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PRICE RELATIONSHIPS BETWEEN HARD RED SPRING AND HARD RED WINTER WHEATS IN THE UNITED STATES

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FOREWORD

Price differentials for Hard Red Spring and Hard Red Winter wheat of different protein levels are examined in this study. This research has benefitted from discussion and suggestions from W. Koo, B. D'Appolonia, J. Carter, and O. Banasik, all of North Dakota State University. This research was conducted under Regional Project NC-160. Performance of the U.S. Grain Marketing System in a Changing Policy and Economic Environment.

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Highlights

Price differentials between Hard Red Spring (HRS) and Hard Red Winter (HRW) wheat frequently evolve and are attributed to the relatively higher percentage of protein in HRS. These price differentials vary in size from year to year depending on fundamental factors in the wheat market. The objectives of this study are to:

1) *evaluate the relationship between prices for HRS and HRW at major markets;*
2) *evaluate the effect of protein percentage of each class of hard red wheat on prices;*
3) *determine if any changes have evolved in this price relationship since 1973; and*
4) *examine the effect of protein percentages on exports.*

Prices were analyzed for the two classes of hard red wheat of different proteins at the Pacific Northwest, U.S. Gulf, Rotterdam, and Minneapolis/Kansas City. Statistical tests were used to test whether the mean prices and variances were significantly different.

A regression model was also developed to explain the variability in HRS prices relative to HRW. Explanatory variables included the price of HRW, per capita income, total supply of HRS, and crop average protein for HRS and HRW. The estimated model explained a large part of the variability in the price of HRS. In all cases, R^2 exceeded 90 percent. The general conclusions from these results are that price relationships between HRS and HRW are largely explainable by fundamental market phenomena. Particularly important are the size of the HRS crop plus carry-in stocks, and the average protein percentage in the HRW crop. The crop average protein in the HRS crop does not significantly affect prices for HRS or HRW. Simulations using the estimated equations indicate that small increases in the protein of the HRW crop results in relatively large decreases in the price of both HRS and the higher protein HRW wheats. However, changes in the protein of the HRS crop results in small and insignificant changes in prices of HRS.

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Introduction

Five classes of wheat are produced in the United States including hard red spring, hard red winter, soft red winter, durum, and white. Of these, the two hard red classes of wheat comprise the basic ingredients in bread flour due to their relatively high percentage of protein. Hard red spring wheat (HRS) is used in specialty breads or is blended with lower protein wheat in flour milling. Hard red winter wheat (HRW) is the most widely used class of wheat in milling bread flour in North America and much of the world.[1] The proportion of each class of wheat blended into flour is influenced by its relative price, the desired baking characteristics and the protein percentage. In addition to substantial domestic use of HRS and HRW, large quantities are exported around the world. The importance of the export market has grown over the past decade and now constitutes about 52 percent of the HRS utilization and 67 percent of HRW utilization. (HRS is grown in the north central part of North America. (Production of HRS in the United States is concentrated in North Dakota, Minnesota, Montana, and South Dakota and normally is about 25 percent of total U.S. wheat production.) Nearly all of Canada's wheat crop is equivalent in quality to HRS. HRW is grown in Central and North Central United States, from Texas to South Dakota. Kansas and Oklahoma are consistently the largest producers. HRW normally accounts for about 50 percent of total U.S. wheat production.

Price differentials between HRS and HRW frequently evolve and are normally attributed to the relatively high percentages of protein in HRS. These price differentials vary in size from year to year depending on fundamental factors in the wheat market. For example, the price differential at the U.S. Gulf ports ranged from a $.44/bushel premium for winter wheat

in the early 1960s to a $.76/bushel premium for spring wheat in 1974. Excluding the two years when premiums for HRW were very large, 1962 and 1963, premiums for HRS have averaged $.18/bushel. Since 1974, however, the average premium has been $.47/bushel. Variability in these price differentials has important implications for decision makers in the grain business. Domestic and overseas users of wheat base procurement decisions on relative prices and protein percentages for each class. Variable price differentials may also be important to producers who have the option of producing HRS or HRW.[2] That decision is based on relative profitability which is affected by relative prices and yields. Plant breeders and cereal technicians also are concerned with movements in price premiums due to the traditional trade-off between higher protein and higher yielding varieties. Lower premiums over an extended period of time would make breeding and growing of higher yielding but lower protein wheats relatively more beneficial to the grower.

Several other studies have addressed the process of price determination in wheat for the different classes. Chai and Wang analyzed the demand for wheat by class. Chai analyzed domestic U.S. demand while Wang analyzed export demand. Mittleider and Anderson (1977a and 1977b) evaluated returns to producers for producing different varieties of wheat. Other studies of wheat markets have recognized price differentials due to class but have treated wheat as a homogeneous product in their empirical analysis (Gallagher et al.; Schmitz and Bowden).

Ryan and Bale investigated price differentials between spring and winter wheat at the Pacific Northwest market. They hypothesized that the increased export demand in the early 1970s was primarily for lower protein wheats and consequently the price ratio of HRS to HRW declined. They developed a model relating the price ratio of HRS and HRW to exports, supplies

and protein percentages. The resulting estimated equation explained 99 percent of the variability in the ratio. The model was estimated using ratios of the exogenous variables, thereby making specific interpretation difficult. All signs were as expected with the exception of those on the protein percentage variables. One of the conclusions of the study was that higher average protein percentages for HRS cause consumers to purchase relatively less HRS since the same quantity would provide a larger amount of protein for milling. Consequently, when the protein percentage for HRS increases, its price falls relative to that of HRW. These conclusions are not intuitively obvious and are investigated further in this study. The analysis by Ryan and Bale covered the period 1965 to 1973.

The objectives of this study are to:

1) evaluate the relationship between prices for HRS and HRW at major markets;

2) evaluate the effect of protein percentage of each class of hard red wheat on prices;

3) determine if any changes have evolved in this price relationship since 1973; and

4) examine the effect of protein percentages on exports.

Empirical Model

Flour from spring and winter wheat can be treated as substitutes in bread making, so the process of price determination must be developed from that perspective. Supply and demand factors for wheat determine the equilibrium level of prices and price differentials between classes of wheat. The process can be treated as two interrelated markets--as the price of one class increases, the demand function for the other shifts, increasing its price. This process of price determination is illustrated in Figure 1. For simplicity, the supply functions are assumed to be perfectly inelastic. As drawn, initial equilibrium price levels are P_{s1} and P_{w1} for the two

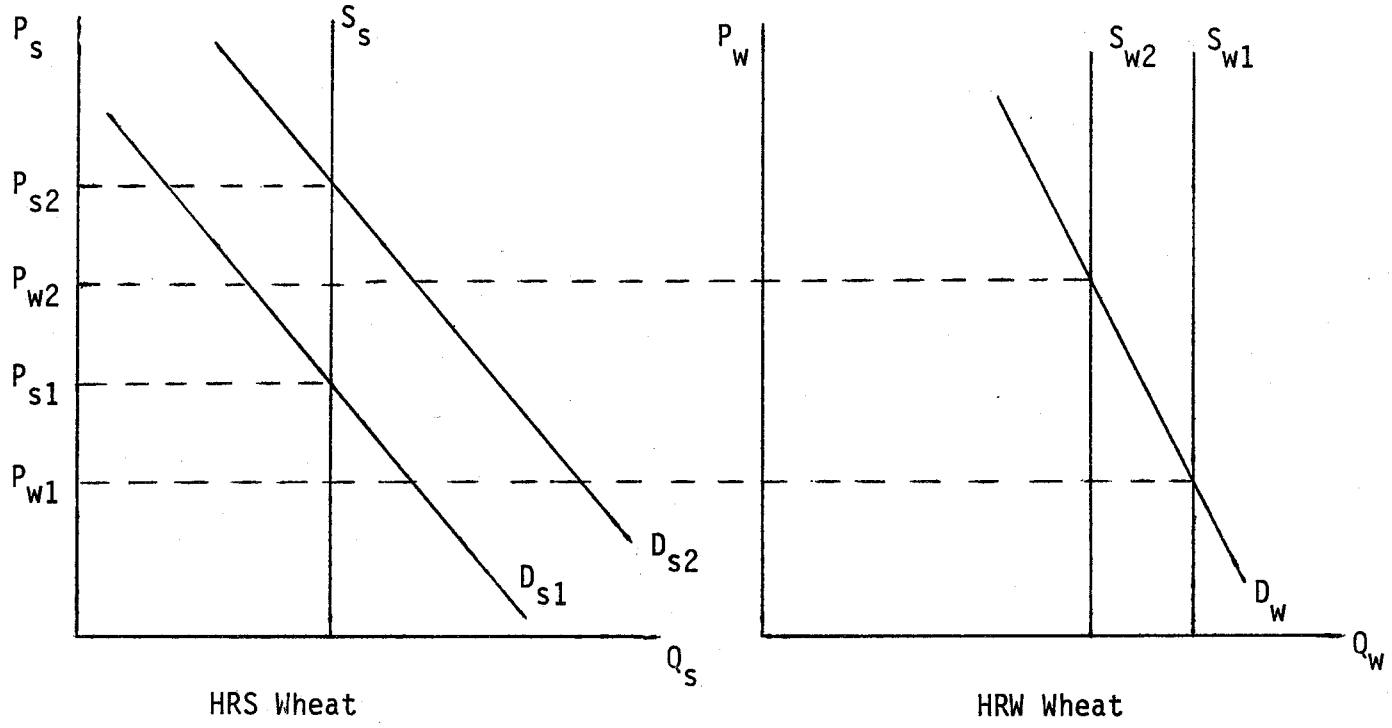

Figure 1. Price Determination in HRS and HRW Markets

classes of hard wheat, respectively, and the price differential is $P_{s1} - P_{w1}$. The effects of an exogenous shift in the supply of winter wheat are shown, and the price of HRW increases to P_{w2}. The higher price for HRW causes a rightward shift in the demand function for HRS to D_{s2}. The equilibrium price level for HRS increases to P_{s2} and a new price differential equal to $P_{s2} - P_{w2}$.

The above process of price determination illustrates the effects of changes in supply and demand on equilibrium price levels and differentials. Spring and winter wheat are treated as substitutes, and the extent of substitution depends upon the technical characteristics of the available wheat and relative prices. Primary among the technical factors is the protein percentage. Other factors interact with those above to determine equilibrium prices and differentials. For purposes of this study, the factors affecting the overall wheat market are taken as given. In other words, the overall price level of wheat is treated as exogenous and is reflected in the price of HRW. The analysis concentrates on factors affecting price relationships within the class of hard red wheats. Several model specifications are possible, including one using a ratio formulation following Ryan and Bale. However, results using ratio data (i.e., price ratios, supply ratios, export ratios--of the two classes of wheat) are difficult to interpret. Price differentials also could be used, but similar problems exist in the interpretation of the parameters. As an alternative, a behavioral model is specified directly, as follows:

$$P^i_{s_t} = f(P^i_{w_t}, Y_t, TS_{s_t}, PR_{s_t}, PR_{w_t}) + U_t$$

where $P^i_{s_t}$ and $P^i_{w_t}$ are prices for the ith protein percentage of HRS and HRW respectively. Y is per capita income and TS_s is total supply of HRS (beginning stocks plus production). PR_s and PR_w are crop year average protein percentage

for the HRS crop in North Dakota and HRW crop in Kansas, respectively. U_t is the random error term. Effects of other variables are reflected in the error term. Each of the monetary values were deflated using the Consumer Price Index (CPI) with 1967 = 100 to account for a changing value of the dollar.

