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Working Paper Series

FSWP2001-5

Evaluating the U.S. Wheat Protein Complex

by

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May 22, 2001

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Evaluating the Wheat Protein Complex

Abstract

In this paper, we modeled the economic linkages between a commodity (wheat gluten) and a commodity characteristic (wheat protein). The purpose of this research was to address several issues in the wheat protein complex including the impact of the U.S. gluten import quota on producer protein premiums. Four important conclusions were found. First, the hard red winter (HRW) protein market strongly influenced wheat gluten market but the wheat gluten market had its greatest influence on the hard red spring (HRS) protein market. Second, the demand for intrinsic protein was estimated to be very elastic. Thus, the returns to breeding or biotechnology programs designed to raise protein levels of wheat are likely to remain stable in response to small increases in wheat protein content. Third, the U.S. import quota on wheat gluten was estimated to provide a 14% increase in the price of wheat gluten in the first year. By the third year, prices will be only 5% above the pre-quota price. U.S. gluten supplies will increase about 15% in the first year and remain at about that level for the next two years. Although these are small estimated impacts, they are not far from what the USITC had anticipated. Finally, the 3-year quota increased protein premiums and provided about \$500 (\$1000) in additional revenue for an average 1000 acre farm producing HRW (HRS) wheat.

Introduction

The U.S. wheat protein complex is defined as the markets for vital wheat gluten and intrinsic wheat protein. Wheat gluten consists of approximately 75-80 percent protein. For every pound of gluten produced, the wet-milling process also produces about 4 pounds of wheat starch. Gluten is used primarily as a food additive serving to enhance the nutritional value, texture, and taste of baked foods or to fortify the protein content of hard wheat flour.¹ For some end uses, there is no substitute input. Gluten's only substitute is intrinsic hard wheat protein, which varies in supply based principally on the types of wheat varieties planted and weather factors late in the growing season.

¹ Hard wheats are used in bread and hard roll type products which require high protein contents. Soft wheats and durum wheat are generally not used in products requiring high protein.

Hard wheat protein value depends on its scarcity, which is defined as a shadow value on the protein constraint of an aggregate cost minimization problem for the milling and baking industries. Indeed, there are crop years in which the intrinsic protein content is high enough to drive the value of protein to zero and in other years in which 30-40% of the value of high protein wheat is derived simply by the added value of scarce protein.

The purpose of the present study is to evaluate and quantify the economic linkages between the wheat gluten and wheat protein. No previous research has looked at this two-way economic relationship.² There are two key reasons why this research is important. First, an improved understanding of protein price sensitivity is needed. This is a critical gap in the literature given the focus of breeding programs worldwide to raise protein levels in wheat varieties. If protein premiums were to drop precipitously because of higher and, therefore, less binding levels of intrinsic protein, then the long run returns to investing in high protein varieties will be much smaller than commonly perceived.

Second, in recent years, the global wheat gluten market has become a political battleground between the U.S. and E.U. The U.S. claims E.U. food starch subsidies provide incentives to increase gluten production which, in turn, act to lower the world gluten price. In response to these claims, the U.S. implemented a three year import quota beginning June 1, 1998 with binding limits on E.U. imports. The U.S. gluten import quota excludes NAFTA trade flows but obviously limits transshipments of gluten

² Although gluten represents a very small percentage of total wheat processed in the U.S. (3/10th of one percent in the 1996/1997 crop year [International Wheat Council]); at least anecdotally, the gluten market seems poised to influence wheat protein markets. Of the total wheat processed in 1996/1997, only 62% was hard wheat, and even the lowest protein hard wheat contains 10% protein (Kansas Department of Agriculture). Gluten inputs represent 9% of the amount of protein in the market above a 10% base content present in all hard wheat.

into the U.S. through Canada and Mexico. Because of strict wheat product quotas in Canada, and Mexico's noninvolvement in gluten markets, the U.S. quota is essentially a NAFTA region quota. Although the political debate remains uncertain, but the linkages to E.U. policies and wheat protein markets were in the political dialogue leading up to the U.S. quota and are likely to be raised again.^{3,4}

Although both U.S. and E.U. processors compete for wheat gluten buyers in world markets, the same does not hold true for wheat starch markets. Domestic E.U. starch processors are protected from foreign competition through a combination of starch import levies and production and export subsidies. These policies act to raise the E.U.'s domestic starch price above the world price, which gives the E.U. firms incentives to produce more starch and subsequently gluten (Balzer and Stiegert).

