Harvest-Time Protein Shocks and Price Adjustment in U.S. Wheat Markets

Barry K. Goodwin and Vincent H. Smith

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***Barry Goodwin is professor of agricultural economics at North Carolina State University. Vince Smith is professor of agricultural economics at Montana State University. Professor Smith is the corresponding authot. His postal address is Department of Agricultural Economcis and Economics, Montana State University, Bozeman, MT 59715. His e-mail address is vsmith@montana.edu.**

Abstract

Dynamic relationships between three classes of wheat are investigated using threshold VAR models incorporating the effects of protein availability. Changes in the stock of protein are found to generate significant impulse responses in the price of hard red spring wheat and hard red winter wheat but not soft red wheat. These impulse responses to identical changes in protein stocks are larger when the absolute deviation of protein stocks from normal levels are large. Shocks to the prices of individual classes of wheat result in complex impulse responses in the prices of the other wheats. Notably, however, a shock to the price of hard red winter weak appears to result in little or no impulse response in the price of hard spring wheat, though the opposite is not true.

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Agricultural commodities such as wheat are typically heterogeneous, with quality characteristics that differ across space, time, and variety. The extent to which market prices account for such quality differences has been an important issue to the overall efficiency of markets for agricultural commodities. The benefits associated with accurate measurement of qualities by buyers and sellers in a market must be weighed against the potential costs associated with such an accurate quality assessment. Some characteristics (foreign matter, shrunken and broken kernels, etc.) are easy to measure while others (valorimeter and farinograph measures) are much more difficult to uncover.

Protein content is one of the most basic quality characteristics shaping the potential utility of a particular class of wheat for various uses. It plays such an important role in price interrelationships among different types and grades of wheat that it also forms the basis for U.S. standard variety grades. For example, high protein wheat varieties such as dark northern spring and hard red winter typically command a price premium over wheat varieties with lower protein contents (for example, see Espinosa and Goodwin, 1991), and that the price premium varies over time almost surely in accord with shifts in supply and demand for that attribute (Parcell and Stiegert, 1998), as implied by the theoretical hedonic pricing framework developed by Rosen (1974).

Several studies have examined the dynamics of domestic and international wheat price relationships (see, for example, Goodwin and Schroeder, 1991; International Trade Commission, 1994; Mohanty, Meyers, and Smith,1999). However, relatively little attention has been directed toward interrelationships among different types of wheat prices and quality shocks that may relate to the aggregate level of quality. Failure to account for these shocks is likely to distort estimates of these relationships and provide misleading assessments of the extent to which prices of different types of wheat related to one another and the extent to which different types of wheat are substitutes for one another.[1]

In this paper, we are primarily concerned with the aggregate market for protein (wheat gluten) and its effect of price relationships among different classes of wheat. We consider multivariate time-series models containing three classes of wheat—hard red spring, hard red winter, and soft red winter. We are interested in quantifying the relationships between the protein content associated with each year's harvest for each type of wheat and the differentials (reflecting protein supply and demand effects) between various classes of wheat. Monthly price data are used in conjunction new data constructed by the authors that reports the average (aggregate) protein content associated with each year's harvest. The relationships between wheat prices and protein content may vary substantially from year-to-year, depending on overall wheat yields and other quality factors.[2] Further, protein content in one year may be affected by the characteristics of the market for protein in preceding years, since grain stocks are held from year to year and production practices and variety choices may be important considerations in the realized protein content of a wheat crop.

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[1] The issue of elasticities of substitution among wheat classes has been addressed by two recent studies by Marsh and Barnes and Shields using structural models of derived demand estimated with annual data. Both studies, while providing different estimates, find that wheat is not just wheat, in the sense that Elasticities of substitution among different classes of wheat are by no means very large.

[2] Parcell and Steigert (1998) and Stiegert and Blanc both report that the effect of a marginal increase in protein on protein premiums varies among different classes of wheat such as hard red spring, hard red winter and soft red winter.

We use nonstructural time-series models that also allow for costly adjustment by incorporating threshold procedures to evaluate the effects of protein content shocks on the time paths of wheat prices. We account for protein availability effects on price interrelationships from year to year and quantify the extent to which shocks in the levels of protein in a particular type of wheat affect the differentials in wheat prices among the individual wheat classes. Our analysis uses dynamic impulse responses to track price responses to shocks in the protein market and other shocks to specifics wheat class prices.