In the empirical analysis, many different equations corresponding with different classes and protein percentages were estimated similar to the model above. HRS prices for various protein percentages were treated as dependent variables and those for HRW were the independent variables. In addition, prices for HRS with different protein percentages were analyzed. The model was estimated for the period 1962 to 1980. Positive signs are expected for the parameters on P_W^i, Y, and PR_S. Negative values are expected for the others. In preliminary estimation, total supply of winter wheat also was used as an exogenous variable. However, it was insignificant in all cases and since its effect is reflected in P_W, it was not included in the results presented here.

Separate equations were estimated for three primary U.S. markets and the Rotterdam market for hard red wheat. The U.S. markets were the Pacific Northwest (PNW), U.S. Gulf, and Minneapolis-Kansas City. The former two represent the export market and are ideal for analysis since price differences can not be attributed to location. The Minneapolis-Kansas City markets represent both domestic and export influences.

Results

Data Sources and Summary Statistics

Protein percentages for HRS and HRW used in the analysis were state averages for North Dakota and Kansas, respectively. All prices were taken from the annual reports of U.S. Grain Market News with the exception of Rotterdam

prices which were taken from World Wheat Statistics published by the International Wheat Council. Separate analyses were conducted for price relationships at the Pacific Northwest (PNW), U.S. Gulf, Rotterdam, and Minneapolis and Kansas City. Prices analyzed at the PNW were HRS 14 percent protein, HRW 12 percent protein, and HRW "ordinary" protein. Those analyzed at the U.S. Gulf were HRS 14 percent protein and HRW ordinary protein. Prices analyzed at Rotterdam were HRS 14 percent protein and HRW 13.5 percent protein. Those at Minneapolis-Kansas City were HRW ordinary protein and HRW 13 percent protein at Kansas City and HRS 14 percent, 15 percent, and 17 percent protein at Minneapolis.

The time series behavior of each of the variables is presented in Figures 2-6. Average protein for the crop of each class of hard red wheat is shown in Figure 2. Protein percentages are affected primarily by growing conditions and varieties planted. The average protein for the two classes of wheat have been quite variable through the years and do not exhibit any apparent long-term trends. However, in recent years it appears the protein percentages for HRW have been increasing. Average protein for HRS and HRW were 14.6 and 12.0 percent, respectively, over the time series. Total supplies for each of the classes of wheat are presented in Figure 3. Exports of the two classes of wheat are shown in Figure 4. Both classes of wheat exhibit a sporadic but generally increasing trend in total supply and exports over the time series.

Prices for each of the classes of wheat and price differentials at the Pacific Northwest are presented in Figures 5 and 6. Similar figures for the other three markets are presented in the Appendix. Both the absolute prices and the differences between prices are presented. The figures indicate that at each market the absolute prices for each of the types of wheat move together and in fact form a constellation of prices. Of particular

