

**HARD RED SPRING AND HARD RED WINTER WHEAT PROTEIN PREMIUMS
AND PRICE DIFFERENCES IN THE PACIFIC NORTHWEST MARKET**

by

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APPROVAL

of a thesis submitted by

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

The purpose of this study was to forecast protein premiums and price differences for hard red spring and hard red winter wheat in the Pacific Northwest market. Models were estimated using the ordinary least squares and Cochrane-Orcutt procedures. Forecast results were evaluated using Theil's U statistic. The cumulative effect of three supply factors; hard red spring wheat supply, hard red winter wheat supply and Canadian wheat supply; provided the best forecast model of spring wheat protein premiums. Another model using different combinations of these factors provided a similar forecast. No model provided an adequate forecast of winter wheat protein premiums. Price differences were forecasted primarily by wheat supply. The addition of export demand to this model improved the forecast. The addition of average crop protein content to this model improved the forecast for some price differences. Another model using wheat supply and the Canadian-United States exchange rate provided an adequate forecast model.

CHAPTER 1

INTRODUCTION

Hard red spring and hard red winter wheat are the two most commonly grown wheat classes in the United States and Montana. Most of Montana's spring and winter wheat is shipped out of state and sold in the Pacific Northwest market.

Supply and demand factors determine prices for both spring and winter wheat. These factors include quality characteristics such as the falling number, moisture content, percent defects, protein content and test weight. Some characteristics can be influenced by producers. Producers will use production practices, if economical, to change those characteristics that provide them with the highest possible price for their wheat.

A premium is often paid for different levels of wheat protein. High protein wheat usually receives a higher price than low protein wheat. The protein premium is the price difference due to different protein levels in each wheat class. Besides this, the price difference between the two classes of hard wheat has also been called a protein premium, since spring wheat consistently has a higher average protein content than winter wheat.

Varietal selection, fertilization and other factors of production can have a significant influence on the protein content of the wheat produced. Producers will alter these factors of production when the benefits of doing so outweigh the costs. Therefore, the expected protein premium may influence input decisions.

Not only are protein premiums unknown when input decisions are made, but protein premiums can vary significantly from year to year. This makes it difficult for a profit maximizing producer to decide upon the correct level of input use.

The ability to forecast protein premiums and price differences can improve resource allocation. Not only would it help producers allocate inputs properly, but it may help domestic and foreign buyers (whether they be intermediate handlers or final processors) find the most cost effective way of obtaining an adequate supply of wheat with protein levels suited to their particular use.

Purpose of Study

Determination of prices and protein premiums in the Pacific Northwest market is important to all who are involved with Montana wheat. The purpose of this study was to evaluate the factors influencing protein premiums within and price differences between the hard red spring and hard red winter wheat class. These factors will be incorporated into econometric models that are used to forecast protein premiums and price differences of both wheat classes in the Pacific Northwest market.

CHAPTER 2

LITERATURE REVIEW

The Law of One Price

The law of one price, where arbitrage activities result in a single price for a good, is often assumed to hold true in markets after all short term adjustments have been made and all costs have been measured. Yet, empirical studies have not always supported this assumption.

Ardeni (1989) used nonstationarity and cointegration tests to evaluate the law of one price for several commodities traded in four international markets. He found that the long run relationship of commodity prices and exchange rates did not support the law of one price. Reasons given for this failure included: institutional factors, high short term arbitrage costs, data errors and price definitions.

Later, Goodwin (1992) evaluated the law of one price in international wheat markets using multivariate cointegration procedures. He found strong support for the law of one price for five wheat markets when transportation costs were included.

Characteristics Models

Lancaster (1966) put forward an approach that differed from traditional consumer theory. This approach posited that a good is considered a bundle of characteristics. It is these characteristics that give consumers utility. Furthermore, these characteristics may be shared by different goods. Goods used in combination with each other may possess characteristics that are different from what each good possesses individually.

Ladd and Suvannunt (1976) expanded on the approach used by Lancaster. They developed a consumer goods characteristics model "whose assumptions are less restrictive than Lancaster's" and another model "whose assumptions are less restrictive than those of the consumer goods characteristics model." These models can be used to estimate "marginal implicit prices to evaluate grading schemes for consumer products." They did this for nutritional elements in thirty-one food items.

In addition, Ladd and Suvannunt also derived several models that show "consumer demands are affected by characteristics of goods." This, they note, may be applied to product design. Firms, knowing consumer purchases of particular characteristics, can design products by packaging characteristics to maximize profit.

Ladd and Martin (1976) used a similar approach for production inputs where they consider a product a bundle of characteristics. They developed an input characteristics model that estimates marginal implicit prices for input characteristics. This model was used to evaluate the United States corn grading system.

Wilson (1989) used the Hufbauer index of differentiation and a hedonic price model to determine price differentiation in the international wheat market. He found that

price differences between competing wheats have increased in this market since 1973. The price difference between high protein wheats, Canadian Western Red Spring and Dark Northern Spring, has increased relative to all other wheat classes. Canadian wheat, in particular, had a "substantial implicit premium" above the United States spring wheat in the import markets examined.

Wilson's results from the United States Pacific export market suggested that a premium of 67.8 cents per bushel may exist for spring wheat relative to winter wheat. The implicit value for protein was significant and had been stable during the period studied. This protein premium was 22.3 cents per bushel for each percentage point of protein present in hard wheat.

Wilson's results from the Japanese import market showed a premium of 13.5 cents per bushel for spring wheat relative to winter wheat "at least at the higher protein levels." The implicit value for protein was also significant. The protein premium increased over the period studied from 5.3 cents per bushel to 8.5 cents per bushel for each percentage point of protein present in hard wheat.

Espinosa and Goodwin (1991) used hedonic price models to estimate marginal implicit prices of several wheat characteristics. These characteristics represented wheat quality and affected its price. One model used current conventional quality measurements that indirectly measure milling and dough properties. Another model used alternative quality measurements that directly measure milling and dough properties.

Conventional quality characteristics that Espinosa and Goodwin found significant were percent moisture, protein and test weight. For protein, "a premium of 4.92 cents per bushel for an additional percentage point of protein" was estimated over the period

studied. Their results showed that Kansas wheat prices do respond to conventional and alternative quality characteristics and that these characteristics reflect, at least in part, the value of wheat in its end uses.

Wheat Economy Studies

Schmitz and Bawden (1973) used a spatial price model to predict prices, production, consumption and trade flows in the world wheat economy. Then, they changed specific government policy assumptions that may occur in the future to analyze the effects on prices, production, consumption and trade flows. These results are discussed in light of current policy issues.

Barr (1973) studied demand and price relationships for the United States wheat economy. He indicated that United States cash prices are more influenced by export demand related to shortfalls in foreign wheat supplies than export demand related to the price of United States wheat.

Gallagher et al. (1981) presented a structural econometric model of the United States wheat economy. They examined how government policies and market forces influence commercial inventories, domestic demand, foreign demand and production to quantify expected market prices. They examined exports in two types of markets. The market of developed countries, Japan and the European Economic Community, did not respond to world prices because of their price-setting policies, but the markets of less developed countries did respond to world prices.

Roe et al. (1986) examined the effect government intervention has on price responsiveness of world wheat and rice markets. They used an estimated import equation

to measure "the responsiveness of import demand and excess demand to price changes and the extent to which price changes are transmitted to final consumers." They found that "increased per capita income does not necessarily increase demand for imported goods; rather, increased per capita export revenues generate the basis for increased purchases of imports." Their results showed a 1 percent increase in per capita exports increased wheat imports 0.44 percent. Other findings included that when government intervention increases, import decisions tend to be less responsive to price changes and that world prices react to economic shocks more drastically; however, the governments studied reduced intervention over time.

Bailey (1987) used a nonspatial equilibrium model to evaluate the Canadian wheat sector. Among his results, the elasticities of Canadian wheat exports with respect to the United States wheat loan rate were 0.98, 2.09, 4.81 for the short, intermediate and long run, respectively. The United States wheat loan rate was linked to United States wheat prices "to avoid the possibility of U.S. market prices falling below the loan rate." He concluded that a 10 percent increase in the United States wheat price will increase Canadian wheat exports 9.8 percent in the first year, 20.9 percent in the fifth year and 48.1 percent in the long run.

Bailey also evaluated the elasticities of Canadian wheat exports with respect to the Canadian-United States exchange rate. The effect that an appreciation of the Canadian dollar relative to the United States dollar has on the Canadian wheat sector is shown below in Figure 1. He describes this effect on the Canadian wheat sector as follows:

"The Canadian wheat excess supply function $ES(P_c)_c$ in the lower panel is a function of the Canadian price P_c . When the price transmission equation is substituted into $ES(P_c)_c$, the result is a Canadian wheat excess supply function in U.S. dollars $ES(P_{us})_c$. An appreciation in the Canadian dollar relative to the U.S. dollar results in a

decrease in the Canadian-U.S. exchange rate which lowers Canadian prices relative to U.S. prices. This results in a shift from $ES(P_{US})_C$ to $ES(P'_{US})'_C$. The effect of this change on the Canadian wheat sector is a drop in Canadian wheat prices from P_C to P'_C , a decrease in area planted and, hence, supply from OB to OA , and an increase in domestic use and ending stocks from OC to OD . The combined effect of changes in domestic supply and demand is to decrease Canadian wheat exports from OF to OE ."

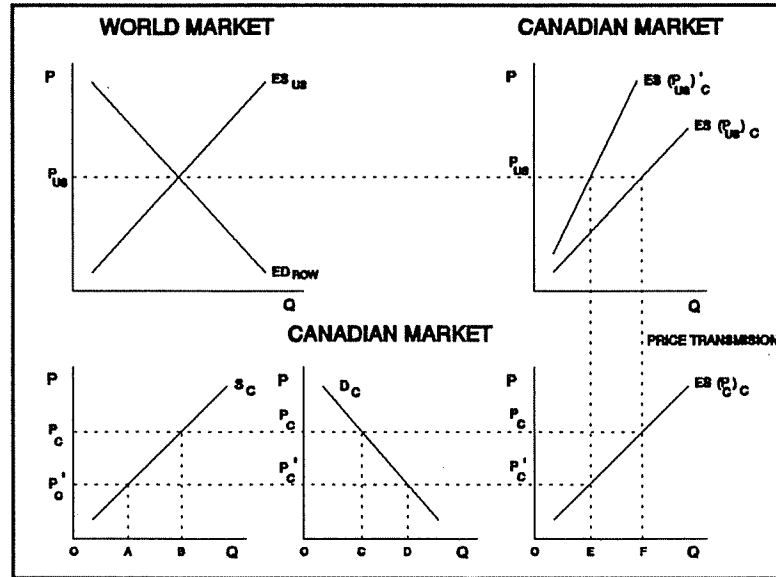


Figure 1. The Effect of the Canadian-United States Exchange Rate on the Canadian Wheat Sector.