The analysis provides new insights about the substitutability of different classes of wheat among end uses, a critical issue in recent trade dispute cases. For example, if hard red spring wheat and hard red winter wheat are perfect or very close substitutes, as suggested by Canadian Wheat Board expert witnesses in testimony before the International Trade Commission on behalf of the Canadian Wheat Board in September, 2003, then hard red winter prices are likely to respond rapidly in similar ways to a shock in hard red spring prices, and vice versa. This does not appear to be the case.

The paper is organized as follows. Empirical methods are discussed in the next section. The data are then described and empirical results are presented and discussed.

Empirical Methods

The primary objective of the empirical analysis is to evaluate the extent to which dynamic relationships among prices for different classes of wheat are affected by shocks to the quality of the overall U.S. wheat harvest. In particular, we are interested in the role played by protein content—one of the major determinants of the quality and functionality of different wheats for different uses. Certainly a wide variety of wheat characteristics may be pertinent to the quality of any given quantity of wheat. These include factors such as variometer and farinograph measures, foreign materials, falling numbers, ash content and so forth[3]. However, in terms of the aggregate wheat market and the price relationships between different types of wheats, both the results of several hedonic studies and industry pricing practices indicate that each wheat's harvest protein content is likely to be the most relevant factor influencing dynamic relationships among the prices of different types of wheat.

In the spirit of the relatively extensive literature that has addressed these issues, we adopt a standard vector autoregression (VAR) model that includes prices of the three major wheats—Dark Northern Spring (DNS) in Minneapolis, Hard Red Winter (HRW) in Kansas City, and Soft Red Winter (SRW) in Chicago. DNS and HRW wheats typically have much higher protein contents and are directed toward end-uses that require stronger gluten content (e.g., breads). We also include a measure of the overall protein content implicit in stocks at any point in time. Our specific measure of this protein content variable is described in detail below.

A standard VAR model can be written as:

$$y_t = \Gamma X_t + e_t \,,$$

where y_t is a vector of endogenous variables for which dynamic adjustment paths are to be evaluated, Γ is a matrix of parameters to be estimated, e_t is a vector of random error terms, and $X_t = [1, y_{t-1}, ..., y_{t-j}, x_t]$ where x_t is a vector of other exogenous factors.

[3] See Espinosa and Goodwin for a detailed discussion of how different quality factors are related to wheat prices.

In addition to estimating a simple VAR model, we are interested in considering the potential for nonlinearities in the underlying relationships represented by the VAR model. To this end, we appeal to recent developments in the time series literature that consider nonlinearities in the relationships inherent in nonstructural VAR type models. We hypothesize that adjustments to shocks in the inherent qualities of wheat by end-users (e.g., bakers, millers, and food processors) are costly. In particular, most production processes are tightly calibrated and have specific quality requirements. End-users may be able to make adjustments in production processes, though these adjustments are likely require significant technological modifications and to be costly.[4]

To capture these effects, we utilize a threshold modification to the standard VAR modeling framework. In particular, we allow the underlying structure of the model (represented by the nonstructural, reduced-form parameters of the VAR system of equations) to vary according to implied protein availability in the market. In particular, we consider a threshold defined by deviations from normal levels of protein in the market. The "normal" level of protein is defined by using a regression of protein availability on a third-order fourier series expansion, which is intended to capture the large degree of seasonality that accompanies the wheat harvests and subsequent adjustments to stocks.

[4] This is widely recognized by the milling industry. In the September 2003 International Trade Commission (ITC) antidumping hearings with respect to Canadian dumping of hard red spring wheat and durum wheat, in oral testimony before the ITC U.S. milling industry executives indicated that they tended to determine blends of different wheat at the beginning of each marketing year just after harvest once the quality characteristics of different wheat classes were known. Thereafter, they were generally reluctant to change those blends.