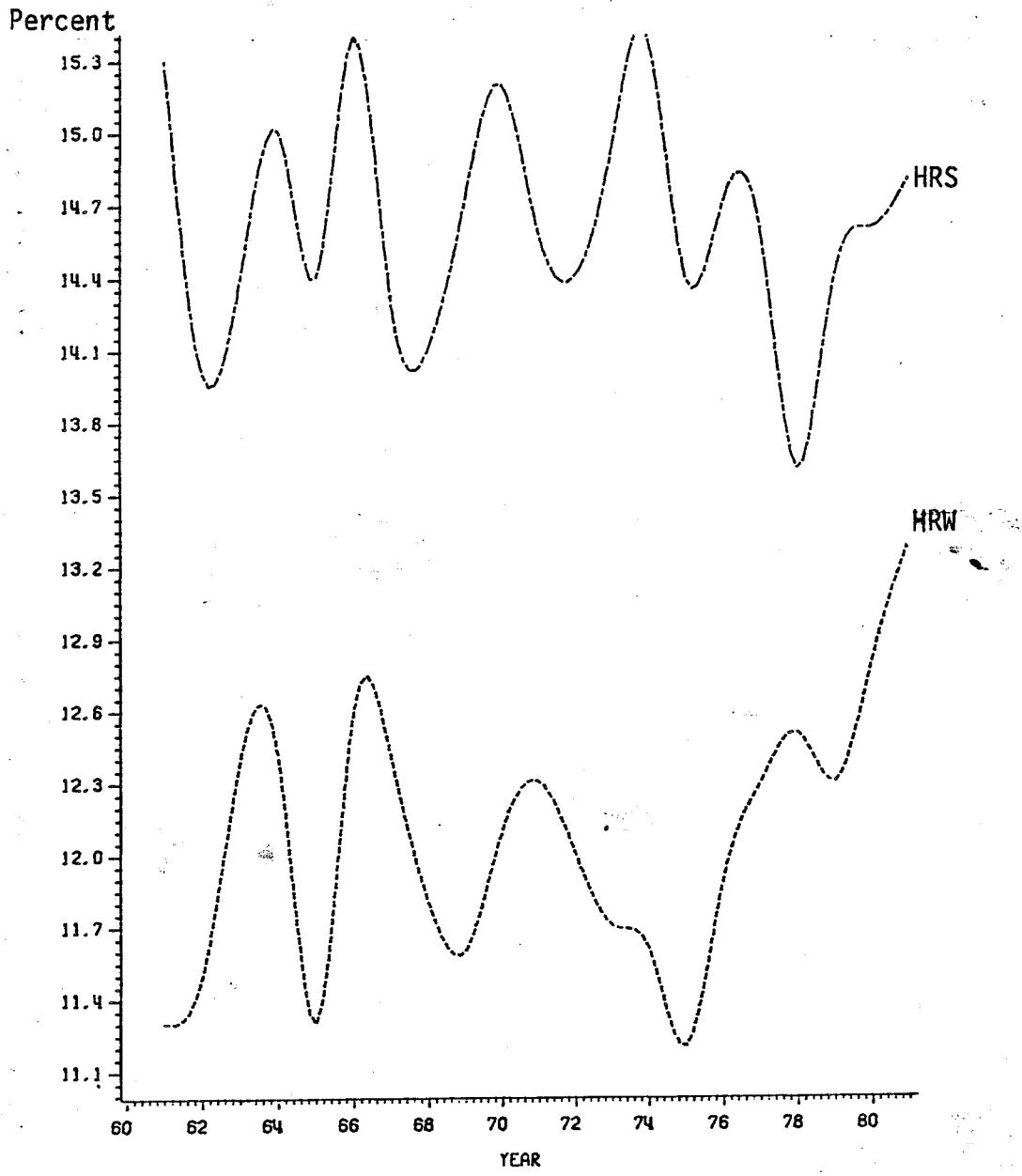

Figure 2. Average Protein for HRS in North Dakota and HRW in Kansas

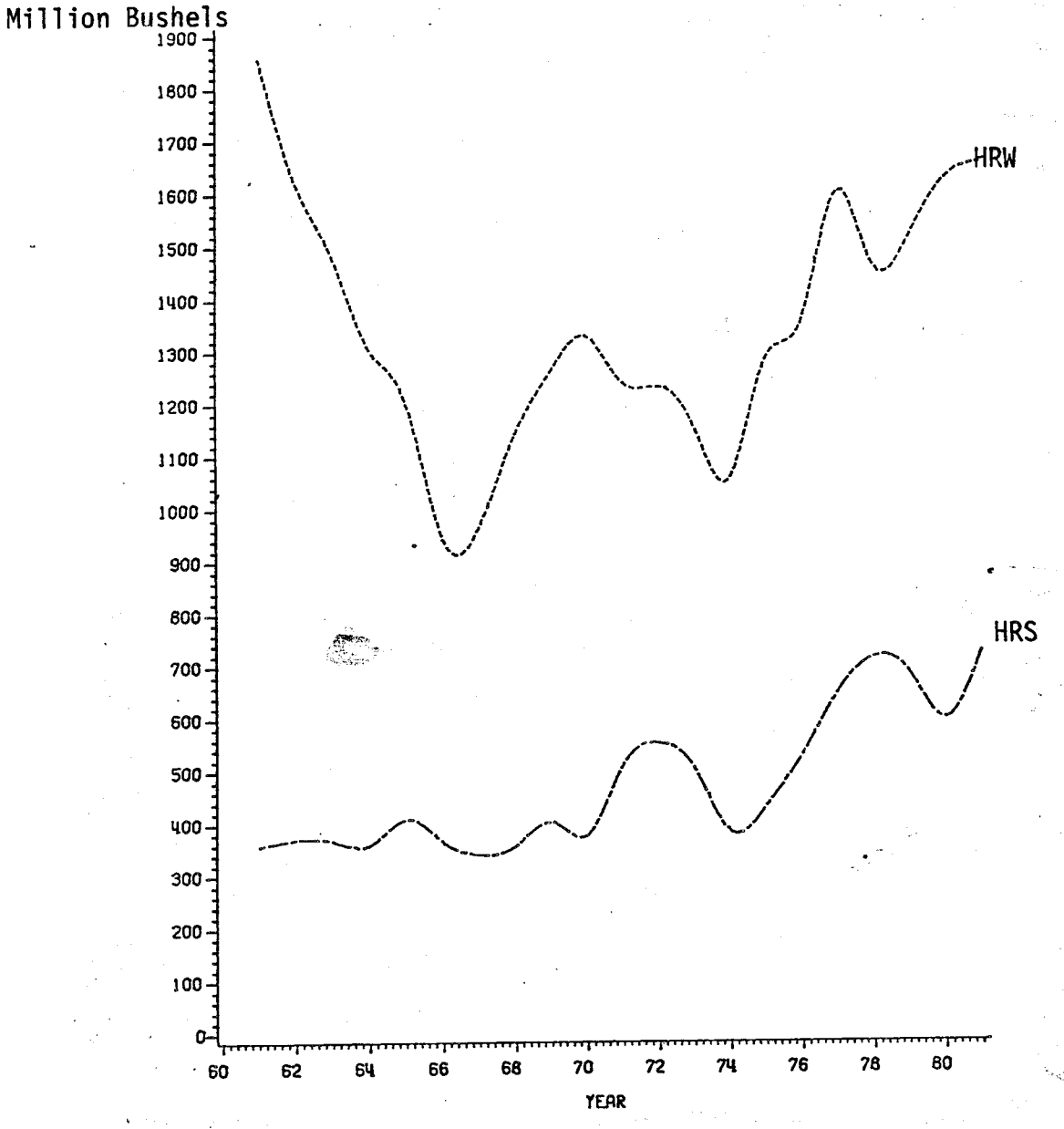

Figure 3. Total Supply (Production Plus Beginning Stocks) of HRS and HRW

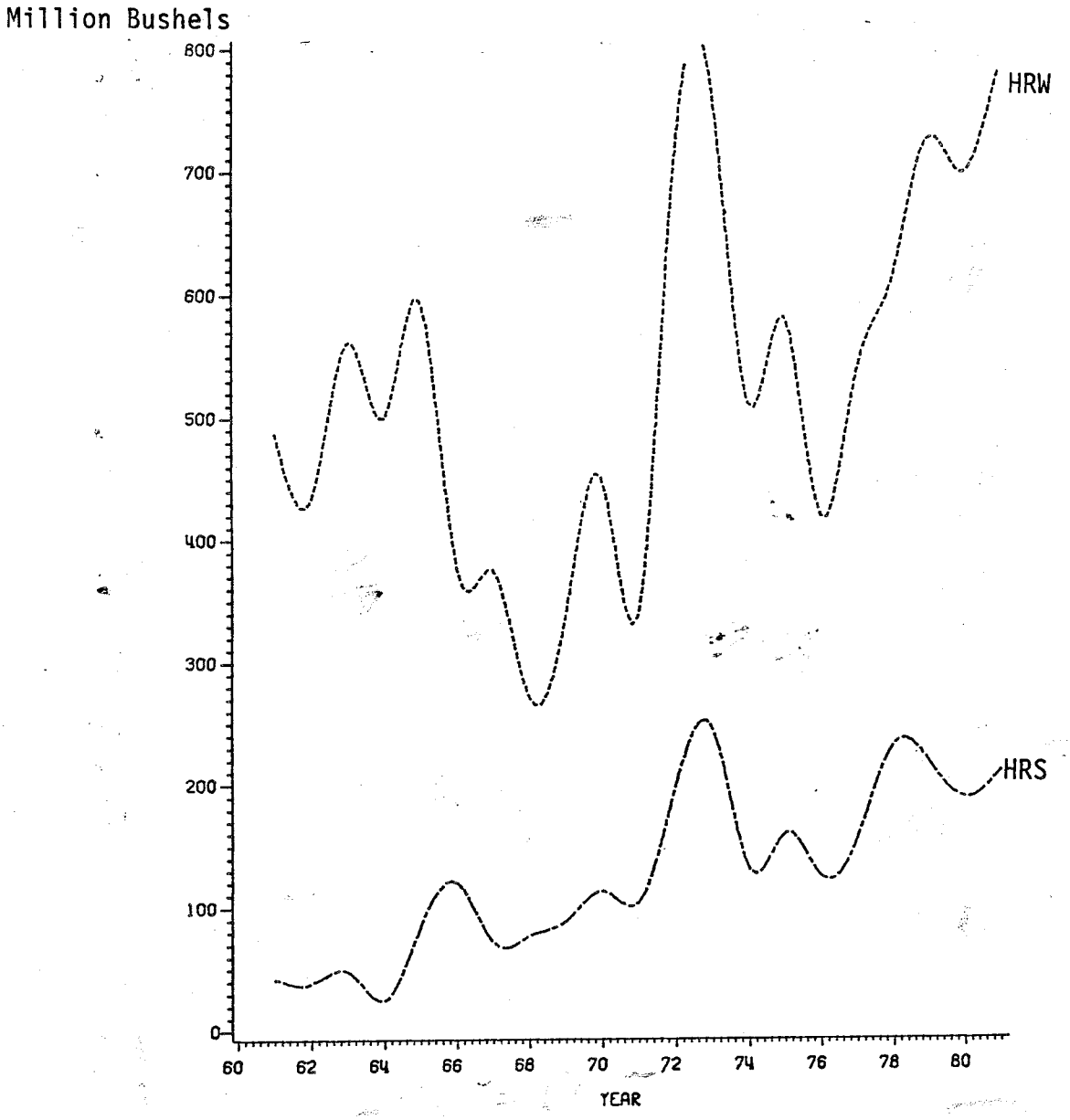

Figure 4. Exports of HRS and HRW

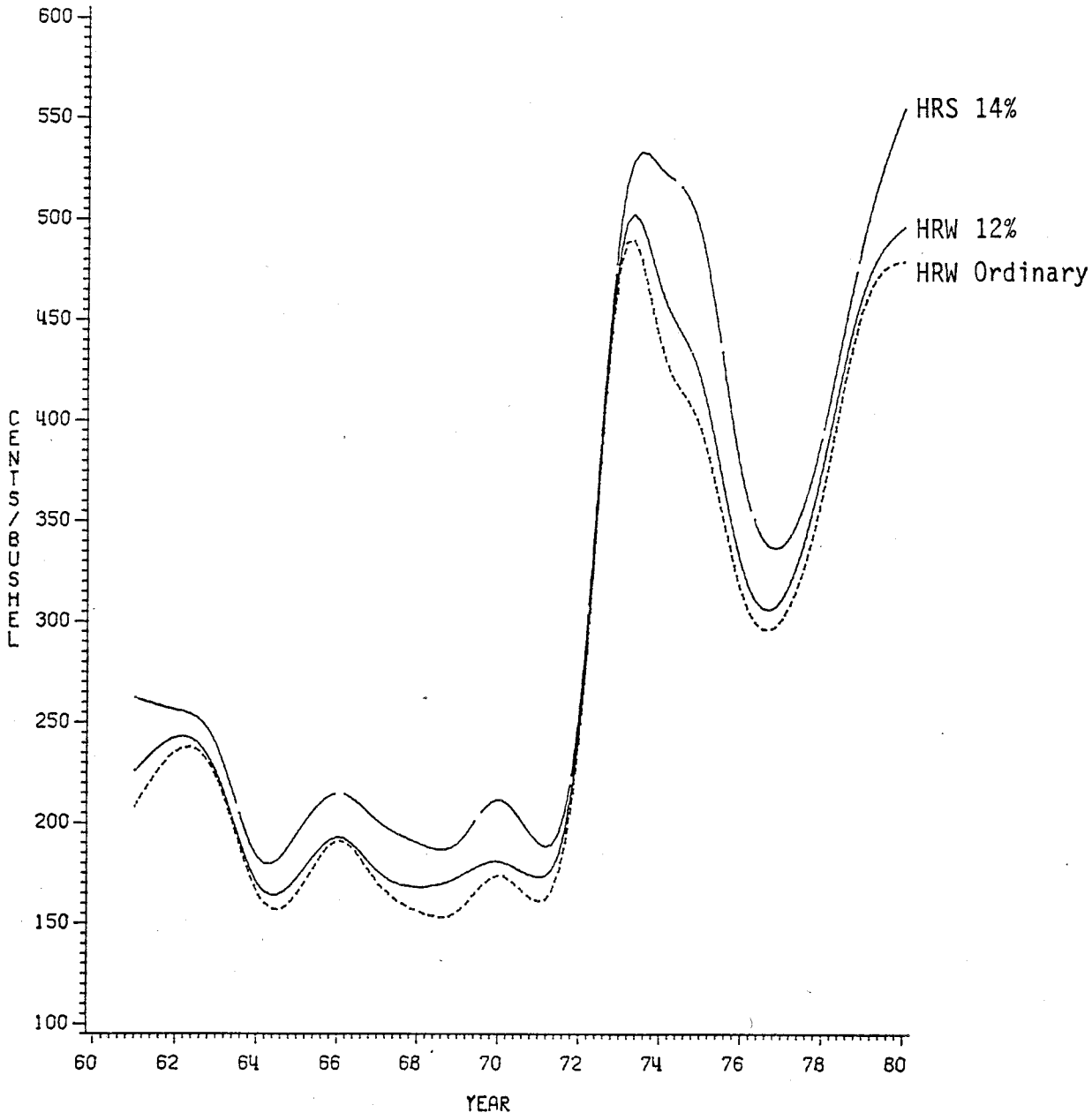

Figure 5. Average Pacific Northwest Prices for HRW Ordinary, HRW 12%, and HRS 14%

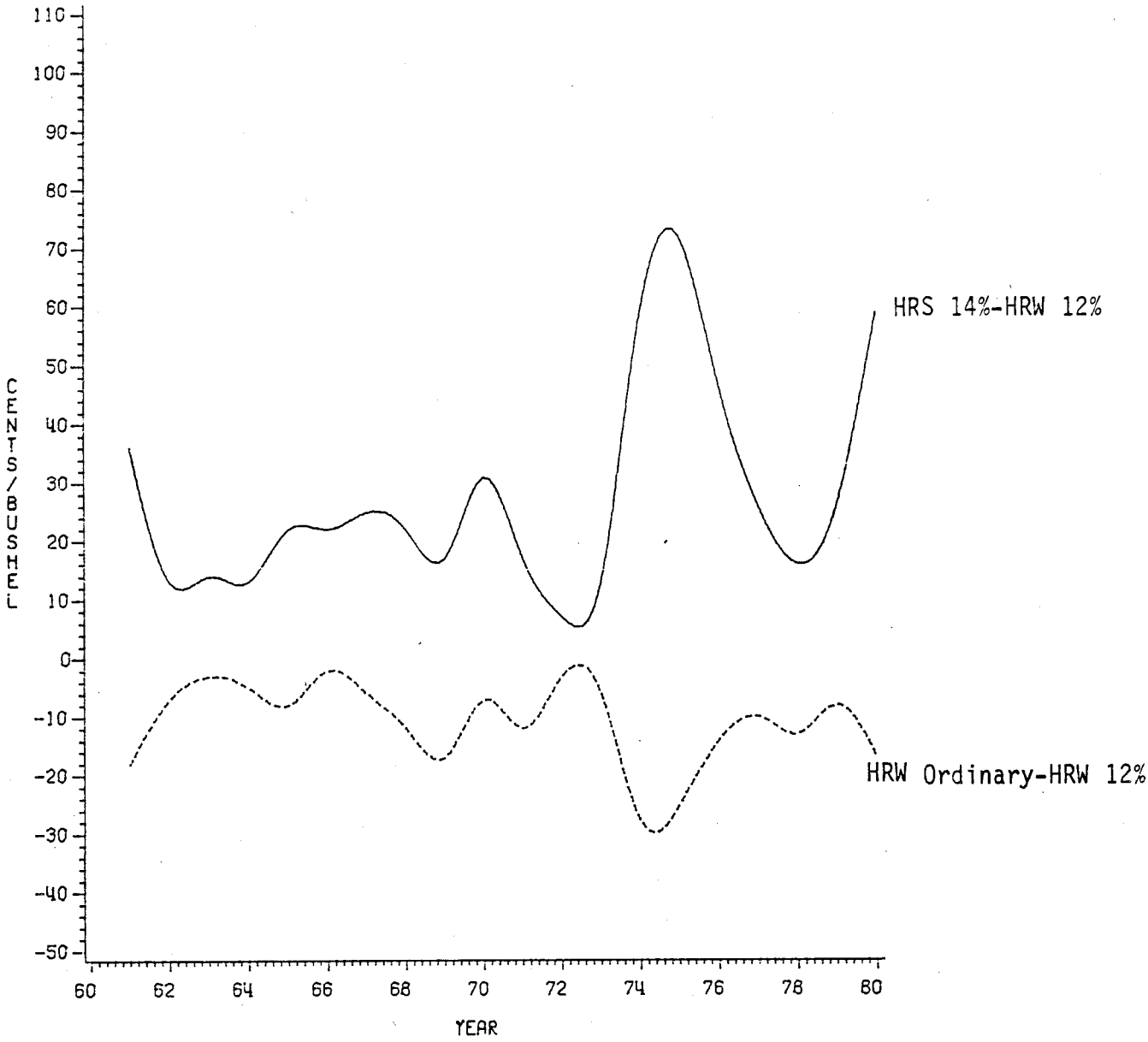

Figure 6. Price Differentials at the Pacific Northwest Between HRW 12%, HRW Ordinary, and HRS 14%

importance for decision makers in many marketing decisions is not so much the level of prices, but the differences. In nearly all cases, the prices of HRS wheat exceed those of HRW. However, these differences vary through time and by market.

