effect on malting barley prices, and in 1981/82 it was statistically insignificant. In addition, the unexplained variability in malting barley prices increased in each year of the study.

Marginal implicit prices were derived from the estimated equation. These can be interpreted as the premiums and discounts for plumpness and protein which are implied in the price of malting barley. Separate marginal implicit prices for plumpness and protein were estimated for each crop year and variety where appropriate. The marginal implicit price for protein was negative (implying a discount) as expected, constant across the range of protein, and constant across varieties every year except 1979/80. In 1981/82 the marginal implicit price for protein was -13¢/bushel indicating the implied discount associated with 1 percent higher protein. The marginal implicit price for plumpness was not constant throughout the range of plumpness, and varied across varieties except in 1981/82. In that year it was 1.9¢/bushel (at the 60 percent level of plumpness) meaning that a 1 percentage point greater level of plumpness was valued at about 2¢/bushel. The nonlinearity in this implicit price means there is a level of plumpness which is associated with a maximum price. These varied across years and varieties and in 1981/82, 92 percent plumpness was optimum. An important observation on the behavior of these marginal implicit prices is that the premium for plumpness increased during the first three years of the study and the discounts for protein increased every year from 7.2¢/bushel to 13¢/bushel for a 1 percentage point change in protein.

These results and/or methodology could be useful throughout the production/marketing system for malting barley. In the case of malting barley, large expenditures are made in plant breeding to improve its quality through improved varieties. The results of this study provide a measure of economic value of plumpness and protein that could be incorporated in trait selection in plant breeding programs. These results could also be useful for producers in variety selection and production decisions to the extent that protein and plumpness levels can be influenced by soil selection and nitrogen use. The implicit prices for plumpness and protein indicate the economic value of an additional unit of that characteristic, which may be weighed against additional input cost and/or reduced yield. These results and extensions of the methodology could also be used by participants directly involved in the market for malting barley. Country elevators, merchandisers, maltsters, and, to a certain extent, brewers have long been aware of the uncertainty associated with marketing malting barley and the implicit discounts for protein and premiums for plumpness. This study provides empirical results of the value of these implicit discounts for protein and premiums for plumpness as well as varietal premiums. The analysis could be updated on a periodic basis (daily, weekly, monthly, or annually) to determine the value of the implicit prices for the quality characteristics. These could then be used in analysis of current price relationships, or incorporated into explicit premiums and discounts which would be useful in transactions throughout the marketing system and in to-arrive contracts which have the potential to become increasingly popular. This would eliminate some of the uncertainty associated with marketing malting barley. Finally, the analysis could be expanded to estimates of implicit prices for other quality characteristics important in the malting barley market if more detailed data were available.

Appendix I

Theoretical Development of the Demand for Input Characteristics

An important characteristic in the malting barley market is that quality and price vary across samples. Quality variability and its effect on prices has been introduced in theoretical and empirical models by Abbott, Lancaster, and Waugh. The demand for input characteristics has been developed further and applied in the case of agriculture by Ladd and Martin. These concepts have been extended and applied to problems associated with plant and animal breeding (Ladd, May 1978). More recent research in the area of hedonic prices have been reported in Rosen, Carl, and Kilmer, and Margolius and Tilley.

Malting barley is used to produce malt and eventually beer, and consequently, can be treated as a production input, with several quality characteristics. Of primary importance are the levels of protein and plumpness and the inherent characteristics of each variety. The market value of a particular sample of malting barley varies depending on the variety, and the levels of protein and plumpness. The latter two affect the quantity of malt and eventually the amount of beer that can be brewed from a bushel of malting barley. Traditional theory of the firm can be expanded to derive input demand functions for each quality characteristic. The results can then be used to derive implicit prices, or premiums and discounts for each of the quality characteristics.

The theoretical development assumes a perfectly competitive, multi-product firm where each production function is independent of the other production functions. The production function using input characteristics is:

$$q_y = f_y (q_{1y}, q_{2y}, \ldots q_{my}) \qquad (1)$$

where q_y is the quantity of output y produced, and q_{jy} is the total quantity of characteristic j used in the production of y. The firms' profit function is:

$$\pi = \sum_{y=1}^{Y} P_y f_y (q_{1y}, q_{2y}, \ldots q_{my}) - \sum_{y=1}^{Y} \sum_{i=1}^{n} P_{x_i} X_{iy} \qquad (2)$$

where P_y and P_{x_i} are output and input price respectively, and X_{iy} is the quantity of input i used in the production of y. The total quantity of each characteristic, q_{jy}, is a function of the quantity of input use, x_{iy}, and the quantity of characteristic j contained in each unit of x_{iy}. Consequently, maximization of (2) requires the function of a function rule for differentiation.

In particular:

$$q_{jy} = f_j (x_{1y}, x_{2y}, \ldots x_{iy}, x_{j1y}, x_{j2y}, \ldots x_{jny}) \qquad (3)$$

where x_{jiy} is the quantity of the characteristic j contained in each unit of x_{iy}. It follows that the production function can be restated as:

$$q_y = G_y (x_{1y}, x_{2y}, \ldots x_{ny}, x_{j1y}, x_{j2y}, \ldots x_{mny}). \qquad (4)$$

Using the function of a function rule for differentiating (2), setting the results equal to zero and solving for P_{x_i} yields:

$$P_{x_i} = P_y \sum_{j=1}^{m} (\partial f_y / \partial q_{jy}) (\partial q_{jy} / \partial x_{iy}) \qquad (5)$$

where $\partial q_{jy} / \partial x_{iy}$ is the marginal yield of characteristic j in the production of y from input i, and $P_y \ \partial f_y / \partial q_{jy}$ is the value of the marginal product of characteristic j used in the production of y. This can be interpretted as the marginal implicit price of the characteristic, or the imputed price of the j^{th} characteristic in the production of y and is also frequently referred to as the "hedonic price."

The hedonic price function in (5) is simplified by setting $P_y\ (\partial f_y / \partial q_{jy}) = B_j$. The right hand side of (5) becomes $\sum_{j=1}^{m} B_j\ \partial q_{jy} / \partial x_{iy}$ which is the value of the marginal yield of characteristic j from the i^{th} input. It is simplified further by assuming that $\partial q_{jy} / \partial x_{iy} = x_{jiy}$ and is constant. Where x_{jiy} is the quantity of characteristic j contained in each unit of x_{iy}. With these assumptions, the hedonic price function can be written as:

$$P_{x_i} = \sum_{j=1}^{m} B_j\ (x_{jiy}) \qquad (6)$$

where B_j is the marginal implicit price for characteristic j.

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