We define the "normal" level of protein (given by a function *f(t)* consisting of a fourier series expansion) by $\hat{p} = f(t)$. Departures from normal levels are therefore determined as:

$$P_t - f(t) = v_t$$

The explicit definition of the threshold is given by *c*, where the switch in regimes is triggered when the departures from normal levels of protein exceed *c* in absolute value. In other words, two alternative regimes are defined by the absolute value of v_t. The regime switching model is thus given by:

$$y_t = \begin{cases} \Gamma^{(1)} X_t & if \quad |v_t| \leq c \\ \Gamma^{(2)} X_t & if \quad |v_t| > c \end{cases},$$

where $\Gamma^{(i)}$ represents the parameter estimates associated with the ith regime and *c* is the unknown threshold parameter. An alternative representation of this model is as follows:

$$y_t = (1-\delta)\Gamma^{(1)} + \delta\Gamma^{(2)},$$

where δ =1 if $|v_t| \leq c$ and is zero otherwise.

Several alternative threshold modeling procedures have been developed. Here we utilize grid search procedures to find the threshold value, c, that minimizes the log of the determinant of the residual covariance matrix, which is equivalent to maximizing a normal likelihood function. We constrain the grid search procedures to require each regime to have at least twenty-five observations. The parameters describing the two alternative regimes are estimated conditional on the optimal threshold values.

Once the parameters of the standard and regime switching VAR models have been estimated, standard methods of inference can be used to evaluate the relationships among the prices and protein variable. Here we utilize standard impulse response functions to evaluate the dynamic relationships among wheat class prices implied by the alternative parameters. In threshold models, several alternative versions of the impulse responses could be evaluated because in those models, impulse responses may not be unique for alternative observations or sizes of shocks. Potter's nonlinear impulse response analysis procedures of Potter can be used to evaluate the responses at a particular observation and allow for switching among regimes over the period of the response. Alternatively, impulses could be calculated at every observation and then mean responses or some other summary measure could be reported. Finally, the responses could be evaluated at each alternative regime with no shifting between regimes allowed during the response. We adopt the latter approach in that it yields the clearest inferences regarding the differences in regimes.

Data and Empirical Results

We use monthly averages of daily cash prices for three alternative classes of wheat—DNS in Minneapolis, HRW in Kansas City, and SRW in Chicago. The price data were collected from the Bridge database. Average protein content for all classes of U.S. wheat (HRW, DNS, SRW, durum, and white wheats) for each crop year were provided by U.S. Wheat Associates *Grain Quality Reports*, published annually. Quarterly stocks data were obtained from unpublished NASS data.

We calculated an aggregate weighted average protein content for the aggregate U.S. wheat harvest each crop year using USDA statistics on production for each class in each year to form weights. The quarterly stocks data were multiplied by the protein content of the crop to obtain "protein stocks" for each quarter of the year. We then regressed this protein stocks variable on the terms of a third order Fourier series expansion. The data cover the 1989-2003 crop years.

The implied pattern of seasonality in protein is illustrated in Figure 1. Note the presence of a large increase with the winter wheat harvest in June and July and then a second smaller increase that occurs with the spring wheat harvest in the late fall. Deviations from normal protein levels are then given by the deviations from the seasonal patterns indicated in Figure 1. We then utilize cubic spline smoothing to interpolate the quarterly protein stock measures to monthly data. Such interpolation is most likely to adequately represent data at a higher frequency in cases where movements in the variable between observations are likely to be smooth and gradual. This is certainly the case for a highly aggregated variable such as the total protein stocks implied for the aggregate U.S. market. The observed and interpolated protein stocks series are illustrated in Figure 2. The blocks represent observed data while the line represents the interpolated data used to covert from quarterly to monthly frequencies.

Table 1 presents parameter estimates for a standard VAR model. Parameter estimates for nonstructural models of this form are usually of limited interest and inferences are more efficiently extracted from impulse responses. However, the coefficients on the protein stocks variable are certainly of interest in their own right. The coefficients are negative in every case, suggesting that above-normal stocks of protein are likely to have a depressing effect on prices for each class of wheat. The coefficient is largest in the case of the Kansas City hard red winter price. The negative effect is also large for the Minneapolis hard red spring price. The effect for soft wheat prices in Chicago is much smaller and is not statistically significant. These results are consistent with *a priori* expectations. They imply that positive shocks to the aggregate protein content of wheat in the U.S. market have negative effects on hard red winter and hard red spring wheat prices—high protein wheats generally directed to uses demanding a high gluten content. In contrast, the effect is not statistically significant in the case of soft red winter wheat in Chicago. Soft wheats are typically much lower in protein content and are directed toward uses that call for lower gluten wheats (e.g., cakes and crackers rather than bread).