The mean price and standard deviation over the time series for each class of wheat of different proteins at each market are presented in Table 1.

TABLE 1. MEANS AND STANDARD DEVIATIONS OF PRICES FOR HARD RED WHEATS AT VARIOUS MARKETS (1962-1980)[a]

Market and Type of Wheat	N	Mean	Standard Deviation
		$/bushel	$/bushel
PNW			
HRS 14%	20	3.13	1.33
HRW 12%	20	2.85	1.22
HRW Ordinary	20	2.74	1.19
U.S. Gulf			
HRS 14%	20	2.95	1.21
HRW Ordinary	20	2.78	1.39
Rotterdam			
HRS 14%	13	3.84	1.62
HRW 13½%	13	3.73	1.58
Minneapolis			
HRS 17%	18	3.11	1.37
HRS 15%	18	2.93	1.27
HRS 14%	18	2.88	1.26
Kansas City			
HRW 13%	18	2.73	1.23
HRW Ordinary	18	2.61	1.18

[a]Some observations were deleted because of missing data. Only the N most recent observations were used.

Average prices for the higher protein HRS were greater than those for HRW at each market. The difference between the average prices is an indicator of the premiums or discounts in the market for wheat classes and proteins. For example, prices for HRS 17 percent were an average of $.18 greater than those of HRS 15 percent and those of HRS 15 percent were $.05/bushel greater than HRS 14 percent at Minneapolis. The standard deviation provides a measure of variability and is similar at each market.

Statistical tests were used to test whether the mean prices and variances at the different markets were significantly different. The results of the test for differences among means at each of the markets are presented in Table 2. The null hypothesis is that the means of the different prices are

TABLE 2. ANALYSIS OF VARIANCE RESULTS FOR TESTING DIFFERENCES IN MEAN PRICES AT EACH MARKET

Market Class and Protein of Wheat[a]			
PNW[b]	HRS 14%	HRW 12%	HRW Ordinary
HRS 14%		*	*
HRW 12%	*		*
HRW Ordinary	*	*	
U.S. Gulf[c]	HRS 14%	HRW Ordinary	
HRS 14%		*	
HRW Ordinary	*		
Rotterdam[d]	HRS 14%	HRW 13½%	
HRS 14%		*	
HRW 13½%	*		
Minneapolis[e]	HRS 17%	HRS 15%	HRS 14%
HRS 17%		*	*
HRS 15%	*		
HRS 14%	*		
Kansas City[e]	HRW 13%	HRW Ordinary	
HRW 13%		*	
HRW Ordinary	*		

[a]An * in the cell indicates mean prices significantly different at the 5 percent level of significance.
[b]F-values for type of wheat and year were 50.87 and 295.50 respectively.
[c]F-values for type of wheat and year were 6.45 and 72.12 respectively.
[d]F-values for type of wheat and year were 6.12 and 402.31 respectively.
[e]F-values for type of wheat and year were 24.98 and 302.99 respectively.

equal at each market. The alternative is that at least one is not equal to the others. Duncan's procedure of analysis of variance was used to test the null hypothesis. If the null hypothesis is rejected the procedure determines which prices are statistically different. A blocking effect for time was introduced to regulate the effect of variability in prices through time making it possible to appropriately test the null hypothesis. The results indicate that the means of the three prices at the PNW are significantly different

than each other; the means of the two prices at the U.S. Gulf are significantly different; the means of the two prices at Rotterdam are significantly different. At Minneapolis the average price for HRS 17% is significantly different than HRS 15% and HRS 14%. However, the average prices for HRS 15% and HRS 14% are not significantly different. The means of the two prices at Kansas City are significantly different than each other and significantly different than prices at Minneapolis.[3]

Analysis of variance also was used to test whether the variability in prices was different for the classes of wheat at each market. The results are shown in Table 3. The null hypothesis is that the variance for each

TABLE 3. ANALYSIS OF VARIANCE RESULTS FOR TESTING DIFFERENCES IN VARIANCES OF PRICES AT EACH MARKET (1962-1980): F-RATIOS ARE SHOWN IN EACH CASE

Market and Type of Wheat			
PNW	HRS 14%	HRW 12%	HRW Ordinary
HRS 14 percent		1.17	1.24
HRW 12 percent	1.17		1.05
HRW Ordinary	1.24	1.05	
U.S. Gulf	HRS 14%	HRW Ordinary	
HRS 14 percent		1.31	
HRW Ordinary	1.31		
Rotterdam	HRS 14%	HRW 13½%	
HRS 14 percent		1.05	
HRW 13½ percent	1.05		
Minneapolis	HRS 17%	HRS 15%	HRS 14%
HRS 17 percent		1.16	1.19
HRS 15 percent	1.16		1.03
HRS 14 percent	1.19	1.03	
Kansas City	HRS 13%	HRW Ordinary	
HRW 13 percent		1.08	
HRW Ordinary	1.08		

type of wheat is equal. The alternative is that at least one variance does not equal the others. The results indicate the null hypothesis should be accepted at the 5 percent level of significance at all markets. In other words, the variability in prices is the same within each market.

Estimated Equations

The regression models developed above were estimated using both a linear and log-linear specification. The statistical results for each were similar and only the linear equations using constant 1967 dollars are presented. The results for the various regressions are presented in Tables 4-7. The relatively high value of the R^2 in each case indicates the extent that the variability in the price of HRS is explained by the behavioral equation. In all cases, it exceeded 90 percent. In most cases, the Durbin-Watson statistic was in the inconclusive range. In those cases the models were rerun using the Cochrane-Orcutt procedure to adjust for first order autoregression. If the first order autocorrelation coefficient was significant, the ordinary least squares model was rejected and the autoregressive model was accepted. If the autocorrelation coefficient was insignificant, the ordinary least squares results were accepted.

The value of the coefficients indicates the relationship between the independent variables and the price of HRS. Of particular interest in this study is the coefficient associated with the total supply of HRS and the protein percentages for HRS and HRW. The coefficients associated with the total supply of HRS at the U.S. Gulf and Rotterdam are not significant at the 10 percent level. However, they are significant at the Pacific Northwest and Minneapolis-Kansas City markets. These significant coefficients all have negative signs, indicating an inverse relationship between the supply of HRS and the dependent variables.

There are several observations of particular interest. First, the price relationship between HRW 12% and HRW Ordinary at the PNW and HRW 13% and HRW Ordinary at Kansas City are influenced by the total supply of HRS. In other words, if the total supply of HRS increases, the price of the higher protein HRW decreases relative to ordinary protein HRW. The second

TABLE 4. PARAMETER ESTIMATES OF HARD RED WHEAT PRICE RELATIONSHIPS AT PACIFIC NORTHWEST (T-RATIOS IN PARENTHESES) 1962-1980

	Intercept	Pacific Northwest		Per Capita Income	Total Supply	Protein		DW	R^2
		HRW Ord.	HRW 12%		HRS	HRS	HRW		
Dependent Variable									
4a HRW 12 percent	82.64*	0.98*		0.03*	-0.03*	-0.87	-5.52*	2.54	.99
	(2.52)	(58.16)		(1.98)	(1.80)	(0.40)	(2.72)		
4b HRS 14 percent	125.42	0.97*		0.09*	-0.10*	0.74	-10.10*	1.23	.98
	(1.35)	(20.30)		(2.28)	(2.44)	(0.12)	(1.75)		
4c HRS 14 percent	66.70		0.98*	0.09*	-0.11*	-0.45	-3.83	-0.43*	.98
	(1.14)		(24.58)	(2.40)	(3.26)	(0.11)	(0.96)		

*Indicates significance at the 10 percent level.

TABLE 5. PARAMETER ESTIMATES OF HARD RED WHEAT PRICE RELATIONSHIPS AT THE U.S. GULF (T-RATIOS IN PARENTHESES) 1962-1980

	Intercept	U.S. Gulf HRW Ord.	Per Capita Income	Total Supply HRS	Protein HRS	Protein HRW	DW	R^2
Dependent Variable								
5a HRS 14 percent	-32.22 (0.20)	0.89* (11.30)	0.22* (3.11)	-0.09 (1.29)	12.15 (1.16)	-18.27* (1.87)	1.16	.93

*Indicates significance at the 10 percent level.

TABLE 6. PARAMETER ESTIMATES OF HARD RED WHEAT PRICE RELATIONSHIPS AT ROTTERDAM (T-RATIOS IN PARENTHESES) 1962-1980

	Intercept	Rotterdam HRW 13½%	Per Capita Income	Total Supply HRS	Protein HRS	Protein HRW	DW	R^2
Dependent Variable								
6a HRS 14 percent	27.34	1.01*	-0.01	0.007	2.89	-5.15*	2.28	.99
	(0.91)	(27.53)	(0.91)	(0.51)	(1.36)	(2.69)		

*Indicates significance at the 10 percent level.