Protein premiums have the potential to be truncated when gluten is readily available as a protein supplement. Extra supplies and lower prices of gluten emanating from E.U. starch policies could provide U.S. millers and bakers an incentive to combine gluten with lower protein wheats to meet demand for baked goods that require higher levels of protein. If gluten markets influence the protein premium market, then the issue of European market intervention has far wider effects than simply lowering the capital returns to the starch-gluten industry. Indeed, lower intrinsic protein premiums imply

³ In 1997, Frey quoted forcefully then Kansas Wheat Commission Chairman Bunck as stating "with E.U. subsidized gluten, opportunities for wheat producers to benefit from premiums paid for high protein wheat is increasingly in danger not only in the United States and Canada, but in many overseas markets."

⁴ In August of 2000, the E.U. won a WTO ruling against the quota that was partially rescinded in the appeals process (Milling and Baking News). Time extensions of the quota are possible, but the E.U. has threatened to impose import quotas on corn gluten as a retaliatory measure.

lower producer incomes, lower returns to wheat breeding programs, and increased costs of government farm programs.

Wheat markets recognize protein's value through a pricing structure for different grades of wheat at various protein minimums; thus, time series data is readily available to quantify the value of intrinsic wheat protein. Although many studies have evaluated the marginal contributions (i.e., hedonic price models) from protein and other characteristics (see Parcell and Stiegert for a summary), only a few have examined the competitive structure of wheat protein markets. Bale and Ryan first examined the market for hard red winter (HRW) and hard red spring (HRS) protein premiums in U.S. wheat markets. Using 1965-1974 annual time series data, they found that spring wheat supply and the proportion of high protein to low protein spring wheat were consistently important in explaining various HRS/HRW price ratios.

Wilson evaluated real premiums for high protein U.S. winter and spring wheats in domestic and international markets. Although Wilson's results varied at different market locations, several key insights were obtained. In seven of twelve models, HRW protein content had a significant impact on either a HRW and HRS price. In only two of twelve models did the protein content of HRS wheat explain a price series.

Using a hedonic model of regional competition, Parcell and Stiegert modeled the competition for wheat protein at country elevators in the U.S. northern and southern Plains. They found that protein quantity in each region had a statistically significant role in determining the prices of wheat paid to farmers in the other region. Their results indicated that HRW protein content was nearly twice as influential on the HRS price than the marginal impact of HRS protein content on HRW prices.

Ortalo-Magne and Goodwin estimated a single equation import demand model for the U.S. wheat gluten market. They found import demand was inelastic and wheat protein premiums were statistically significant in determining U.S. gluten imports. However, the question of gluten market influence on wheat protein markets was not addressed.

Conceptual Framework

To establish the appropriate linkages in the U.S. wheat protein complex, a partial equilibrium system of wheat gluten and wheat protein premium supply, demand and import equations were used. Table 1 contains definitions for the variables used in this study. The import demand (ID) for wheat gluten is given by:

$$ID_g \equiv D_g - S_g, \quad (1)$$

where D_g is domestic gluten demand and S_g is domestic gluten supply. Gluten demand is given by the following specification:

$$D_g = a_0 + a_1 * D_{g(t-1)} + a_2 * P_g + a_3 * P_f + a_4 * phrs + a_5 * phrw \quad (2)$$

where $D_{g(t-1)}$ is lagged quantity demanded, P_g is the real price of gluten, P_f is the real price of flour, $phrs$ is the price of 15.5% HRS divided by the price of 13.5 HRS, and $phrw$ is the price of 13.5% HRW divided by the price of 11.5% HRW wheat. The supply equation for gluten is given by:

$$S_g = b_0 + b_1 * S_{g(t-1)} + b_2 * P_g + b_3 * P_f, \quad (3)$$

where $S_{g(t-1)}$ is lagged quantity supplied. Lagged supply and demand quantities are introduced because wheat gluten is a storable commodity, significant lags often are

associated with international trade in basic commodities, and because reactions to market factors at the consumer and production levels takes time (Tomek and Robinson).

The price ratio terms (phrs and phrw) are an important mechanism in the overall scheme of this model. In most years, the vast majority of HRW wheat will contain 11%-14% protein while the HRS wheat crop will contain 12%-16% protein.⁵ Most high scale bread production processes require 11.5%-13.5% protein, which closely coincides with the overlap in protein content of the two hard wheat classes (Pyler). Thus, protein premiums are determined principally by the scarcity of wheat in the overlapping protein range.⁶ The HRW price ratio has in the denominator a base price for low protein wheat, which usually is not associated with a protein premium. We consider this a reference point for protein premiums at higher levels. The demand for wheat gluten is expected to increase as the HRW protein premium ratio rises. There is no a priori expectation regarding the price ratio of HRS wheat on gluten demand because both the numerator and denominator reflect different protein scarcity possibilities. In particular, the HRS protein premium ratio could change due to changes in the supply of the very highest protein wheat or because of changes in the supply of wheat in its lower protein range. The phrs term was included to capture any possible trends in gluten prices that might be explained from the HRS market.