Impulse responses for the standard VAR model are presented in Figures 3-6. Figure 3 illustrates the dynamic paths of adjustment in prices to a positive one-unit shock to the protein stocks variable. The largest impact is realized by the Kansas City price—a result entirely consistent with a simple consideration of the VAR model protein coefficients reported in Table 1. The impulse indicates that a one unit increase in protein generates a response of a 42 cent decrease in the Kansas City per bushel price and a 42 cent decrease in the Minneapolis per bushel price. In contrast, the soft wheat price in Chicago shows only a small negative response to the same protein shock. In every case, the largest response occurs two months after the shock, and that responses take ten or more months to die out. This suggests that end users are likely to be somewhat slow to adjust to protein shocks and that market effects from such shocks persist for several months. This finding seems to be consistent with statements by U.S. millers at the 2003 ITC hearings on CWB dumping that they tend to determine blends of different wheats for milling on an annual marketing year basis after harvest and to be relatively unresponsive to price changes.

Adjustments to price shocks are modest once protein shocks are accounted for. Minneapolis and Kansas City prices appear to be more closely linked that either market is with Chicago. The results appear to imply a price leadership role for the Minneapolis market in the Kansas City-Minneapolis relationships. An innovation in the Kansas City price results in almost no impulse response in the Minneapolis price while an innovation the Minneapolis price results in a similar though smaller adjustment in the Kansas City price that peters out after about 6 months.

As we have noted, price adjustment patterns may reflect adjustment costs associated with changes in production technologies that may be needed to respond to substantial changes in wheat protein availability. Table 2 reports estimates from a threshold VAR model that allows shifting between regimes according to the size of shocks (in absolute value) to the overall protein stocks available in the market. The optimal threshold has a value of 0.1659. The band implied by this threshold that defines alternative regimes is illustrated in Figure 2. As one would expect, switching among regimes is infrequent, reflecting the fact that the overall availability of protein in the market is a slowly adjusting variable. This implies that the market tends to remain in a regime for an extended period of time rather than jumping back and forth on a month to month basis between the alternative regimes.

Protein stocks generally have larger (more negative) effects on prices in the "outside" regime, which corresponds to periods of large deviations from normal levels of protein. This is to be expected in that, to the extent that costly adjustments underlie the price relationships, such adjustments are more likely to be undertaken and are likely to be more extreme when deviations from normal protein levels are large. Again, the largest effects are implied for Kansas City (hard red winter) wheat prices. Large responses are also implied for Minneapolis prices, although the adjustments are somewhat smaller than those implied for the hard red winter prices. This is not surprising in that the quantity of hard red winter wheat produced in the U.S. is usually about twice as large as the quantity of hard red spring wheat and that hard red winter is therefore a more prominent source of aggregate protein.

Impulse responses for the alternative regimes are presented in Figures 7-11. Figures 7 and 8, which illustrate price responses to protein shocks in the alternative regimes, are especially striking. A much large response to a one unit shock to protein is implied by the outside regime parameters. When deviations from normal protein levels are more modest, prices scarcely react at all. However, significant adjustments occur when deviations from normal protein levels are large. This result is consistent with our hypothesis that large changes in protein may have more significant effects on prices than when protein shocks are small.[5]

Price adjustments are similar to those found for the standard VAR model, though again a much larger degree of price responsiveness is implied in the outside regime. This suggests that wheat prices are more responsive to shocks in other markets when protein content is above- or below-normal. However, the impulse responses to do imply that when the price of one class of wheat is shocked the prices of other wheat classes adjust in very similar ways. This suggests that wheat is not just wheat and that soft red winter is

[5] Note that our terminology may be somewhat confusing here. All impulse response diagrams illustrate responses to equivalent one-unit shocks. However, the regimes are defined by the size of the protein shock. We could have presented shocks that differed in terms of the size of the shocks in alternative regimes. In such a case, the differences in impulse responses would be exaggerated. Comparing the impulses at a common level of shock allows a clearer view of how the underlying structures of the models differ across regimes.

by no means a perfect substitute for hard red winter or hard red spring. Similarly, the threshold model results also suggest that cross market linkages between hard red spring wheat and hard red winter wheat are complex.