Bailey's results were 0.30, 0.81, 2.00 for the short, intermediate and long run, respectively. For example, a 10 percent decrease in the exchange rate resulted in a 3.0 percent decrease in Canadian exports in the short run.

Bailey (1989) used a nonspatial equilibrium model to assess the effect of United States farm policy and other factors on world wheat trade. His results showed the elasticity of demand for United States wheat exports to be -0.69, -0.86, -0.79 in the short, intermediate and long run, respectively. This suggested "that a sustained 10 percent increase in the price of United States wheat, f.o.b. gulf ports, will reduce United

States wheat net exports by 6.9 percent the first year, 8.6 percent by the fifth year and 7.9 percent in the long run."

Davison and Arnade (1991) did an econometric analysis of demand for United States corn, soybean and wheat exports. Their estimated price, income and exchange rate elasticities for most wheat markets were inelastic. For the high income markets of Japan and the Economic Community, income elasticities were positive, but inelastic. While export sales still rise when income increases, they concluded that increased United States exports will be a result of other factors.

Wheat Class Demand and Export Demand Studies

Wang (1962) analyzed the demand and price structure for individual wheat classes. His results showed that the demand for each wheat class was more elastic than the demand for wheat as a whole. He concluded that hard red spring and hard red winter wheat may be substituted for one another in bread production while wheat, as a homogeneous commodity, has fewer substitutes.

Gomme (1968) stated that hard red winter wheat plays a major role in the price determination of all domestic wheat classes except durum. This depends upon the ability to substitute between other wheat classes and hard red winter wheat. When the price difference between hard red spring and hard red winter wheat increase (decrease), millers substitute winter (spring) wheat for spring (winter) wheat. While winter wheat is important in price determination, Gomme also stated that the price of spring wheat is affected by Canadian prices and supplies at a level comparable to domestic prices and supplies. Canada's influence is indirect through its competition in world export markets.

Chai (1972) investigated the domestic food demand of the five major wheat classes produced in the United States. His results indicated that hard red spring, hard red winter and durum wheat have high price elasticities of demand, but soft red winter and white wheat have low price elasticities of demand. The aggregate effects of per capita disposable income, the degree of urbanization and the level of milling and baking technology were thought to have had a variety of offsetting effects on the demand for different wheat classes. These effects generally were not significant.

Chai concluded that statistical results in addition to information provided by the milling industry indicate that hard red spring and hard red winter wheat substitute easily in bread flour production, that low protein hard red and soft red winter wheat substitute in family flour production, and that hard red winter wheat can be blended with durum for some uses. His findings also showed that the greatest impact on wheat demand by class is the shift away from home baking to commercial bakeries. This increases the demand for hard wheats. While United States domestic demand will unlikely be influenced, because nearly all breads already are commercially supplied, it may have a significant impact on export demand. Countries where home baking is declining or the commercial baking industry is increasing, will increase their demand for hard red spring and high protein hard red winter wheat at the expense of low protein wheats.

Chang (1981) examined the substitution between hard red spring and hard red winter wheat classes in eight international markets. He estimated several models to obtain own-price, cross-price and income elasticities for both wheat classes to determine the extent of substitution between each wheat class. His results suggested that hard red spring wheat is more easily substituted for hard red winter wheat than hard red winter

wheat is substituted for hard red spring wheat. This, he concluded, was reasonable because milling and baking requirements needed for some products cannot always be met by the lower quality winter wheat.

In the Japanese market, Chang found income elasticities were positive for both wheat classes and indicates that they are normal goods. He also found substitution between hard red spring and hard red winter wheat was limited. In the European Economic Community market, income elasticities were negative for both wheat classes which indicates that they are inferior goods. In this market, his results suggested that substitution of hard red spring for hard red winter wheat was done more often than substitution of hard red winter for hard red spring wheat.

Wilson and Gallagher (1990) used a Case function specification to analyze market shares of internationally traded wheat. They determined preferences and price responsiveness for wheat in four markets.

In Asia, Wilson and Gallagher found the market share of Canadian Western Red Spring, hard red spring and soft red winter wheat growing and the market share of hard red winter wheat declining relative to the Australian wheat. In Japan, the market share of the Australian and hard red spring wheat has grown and hard red winter and Canadian Western Red Spring wheat declined relative to white wheat, although Canadian Western Red Spring is still the preferred spring wheat. The United States domestic market still prefers hard red winter wheat, but preferences for hard red spring and soft red winter wheat have shifted to white and durum wheat.

Their results indicated Asia was the most price sensitive market followed by the United States, Latin America and Japan. This implies that Asia can more easily substitute

between different wheat classes. The other markets prefer a particular class of wheat and could be considered more quality conscious. This, however, does not mean that a high price wheat is preferred, just a particular quality wheat is preferred.

Protein Premium and Price Difference Studies

Hyslop (1970) analyzed "official grades for wheat and the measured quality factors that determines them" in addition to "the demand for hard wheat protein." In his efforts to estimate the demand for hard wheat protein, he regressed the protein premium of hard red spring and hard red winter wheat on production, carry-over stocks, average crop protein content of both hard red spring and hard red winter wheat and the ratio of domestic hard wheat consumption divided by domestic consumption of all wheat except durum. Negative signs were expected on all coefficients except that a positive sign was expected on the consumption ratio coefficient.

Hyslop's results generally showed correct signs on the coefficients for production and average protein content, but incorrect signs on the coefficients for carry-over stocks and the consumption ratio. He concluded that the average protein content of spring and winter wheat appeared to be the most important factors determining protein premiums.

Ryan and Bale (1976) formed the hypothesis that price differences and protein premiums are affected by the export demand and the supply of both high protein and low protein wheat. They developed several models that predict price differences between wheat classes and protein premiums between wheat of the same class, but with different protein contents.

Instead of using actual price differences and protein premiums as the dependent variable, Ryan and Bale used a ratio where the high protein wheat price was divided by the low protein wheat price. This ratio eliminated the need to deflate prices. An increase (decrease) in the ratio would increase (decrease) the price difference or protein premium.

Exports were expected to affect the demand for wheat. Increased (decreased) exports of high protein wheat were expected to increase (decrease) the price ratio and increased (decreased) exports of low protein wheat were expected to decrease (increase) the price ratio. They noted that opposite effects could occur if the cross-price elasticity of demand is greater than the own-price elasticity of demand.

Protein supply in each market was represented by the wheat supply, current production plus carry-over stocks, and by the average protein content. Spring wheat average protein content was represented by Montana and North Dakota average protein content. Winter wheat average protein content was represented by Kansas average protein content. They assumed an increase in supply or average protein content would increase the protein supply. When the protein supply of high protein wheat decreased (increased), the price ratio was expected to increase (decrease) and when the protein supply of low protein wheat decreased (increased) the price ratio was expected to decrease (increase).

Their model for the ratio of 14 percent protein hard red spring wheat divided by 12 percent protein hard red winter wheat explained 99 percent of the variation in the data. The coefficients for supply and protein content of spring and winter wheat were of the correct sign and significant. The coefficient for the variable used to show the effect of both spring and winter wheat exports was of the correct sign, but not significant. They

concluded that exports were not as important as the protein supply variables in determining this price difference.

Their models used to predict spring and winter wheat protein premiums did not have any formal economic relationships. This was because export and supply data were not available for wheat with different protein contents.

The spring wheat protein premium model, a ratio of 14 percent protein divided by 13 percent protein wheat, explained 97 percent of the variation in the data. They found four relationships. First, when Pacific Northwest exports of spring wheat increased relative to winter wheat, the protein premium decreased. When Pacific Northwest exports of winter wheat increased relative to spring wheat, the protein premium decreased. Second, when total supply of spring wheat increased, the protein premium decreased. Third, when average spring protein contents in Montana and North Dakota increased, the protein premium decreased. Fourth, when average protein content in Montana winter wheat increased, the protein premium increased. This, they reasoned, was because the aggregate supply of 13 percent protein wheat increased, since high protein winter wheat may be substituted for low protein spring wheat, and caused the protein premium to increase.

The winter wheat protein premium model, a ratio of 12 percent protein divided by ordinary protein wheat, explained 65 percent of the variation in the data. They found three relationships. First, when exports of winter wheat from all ports increased, the protein premium decreased. Second, when average protein content of Kansas and Montana winter wheat and North Dakota spring wheat increased, the protein premium

decreased. Yet, when Montana spring wheat protein content increased, the protein premium increased. Third, the protein premium is increasing through time.

Bale and Ryan (1977) refined their price difference model by eliminating the export variable and included price data from other markets. Results from the Portland market, where both spring and winter wheat are sold, again showed that the coefficients for the protein supply variables (i.e., supply and average protein content for both wheat classes) had correct signs and were significant or close to being significant. The protein supply coefficients had a higher level of significance for high protein spring wheat than for low protein winter wheat. Spring wheat supply had the most significant coefficient.

When prices from Kansas City and Minneapolis markets were used, however, the coefficient for the low protein winter wheat supply was not significant and the coefficient for the low protein winter wheat average protein content, although significant, had the wrong sign. They concluded that this occurred because winter wheat protein supply increased when winter wheat protein content increased. This caused a larger decrease in demand for spring wheat protein and resulted in a reduced price difference.

Wilson (1983) took a different approach estimating price relationships between hard red spring and hard red winter wheat. By assuming a perfectly inelastic supply function, he estimated inverse demand functions.

Each function included, as independent variables, the price of a low protein winter wheat, per capita income, supply of hard red spring wheat and average protein contents of the North Dakota and Kansas wheat crops. North Dakota average protein content represented the spring wheat crop average protein content and Kansas average protein content represented the winter wheat crop average protein content. The dependent

variable was a high protein wheat price using spring as well as winter wheat. Positive signs were expected on coefficients for the low protein wheat price, income and North Dakota average protein content. Negative signs were expected on coefficients for spring wheat supply and Kansas average protein content.

The models explained between 93 and 99 percent of the variation in the data. Results from the Pacific Northwest and Kansas City-Minneapolis market indicated that the high protein wheat price was explained by the low protein wheat price, per capita income, spring wheat supply and the winter wheat average protein content.