⁵ From 1987-1996, only 6.8% of the wheat in Kansas contained protein levels outside the 11%-14% range. With the exception of 1992, over 90% of the HRS wheat produced in all of the crop years from 1987-1996 contained protein in the 12%-16% range.

⁶ Highest protein HRS wheat are commonly used for specialty bread products while the lowest protein HRW will either be fortified with gluten, blended with higher protein wheat, or used for noodle and/or flat bread products that require low protein levels (Stiegert and Blanc).

Substituting equation 2 and 3 into 1 and solving for the real price of wheat gluten yields:

$$P_g = \left(\frac{1}{a_2 - b_2} \right) * \left(b_0 - a_0 + ID_g - a_1 * D_{g(t-1)} + b_1 * S_{g(t-1)} + (b_3 - a_3) * P_f \right) - a_4 * phrs - a_5 * phrw \quad (4)$$

Equation 4 was used to evaluate the effects of gluten imports on U.S. wheat gluten prices.

Up to this point, only the impacts of protein premiums on the gluten market have been modeled. To model the impacts of gluten quantities on protein premiums, four additional equations capturing the supply and demand relationships in the protein markets would typically be required. However, because wheat protein arrives to the market based primarily on weather conditions late in the growing season, protein supply is assumed to be exogenous.⁷ The inverse demand equations for intrinsic protein premiums are given by:

$$phrw = c_0 + c_1 * qhrw + c_2 * qhrs + c_3 * qws + c_4 * D_g \quad (5)$$

$$phrs = d_0 + d_1 * qhrs + d_2 * qhrw + d_3 * qws + d_4 * D_g \quad (6)$$

The term qhrw is a quantity ratio of high protein (wheat containing 12% protein or higher) HRW over the quantity of low protein (below 12%) HRW wheat harvested. Although the 12% break-point between high and low protein HRW wheat was simply driven by data availability, it is also a reasonable middle point of the HRW protein profile. Similarly, the term qhrs is defined as a high protein to low protein quantity ratio, but with a break-point of 14% protein. The coefficients c1 and d1 represent inverse

⁷ In the long run, wheat-breeding programs play an important role in determining specific wheat protein characteristics. Through extensive breeding practices, protein characteristics can be bred into many

demand slopes for wheat protein price ratios. They will be used to calculate flexibility measures to determine how responsive protein premiums are to changes in the protein quantity profile.

The variable qws represents the ratio of the HRW production to HRS production. HRW wheat production accounts for over 2/3rds of total hard wheat production. Thus, the economics of wheat protein and gluten markets are usually more influenced by the size and protein profile of the HRW wheat crop. When the HRW wheat crop is large, *ceteris parabis*, then protein is simply less scarce because of the larger quantities of wheat in the 12-14% protein range. An increase in the qws ratio is expected to reduce the protein premium price ratio for HRW and increase the protein premium price ratio for HRS. The reason underlying this maintained hypothesis is quite simple. The price used as the numerator in the HRW price ratio is of the same protein content (13.5%) as the price of the denominator in the HRS price ratio. When HRW production increases, the supplies of wheat in the 12%-14% protein range become less scarce. Protein needs for the domestic baking industry are viewed as more adequate, and the protein premiums in the high protein ranges of the HRW market decline. This same scenario would put downward pressure on the protein premiums in the lower protein ranges of the HRS market which would raise the protein price ratio.⁸

As domestic demand for gluten increases, the value of protein in the 12-14% range is expected to decline. Thus, the HRW price ratio is expected to decline. Because

different wheat varieties. Regional climate conditions, yield potential, and market demand for specific wheat characteristics are all important considerations in the variety selection process.

⁸ Demand for the very highest protein HRS wheats is influenced partly by its value as a blending input; however, it also has a direct market as the major input for many value-added specialty bread and cereal products.

wheat gluten impacts the relative value of the lower protein HRS market, the HRS price ratio is expected to increase with higher gluten supplies.

Data and Econometric Issues

Summary statistics are reported in Table 2. Annual average data were collected from 1974 through 1997. U.S. production data were obtained from HRA INC. Imported gluten quantities and the value of shipments were obtained from the U.S. Department of Commerce. There was no domestic U.S. price series for wheat gluten available. Therefore, an implied gluten price was calculated using the quantity and value of shipment data from the U.S. Department of Commerce.⁹ Non-edible wheat gluten used for animal feed and other industrial purposes was not included in any of the quantity or price data.