TABLE 7. PARAMETER ESTIMATES OF HARD RED WHEAT PRICE RELATIONSHIPS AT MINNEAPOLIS AND KANSAS CITY (T-RATIOS IN PARENTHESES) 1962-1980

	Intercept	Kansas City		Per Capita Income	Total Supply	Protein Levels		ρ	DW	R^2
		HRW Ord.	HRW 13%		HRS	HRS	HRW			
Dependent Variable (Market and Protein Level)										
7a Kansas City HRW 13 percent	72.09	0.92*		0.11*	-0.07*	4.65	-13.18*		2.41	.98
	(1.09)	(26.80)		(3.53)	(2.37)	(1.05)	(3.18)			
7b Minneapolis HRS 14 percent	251.55	0.99*		0.07	-0.12*	-3.35	-14.04*		1.37	,97
	(2.23)	(16.87)		(1.31)	(2.39)	(0.45)	(1.99)			
7c Minneapolis HRS 15 percent	205.13*	0.94*		0.10*	-0.16*	-1.06	-12.37*	-0.41*		.97
	(2.58)	(17.56)		(2.01)	(3.50)	(0.19)	(2.29)			
7d Minneapolis HRS 17 percent	338.68*	0.96*		0.15*	-0.17*	-3.45	-22.10*		1.97	.93
	(1.77)	(10.41)		(1.75)	(2.22)	(0.29)	(2.00)			
7e Minneapolis 14 percent	174.94*		1.07*	-0.05	-0.04	-8.27	-0.02		1.50	.98
	(1.89)		(20.81)	(1.19)	(1.11)	(1.33)	(0.01)			
7f Minneapolis 15 percent	145.62		1.03*	-0.02	-0.05	-5.74	-0.76		1.43	.98
	(1.62)		(20.58)	(0.62)	(1.36)	(0.95)	(0.13)			
7g Minneapolis 17 percent	322.89*		1.07*	0.01	-0.09	-11.04	-9.25		1.99	.95
	(2.00)		(12.53)	(0.15)	(1.39)	(1.07)	(0.96)			

*Indicates significance at the 10 percent level.

observation is the relationship between the total supply of HRS and HRS prices relative to the price of HRW ordinary. The estimated coefficients are -0.10 for HRS 14% at PNW and -0.12, -0.16, and -0.17 for HRS 14%, 15%, and 17%, respectively, at Minneapolis. These indicate the price response to a change in the total supply of HRS assuming everything else constant. For example, the price of HRS 14% increases (decreases) $.12/bushel for each million bushel decrease (increase) in the total supply of HRS. The response of prices for the higher protein HRS wheats is greater with respect to changes in total supply. In particular, a million bushel change in the total supply of HRS results in a change in price in the opposite direction of $.16 and $.17/bushel for 15% and 17% protein HRS. These values are all stated in 1967 dollars.[4]

The effect of protein for each class of wheat is also of interest. In all cases the coefficients associated with the protein of the HRS crop are not significant. This indicates that given the other factors which affect prices, the protein of the HRS crop has little or no influence on prices. However, the coefficients associated with the protein percentage in the HRW crop are significant in all cases when the price of HRW Ordinary is used as the independent variable. This is true for relationships within the winter wheat market as well as between the spring and winter wheat markets.

The value of these coefficients indicates the effect of changes in the protein percentage in the HRW crop on prices. In all cases there is an inverse relationship between protein in the HRW crop and prices of various wheats. For example, a one unit (i.e., 1 percent) increase in protein in the HRW crop results in a decrease of 5.52 cents/bushel in the price of HRW 12% relative to the price of HRW ordinary protein and vice versa, given the other factors in the relationship. It also results in a 10.10 cents/bushel decrease in the price of HRS 14%. Similar relationships exist at

the other markets but differences exist in the value of the coefficients. The value of the coefficient at the U.S. Gulf is 18.27 cents relative to HRW ordinary,, and at Rotterdam it is 5.15 relative to HRW 13.5%. The value of the coefficient is 13.18 cents for Kansas City HRW 13%, and at Minneapolis the values were 14.04, 12.37, and 22.10 cents/bushel for HRS 14%, 15%, and 17%, respectively. All of these values are estimates of the extent that prices decrease (increase) for a one unit increase (decrease) in the protein level of the HRW crop.[5]

The results in equations 7e-7g (Table 7) indicate that the protein percentage in the HRW crop does not have a significant effect on the price relationship between HRS at the various protein levels and the prices for the higher protein HRW. In these cases the price of HRS increases at a constant rate relative to increases in the price of HRW 13%. For example, for each one cent increase in the price of HRW 13%, the price of HRS 14% increases 1.07 cents.

The equations in Tables 4-7 can be used to assess the price impacts of changes in protein in the two classes of wheat. This is a particularly important assessment since the protein is an operational variable which could possibly be affected by wheat breeding programs. Over the time series the average protein in the Kansas HRW crop was 12 percent and that in the North Dakota HRS crop was 14.6 percent. Breeders in Kansas have been trying to increase the protein of their crop, and in 1981 it was 13.3 percent. Assuming average values of the independent variables, the effects of changes in the protein on price relationships were analyzed at the Pacific Northwest market. The results are shown in Table 8.

The first situation provides a base case from which comparisons can be made. Case 2 assumes an increase in protein in the Kansas crop from 12 percent to 12.8 percent. As a result of the change in protein percentage, the

TABLE 8. EFFECTS OF CROP AVERAGE PROTEIN IN HRW AND HRS ON PRICE RELATIONSHIPS AT THE PACIFIC NORTHWEST (1967 CONSTANT DOLLARS)[a]

	Protein Level		Prices (Cent Per Bushel)		
			HRW Ordinary	HRW 12%	HRS 14%
	HRW	HRS			
1)	12	14.6	273.8[b]	278.4 (+4.6)[c]	295.2 (+21.4)
2)	12.8	14.6	273.8	274.0 (+0.2)	287.1 (+13.3)
3)	12.8	14.0	273.8	274.5 (+0.7)	286.6 (+12.8)

[a]Equations 4a and 4b were used and average values of the independent variables (income = 676.6 and total supply HRS = 463.45 were assumed). All values are in 1967 constant dollars.

[b]This was the average for the time series.

[c]Figures in parentheses are differences relative to HRW ordinary.

relationship between the price changes. First, the premium for HRW 12% over HRW ordinary decreases from 4.6 to 0.2 cents/bushel. Secondly, the premium for HRS 14% relative to HRW ordinary decreases from 21.4 to 13.3 cents/bushel. In the third case the protein of the HRS crop is assumed to decrease from 14.6 percent (as in Case 2) to 14 percent. As a result there is little change in the price of HRW 12% relative to HRW ordinary. In this case the premium for HRS 14% over HRW ordinary decreases from 13.3 to 12.8 cents/bushel. The conclusions from this is that the protein of the HRW crop has a significant negative effect on prices in both the winter wheat and spring wheat markets. However, changes in the protein of the HRS crop results in small and insignificant changes in the prices.[6] Other scenarios could be experimented with at the PNW market, or at other markets, but the same general conclusions prevail.

In the case of Minneapolis-Kansas City, an increase in the protein of the HRW crop from 12.0 to 12.8 percent results in an inversion in the

winter wheat market with the price of HRW 13% 7 cents under the price of HRW ordinary. Prices in the spring wheat market also decrease as a result of the increase in protein in the HRW crop. The price of HRS 14% decreases from 23.31 to 12.11 cents/bushel over the price of HRW ordinary. The price of HRS 15% decreases from 19.3 to 9.4 cents/bushel over the price of HRW ordinary; and the price of HRS 17% decreases from 35.5 to 17.9 cents/bushel over the price of HRW ordinary. In the third case where the HRS crop average protein is 14.0 percent (decrease from 14.6 percent) and the HRW crop average protein is 12.8 percent, the price of HRW 13% is 10 cents under the price of HRW ordinary; the price of HRS 14% decreases from 19.4 to 14.1 cents over the price of HRW ordinary; the price of HRW 15% increases from 9 to 10.1 cents over the price of HRS ordinary; and the price of HRS 17% increases from 17.9 to 19.93 cents over the price of HRW ordinary.

The general conclusions from these results are that price relationships between HRS and HRW are largely explainable by fundamental market phenomena. Particularly important is the size of the HRS crop plus carry-in stocks and the average protein percentage in the HRW crop. The crop average protein in the HRS crop does not significantly affect prices for HRS or HRW. Simulations using the estimated equations indicate that small increases in the protein of the HRW crop result in relatively large decreases in the price of both HRS and the higher protein HRW wheat. However, changes in the protein of the HRS crop results in small and insignificant changes in prices of HRS.

The estimated equations are essentially behavioral functions of price determination in the spring wheat market and perform well to explain these prices through time. They indicate the direction and magnitude of various influences on the price of HRS. For example, large price premiums for HRS existed in 1974/75 and 1975/76 (i.e., $.87 and $.97/bushel respectively, for prices of HRS 14 percent over HRW Ordinary at the PNW). These were

associated with a relatively high protein for HRW (11.6 percent and 11.2 percent). Also, the total supply of HRS was abnormally low at 382 and 432 million bushels, respectively, in those two years. In 1978/79, the premium for HRS over HRW was $.29/bushel, which was relatively low. This was associated with a 12.5 percent protein in the HRW crop in that year, which was one of the highest ever. Also, the total supply of HRS was 715 million bushels, which was the second largest in the time series.

Statistical Testing

Several of the objectives outlined in the introduction can be posed in the form of hypotheses which were tested and the results presented in this section.

Pre- and Post-1973

The analysis by Ryan and Bale covered the period 1965-1973 using ratio data. They implied that the behavioral relationship may change in the post-1973 period--a period characterized by increased and more volatile exports. A Chow Test was used to determine if the behavioral relationship explaining the price of HRS differed in the post-1973 period. Separate models were estimated during the periods 1962-1973 and 1974-1980, and the Chow Test was used to determine if there was a significant difference between the two periods. The null hypothesis is that the coefficients are equal when estimated from the different periods. Rejection of the null hypothesis implies that there was a structural change after 1973. The calculated F values were 2.41, 1.17, and 2.98 for the PNW, U.S. Gulf, and Minneapolis/Kansas City markets, respectively. The theoretical value at the 5 percent level of significance with 6 and 8 degrees of freedom is 3.58. Consequently, the null hypothesis cannot be rejected, implying that a significant difference does not exist in the behavioral equation in the post-1973 period.

The Effects of Exports

Ryan and Bale posed the hypothesis that a negative relationship exists between U.S. exports of lower protein wheat and protein premiums. The logic to the hypothesis was that "the surge in export demand for U.S. wheat was for relatively low protein wheat; this increased the demand for the lower protein wheat relative to the high protein wheat . . ." The hypothesis was tested by regressing the price ratio of the two wheats on the ratio of exports of the two wheats as well as other ratio data. The coefficients were significant, but because the analysis used ratio data, it is difficult to conclusively interpret the results.

The effect of exports on the behavioral relationship was tested in this study by introducing exports of each class of wheat as explanatory variables. A significant sign would indicate that exports do affect the price determination process. The results are shown in Table 9. In all cases, exports were insignificant, indicating inclusion of these variables has little effect on the behavioral relationship explaining prices of HRS. Consequently, variability in exports by class does not have a significant effect on the price determination process for HRS. Their effect is reflected in the overall level of prices, but not in relative prices. The latter are explained by the variables discussed earlier.