As expected, price and income coefficients had positive signs, and increases in these variables increased the high protein wheat price. Spring wheat supply negatively affected the dependent variable, and when spring wheat supply increased, the high protein wheat price decreased relative to the low protein wheat price. The coefficient for winter wheat average protein content had a negative sign. When the winter wheat average protein content increased, the high protein wheat price decreased relative to the low protein wheat price. Spring wheat average protein content was not a significant factor influencing wheat prices.

Wilson also tested the affects of exports on prices. He used exports of each wheat class as independent variables and found the results were insignificant. He concluded that exports affect the level of prices, but not relative prices.

In addition, Wilson developed a model that determined the affect of relative prices and protein contents on spring wheat exports and spring wheat domestic demand. He found three results. First, spring wheat average protein content did not have a significant effect on export demand. Second, winter wheat average protein content had an inverse

effect on spring wheat exports and domestic demand. Third, relative prices of spring wheat divided by winter wheat had an inverse affect on export and domestic demand.

CHAPTER 3

THEORY

Introduction

Determination of the price difference between high protein wheat and low protein wheat in the hard wheat market can be approached in two ways. Both hypotheses are described in this chapter. The process that determines the price difference between high and low protein wheat is briefly discussed for each hypothesis.

Hypothesis I

One hypothesis that can be used to describe the price difference between high and low protein wheat is the price of wheat and the price of wheat protein are determined in separate markets. The price of wheat is determined by one set of supply and demand factors. The price of wheat protein is determined by another set of supply and demand factors. The supply and demand factors that affect one market do not necessarily affect the other market.

The wheat price is the price of low protein wheat. The price of wheat protein is the price difference between high protein wheat and low protein wheat. This price of wheat protein is often called the protein premium.

Figure 2 illustrates an example of a wheat market with a high protein wheat and a low protein wheat. The price of low protein wheat is P_L and the price of high protein wheat is P_L plus P_P . The price difference, or the protein premium, is the value of P_P .

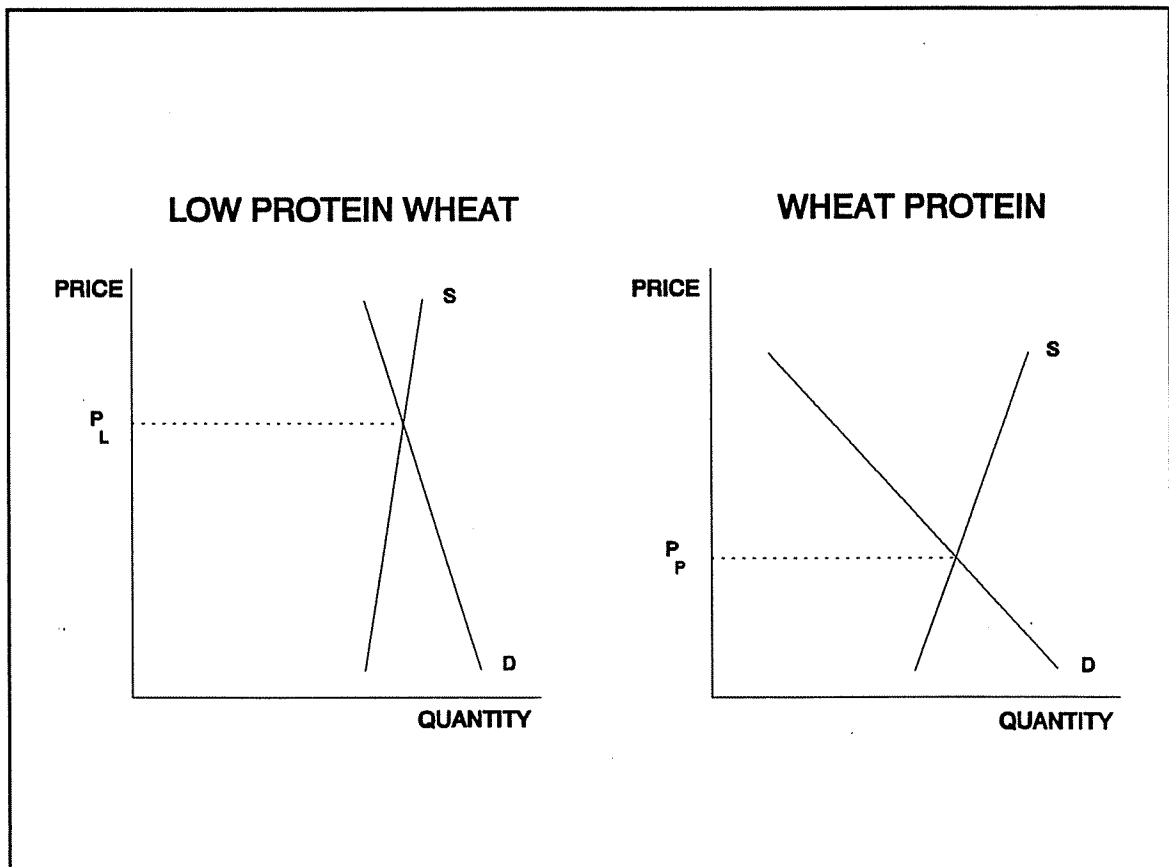


Figure 2. Price of Low Protein Wheat and Wheat Protein Based on Hypothesis I.

The expected affects that supply and demand factors have on the price of low protein wheat and wheat protein are described below and summarized in Table 1. Supply factors are expected to have an inverse affect on prices given a constant demand. Demand factors are expected to have a direct affect on prices given a constant supply.

Table 1. Price Response to an Increase^a in Supply or Demand (ceteris paribus).

Price	Low protein wheat		Wheat protein	
	Supply	Demand	Supply	Demand
P_L	-	+	NA	NA
P_P	NA	NA	-	+

Note: NA indicates not applicable.

^a A decrease would have opposite effects.

Hypothesis II

An alternative hypothesis can be used to describe the price difference between high and low protein wheat. This hypothesis states that the price of high protein wheat and the price of low protein wheat are determined in separate markets. The high protein wheat price is determined by one set of supply and demand factors and the low protein wheat price is determined by another set of supply and demand factors. The price difference between high protein wheat and low protein wheat is often called the protein premium.

Figure 3 illustrates an example of a wheat market with a high protein wheat and a low protein wheat. The price of high protein wheat is P_H and the price of low protein wheat is P_L . The price difference, or protein premium, between high protein and low protein wheat is P_H minus P_L .

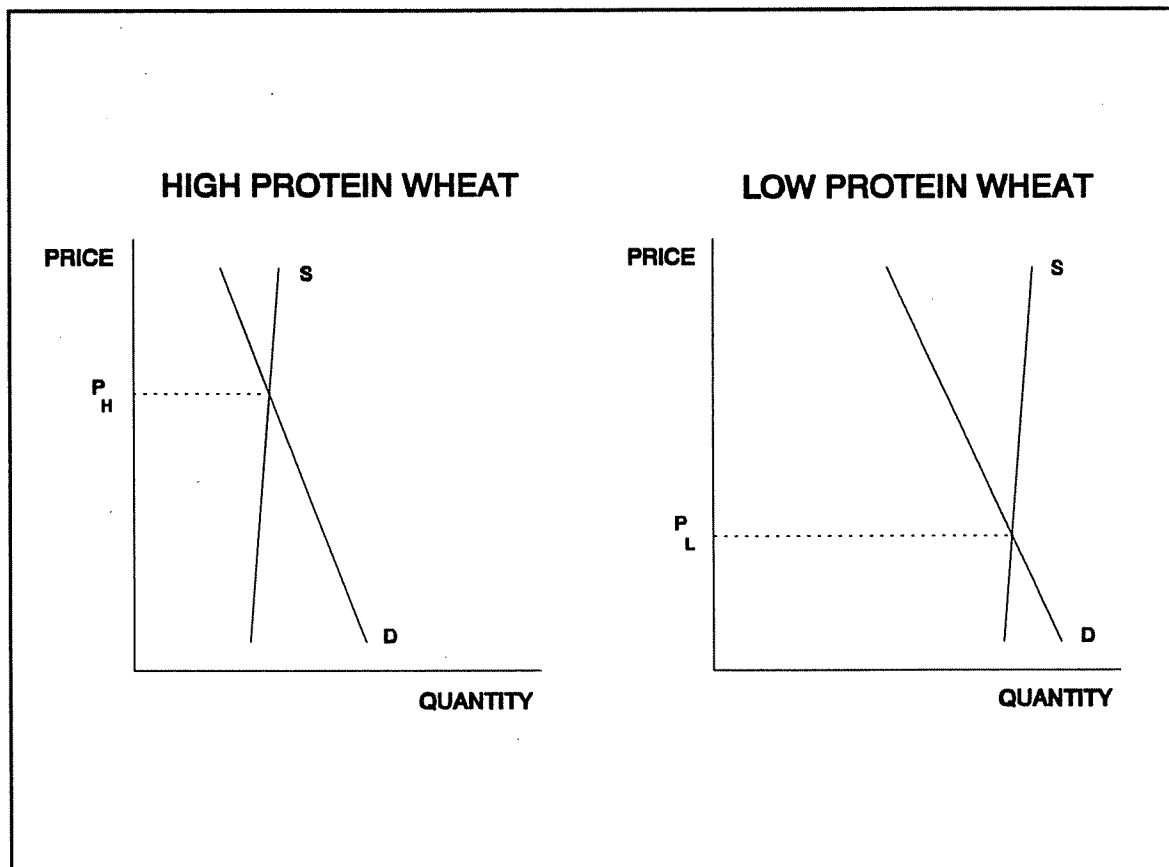


Figure 3. Price of High Protein and Low Protein Wheat Based on Hypothesis II.

The expected affects that supply and demand factors have on the price difference between high protein and low protein wheat are described below and summarized in Table 2. Factors that influence the supply of high protein wheat are expected to have an inverse affect on the price difference given a constant demand. Factors that influence the demand of high protein wheat are expected to have a direct affect on the price difference given a constant supply. Factors that influence the supply of low protein wheat are expected to have a direct affect on the price difference given a constant demand. Factors that influence the demand of low protein wheat are expected to have an inverse affect on the price difference given a constant supply.

Table 2. Price Difference Response to an Increase^a in Supply or Demand (ceteris paribus).

Price difference	High protein wheat		Low protein wheat	
	Supply	Demand	Supply	Demand
$P_H - P_L$	-	+	+	-

^a A decrease would have opposite effects.

CHAPTER 4

DATA

Price and Balance Table Data

The prices used in this study were Grade No. 2 Montana Dark Northern Spring wheat containing 14 and 13 percent protein and Grade No. 1 hard red winter wheat containing 12 percent and ordinary protein. All were coast delivery prices. This data was obtained from the Liveness and Grain Market News for market years 1965-66 through 1991-92. Market year average wheat prices were determined by averaging monthly prices (the monthly prices used were a simple average of daily prices).¹ The price data was not deflated in this study. The primary objective was to forecast nominal price differences and not to explain how real price differences are determined.