An annual average Kansas City cash flour price was used based on standard flour milled from HRW. The protein availability data for Kansas HRW were collected from the Kansas Wheat Quality Report series (Kansas Department of Agriculture). These data were used to calculate the ratio of high protein wheat quantity to low protein wheat quantity for each year. Similarly, protein availability data for the North Dakota HRS wheat were collected from the Regional Hard Red Spring Wheat Quality Report series (North Dakota State University).

The protein price ratios were calculated from individual high and low protein price series' that were obtained from the Quarterly Wheat Outlook Report (Tierney).

⁹ Using the implied import price as a proxy for the domestic price is supported by the results of a questionnaire completed by U.S. end users of wheat gluten. U.S. domestic wheat gluten generally was rated comparable to the imported wheat gluten, and U.S. producers generally were considered to offer pricing that was comparable to that offered by importers (USITC 1998C, p 7).

Aggregate production data for the U.S. HRW and HRS wheat classes were collected from the Quarterly Wheat Outlook Report (Tierney). The U.S. index of producer prices for industrial goods was used to deflate all nominal prices (Bureau of Labor Statistics).

Equations 2-6 were estimated using three-stage least squares (3SLS) available in Shazam version 8.0 software. All exogenous variables were used as instruments. Import demand was modeled as an endogenous variable. Because the wheat protein and wheat gluten markets are quite small relative to the total wheat and wheat flour markets, flour prices and the wheat quantity ratios were considered as exogenous to the system.

Results

Model estimates are reported in Table 3 followed by elasticity and flexibility results in Table 4. All of the coefficients had the correct sign and most were statistically significant. The partial adjustment coefficients (a_1 and b_1) indicated gluten supply and demand adjustments took time to incorporate.¹⁰ The short-run demand elasticity, calculated at the mean of the data, was estimated at -0.3034 and was statistically significant. The long-run demand elasticity was estimated at -1.9277 and statistically significant. Gluten supplies are unitary price elastic in the short run (1.02) and very elastic in the long run (10.21). Apparently, gluten firms compete very aggressively in response to price changes.

The coefficients for the HRW and HRS protein price ratios on wheat gluten demand are positive and about the same in magnitude, but only the HRW coefficient was significant. Given that the HRW crop usually comprises more than 2/3rd of total hard

¹⁰ In a simulation exercise below, we used the dynamic adjustment process implied from parameters a_1 and b_1 to trace the full impact of the three year quota on gluten imports.

wheat production, it is reasonable that gluten demand was more responsive to independent price changes in the winter wheat market than to the spring wheat market. The elasticity results indicated that a 1% increase in the protein premium of either HRW or HRS wheat increased demand for gluten by 0.64% and 0.61%, respectively. This result is nearly identical to the estimate obtained by Ortalo-Magne and Goodwin for the impact of protein prices on import demand (0.61%). The result indicates that protein premiums have a major role in determining the demand for gluten.

The HRW and HRW protein premium equations provided important information about the market conditions for wheat protein. The parameters c_1 and d_1 measure the marginal relationship between protein price ratios and the own-quantity price ratios for the HRW and HRS markets, respectively. The results for c_1 and d_1 were nearly identical (-0.042 and -0.043, respectively) as were the subsequent flexibility estimates (-0.013 and -0.012, respectively). The flexibility measure indicated that a 10% increase in the either quantity ratio lowers the own price ratio by about 0.1%.¹¹

The results with respect to parameters c_1 and d_1 provided an important piece of information about the wheat protein market and addressed one of our two major objectives. In particular, protein premiums appear to be very stable across a wide range of quantity profiles and investment returns to wheat breeding programs that increase protein contents are not likely to deteriorate much. It is true that we observe tremendous volatility in the protein premium market. However, the underlying reason for this is simply that there is much more volatility in the protein quantity profile. Using the data

¹¹ The flexibility estimate from using a single price and single quantity ratios is the same as the flexibility using the price and quantity for high protein. Thus, a 10% increase in the quantity of high protein wheat leads to a .155% decrease in the price of high protein wheat *ceteris parabis*.

from this study, we note that a one-standard deviation increase from the mean in the price ratio for HRW wheat (see Table 2) generates a 5.2% increase in the price ratio. A one-standard deviation increase from the mean in HRW protein quantity generates a 192% increase in the quantity ratio.

The coefficient on the HRS protein quantity ratio (c_2) was positive and significant. When the spring crop maintains a high protein profile, this result suggests that there is scarcity of protein in the higher range of winter wheat protein. The coefficient on the production ratio (c_3) was negative and highly significant. This result is consistent with our maintained hypothesis that relative increases in the lower protein crop will reduce the scarcity of protein in the U.S. overall. A negative relationship was estimated for the effects of increased wheat gluten supplies on the HRW protein price ratio, but it was not statistically significant. Based on the flexibility results, a 10% increase in wheat gluten to the market will depress the HRW price ratio by 0.45%.