A more appropriate relationship which may be tested is the effect of protein on exports of HRS. This is of particular concern from an export development perspective. To test this, the following model was specified:

$$ED_s = f(ED_w, P_s/P_w, PR_s, PR_w, Y) + e_t$$

where ED_s and ED_w are export demand for HRS and HRW, respectively. The other variables are as previously defined. Y is U.S. per capita income and serves as a proxy for world income. A similar equation was estimated for domestic utilization using domestic demand for the two classes of wheat,

TABLE 9. INCLUSION OF EXPORTS IN THE HARD RED SPRING WHEAT PRICE EQUATION, 1962-1980 (T-RATIOS IN PARENTHESES)

	Intercept	HRD Ordinary Protein	Per Capita Increase	Total Supply of HRS	Protein		Exports		ρ	DW	R^2
					HRS	HRW	HRS	HRW			
Dependent Variables (Market Type of Wheat)											
PNW HRS 14%	59.23	0.98*	0.09*	-0.10*	-0.45	-3.65	-0.02	0.008	-0.41		.98
	(0.88)	(17.58)	(1.951)	(2.80)	(0.10)	(0.84)	(0.27)	(0.43)			
U.S. Gulf HRS 14%	28.48	0.89*	0.21*	-0.09	12.28	-18.24*	0.02	-0.005		1.16	.93
	(0.16)	(7.41)	(1.93)	(1.00)	(1.07)	(1.72)	(0.12)	(0.09)			
Minneapolis/Kansas City HRS 14%	185.78	1.11*	0.14*	-0.07	-3.41	-13.66*	-0.20	-0.02		1.38	.98
	(1.74)	(14.17)	(2.17)	(1.38)	(0.50)	(2.14)	(1.71)	(0.75)			

*Indicates significance at the 10 percent level.

respectively. ED_W was included as an explanatory variable to capture the effects of the export demand for hard red wheat. In other words, its value reflects fundamental factors such as income and supply in other countries, exchange rates, etc. Prices were introduced as a ratio, P_S/P_W, due to multicollinearity and should be interpreted as relative prices. Prices used were for HRS 14% and HRW ordinary at the PNW. The other variables were included to determine if they have a significant effect on demand for HRS in particular.

The results are shown in Table 10. The R^2 values are relatively high, indicating the explanatory power of the equation and the Durbin-Watson (DW) statistics indicate the absence autocorrelation. The parameters indicate that relative prices (P_S/P_W) are significant in explaining the quantity of HRS utilization, given the other variables. Specifically, if the price of HRS decreases relative to that of HRW, exports and domestic use of HRS will increase. Throughout the time series, average prices for HRS and HRW at the PNW were \$3.13 and \$2.74/bushel which yields a price ratio of 1.14. The values of the coefficients in Table 10 indicate that as the price ratio increases (decreases), exports and domestic use decrease (increase). For example, if the ratio increased by 10 percent, i.e., from 1.14 to 1.26 (which could result from a P_S of \$5.04 and P_W of \$4.00), exports of HRS would decrease by 22.65 million bushels and domestic use of HRS would decrease by 16.54 million bushels. Just the opposite effect would occur if the price of HRS decreased relative to that of HRW.

The crop average protein percentage for HRS is not significant in explaining the variability in exports and domestic utilization. However, the protein for HRW is significant at the 10 percent level in the domestic market and the 12 percent level in the export market. These values indicate that an increase in the protein level for HRW results in a decrease in exports and

TABLE 10. EFFECT OF PROTEIN LEVELS ON UTILIZATION OF HRS WHEAT (T RATIOS IN PARENTHESES)

Market	Intercept	Demand for HRW Wheat	Price Ratio[a]	Protein		Per Capita Income	DW	R^2
				HRS	HRW			
Export	352	.08	-226.54*	0.79	-26.32	0.42*	2.32	.90
	(1.03)	(1.19)	(1.95)	(0.07)	(1.65)	(7.64)		
Domestic	532	-0.006	-165.40*	0.82	-22.80*	0.10*	1.79	.68
	(3.27)	(0.70)	(3.61)	(0.11)	(2.66)	(3.00)		

[a] P_s/P_w where P_s is the price of HRS and P_w is the price of HRW.

domestic use of HRS, assuming everything else is constant. However, the responsiveness to this parameter is not very great.

Summary and Conclusion

The purpose of this study was to evaluate and explain the relationship between prices of HRS and HRW at major U.S. markets. The effect of protein in the HRS and HRW crops on the process of price determination also was analyzed. A model was developed and estimated which explains the behavior of HRS prices as a function of the price of HRW, income, total supply of HRS, and protein levels of the two types of wheat.[7]

Prices were analyzed from 1962-1980 for various classes of hard red wheat of different proteins at the Pacific Northwest, U.S. Gulf, Rotterdam, and Minneapolis/Kansas City. Statistical tests indicated that average prices of the various types of wheat at each of the markets were significantly different than each other with one exception. At the Minneapolis market the average price of HRS 17% was significantly different than prices of HRS 15% and HRS 14%. However, average prices for the latter two were not significantly different. The average prices for HRS 17%, 15%, and 14% protein at Minneapolis were $3.11, $2.93, and $2.88 per bushel, respectively.

In any year prices may differ due to various fundamental factors. The results of the regression analysis indicate the nature and extent of factors affecting price differences among the various classes of wheat. Variables which were statistically significant in explaining the price relationships were the price of HRW, income, total supply of HRS, and the protein percentage of HRW. Of particular interest are the latter two variables. Increases in the total supply of HRS results in lower prices for HRW and HRS. Also, increases in the protein percentage of the HRW crop results in lower prices of HRS and the higher protein HRW (i.e., 12 percent and 13 percent) relative

to the price of HRW Ordinary. However, the effect of the protein percentage of the HRS crop on its price is insignificant. The results indicate that variability in the premium for HRS relative to HRW is largely explained by market phenomena other than the protein of the HRS crop.

The values of the estimated coefficients explain the effects of the protein of the HRW crop and HRS crop on prices at each of the markets. For example, a 1 percent increase (i.e., an increase from 12 percent to 13 percent) in the protein percentage in the HRW crop results in a decrease of 5.52 cents/bushel in the price of HRW 12% relative to HRW ordinary. It also results in a 10.10 cents/bushel decrease in the price of HRS 14% relative to HRW ordinary. These values are stated in 1967 constant dollars. Similar values were estimated at the other markets for the different types of hard red wheat.

The results also can be used to analyze the impact of a change in average protein percentages of either HRW or HRS on the price relationships between the two classes of wheat. The general conclusion is that a small increase in the protein level of Kansas HRW results in relatively large decreases in the price of both higher level protein HRW wheat and the prices for HRS wheat. However, changes in the protein of the North Dakota HRS crop results in small and insignificant changes in those prices. These implications are very important for promoters of various classes of wheat as well as directors of plant breeding programs.

Statistical tests were used to determine if a change has occurred in the process of price determination since 1973 or if variability in exports affects the behavior of prices. The period since 1973 has been characterized by increased and more variable exports for both HRS and HRW. Statistical tests indicated, however, that the behavior of prices was not significantly different in the post-1973 period. In other words, the effects of market phenomena on prices of HRS were the same prior to, and post-1973. A second

test was conducted to determine the effects of exports on price behavior, and the conclusions were similar. An alternative model was specified to determine the effect of relative prices and protein on exports of HRS. The results indicated that average protein for HRS did not have a significant effect on exports, which is particularly important for the general direction of export promotion. However, changes in crop average protein in the HRW crop do result in negative effects on HRS exports and domestic utilization. Relative prices, i.e., prices for HRS relative to HRW, also are important in explaining exports and domestic utilization. Specifically, increases in prices for HRS relative to HRW result in decreases in exports and domestic utilization of HRS.

The results of this study have several implications for producers.[8] First, the difference between the historical average prices of the various types of wheat at each of the markets indicates relative prices which can be used in production decisions. For example, a statistically significant difference does not exist between HRW 14% and HRS 15% protein at Minneapolis. However, the price of HRS 17% is significantly different than each of these. On average, HRS 17% has been 23 and 18 cents/bushel greater than HRS 14% and HRS 15%, respectively. Second, producers frequently store higher protein HRS in quest of greater "protein premiums". The results of this study indicate that if the average protein of the HRW crop is low and/or the total supply of HRS is small, storing of HRS may result in a larger protein premium. However, it is unlikely that larger protein premiums would evolve if the total supply of HRS were large and/or if the protein level of HRW were high.

Footnotes

[1]A complete discussion of the uses for the different types of wheats is contained in the Canada Grain Councils, Wheats of the World.

[2]Recent developments of more hardy winter varieties and favorable production practices have made this choice more viable in North Dakota and Montana.

[3]Part of the difference in prices between HRS prices at Minneapolis and HRW prices at Kansas City is due to transportation. This effect was not subtracted out in the analysis.

[4]Indexes for the years 1980 and 1981 and 254.6 and 274.5, respectively.

[5]All of these prices and effects are analyzed in terms of 1967 constant dollars. To convert the value of the effect to 1980 dollars it should be multiplied by 2.546 and 2.746 for 1981 constant dollars.

[6]An important distinction here is that the assumed changes in the protein level were for the crop, not a particular sales. These results are on a crop year basis and should not be intended to imply premiums and discounts for individual sales.

[7]The estimated models were descriptive of the price determining variables. However, because of the nature of the data it could easily be reformulated and estimated for forecasting purposes. The results could then be used for making expectations about future price relationships.

[8]This study did not address producer problems associated with risk and returns of producing different varieties of wheat. This is in itself a very important area for analysis; variability in not only protein premiums but also yields and protein would have to be analyzed. Such an analysis lends itself to the general problem of production under uncertainty and should be evaluated in that framework.