The data for United States hard red spring and hard red winter wheat production, carry-over stocks, domestic use, exports and the United States wheat loan rate was taken from various issues of Wheat Situation and Wheat Situation and Outlook Yearbook for market years 1960-61 to 1991-92.²

¹ The market year changed June 1, 1976 from July 1 through June 30 to June 1 through May 31.

² The market year begins July 1 for years 1959-60 to 1973-74. The market year begins June 1 for years 1974-75 to 1991-92.

The data for Canadian spring wheat production (spring wheat other than durum) and carry-over stocks (all wheat) was obtained from the Canada Grains Council for market years 1964-65 to 1991-92.

The Canadian-United States exchange rates were obtained from the Economic Report of the President. The yearly exchange rates were given in units of Canadian dollars per United States dollar. This data was available from 1967 to 1991.

The North Dakota hard red spring wheat average protein content was obtained from North Dakota State University, Department of Cereal Science and Food Technology for years 1962 to 1991. The Kansas hard red winter wheat average protein content was obtained from Kansas Agricultural Statistics for years 1960 to 1991. All average protein contents were converted to a 12 percent moisture basis.

Tables 7 and 8 on pages 53 and 54 provide a summary of all dependent and independent variables used in this study. All prices are measured in cents per bushel, wheat balance data is measured in million bushels, average protein content is measured in percentage terms.

Protein Balance Table Data

One method used to measure wheat protein supply and wheat protein demand in the hard wheat market was to weigh the supply and demand factors (i.e., production, carry-over stock, domestic use and exports) by the average protein content of each factor. The average protein content of each factor was not known. As an alternative, the average protein content from the state producing the largest share of each wheat class was used.

The process used to derive quantity weighted estimates of protein supply and demand factors is shown in Table 9 on page 56 and described below. A base year value for protein supply and protein carry-over stocks was determined first.³ These values were used to derive a data series for all protein supply and demand factors. This was done for United States hard wheat classes individually and for hard wheat as a whole. All data was measured in million pounds of protein.

The base year protein supply value was determined by multiplying the base year wheat supply (i.e., production plus carry-over stocks) by the average protein content of production in the base year. The average protein content of the carry-over stocks was assumed to be equal to the average protein content of production in the base year.

The base year protein carry-over stocks value was determined by subtracting the base year protein use from the base year protein supply. The base year protein use value was determined by multiplying the base year wheat use (i.e., domestic use plus exports) by the average protein content of production for that year.

The protein carry-over stocks data series was derived using the base year data. First, protein supply was determined by multiplying current production by its average protein content and adding it to the protein carry-over stocks from the previous year. Next, protein use was determined by multiplying current wheat use by the average protein content of the current year's production. Finally, protein use was subtracted from protein supply to obtain the protein carry-over stocks for the market year.

³ The base year for hard red spring wheat was 1962 and the base year for hard red winter wheat was 1960.

The protein supply data series was derived by multiplying current production by its average protein content to obtain protein production. This was added to the protein carry-over stocks.

The protein use data series was derived by multiplying the wheat use (i.e., domestic use plus exports) by the average protein content of production that year. The average protein content of domestic use and exports was assumed to be equal to the average protein content of production that year.

The protein stocks-to-use ratio data series was derived using the protein carry-over stocks and protein use data. The protein carry-over stocks was divided by the protein use for each market year.

The protein supply, carry-over stocks and use data series derived for each wheat class was combined to obtain protein supply and protein stocks-to-use ratio for all United States hard wheat. Total protein supply data was derived by adding the spring wheat protein supply to the winter wheat protein supply for each market year. The total protein stocks-to-use ratio was derived by adding the spring and winter wheat protein carry-over stocks and dividing by the sum of the spring and winter wheat protein use for each market year.

CHAPTER 5

ECONOMETRIC MODELS AND RESULTS

Introduction

This chapter describes the development of the econometric models used followed by the forecasting results. The models and results based on hypothesis I are presented first, followed by the models and results based on hypothesis II.

First, a model developed by William I. Tierney Jr. of Kansas State University was used to forecast the price of low protein wheat in each class. The results of the model are then presented and discussed.

Second, the factors influencing the supply and demand of wheat protein are discussed. These factors are incorporated into models that forecast the price of wheat protein, or the protein premium, in each hard wheat market. The results of the models are then presented and discussed.

Third, the factors influencing the supply and demand of high protein and low protein wheat in the same wheat class are discussed. These factors are incorporated into models that forecast the protein premium in each hard wheat market. The results of the models are then presented and discussed.

Fourth, the factors influencing the supply and demand of both wheat classes are discussed. These factors are incorporated into models that forecast the price difference

between hard red spring and hard red winter wheat. The results of the models are then presented and discussed.

Each model was first estimated using the ordinary least squares (OLS) procedure. If this procedure produced a Durbin-Watson (D-W) statistic indicating first-order autocorrelation existed or may exist (the D-W statistic was located in the inconclusive range), the model was reestimated using the Cochrane-Orcutt procedure. If the Cochrane-Orcutt procedure produced an autocorrelation coefficient (ρ) that was statistically significant at the 90 percent confidence level, it was reported. If the value of ρ was not significant, the OLS procedure was reported.

To evaluate forecasting performance, each model was recursively estimated from 1965-66 through 1986-87 to 1990-91 market year and out-of-sample, one-step ahead market year forecasts were produced. The forecast accuracy of each model was evaluated using Theil's U statistic. Theil's U statistic is "given as the square root of the ratio of the mean square error of the predicted change to the average squared actual change."⁴ This statistic, unlike the mean square error, is a unit-free measurement and can easily be compared to a "naive" forecasting procedure of using the current value of the forecasted variable as its future value. If the U statistic equals zero, the simulated values equal the actual values in all time periods, indicating that the model forecast is perfect. If the U statistic equals one, the simulated values are zero (nonzero) when the actual values are nonzero (zero) or the simulated values are negative (positive) when the actual values are positive (negative), indicating that the model forecast is no better than a naive forecast. A

⁴ Peter Kennedy, A Guide to Econometrics 2nd ed. (Cambridge: MIT Press, 1987), p. 212.

U statistic less than one is not necessarily better than a naive forecast if the time series data used has a strong trend.

Other test statistics reported are the mean square error and the adjusted R^2 . The mean square error (also known as the root mean square error or R.M.S.E.) was reported for comparison to Theil's U statistic. The adjusted R^2 was reported to show the extent that the independent variable(s) explain the dependent variable. The percentage of correctly forecasted directional changes in the price or price difference by each model are also reported.

Models and Results Based on Hypothesis I

Low Protein Wheat Price Models

To describe or forecast accurately the low protein wheat price of either hard wheat class was beyond the scope of this paper. Still, a model developed by William I. Tierney, Jr. of Kansas State University was used to forecast the low protein wheat price in each wheat class for an illustrative purpose. This model hypothesizes that the wheat price is a function of the United States wheat loan rate, last year's price and the stocks-to-use ratio.

The dependent variable used for the low protein spring wheat was the price of 13 percent protein hard red spring wheat. The dependent variable used for the low protein winter wheat was the price of ordinary protein hard red winter wheat. These variables are defined in Table 7 on page 53.

The independent variables used and their expected affects on the low protein wheat price are described below and summarized in Table 3. The United States wheat

loan rate and last year's wheat price were expected to have a direct affect on the current wheat price. The stocks-to-use ratio was expected to have an inverse affect on the wheat price. These variables are defined in Table 8 on page 54.

Table 3. Price Response of Low Protein Wheat to an Increase^a in the Independent Variables.

Dependent variables	Independent variables			
	LNRATE	HRS13 _{t-1}	HRWORD _{t-1}	STKUSE
HRS13	+	+	NA	-
HRWORD	+	NA	+	-

Note: NA indicates not applicable.

^a A decrease would have opposite effects.

Results

The results of the regression model used to forecast the price of low protein wheat in each wheat class are shown in Table 10 on page 57 and Table 11 on page 58. Table 10 shows the result from the hard red spring wheat class. Table 11 shows the result from the hard red winter wheat class.

The model used to forecast the low protein wheat price in each wheat class was estimated using the OLS procedure. The coefficients for the United States wheat loan rate (i.e., LNRATE), stocks-to-use ratio (i.e., STKUSE) and last year's price (i.e., HRS_{t-1} and HRW_{t-1}) were significant at the 99 percent confidence level except one; the coefficient for the loan rate for the spring wheat class was significant at the 95 percent confidence level. All coefficients had the correct signs. The Theil U statistic was 0.77 for the low protein spring wheat price and 0.69 for the low protein winter wheat price.

This indicates that the model forecasts the low protein wheat price better than a naive forecast. The model also correctly predicted three out of four directional changes in the forecasted price.

Wheat Protein Price Models

The models used to forecast the price of wheat protein were hypothesized to be a function of the protein supply (defined as protein production plus protein carry-over stocks) and the protein stocks-to-use ratio (defined as the protein carry-over stocks divided by the total protein use). These supply and demand factors were derived using quantity weighted estimates of protein supply and demand using a balance table approach described in Chapter 4. Estimates for protein supply and stocks-to-use ratio were made for each hard wheat class and for hard wheat as a whole.

One dependent variable was used to represent the price of wheat protein, or the protein premium, in each class. The dependent variable for the spring wheat class is the price difference between 14 and 13 percent protein hard red spring wheat. The dependent variable for the winter wheat class is the price difference between 12 percent and ordinary protein hard red winter wheat. These variables are defined in Table 7 on page 53.

The independent variables used and their expected affects on the price of wheat protein are described below and summarized in Table 4. These variables are defined in Table 8 on page 54.

Protein supply was expected to have an inverse affect on the price of wheat protein. Protein supply was considered highly inelastic during the marketing year because protein production and carry-over stocks are essentially fixed. The assumption was made that no other protein could be substituted for wheat protein in the market.

Table 4. Price Response of Wheat Protein to an Increase^a in the Independent Variables.

Independent variables	Dependent variable	Independent variables	Dependent variable
	S14S13		W12WORD
HSPRSUP	—	HWPRSUP	—
HSPRSTKUSE	—	HWPRSTKUSE	—
TPRSUP	—	TPRSUP	—
TPRSTKUSE	—	TPRSTKUSE	—

^a A decrease would have opposite effects.