For the price-dependent HRS equation, the coefficient for the HRW quantity protein ratio (d_2) was negative and significant. The counterpart flexibility was estimated at -0.14% , which was considerably higher than the own-quantity ratio impact for HRS wheat. Apparently, the protein profile in the HRW region is a very important component in shaping the protein premiums in both regions, while the protein profile in the HRS region has its greatest impact only in its own region. These results are highly consistent with the findings in Parcell and Stiegert.

The coefficient on the production quantity ratio was positive and highly significant. The implication here is that greater relative supply of HRW wheat will lower the value of HRS wheat that is low protein thereby raising the protein ratio.

The coefficient on the gluten demand term was positive and significant. As gluten supplies rise, protein in the 12-14% range become relatively less scarce. The value of lower protein HRS wheat is reduced relative to the higher protein HRS wheat and the protein price ratio widens. The flexibility indicates that a 10% increase in gluten supplies will widen the protein price ratio by about 1%.

The flexibility calculations for the real price of wheat gluten (equation 4) from the HRS quantity protein ratio, HRW quantity protein ratio, and the production ratio (qws) all were negative, and the import demand and HRW quantity ratio were statistically significant. The short run import demand flexibility was -0.60 and statistically significant. The implied import demand elasticity is -1.66 , which is quite a bit higher than that estimated by Ortalo-Magne and Goodwin (-0.27). Ortalo-Magne and Goodwin support their result by citing an industry expert claiming “that the international market is not especially responsive to price changes.” (p. 72). Although this claim is probably true, it is also true that domestic supply can be very price responsive. In this paper, we found domestic supply to be unitary elastic in the short run, which seems quite reasonable given available unused capacity that existed in this industry during the study years (Balzer and Stiegert). Thus, international demand for gluten should be elastic by virtue of domestic supply side responses to price.

Simulation

We turn now to our second objective: that is, to evaluate the impact of the U.S. wheat gluten quota on the gluten and protein market. The econometric model provided all the domestic supply and demand information we needed to evaluate the 3-year

impacts of the quota. With regard to the quota impacts on wheat protein premiums, the following relationships exist between the protein premium and gluten imports:

$$\frac{\partial PHRW}{\partial ID_g} \frac{\overline{ID_g}}{phrw} = \frac{\partial PHRW}{\partial D_g} \frac{\partial D_g}{\partial P_g} \frac{\partial P_g}{\partial ID_g} \frac{\overline{ID_g}}{phrw} = F_{Phrw,Dg} \times E_{Dg,Pg} \times F_{Pg,id} \quad (7)$$

$$\frac{\partial PHRS}{\partial ID_g} \frac{\overline{ID_g}}{phrs} = \frac{\partial PHRS}{\partial D_g} \frac{\partial D_g}{\partial P_g} \frac{\partial P_g}{\partial ID_g} \frac{\overline{ID_g}}{phrs} = F_{Phrs,Dg} \times E_{Dg,Pg} \times F_{Pg,id} \quad (8)$$

where the first of the middle terms are obtained from equations (5) or (6) for HRW and HRS markets, respectively, the second term are obtained from equation (2) and the third term is from equation (4).

The import quota level established by the USITC came together from a group of arguments all designed to remedy serious injury to the gluten industry. After ruling out tariffs and tariff-rate quotas, the Commission successfully argued for a quota to exceed the limits implied by Section 203(3)(4), which would have been the average of 1995-1997 imports of 138 million pounds.¹² The Commission recommended a quota based on the 1993-1995 import level, citing industry profitability in that time period and a rapid increases in imports in 1996 and 1997. The recommendation was an import quota level of 126 million pounds in the first year with 6% increases in the remaining two years (the final quota for from June 1, 1998 to May 30, 1999 was set at 126.8 million pounds).

¹² Section 203(3)(4) states “shall permit the importation of a quantity or value of the article which is not less than the average quantity or value of such article entered into the United States in the most recent 3 years that are representative of imports of such article and for which data are available, unless the President finds that the importation of a different quantity or value is clearly justified in order to prevent or remedy the serious injury.”

Given that 173 million pounds were imported in 1997, if we assume a conservative 5% growth in imports without the quota, we would conclude that the quota limited imports by 31% from 1997 levels (55 million pounds).¹³ On the other hand, the E.U. was expected to bring on line an additional 30% of capacity in 1998. The gluten industry claimed this would have led to substantially higher levels of imports. If the E.U. did increase exports to the U.S. by 35% in 1998, and all other nations had increased imports by 5%, then total imports would have risen by about 15% implying the quota would limit imports by 41% from 1997 levels (71.2 million pounds).