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APPENDIX FIGURES A1-A6

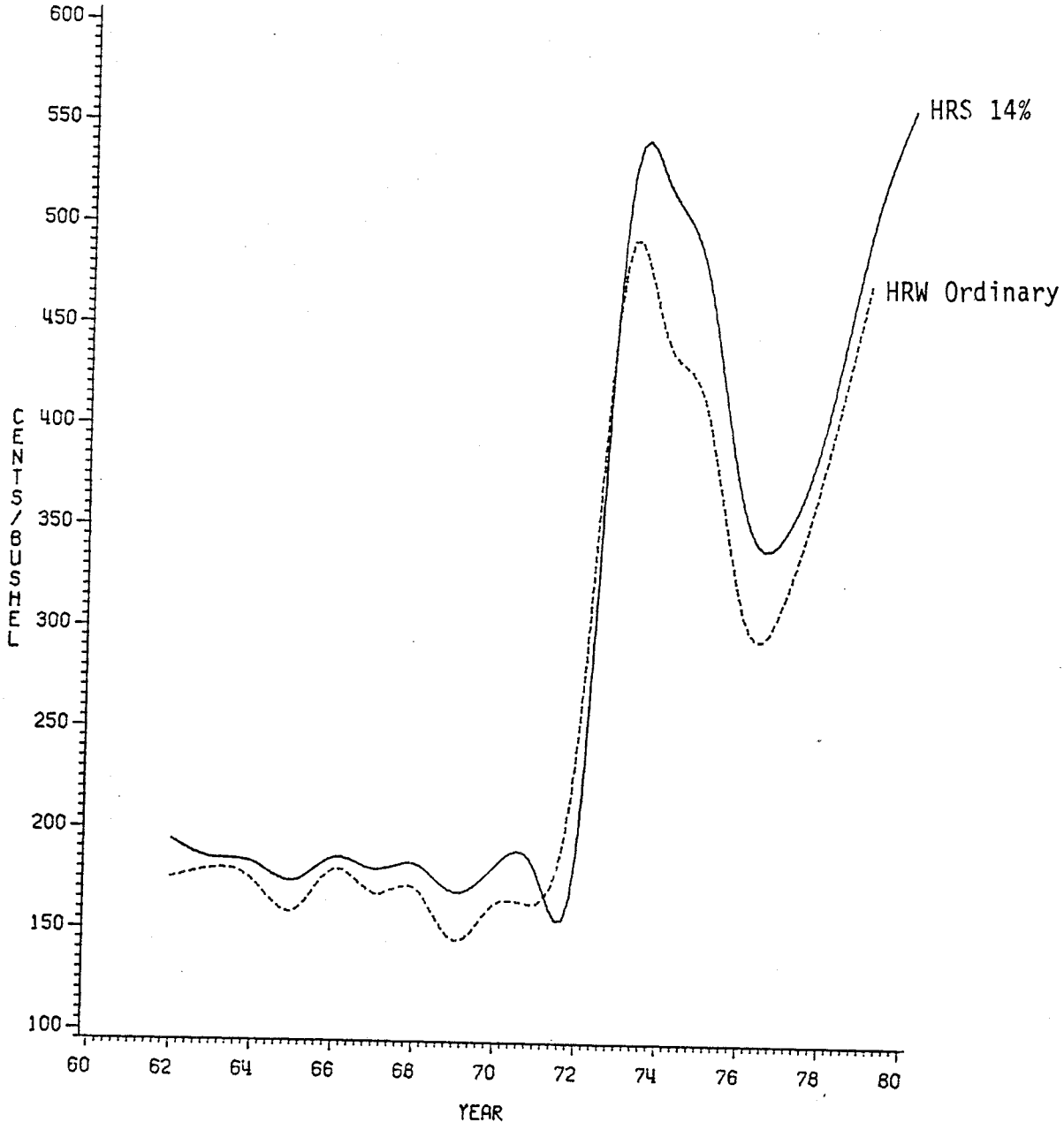

Figure A1. Average U.S. Gulf Prices for HRW Ordinary and HRS 14%

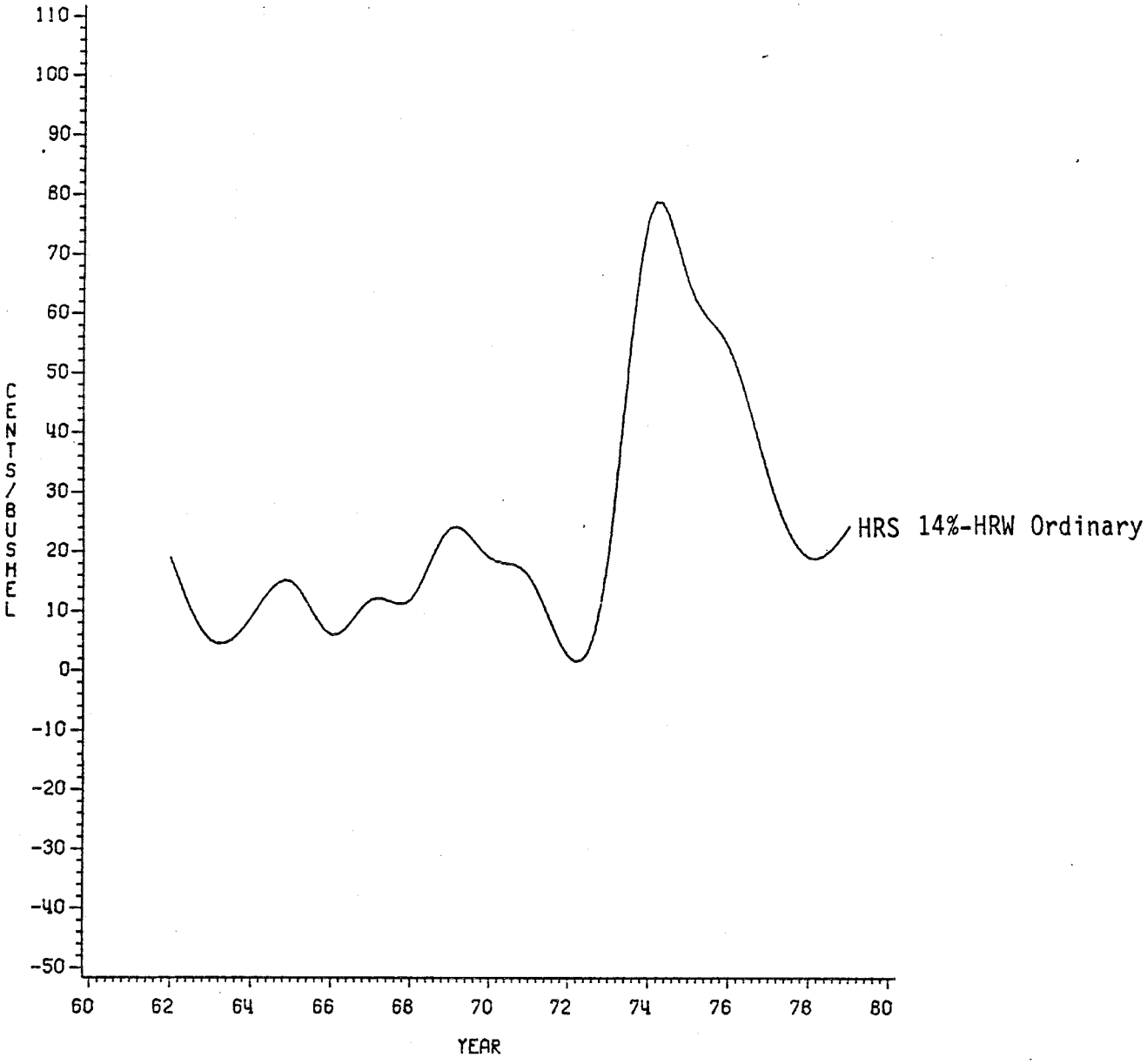

Figure A2. Price Differentials at the U.S. Gulf Between HRS 14% and HRW Ordinary

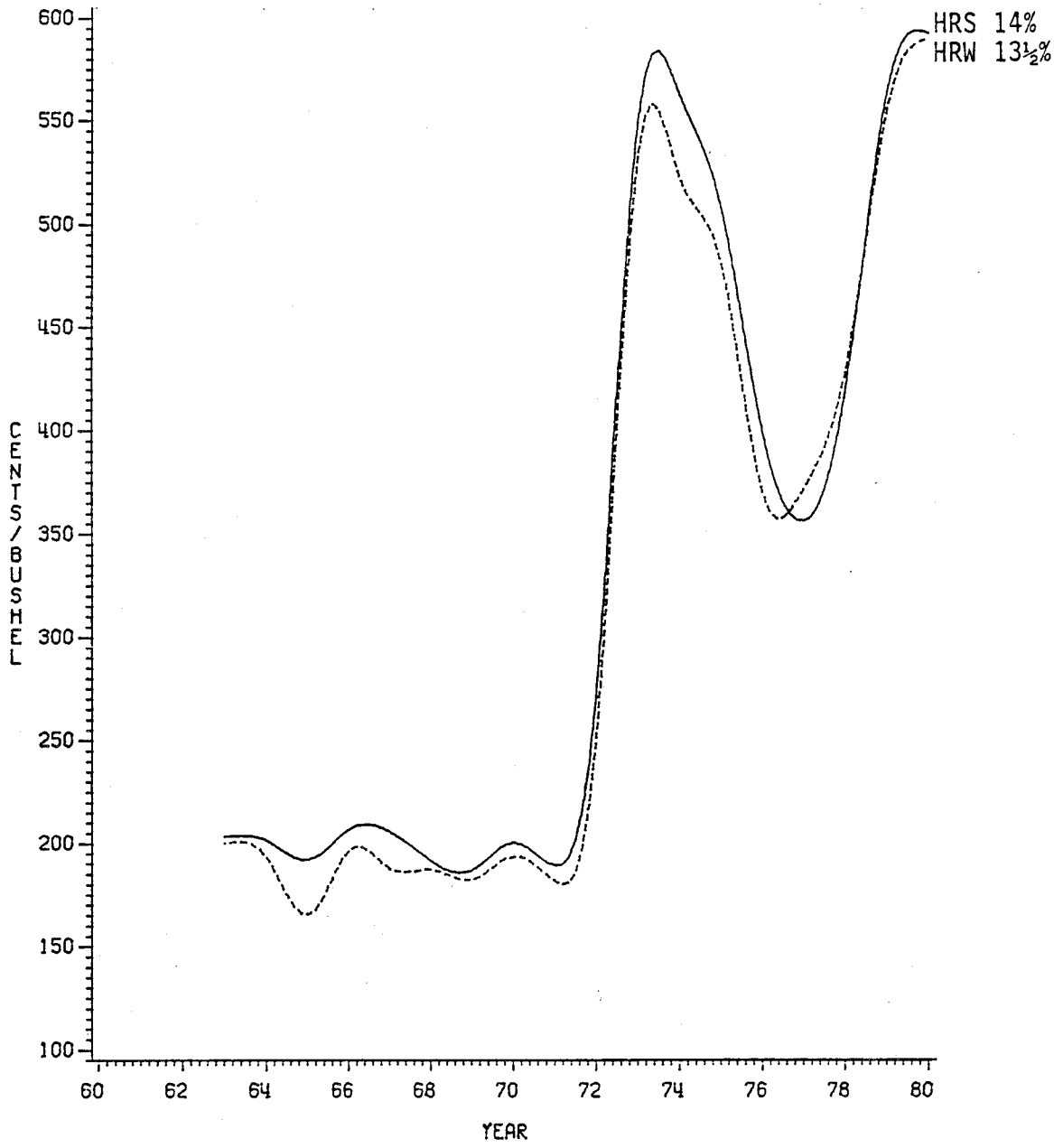

Figure A3. Average Prices at Rotterdam for HRS 14% and HRW 13.5%

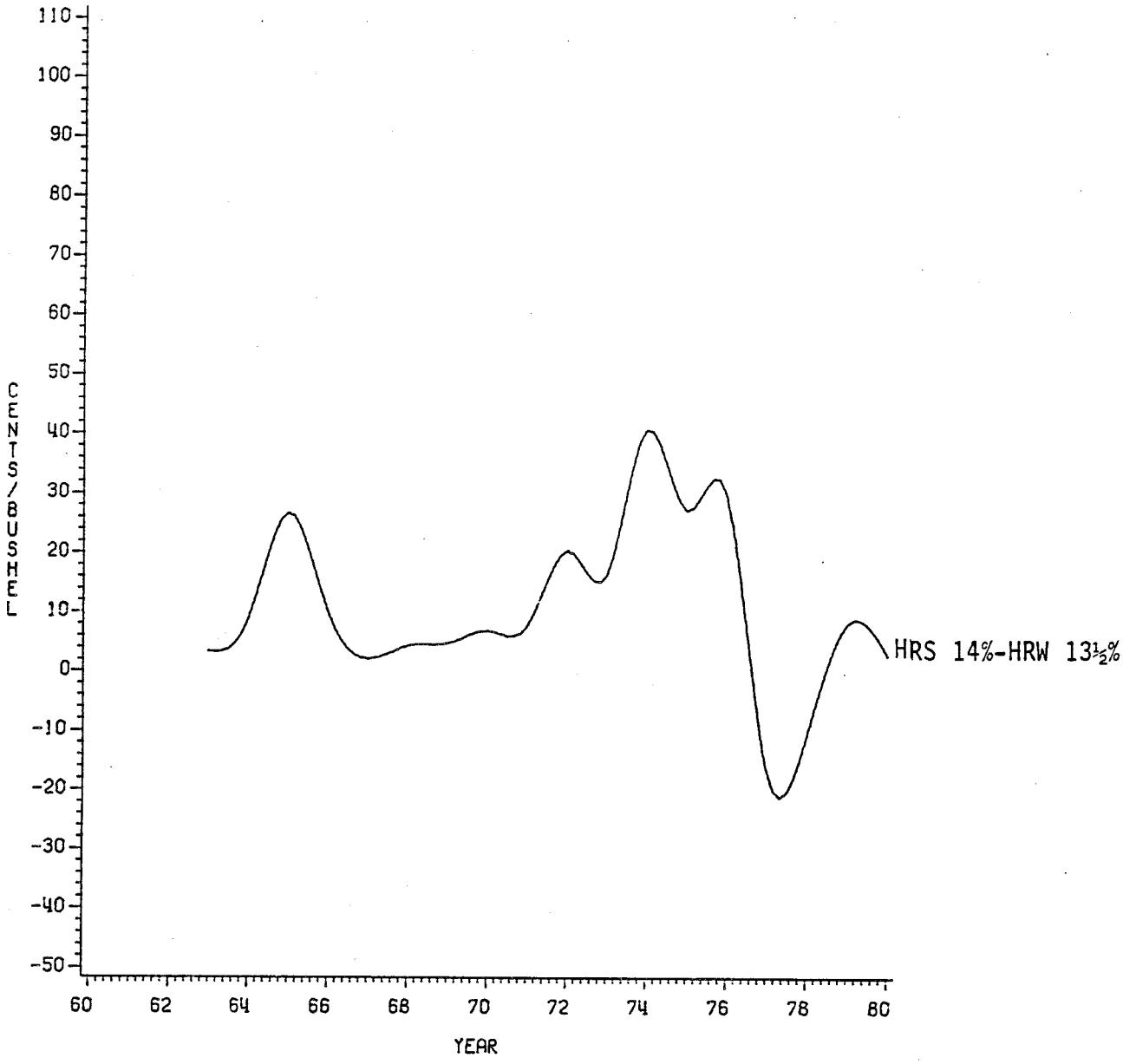