The protein stocks-to-use ratio was expected to have an inverse affect on the price of wheat protein. This inverse relationship was expected because of shifts likely to occur in the supply and demand schedules of wheat protein. When the protein stocks-to-use ratio increases from one year to the next year, either the carry-over stock of wheat protein is larger or the total use of wheat protein is smaller than the previous year. This suggests that wheat protein supplies have increased during the year relative to wheat protein use.

Results

The results of the regression models used to forecast the price of wheat protein in each wheat class are shown in Table 10 on page 57 and Table 11 on page 58. Table 10 shows the results from the hard red spring wheat class. Table 11 shows the results from the hard red winter wheat class.

The models used to forecast the price of spring wheat protein were estimated using the Cochrane-Orcutt procedure. The coefficients obtained from all models were not as expected. The coefficient for the spring wheat protein stocks-to-use ratio (i.e., HSPRSTKUSE) used in model 2 and the coefficient for the total wheat protein stocks-to-use ratio (i.e., TPRSTKUSE) used in model 4 were not significant and had the wrong sign. The coefficient for the spring wheat protein supply (i.e., HSPRSUP) used in model 1 and the coefficient for the total protein supply (i.e., TPRSUP) used in model 3 were significant, however, they had the wrong sign. For example, the results from model 1 indicate that a one unit (i.e., one million pounds of protein) increase in spring wheat protein increased the price of wheat protein 0.006 cent per bushel.

The models used to forecast the price of winter wheat protein were estimated using the Cochrane-Orcutt procedure. The coefficients obtained from all models were uninformative. Not only were all coefficients insignificant, they also had the wrong sign.

Models and Results Based on Hypothesis II

Protein Premium Models within Wheat Classes

Data for the supply and demand factors affecting different protein wheat within a class was not available. Independent variables were chosen that are currently available and have the potential to show the relative supply of high and low protein wheat in a hard wheat class as described in hypothesis II. The independent variables were used in many combinations to determine which models did the best job forecasting the protein premium in each wheat class.

One dependent variable was used to represent the price difference, or the protein premium, between a high and a low protein wheat within each class. The dependent variable for the spring wheat class is the price difference between 14 and 13 percent protein hard red spring wheat. The dependent variable for the winter wheat class is the price difference between 12 percent and ordinary protein hard red winter wheat. These variables are defined in Table 7 on page 53.

The independent variables used and their expected affects on the protein premium are described below and summarized in Table 5 on page 38. These variables are defined in Table 8 on page 54.

Wheat production can affect the quantity of high and low protein wheat within a class in two ways. When production increases, the quantity of high protein wheat produced can either increase or decrease relative to the quantity of low protein wheat produced. The quantity of high and low protein wheat produced depends on environmental conditions and producer decisions that occur during the crop year.

If wheat production increases and the quantity of high protein wheat increases relative to the quantity of low protein wheat, the price difference will decrease. Production has an inverse affect on the price difference. Previous research has focused on this effect (Hyslop, 1970). Yet, this may not always happen. If wheat production increases and the quantity of high protein wheat decreases relative to the quantity of low protein wheat, the price difference will increase. Production has a direct affect on the price difference.

The assumption was made that production has a direct affect on the price difference. While an indirect relationship can occur, a direct relationship was expected

more often because of the agronomic nature of wheat. Production practices, such as nitrogen fertilization, that affect both yield and protein content cannot usually be changed when a high yield appears likely. When the wheat yield increases, protein content often decreases. This occurs because the wheat plant tends to use soil and fertilizer nitrogen to increase the number of kernels (yield) at the expense of kernel protein (protein content).

Production of one hard wheat class can affect the price difference between high and low protein wheat in the other hard wheat class differently. Spring wheat production affects price differences in the winter wheat class differently than winter wheat production affects price differences in the spring wheat class. This is because of the way substitution usually takes place in the wheat market.

The assumption was made that hard red spring wheat production has an inverse affect on the price difference between high and low protein hard red winter wheat. When spring wheat production increases, the quantity of low protein spring wheat increases. Low protein spring wheat can be substituted for high protein winter wheat when availability and transportation conditions are favorable. This occurs because low protein spring wheat, on average, has protein levels equal to or greater than high protein winter wheat. The competition from low protein spring wheat drives the high protein winter wheat price down, decreasing the price difference between high and low protein winter wheat.

The assumption was made that hard red winter wheat production has a direct affect on the price difference between high and low protein hard red spring wheat. When the production of winter wheat increases, the quantity of low protein winter wheat increases. The milling and baking properties of low protein winter wheat, however, may

not be adequate to produce some products. Insufficient wheat protein requires millers and bakers to blend a high protein wheat with the low protein winter wheat. Yet, an adequate supply of high protein winter wheat may not be readily available. High protein spring wheat can be substituted for high protein winter wheat. This increases the demand for high protein spring wheat, increasing the price difference between high and low protein spring wheat.

Estimating the relative supply of high and low protein wheat in carry-over stocks of both classes is more complicated than production. Not only is the average protein content of wheat production unknown for the previous year, but carry-over stocks often contain wheat from earlier years. Yet, the assumption was made that carry-over stocks affect protein premiums in a manner similar to wheat production for each wheat class.

The supply of each wheat class affects protein premiums depending on the combined effects of its components, production and carry-over stocks. The assumption was made that the affects of each component are cumulative. This assumption has three affects on protein premiums. First, the supply of each wheat class has a direct affect on protein premiums in its own class. Second, the supply of hard red spring wheat has an inverse affect on the protein premium in the hard red winter wheat class. Third, the supply of hard red winter wheat has a direct affect on the protein premium in the hard red spring wheat class.

The North American spring wheat supply is defined as the supply of United States hard red spring wheat plus the supply of Canadian spring wheat. The assumption was made that the addition of Canadian spring wheat was expected to increase the affect that the United States spring wheat supply has on protein premiums. This is because of the

affect that Canadian wheat exports have on the Pacific Northwest wheat market from its competition in the export market.

United States total wheat supply is defined as the supply of both hard wheat classes. The assumption was made that the United States total wheat supply was expected to have a direct affect on the protein premium in both hard wheat markets.

The direct relationship in the spring wheat market was expected because of the cumulative effect that the spring and winter wheat supply have on the spring wheat protein premium. The direct relationship in the winter wheat market was uncertain. Because the winter wheat supply has a direct affect on protein premiums and the spring wheat supply has an inverse affect on protein premiums, the total affect depended on which was greater. Since the United States winter wheat supply is approximately twice as large as the United States spring wheat supply, the affect of the winter wheat supply is expected to dominate the affect of the spring wheat supply.

The North American total wheat supply is defined as the United States total wheat supply plus the Canadian spring wheat supply. The assumption was made that the addition of the Canadian spring wheat supply to the United States total wheat supply has two affects. One, it increases the affect that the United States spring wheat supply component has on protein premiums in the United States total wheat supply variable described above. Two, it decreases the affect that the United States winter wheat supply component has on protein premiums in the United States total wheat supply variable described above.

The ratio of the United States hard red spring wheat supply divided by the United States hard red winter wheat supply was expected to have an inverse affect on the protein

premiums in both wheat classes. When the ratio increases, the supply of spring wheat increases relative to the supply of winter wheat. This was expected to decrease the protein premiums in both wheat classes because more high protein spring wheat exists in the market.

The ratio of North American spring wheat supply divided by the United States hard red winter wheat supply was also expected to have an inverse affect on the protein premium in both wheat classes. The addition of Canadian spring wheat supply to the ratio was expected to increase the affect that the spring wheat supply has on the ratio described above.

Table 5. Protein Premium Response to an Increase^a in the Independent Variables.

Independent variables	Dependent variables		Independent variables	Dependent variables	
	S14S13	W12WORD		S14S13	W12WORD
HSPROD	+	-	USTSUP	+	+
HWPROD	+	+	NATSUP	+	+
HSCAR	+	-	HSHWRATIO	-	-
HWCAR	+	+	NASHWRATIO	-	-
HSSUP	+	+	NDPR	-	NA
HWSUP	+	+	KSPR	NA	-
NASSUP	+	-			

Note: NA indicates not applicable.

^a A decrease would have opposite effects.

The average protein content of both wheat classes would provide some indication of the relative supply of high and low protein wheat in a wheat class. This information is

not available for the period studied. The average hard red spring wheat protein content from North Dakota, the leading producer of spring wheat, and the average hard red winter wheat protein content from Kansas, the leading producer of winter wheat, is known. This state data was used as a proxy for the average protein content in each wheat class. The average protein content from each state was expected to have an inverse affect on the protein premium for the wheat class it represents.

Results

The results of the regression models used to forecast the protein premium in each hard wheat class are shown in Table 12 on page 59 and Table 13 on page 60. Table 12 shows the results from the hard red spring wheat class. Table 13 shows the results from the hard red winter wheat class.

The models used to forecast the spring wheat protein premium were estimated using the Cochrane-Orcutt procedure. The models generally produced good statistical results. While all coefficients were not significant, all had the correct signs. The results of these models are compared and discussed below.

The coefficient for the hard red spring wheat supply (i.e., HSSUP), United States total wheat supply (i.e., USTSUP) and North American wheat supply (i.e., NATSUP); in model 1, model 2 and model 3 respectively; was significant at the 99 percent confidence level. These results show the affect that hard red spring wheat supply, hard red winter wheat supply and Canadian wheat supply have on the spring wheat protein premium. The Theil U statistic improves as the affect of each supply component was added into the model. The Theil U statistic for model 1, model 2 and model 3 was 0.70, 0.64 and 0.53 respectively. The percentage of correctly predicted changes in the protein premium

improves from 50 percent in model 1 to 75 percent in model 2 and model 3. For example, the results from model 3 suggest that a one unit (i.e., one million bushel) increase in the North American wheat supply increased the spring wheat protein premium 0.014 cent per bushel.

The results from model 4 show the affect that North American spring wheat supply (i.e., NASSUP) and the ratio of North American spring wheat supply to winter wheat supply (i.e., NASHWRATIO) have on the spring wheat protein premium. The coefficient for the North American spring wheat supply was significant at the 99 percent confidence level. The coefficient for the supply ratio was not significant, but its t-statistic was greater than one and the ratio improved the model's Theil U statistic. The Theil U statistic obtained was 0.63.

The models used to forecast the winter wheat protein premium were estimated using the Cochrane-Orcutt procedure. The results suggest that the variables used behave as they were expected, but the empirical evidence was weak. While all coefficients had the correct signs, none were significant. The Theil U statistics obtained were 2.55 or higher. This indicates that forecasts using these models were not as good as a naive forecast.