The results from a conservative (31%) and aggressive (41%) reduction in gluten imports on the gluten price and on the price ratio of both hard wheats are reported in table 5. The last two columns of table 5 contain the conservative and aggressive estimates of import reductions under the quota but are adjusted for an additional 30 million pounds of Canadian imports. Not only was Canada excluded from the quota, but also 32 million pounds of gluten production capacity came on-line in 1998 (Balzer and Stiegert). With added capacity and a price in the U.S above the world price, it is likely any extra production from Canada will be exported into the U.S. In all columns, the impact of the quota is assessed by considering the first, second and third year adjustments implied from the partial adjustment process in the gluten supply and demand equations.

The results indicate that gluten prices, based solely on the quota's influence, would rise initially from 8.44% (reduction scenerio III: conservative import reduction with additional Canadian imports) to 18.93% (reduction scenerio II: aggressive import

¹³ The USITC noted that imports had been increasing at a 4.2% rate prior to 1996. The gluten industry had requested a 5% limit on import increases.

estimate and assuming no changes in Canadian imports). By year 3, long term adjustments to demand reduced price benefits to a 3.22%-9.45% range. Domestic gluten production in the U.S. remains fairly constant after the initial reaction to the subsidy for all scenerios. The long term supply-increasing impacts inferred by the partial adjustment parameter are roughly offset by the reductions in price after the initial shock.¹⁴

The anticipated rise in the price ratio of HRW wheat was estimated to be in the 0.11% to 0.33% range. The fall in the price ratio for HRS wheat is estimated in the 0.25% to 0.75% range. To bring more clarity to these results, consider the mean price ratios of the data (1.048 for 13.5%/11.5% HRW wheat and 1.056 15.5%/13.5% for HRS wheat), assume the base price of 11.5% protein wheat is \$3.00/bu and assume that the price of 13.5% HRW is equal to that of 13.5% HRS. Thus, before the quota, the price of 15.5% HRS would be 3.32 \$/bu. Under these circumstances, the model predicts that producers of 13.5% HRW wheat would gain from 0.4¢/bu to 1.1¢/bu in each of the 3-year quota period. The HRS wheat price ratio is more responsive to the quota. The model estimates that producers of 13.5% HRS wheat will gain from 0.5¢/bu to 2.1¢/bu depending on the quota assumptions. Furthermore, the HRS estimate may be somewhat conservative because it presumes the price of 15.5% HRS wheat remained the same. If the value of 15.5% HRS wheat increases in response to the quota, then the value of 13.5% wheat would have to increase by more than the values estimated above to generate the change in the ratio predicted by the model.

¹⁴ Using supply elasticities between 1.7 and 6.2, the USITC estimated that a quota of 126 million pounds would raise price from 3-8% and increase production 14-19%. Our third-year impacts are generally consistent with their anticipated calculations.

Our final assessment was to estimate the three-year revenue gain for a typical farm in the southern and northern plains of the U.S. growing HRW and HRS wheat, respectively. The documented capacity expansion conditions in the E.U. and in Canada suggest reduction scenerio IV was perhaps the most reasonable. Based on average yields from the 1994-1997 crop years, the reduction scenerio IV model indicated that a typical 1000-acre farm producing high protein HRW wheat received \$497 in additional revenue over the life of the quota. For HRS wheat, the return was \$1009 per 1000-acre farm. Although these are certainly not gigantic impacts, they do highlight the importance that agribusiness policies can have in shaping the overall returns to traditional farming operations.

Conclusions

In this paper, we modeled the demand and supply conditions for a commodity (wheat gluten) and a commodity characteristic (intrinsic wheat protein). The purpose was to shed light on several issues in the wheat protein complex including the impact of the U.S. gluten import quota on protein premiums paid to producers in the U.S. Four major conclusions were drawn from this study. First, there was found to be a strong disciplining influence on wheat gluten markets emanating from the HRW wheat market. Specifically, a 1% increase in the protein price ratio for HRW wheat increased the demand for gluten by about 0.64%. This is not a surprising result given that about 91% of the U.S. demand for wheat protein is supplied directly from hard wheat markets (see our earlier discussion), two-thirds of the hard wheat supplies typically are derived from HRW wheat, and wheat gluten is produced primarily from HRW wheat. Interestingly, the gluten market had a much greater influence on the HRS wheat protein market than on

the HRW protein market. The result makes sense given that nearly 100% of the HRS wheat participates in protein markets, HRS grain storage strategies emphasize segregation based on protein levels and HRS wheat most often sells at a premium to HRW wheat.