Figure A4. Price Differentials at Rotterdam Between HRS 14% and HRW 13.5%

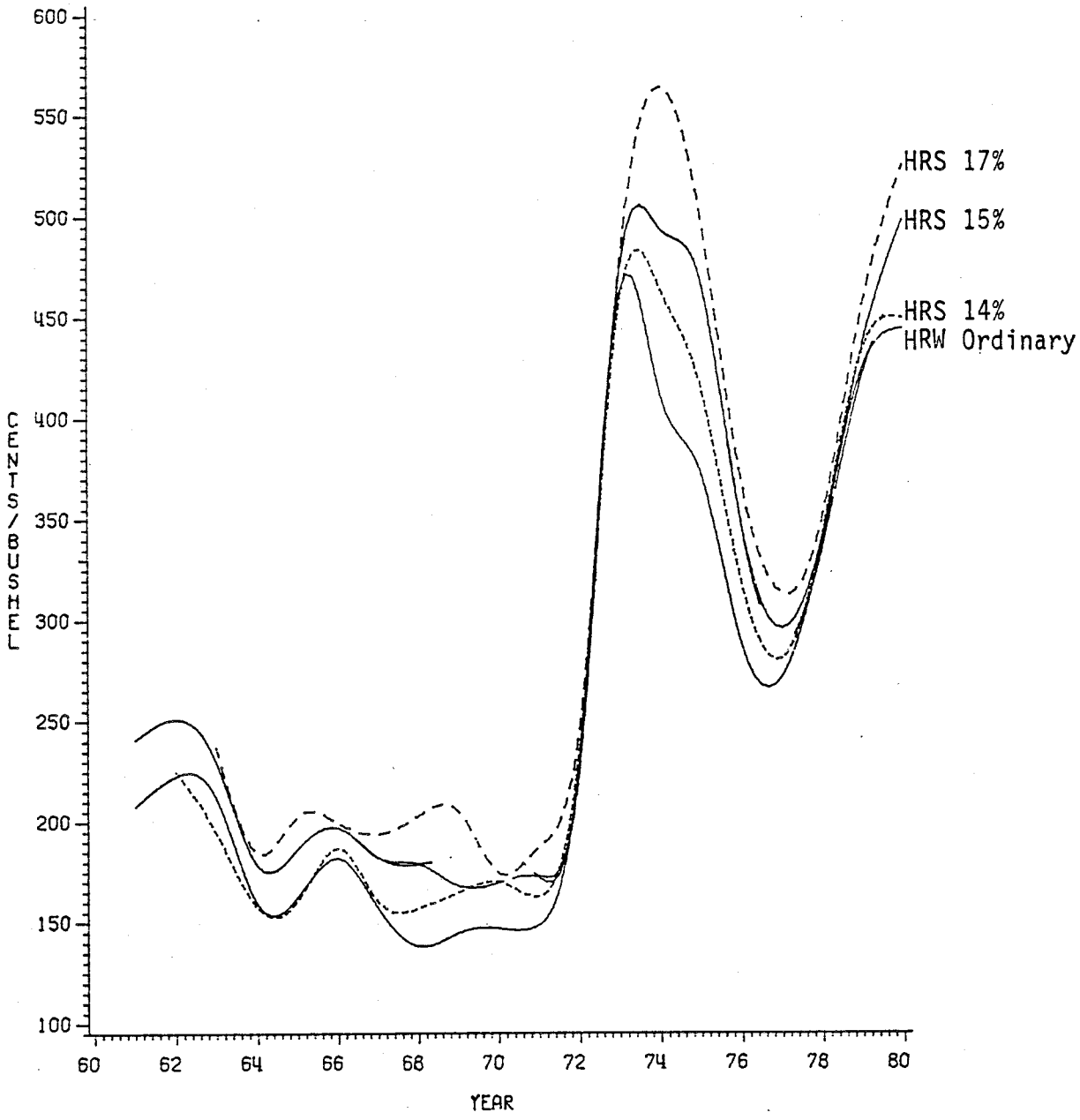

Figure A5. Average Prices for Kansas City for HRW Ordinary at Minneapolis for HRS 14%, HRS 15%, and HRS 17%

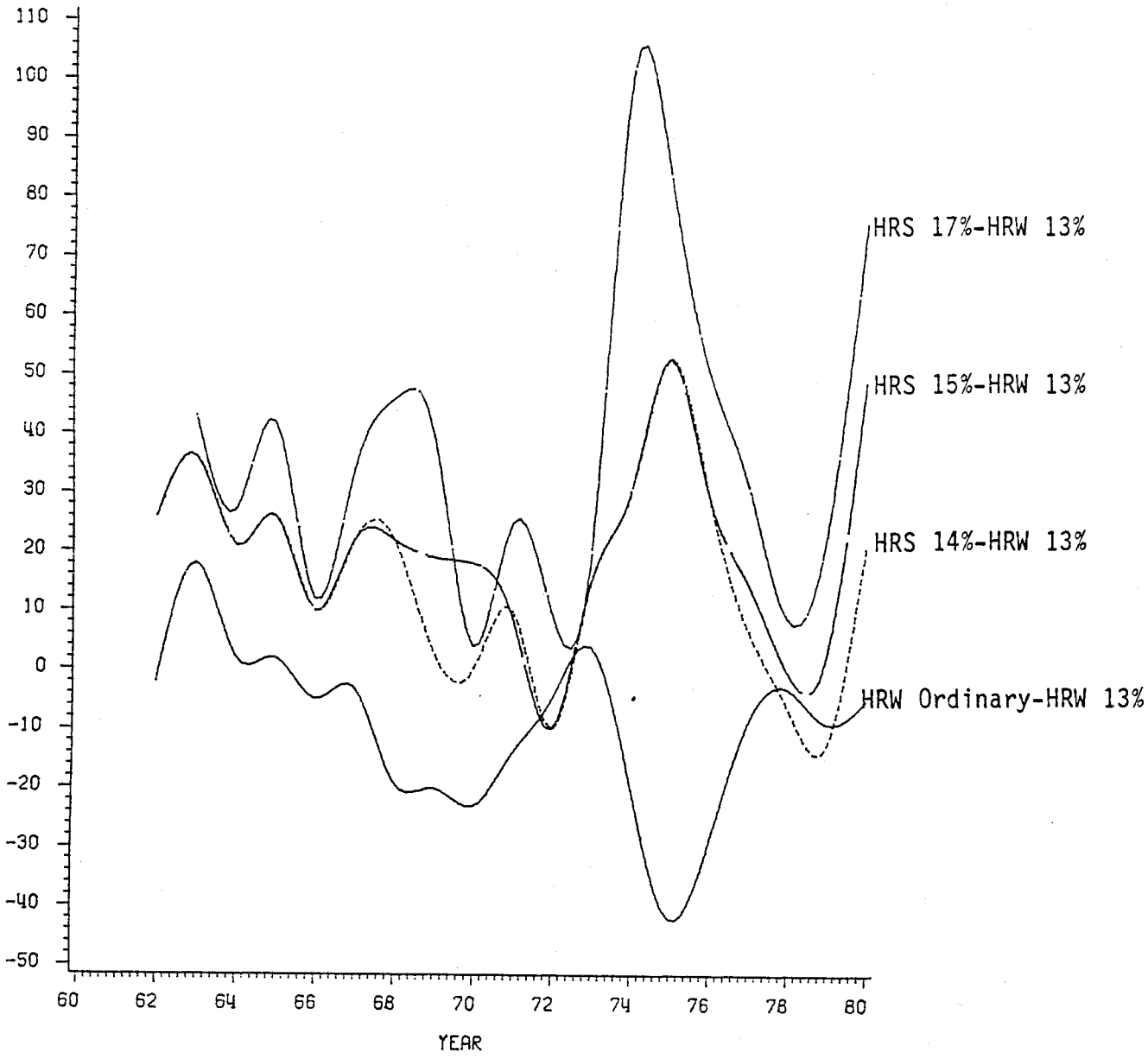

Figure A6. Price Differentials at Kansas City Between HRW Ordinary and HRW 13% and at Minneapolis Between HRS 14%, HRS 15%, HRS 17%, and HRW 13% at Kansas City

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