Price Difference Models between Wheat Classes

The price difference between the hard red spring wheat class and hard red winter wheat class has been called a protein premium. This comparison has been made because the use of each wheat class is similar and the only apparent difference is the protein

content of each wheat class. Yet, differing protein levels is only one part of the price difference.

The price difference between the two hard wheat classes is affected by both the supply and demand schedules of each wheat class. While the protein content can affect the demand schedule for each wheat class, the supply schedule is not affected. The supply schedule is affected by other factors. The supply and demand factors affecting price differences are described below.

Several supply and demand factors are hypothesized to influence the price difference between high and low protein wheat. They include supply, export demand, and the protein content.

The supply of wheat is defined as production plus carry-over stocks. Supply was considered highly inelastic during the marketing year because production and carry-over stocks are essentially fixed. Imports are not considered a significant factor.

The supply of both high and low protein wheat affect the price difference. The supply of high protein wheat was expected to have an inverse affect on the price difference. The supply of low protein wheat was expected to have a direct affect on the price difference.

The export demand of both high and low protein wheat affect the price difference. The export demand of high protein wheat was expected to have a direct affect on the price difference. The export demand of low protein wheat was expected to have an inverse affect on the price difference.

From a consumer goods characteristics approach, protein quality is one characteristic that buyers look at when purchasing wheat. Although protein quality cannot

be easily measured, the protein content can be easily measured. The protein content of wheat is used as a proxy for protein quality. For some wheat uses, wheat must contain a sufficient quality, or quantity, of protein. High protein wheat usually has better milling and baking properties than low protein wheat for many products made from hard wheat. As a result, when the protein content of wheat increases the demand for that wheat increases.

The affect protein content may have on the price difference depends on which demand schedule is being affected. An increase in the protein content of high protein wheat was expected to have a direct affect on the price difference. An increase in the protein content of low protein wheat was expected to have an inverse affect on the price difference.

The dependent variables used are four price differences between a high protein wheat and a low protein wheat. The high protein wheat was represented by hard red spring wheat and the low protein wheat was represented by hard red winter wheat. The prices used from each class included spring wheat of 14 and 13 percent protein and winter wheat of 12 percent and ordinary protein. These variables are defined in Table 7 on page 53.

The independent variables used to represent supply and demand factors in the models reported are described below and summarized in Table 6 on page 44. Ratios were used whenever appropriate to reduce problems associated with multicollinearity. These variables are defined in Table 8 on page 54.

Two variables were used to represent the supply of spring and winter wheat. One supply variable was the ratio of the United States hard red spring wheat supply divided by

the United States hard red winter wheat supply. The other supply variable was the ratio of North American spring wheat supply divided by the United States hard red winter wheat supply.

An inverse affect was expected for both supply ratios. When the ratio increased, the supply of spring wheat increased relative to winter wheat. This was expected to cause the price difference to decrease between the two hard wheat classes.

Two variables were used to represent the export demand for spring and winter wheat. Each variable was expected to have a different affect on the price difference between spring and winter wheat.

One export demand variable was the ratio of the United States hard red spring wheat exports divided by the United States hard red winter wheat exports. This ratio was expected to have a direct affect on the price difference. When the export ratio increased, the demand for spring wheat increased relative to winter wheat. This would increase the price difference between the two hard wheat classes.

The other export demand variable was the Canadian-United States exchange rate. This variable was used to represent changes in export demand due to changes in the exchange rate. This variable was expected to have an inverse affect on the price difference. When the exchange rate increases, the Canadian dollar depreciates relative to the United States dollar. As a result, United States spring wheat becomes more expensive when compared to Canadian spring wheat, decreasing United States spring wheat export demand. This was expected to decrease the price difference between United States spring and winter wheat.

The variable used to show the affect that protein content has on the price difference was a ratio of the North Dakota average spring wheat protein content divided by the Kansas average winter wheat protein content.⁵ A direct affect was expected for this ratio. When the protein ratio increased, the demand for spring wheat increased relative to winter wheat. This was expected to increase the price difference between the two wheat classes.

Table 6. Price Difference Response to an Increase^a in the Independent Variables.

Independent variables	Dependent variable	Independent variables	Dependent variable
	Price difference		Price difference
HSHWRATIO	-	CAUSEXR	-
NASHWRATIO	-	PRRATIO	+
EXRATIO	+	TREND	?

^a A decrease would have opposite effects.

A time trend variable was used to determine if a trend in the price difference had occurred over the period studied and what affect it had on the forecast model. No prior relationship was expected.

⁵ The average hard red spring wheat protein content from North Dakota, the leading producer of spring wheat, and the average hard red winter wheat protein content from Kansas, the leading producer of winter wheat, were used to represent both the quality and the average protein content of each wheat class.

Results

The results of the regression models used to forecast the price difference between both hard wheat classes are shown in Table 14 on page 61. The results show that most coefficients were significant. All coefficients, except those for the protein ratio, had the correct signs. The models had Theil U statistics between 0.08 and 0.80, indicating that the price differences forecasted were better than a naive forecast. The models also correctly predicted all directional changes in the price differences that were forecasted. The results of these models are compared and discussed below.

Model 1 and model 5 differ only in the supply variable used. Model 1 used the ratio of hard red spring wheat supply to hard red winter wheat supply (i.e., HSHWRATIO) while model 5 used the ratio of North American spring wheat supply to hard red winter wheat supply (i.e., NASHWRATIO). Model 1 was estimated using the Cochrane-Orcutt procedure. Model 5 was estimated using the OLS procedure. The statistical results of both models were similar. The coefficients for the supply ratios were significant at the 99 percent confidence level except one; the price difference between 13 percent protein spring wheat and 12 percent protein winter wheat (i.e., S13W12) in model 5 was significant at the 95 percent confidence level. Model 1 had better Theil U statistics when ordinary protein winter wheat was used in determining the dependent variable. Model 5 had better Theil U statistics when 12 percent protein winter wheat was used in determining the dependent variable.

Model 6 was similar to model 5 except that an export demand variable was added to determine the effect it had on the forecast results. The export demand variable used was the Canadian-United States exchange rate (i.e., CAUSEXR). Model 6 was estimated

using the OLS procedure. The coefficient for the supply ratio (i.e., NASHWRATIO) in model 6 was significant at the 99 percent confidence level for all price differences. The coefficient for the export demand variable was significant at the 90 percent confidence level for two price differences; the price difference between 13 percent protein spring wheat and ordinary protein winter wheat (i.e., S13WORD) and 13 percent protein spring wheat and 12 percent protein winter wheat (i.e., S13W12). The export demand coefficients for the two other price differences were not significant. While these results suggest the Canadian-United States exchange rate is not as important as the supply of wheat, the exchange rate did slightly improve the Theil U statistics when compared to model 5. The Theil U statistics improved from a range between 0.28 and 0.72 in model 5 to a range between 0.23 and 0.63 in model 6.

Model 2 was similar to model 1 except that a trend variable (i.e., TREND) was added to determine what affect time had on the forecast results. The coefficients for two price differences, the price differences using 13 percent protein spring wheat to determine the dependent variables, were estimated using the OLS procedure and the coefficients for the other two price differences were estimated using the Cochrane-Orcutt procedure. The coefficient for the trend variable was significant at the 99 percent confidence level for the price difference between 13 percent protein spring wheat and ordinary protein winter wheat (i.e., S13WORD). The other price differences were significant at the 95 percent confidence level. Although the time trend was significant, only one Theil U statistic improved, the price difference between 13 percent protein spring wheat and 12 percent protein winter wheat (i.e., S13W12). The other Theil U statistics did not change or became worse.

Model 3 was similar to model 1 except that an export demand variable was added to determine the effect it had on the forecast results. The export demand variable used was the ratio of the United States hard red spring wheat exports to the United States hard red winter wheat exports (i.e., EXRATIO). Model 3 was estimated using the Cochrane-Orcutt procedure. The coefficient for the supply ratio (i.e., HSHWRATIO) in model 3 was significant at the 99 percent confidence level for all price differences. The coefficient for the export demand ratio was significant at the 90 percent confidence level for only one price difference, the price difference between 13 percent protein spring wheat and 12 percent protein winter wheat (i.e., S13W12). The export demand coefficient for the other price differences had t-statistics greater than one. While these results suggest export demand is not as important as the supply of wheat, export demand did improve the Theil U statistics when compared to model 1. The Theil U statistics improved from a range between 0.34 and 0.71 in model 1 to a range between 0.08 and 0.54 in model 3. For example, the results from model 3 show the price difference between 13 percent protein spring wheat and 12 percent protein winter wheat are affected in two ways. First, a one percent increase in the supply ratio decreases the price difference by 2.6940 cents per bushel. Second, a one percent increase in the export demand ratio increases the price difference by 0.7087 cents per bushel.

Model 4 was similar to model 3 except that a demand variable was added to determine the affect it had on the forecast results. The demand variable used was the ratio of North Dakota average spring wheat protein to Kansas average winter wheat protein (i.e., PRRATIO). Model 4 was estimated using the Cochrane-Orcutt procedure. The coefficient for the supply ratio (i.e., HSHWRATIO) in model 4 was significant at the

99 percent confidence level for all price differences. The coefficient for the export demand ratio (i.e., EXRATIO) in model 4 was significant at the 90 percent confidence level for two price differences, the price difference between 13 percent protein spring wheat and ordinary protein winter wheat (i.e., S13WORD) and 13 percent protein spring wheat and 12 percent protein winter wheat (i.e., S13W12). The coefficient for the export demand ratio for the other two price differences had t-statistics greater than one. The coefficient for the demand ratio was not significant and had the wrong sign. The Theil U statistic improved when compared to model 3 for two price differences, the price difference between 13 percent protein spring wheat and ordinary protein winter wheat (i.e., S13WORD) and 13 percent protein spring wheat and 12 percent protein winter wheat (i.e., S13W12). The Theil U statistic did not improve for the other two price differences. These results suggest the average protein content of both wheat classes may not affect price differences.

CHAPTER 6

SUMMARY AND CONCLUSION

The purpose of this study was to evaluate the factors influencing protein premiums and price differences of hard red spring and hard red winter wheat in the Pacific Northwest market. These factors were incorporated into econometric models that forecast protein premiums and price differences. The models were developed from two different hypotheses of how protein premiums and price differences are determined. The results were compared to determine which factors provided the best forecast model.

The models used to forecast the protein premium in both hard wheat classes based on hypothesis I did not produce good statistical results. All coefficients had the wrong signs.

The models used to forecast the protein premium in the hard red spring wheat class based on hypothesis II generally produced good statistical results. Supply factors provided the best indicators showing the relative supply of high and low protein wheat. The cumulative affect of three supply factors; hard red spring wheat supply, hard red winter wheat supply and Canadian wheat supply; provided the best forecast of the protein premium. The Theil U statistics indicated that the models developed forecast protein premiums better than a naive forecast.