Second, this study showed that changes in the relative proportion of high protein to low protein HRW wheat had a statistically significant impact on the price ratios of both HRW wheat and HRS wheat. The proportion of high protein to low protein HRS wheat was statistically significant in both protein markets, but the economic impacts on the HRW price ratio were shown to be very small. In all cases, the measured flexibilities imply the market for wheat protein is very elastic. The observed volatility of the protein premiums over the past twenty year are more a result of extreme shifts in protein supply and size of the crop. Thus, the returns to breeding higher quality wheat seem to be well shielded from endogenous price degradation caused by too much intrinsic protein. One must view this conclusion with caution because the quantitative results can only be accurately generalized to small changes. It is not clear that returns on investments to breed for high protein wheat would remain high if breeders were successful in providing varieties that consistently produced 12% or higher wheat protein. Even with the wheat varieties used over the past 25 years, protein supply/demand conditions have driven protein premiums to zero in some years.

Third, using a plausible quota-reduction scenerio involving additions to E.U. gluten capacity that made the quota more binding and greater Canadian gluten capacity that made the quota less binding, the model suggested the U.S. wheat gluten import quota has provided some economic relief to the starch gluten industry. In particular, the quota

was estimated to provide a 14% increase in the price of wheat gluten in the first year. By the third year, the dynamics in the model suggest most of this price gain will be lost and prices will be only 5% above the pre-quota price. U.S. gluten supplies will increase about 15% in the first year and remain at about that level for the next two years. These are relatively small impacts to the industry. Although these are small estimated impacts, they are not far from what the USITC had anticipated.

Our fourth result indicated that wheat gluten markets had a considerable influence on the HRS protein premiums and less of an impact on the HRW protein premiums. Using the parameter estimates, a reasonable pricing scenario for wheat at different price levels and the assumption of new E.U. and Canadian capacity, we estimated the benefit to an average producer in Kansas growing HRW wheat and in North Dakota growing HRS wheat. Based on a 1000 acres of production and average yield estimates, the aggregate impact of the 3-year quota provided nearly \$500 in benefits to the Kansas producer and just over \$1000 to the North Dakota producer.

Table 1. Definitions of Variables Employed in Empirical Model

Variables	Definitions
D_g	U.S. wheat gluten production plus U.S. gluten imports (1,000 tons)
P_g	Weighted average of the U.S. wheat gluten import price deflated by the index of the producer prices for industrial goods (PPI) (\$/lb.)
P_f	Average Kansas City flour price deflated by PPI (cents/cwt.)
phrs	HRS protein price ratio: (MNPLS 14.5%)/(MNPLS 13.5%)
phrw	HRW protein price ratio (KC 13.5%)/(KC 11.5%)
S_g	Annual U.S. wheat gluten production (1,000's of tonnes)
id	U.S. imports of wheat gluten (1,000's of tonnes)
qhrw	HRW quantity ratio (>12% protein wheat)/(<12% protein wheat)
qhrs	HRS quantity ratio (>14% protein wheat)/(<14% protein wheat)
qws	(HRW production)/(HRS production)

Table 2. Summary Statistics of Variables

Variables	Average	Std. Dev.	Minimum	Maximum
D _g	17.76	7.08	7.85	30.75
rp gluten	5.18	0.91	3.73	7.29
rp flour	9.69	2.16	6.82	16.23
phrs	10.58	0.55	10.01	11.83
phrw	10.47	0.48	9.97	12.06
S _g	8.91	3.42	4.10	17.10
id	8.85	3.94	3.75	18.13
qhrw	3.29	6.31	0.20	29.33
qhrs	3.01	6.35	0.47	31.45
qws	2.49	0.83	1.20	4.87

Table 3. Three-stage least squares estimates of system equations

Time period: 1974 - 1997

Number of observations: 23

Variable	Coefficient	Estimate	t-ratio
<i>Domestic Wheat Gluten Demand Equation</i>			
Intercept	a0	-13.1200	-1.2600
D _{g(t-1)}	a1	0.8422	12.0890 *
rpgluten	a2	-1.0396	-1.9454 *
rpflour	a3	-0.0446	-0.2247
phrs	a4	1.0401	1.2123
phrw	a5	1.0904	2.7464 *
R ²	0.9377		
D.W.	2.5977		
<i>Domestic Wheat Gluten Supply Equation</i>			
Intercept	b0	-0.3087	-0.1919
S _{g(t-1)}	b1	0.9001	11.1020 *
rpgluten	b2	1.7547	3.7588 *
rpflour	b3	-0.7804	-4.0319 *
R ²	0.8507		
D.W.	1.8597		
<i>Price-dependent HRW Equation</i>			
Intercept	c0	12.4600	32.5040 *
qhrw	c1	-0.0422	-2.5030 *
qhrs	c2	0.3497	2.0332 *
qws	c3	-0.5976	-12.9940 *
D _g	c4	0.0264	-1.5010
R ²	0.9323		
D.W.	1.9843		
<i>Price-dependent HRS Equation</i>			
Intercept	d0	9.2703	31.1700 *
qhrs	d1	-0.0429	-3.1290 *
qhrw	d2	-0.0425	-3.2060 *
qws	d3	0.2006	5.6105 *
D _g	d4	0.0607	4.4446 *
R ²	0.5948		
D.W.	1.6236		