The models used to forecast the protein premium in the hard red winter wheat class based on hypothesis II suggested similar results, but they did not produce good statistical results. The Theil U statistics indicated that these models did not forecast protein premiums better than a naive forecast.

These results indicate that protein premiums are not determined by hypothesis I, using quantity weighted estimates of protein supply. These results suggest that hard wheat protein premiums may be determined by using existing data in combinations that indicate the relative supply and demand between wheat with different protein contents.

The models used to forecast price differences between the two hard wheat classes based on hypothesis II generally produced good statistical results. Supply factors, indicating relative supply of both wheat classes, provided the best indicators that determine price differences. Export demand factors, indicating relative export demand of both wheat classes, provided some additional help determining price differences. The average crop protein levels had little affect and may not affect price differences. The Theil U statistics indicated that the models developed forecast price differences better than a naive forecast. These results suggest that price differences are determined by relative supply and demand of the two wheat classes.

Supply and demand data for wheat with different protein contents within a class is not currently available. This lack of information makes forecasting protein premiums difficult. The models developed in this study offer several methods to forecast protein premiums in both hard wheat classes. These models may provide individuals and organizations involved in the Pacific Northwest wheat market additional information about protein premiums. If organizations involved in the wheat market feel that more detailed

data collection of individual wheat classes is beneficial, this data could be used to develop a more accurate and useful forecast model of protein premiums.

Supply and demand data for individual hard wheat classes is currently available. The models developed in this study offer several methods to forecast price differences between the hard red spring and hard red winter wheat class. These models may provide individuals and organizations involved in the Pacific Northwest wheat market additional information about price differences between these two wheat classes.

APPENDIX

Table 7. Dependent Variables Used in the Models.

Variable	Variable description	Units
<u>Prices</u>		
HRS13 ^a	Average market year price for hard red spring wheat (13 percent protein)	¢/bu
HRWORD ^a	Average market year price for hard red winter wheat (ordinary protein)	¢/bu
<u>Protein premiums</u>		
S14S13 ^{ab}	Price difference between hard red spring wheat (14 percent protein) and hard red spring wheat (13 percent protein)	¢/bu
W12WORD ^{ab}	Price difference between hard red winter wheat (12 percent protein) and hard red winter wheat (ordinary protein)	¢/bu
<u>Price differences</u>		
S14WORD ^c	Price difference between hard red spring wheat (14 percent protein) and hard red winter wheat (ordinary protein)	¢/bu
S14W12 ^c	Price difference between hard red spring wheat (14 percent protein) and hard red winter wheat (12 percent protein)	¢/bu
S13WORD ^c	Price difference between hard red spring wheat (13 percent protein) and hard red winter wheat (ordinary protein)	¢/bu
S13W12 ^c	Price difference between hard red spring wheat (13 percent protein) and hard red winter wheat (12 percent protein)	¢/bu

^a Dependent variables used in models to test protein premiums based on hypothesis I.

^b Dependent variables used in models to test protein premiums based on hypothesis II.

^c Dependent variables used in models to test price differences based on hypothesis II.

Table 8. Independent Variables Used in the Models.

Variables	Variable description	Units
<u>Supply factors</u>		
HSPROD ^b	U.S. hard red spring wheat production	mil bu
HSCAR ^b	U.S. hard red spring wheat carry-over stocks	mil bu
HSSUP ^b	U.S. hard red spring wheat supply (HSPROD+HSCAR)	mil bu
HWPROD ^b	U.S. hard red winter wheat production	mil bu
HWCAR ^b	U.S. hard red winter wheat carry-over stocks	mil bu
HWSUP ^b	U.S. hard red winter wheat supply (HWPROD+HWCAR)	mil bu
CPROD ^b	Canadian wheat production	mil bu
CCAR ^b	Canadian wheat carry-over stocks	mil bu
CSUP ^b	Canadian wheat supply (CPROD+CCAR)	mil bu
NASSUP ₁	North American spring wheat supply (HSSUP+CSUP)	mil bu
USTSUP ^b	U.S. total wheat supply (HSSUP+HWSUP)	mil bu
NATSUP ^b	North American total wheat supply (HSSUP+HWSUP+CSUP)	mil bu
PRODRATIO ^b	Hard red spring production to hard red winter production (HSPROD/HWPROD)	--
CARRATIO ^b	Hard red spring carry-over stocks to hard red winter carry-over stocks (HSCAR/HWCAR)	--
HSHWRATIO ^{bc}	Hard red spring supply to hard red winter supply (HSSUP/HWSUP)	--
NASHWRATIO ^{bc}	North American spring supply to hard red winter supply (NASSUP/HWSUP)	--

Table 8, continued.

Variables	Variable description	Units
<u>Demand factors</u>		
NDPR ^b	North Dakota average spring wheat protein content	%
KSPR ^b	Kansas average winter wheat protein content	%
PRRATIO ^c	North Dakota average protein to Kansas average protein (NDPR/KSPR)	--
EXRATIO ^c	U.S. hard red spring exports to U.S. hard red winter exports	--
CAUSEXR ^{bc}	Canadian-U.S. exchange rate	--
<u>Supply and demand factors</u>		
STKUSE ^a	Stocks-to-use ratio	--
<u>Protein supply factors</u>		
HSPRSUP ^a	Hard red spring wheat protein supply	mil lbs
HWPRSUP ^a	Hard red winter wheat protein supply	mil lbs
TPRSUP ^a	Total protein supply (HSPRSUP+HWPRSUP)	mil lbs
<u>Protein supply and demand factors</u>		
HSPRSTKUSE ^a	Hard red spring wheat protein stocks-to-use ratio	--
HWPRSTKUSE ^a	Hard red winter wheat protein stocks-to-use ratio	--
TPRSTKUSE ^a	total hard wheat stocks-to-use ratio	--
<u>Prices</u>		
LNRATE ^a	U.S. wheat loan rate	¢/bu
HRS13 ^a	Average market year price of hard red spring wheat (13 percent protein)	¢/bu
HRWORD ^b	Average market year price of hard red winter wheat (ordinary protein)	¢/bu
<u>Other factors</u>		
TREND ^{bc}	Time trend	--

^a Independent variables used in models to test protein premiums based on hypothesis I.

^b Independent variables used in models to test protein premiums based on hypothesis II.

^c Independent variables used in models to test price differences based on hypothesis II.

Table 9. Formulas Used to Generate the Protein Balance Table Data.

<u>Base year values</u>	
HSPRSUP	=HSSUP*NDPR*.6
HSPRCAR	=HSPRSUP - [(HSDOM + HSEXP)*NDPR*.6]
HWPRSUP	=HWSUP*KSPR*.6
HWPRCAR	=HWPRSUP - [(HWDOM + HWEXP)*KSPR*.6]
<u>Data series</u>	
HSPRCAR	=[(HSPROD*NDPR*.6) + HSPRCAR _{t-1}] - [(HSDOM + HSEXP)*NDPR*.6]
HSPRSUP	=(HSPROD*NDPR*.6) + HSPRCAR _{t-1}
HSPRUSE	=(HSDOM + HSEXP)*NDPR*.6
HSPRSTKUSE	=HSPRCAR/HSPRUSE
HWPRCAR	=[(HWPROD*KSPR*.6) + HWPRCAR _{t-1}] - [(HWDOM + HWEXP)*KSPR*.6]
HWPRSUP	=(HWPROD*KSPR*.6) + HWPRCAR _{t-1}
HWPRUSE	=(HWDOM + HWEXP)*KSPR*.6
HWPRSTKUSE	=HWPRCAR/HWPRUSE
TPRSUP	=HSPRSUP + HWPRSUP
TPRSTKUSE	=(HSPRCAR + HWPRCAR)/(HSPRUSE + HWPRUSE)

Note: A description of the variables used can be found in Table 8 except for HSDOM, HSEXP, HWDOM and HWEXP. HSDOM is defined as the United States hard red spring wheat domestic use. HSEXP is defined as total United States hard red spring wheat exports. Similarly, HWDOM and HWEXP is defined for United States hard red winter wheat. These variables are measured in million bushels.

Table 10. Model Results for the Low Protein Wheat and Wheat Protein Price in the Hard Red Spring Wheat Class (t-statistics in parentheses).

Independent variable	Dependent variable				
	HRS13	Model 1 S14S13	Model 2 S14S13	Model 3 S14S13	Model 4 S14S13
Constant	208.46 [‡] (4.71)	-10.16 (-1.34)	10.93 [†] (2.74)	-17.90 [*] (-1.79)	7.71 (1.60)
HRS13 _{t-1}	0.51 [‡] (3.91)	--	--	--	--
STKUSE	-2.83 [‡] (-4.55)	--	--	--	--
LNRATE	0.53 [†] (2.58)	--	--	--	--
HSPRSUP	--	0.0056 [‡] (3.37)	--	--	--
HSPRSTKUSE	--	--	7.83 (1.21)	--	--
TPRSUP	--	--	--	0.0021 [‡] (3.26)	--
TPRSTKUSE	--	--	--	--	12.74 (1.67)
<u>Statistical results</u>					
rho	--	0.50 [†] (2.76)	0.50 [†] (2.81)	0.46 [†] (2.46)	0.51 [†] (2.80)
DW	1.65	1.47	1.60	1.72	1.63
adj R ²	0.78	0.49	0.28	0.47	0.32
RMSE	77.78	11.47	17.35	11.36	18.01
Theil U	0.77	0.66	1.00	0.66	1.04
Correct direction ^a	75%	50%	25%	75%	50%

Note: A description of the dependent variables used can be found in Table 7 and a description of the independent variables used can be found in Table 8.

^a Percentage of correct directional forecasts.

^{*} Statistically significant at the 90 percent confidence level.

[†] Statistically significant at the 95 percent confidence level.

[‡] Statistically significant at the 99 percent confidence level.

Table 11. Model Results for the Low Protein Wheat and Wheat Protein Price in the Hard Red Winter Wheat Class (t-statistics in parentheses).

Independent variable	Dependent variable				
	HRWORD	Model 1 W12WORD	Model 2 W12WORD	Model 3 W12WORD	Model 4 W12WORD
Constant	203.89 [‡] (5.04)	-1.44 (-0.13)	8.69* (1.72)	4.01 (0.35)	8.61* (1.84)
HRWORD _{t-1}	0.45 [†] (3.48)	--	--	--	--
STKUSE	-2.76 [‡] (-4.82)	--	--	--	--
LNRATE	0.56 [†] (2.91)	--	--	--	--
HWPRSUP	--	0.0013 (1.19)	--	--	--
HWPRSTKUSE	--	--	5.66 (0.77)	--	--
TPRSUP	--	--	--	0.00052 (0.69)	--
TPRSTKUSE	--	--	--	--	6.61 (0.90)
<u>Statistical results</u>					
rho	--	0.47 [†] (2.22)	0.52 [†] (2.68)	0.50 [†] (2.38)	0.52 [†] (2.63)
DW	1.70	2.06	2.13	2.08	2.12
adj R ²	0.80	0.28	0.26	0.26	0.27
RMSE	61.44	7.20	5.50	6.93	5.32
Theil U	0.69	3.14	2.40	3.02	2.32
Correct direction ^a	75%	50%	50%	50%	50%

Note: A description of the dependent variables used can be found in Table 7 and a description of the independent variables used can be found in Table 8.

^a Percentage of correct directional forecasts.

* Statistically significant at the 90 percent confidence level.

† Statistically significant at the 95 percent confidence level.

‡ Statistically significant at the 99 percent confidence level.

Table 12. Model Results for the Protein Premium in the Hard Red Spring Wheat Class (t-statistics in parentheses).

Independent variable	Dependent variable				
	<u>Model 1</u> S14S13	<u>Model 2</u> S14S13	<u>Model 3</u> S14S13	<u>Model 4</u> S14S13	<u>Model 5</u> S14S13
Constant	-12.26 (-1.38)	-18.36* (-1.84)	-30.80† (-2.57)	-18.70 (-1.45)	-13.17 (-1.11)
HSSUP	0.041‡ (3.11)	--	--	--	--
USTSUP	--	0.015‡ (3.32)	--	--	--
NATSUP	--	--	0.014‡ (3.82)	--	--
NASSUP	--	--	--	0.026‡ (3.77)	--
NASHWRATIO	--	--	--	-10.03 (-1.20)	--
HSPROD	--	--	--	--	0.0033 (0.30)
HSCAR	--	--	--	--	0.022 (1.52)
HWPROD	--	--	--	--	0.027 (1.44)
HWCAR	--	--	--	--	0.011 (0.40)
<u>Statistical results</u>					
rho	0.54‡ (3.03)	0.48† (2.59)	0.56‡ (3.20)	0.59‡ (3.35)	0.51† (2.36)
DW	1.46	1.69	1.62	1.53	1.53
adj R ²	0.46	0.48	0.53	0.52	0.45
RMSE	12.11	11.04	10.22	10.91	11.59
Theil U	0.70	0.64	0.59	0.63	0.67
Correct direction ^a	50%	75%	75%	75%	50%

Note: A description of the dependent variables used can be found in Table 2 and a description of the independent variables used can be found in Table 3.

^a Percentage of correct directional forecasts.

* Statistically significant at the 90 percent confidence level.

† Statistically significant at the 95 percent confidence level.

‡ Statistically significant at the 99 percent confidence level.

Table 13. Model Results for the Protein Premium in the Hard Red Winter Wheat Class (t-statistics in parentheses).

Independent variable	Dependent variable				
	Model 1 W12WORD	Model 2 W12WORD	Model 3 W12WORD	Model 4 W12WORD	Model 5 W12WORD
Constant	0.20 (0.02)	5.17 (0.45)	8.64 (0.61)	11.86 (0.86)	31.32 (0.89)
HWSUP	0.0079 (1.13)	--	--	0.0086 (1.14)	0.0051 (0.66)
USTSUP	--	0.0031 (0.59)	--	--	--
NATSUP	--	--	0.00093 (0.22)	--	--
HSHWRATIO _{t-1}	--	--	--	-29.44 (-1.18)	--
KSPR _{t-1}	--	--	--	--	-2.24 (-0.84)
<u>Statistical results</u>					
rho	0.46 [†] (2.07)	0.51 [†] (2.35)	0.55 [†] (2.74)	0.43 [*] (1.75)	0.47 [*] (1.99)
DW	2.08	2.09	2.12	2.07	2.04
adj R ²	0.28	0.26	0.25	0.26	0.24
RMSE	7.33	7.26	6.53	5.85	6.64
Theil U	3.20	3.17	2.85	2.55	2.90
Correct direction ^a	50%	50%	50%	50%	50%

Note: A description of the dependent variable used can be found in Table 2 and a description of the independent variables used can be found in Table 3.

^a Percentage of correct directional forecasts.

^{*} Statistically significant at the 90 percent confidence level.

[†] Statistically significant at the 95 percent confidence level.

[‡] Statistically significant at the 99 percent confidence level.

Table 14. Model Results for the Price Difference between the Hard Red Spring and Hard Red Winter Wheat Classes (t-statistics in parentheses).

Independent variable	Model 1			
	Dependent variable			
	S13WORD	S13W12	S14WORD	S14W12
Constant	115.79 [‡] (5.07)	89.11 [‡] (4.86)	132.84 [‡] (5.78)	111.91 [‡] (6.23)
HSHWRATIO	-201.39 [‡] (-3.93)	-166.51 [‡] (-4.01)	-206.91 [‡] (-4.25)	-183.92 [‡] (-4.97)
<u>Statistical results</u>				
rho	0.47 [†] (2.57)	0.43 [†] (2.15)	0.63 [‡] (4.10)	0.67 [‡] (4.46)
DW	1.94	1.75	2.08	1.78
adj R ²	0.36	0.29	0.48	0.48
RMSE	22.48	22.96	11.43	8.54
Theil U	0.71	0.71	0.45	0.34
Correct direction ^a	100%	100%	100%	100%
Independent variable	Model 2			
	Dependent variable			
	S13WORD	S13W12	S14WORD	S14W12
Constant	109.12 [‡] (5.47)	76.33 [‡] (4.76)	118.32 [‡] (5.71)	93.85 [‡] (5.97)
HSHWRATIO	-245.79 [‡] (-4.22)	-176.85 [‡] (-3.78)	-241.57 [‡] (-4.51)	-202.72 [‡] (-5.07)
TREND	1.64 [‡] (2.84)	1.10 [†] (2.37)	1.83 [†] (2.26)	1.58 [†] (2.53)
<u>Statistical results</u>				
rho	--	--	0.40 [*] (1.99)	0.42 [†] (2.16)
DW	1.41	1.45	1.93	1.68
adj R ²	0.38	0.32	0.52	0.53
RMSE	25.37	21.07	18.74	8.44
Theil U	0.80	0.65	0.75	0.34
Correct direction ^a	100%	100%	100%	100%

Table 14, continued.

Independent variable	Model 3			
	Dependent variable			
	S13WORD	S13W12	S14WORD	S14W12
Constant	136.33 [‡] (5.42)	107.50 [‡] (5.39)	148.08 [‡] (5.95)	124.24 [‡] (6.53)
HSHWRATIO	-313.95 [‡] (-3.71)	-269.40 [‡] (-3.94)	-297.95 [‡] (-3.80)	-259.68 [‡] (-4.42)
EXRATIO	76.49 (1.55)	70.87* (1.77)	64.90 (1.41)	54.49 (1.58)
<u>Statistical results</u>				
rho	0.53 [‡] (2.97)	0.46 [†] (2.30)	0.67 [‡] (4.45)	0.70 [‡] (4.72)
DW	2.02	1.82	2.15	1.84
adj R ²	0.39	0.35	0.50	0.51
RMSE	15.25	17.47	4.29	2.11
Theil U	0.48	0.54	0.17	0.08
Correct direction ^a	100%	100%	100%	100%
Independent variable	Model 4			
	Dependent variable			
	S13WORD	S13W12	S14WORD	S14W12
Constant	245.78 [‡] (2.95)	169.94 [†] (2.46)	234.30 [‡] (2.96)	167.31 [†] (2.76)
HSHWRATIO	-380.58 [‡] (-4.18)	-308.62 [‡] (-4.10)	-346.47 [‡] (-4.03)	-283.29 [‡] (-4.29)
EXRATIO	93.97* (1.92)	78.27* (1.93)	78.35 (1.69)	60.50 (1.70)
PRRATIO	-70.92 (-1.32)	-39.21 (-0.88)	-57.23 (-1.13)	-28.55 (-0.73)
<u>Statistical results</u>				
rho	0.63 [‡] (3.74)	0.55 [‡] (2.85)	0.72 [‡] (4.96)	0.72 [‡] (4.94)
DW	1.99	1.81	2.15	1.89
adj R ²	0.40	0.34	0.50	0.50
RMSE	12.23	16.31	8.48	4.55
Theil U	0.39	0.50	0.34	0.18
Correct direction ^a	100%	100%	100%	100%

Table 14, continued.

Independent variable	Model 5			
	Dependent variable			
	S13WORD	S13W12	S14WORD	S14W12
Constant	98.06 [‡] (4.92)	57.95 [‡] (3.44)	131.52 [‡] (7.03)	91.41 [‡] (5.87)
NASHWRATIO	-56.31 [‡] (-3.48)	-32.85 [†] (-2.40)	-72.86 [‡] (-4.80)	-49.40 [‡] (-3.91)
<u>Statistical results</u>				
DW	1.57	1.66	1.55	1.41
adj R ²	0.30	0.16	0.46	0.35
RMSE	22.86	19.12	14.32	7.06
Theil U	0.72	0.59	0.57	0.28
Correct direction ^a	100%	100%	100%	100%
Independent variable	Model 6			
	Dependent variable			
	S13WORD	S13W12	S14WORD	S14W12
Constant	183.78 [‡] (3.70)	135.40 [‡] (3.27)	167.56 [‡] (3.42)	119.18 [‡] (2.93)
NASHWRATIO	-72.19 [‡] (-3.86)	-47.62 [‡] (3.04)	-82.58 [‡] (-4.47)	-58.01 [‡] (-3.79)
CAUSEXR	-58.52 [*] (-1.81)	-52.52 [*] (-1.95)	-21.57 (-0.68)	-15.57 (-0.59)
<u>Statistical results</u>				
DW	1.64	1.67	1.56	1.36
adj R ²	0.35	0.25	0.44	0.35
RMSE	19.82	17.31	13.03	5.63
Theil U	0.63	0.53	0.52	0.23
Correct direction ^a	100%	100%	100%	100%

Note: A description of the dependent variables used can be found in Table 7 and a description of the independent variables used can be found in Table 8.

^a Percentage of correct directional forecasts.

^{*} Statistically significant at the 90 percent confidence level.

[†] Statistically significant at the 95 percent confidence level.

[‡] Statistically significant at the 99 percent confidence level.

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