* denotes significance at the 5% level

Table 4. Gluten - Protein Model Elasticities and Flexibilities

Time period: 1974 - 1997

Variable	Description	Elasticity	t-ratio
$E_{Dg(t-1),Pg}$	long-run own-price demand elasticity	-1.9227	-2.2258 *
$E_{Dg,Pg}$	short-run own-price demand elasticity	-0.3034	-1.9454 *
$E_{Dg,Phrs}$	cross hrs elasticity	0.6195	1.2122
$E_{Dg,Phrw}$	cross hrw elasticity	0.6431	2.7464 *
$E_{Sg(t-1),Pg}$	long-run price elasticity of supply	10.2120	1.1350
$E_{Sg,Pg}$	short-run price elasticity of supply	1.0204	3.7587 *
$E_{Sg,Pflour}$	cross flour supply elasticity	-0.8486	-4.0318 *
Variable	Description	Flexibility	t-ratio
$F_{Phrw,qhrw}$	Own protein quantity ratio	-0.0128	-2.3834 *
$F_{Phrw,qhrs}$	Cross protein quantity ratio	0.0101	2.0698 *
$F_{Phrw,qws}$	Wheat quantity	-0.1403	-13.7745 *
$F_{Phrw,Dg}$	Wheat gluten	-0.0448	-1.5010
$F_{Phrs,qhrs}$	Own protein quantity ratio	-0.0123	-2.9433 *
$F_{Phrs,qhrw}$	Cross protein quantity ratio	-0.1432	-3.1523 *
$F_{Phrs,qws}$	Wheat quantity	-0.0432	4.9847 *
$F_{Phrs,Dg}$	Wheat gluten	0.1020	4.4446 *
$F_{Pg,id}$	Import demand	-0.6029	-7.7067 *
$F_{Pg,qhrs}$	Spring protein quantity ratio	-0.0014	-0.1521
$F_{Pg,qhrw}$	Winter protein quantity ratio	-0.0210	-1.7688
$F_{Pg,qws}$	Wheat quantity	-0.0779	-1.9098 *

* denotes significance at the 5% level

Table 5: Impacts from U.S. Wheat Gluten Import Quota: 1998, 1999, 2000

		Import Quota Impact Reduction Scenarios			
Changes from 1997		Reduction I.	Reduction II.	Reduction III.	Reduction IV.
Decrease in imports (%)		-31%	-41%	-14%	-24%
Change in U.S.	1998	18.93	24.71	8.44	14.46
Gluten price from	1999	10.08	13.33	4.55	7.80
1997 (%):	2000	7.14	9.45	3.22	5.53
Change in U.S. Gluten	1998	19.32	25.22	8.61	14.76
production from	1999	19.54	25.85	8.82	15.13
1997 (%):	2000	19.75	26.12	8.92	15.29
Change in HRW	1998	0.26	0.34	0.11	0.20
price ratio from	1999	0.25	0.33	0.11	0.20
1997 (%):	2000	0.25	0.33	0.11	0.19
*Change in 13.5%	1998	0.008	0.011	0.004	0.006
HRW price from	1999	0.008	0.010	0.004	0.006
1997 (\$/bu):	2000	0.008	0.010	0.004	0.006
Change in HRS	1998	-0.58	-0.76	-0.26	-0.45
price ratio from	1999	-0.57	-0.76	-0.26	-0.44
1997 (%):	2000	-0.56	-0.75	-0.25	-0.44
*Change in 13.5%	1998	0.015	0.021	0.005	0.011
HRW price from	1999	0.015	0.021	0.005	0.011
1997 (\$/bu):	2000	0.015	0.020	0.005	0.011

I:	Conservative import reduction estimate. Assumes all importers increase imports by 5%
II:	Aggressive import reduction estimate: Assumes the E.U. increases imports by 30% and all other importers increase imports by 5%.
III:	Import reduction estimate I adjusted for additional 30 million pounds imported from Canada.
IV:	Import reduction estimate II adjusted for additional 30 million pounds imported from Canada.
*	Estimates of an increase in the 13.5% HRW price or 13.5% HRS wheat price given that: the ratio of 13.5%/11.5% HRW and 15.5%/13.5% wheat prices are at their respective means, the price of 13.5% HRW is equal to the price of 13.5% HRS, and the price of 11.5% HRW wheat is \$3.00/bushel.

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