Conclusion

This study has utilized new data and innovative econometric techniques to address a longstanding issue - the dynamic relationship between the prices of different classes of wheat. A key data innovation was the development and utilization of a measure of the aggregate stock of protein in the U.S. wheat crop. Data on average protein content by class of wheat was combined with USDA statistics on production by class and quarterly stock data to obtain protein stocks for each quarter of the year. A third order Fourier expansion was then utilized to obtain estimates of normal protein levels that accounted for quarterly seasonal effects. The quarterly data were then interpolated using cubic splines to obtain month-by-month estimates of protein stocks.

A key econometric and modeling innovation with respect to wheat price dynamics has been the utilization of a threshold modification of the VAR model to account for potential adjustment costs associated with changing use patterns of different classes of wheat. The results from the estimated threshold variant of the VAR model were also compared with those from a standard VAR model in which adjustment costs are ignored.

The major findings of the research are as follows. In the standard VAR model, positive one unit shocks to protein stocks has the largest and statistically significant negative effect on the Kansas City hard red winter price and a still large, but smaller, effect on the Minneapolis hard red spring price, as measured by impulse responses. The impulse response of the Chicago soft red price was not statistically significant and small.

Similar effects were identified in the threshold model in which two regimes were identified. The first "inside" regime is one in which protein levels did not deviate very much in absolute terms (either up or down) from normal seasonal levels. The second "outside" regime is one in which protein levels did deviate substantially. The range within which protein levels were deemed to be normal was computed in the econometric estimation procedure. In the threshold models, the effects of a unit change in the protein stock level were qualitatively similar to those reported for the standard VAR model. When the absolute deviation of protein levels was small (the "inside" regime), price impulse responses were also small, and when the absolute deviation of protein levels was large (the "outside" regime) the impulse responses were much larger. In the outside regime, the impulse response of the Kansas City hard red winter price was much larger than the impulse response of the Minneapolis hard red spring price. These results are consistent with the hypothesis that adjustment costs associated with buyers (millers, etc) of different wheats changing their patterns of use are relatively large.

In the threshold models, the effects of price shocks for a specific class of wheat also depend on the regime. However, one interesting result is that shocks to the Kansas City hard red winter price result in almost no impulse responses on the part of Minneapolis Hard red spring prices, although shocks to the Minneapolis price do generate a somewhat similar impulse response on the part of the Kansas City price. In addition, an exogenous shock to the Chicago soft red price generates very weak impulse responses in the Minneapolis price, although somewhat stronger impulse responses in the Kansas City price.

These results also provide some further insights about a long-standing argument between the Canadian Wheat Board and U.S. wheat producers. Fairly consistently, in a variety of wheat trade cases brought before the U.S. ITC between 1992 and 2004, the CWB has claimed that wheat is just wheat and, in particular, hard red winter and hard red spring are almost perfect substitutes for one another. The evidence from this study tends to suggest that such is not the case. The markets may be related but an exogenous shock in the price of hard red winter wheat does not generally result in a similar impulse response in the price of hard spring wheat.

Table 1. Standard VAR Model of Wheat Prices: Parameter Estimates

Dependent Variable	Explanatory Variable	Parameter Estimate	Standard Error	t Ratio
Chicago Price	Constant	37.3687	17.1231	2.18
	Protein Stocks (t)	-20.7671	13.1919	-1.57
	Chicago Price (t-1)	0.7734	0.1183	6.54
	Kansas City Price (t-1)	0.2567	0.1234	2.08
	Minneapolis Price (t-1)	-0.0638	0.0922	-0.69
	Chicago Price (t-2)	0.0341	0.1184	0.29
	Kansas City Price (t-2)	-0.1826	0.1220	-1.50
	Minneapolis Price (t-2)	0.0585	0.0912	0.64
Kansas City Price	Constant	67.6815	17.8796	3.79
	Protein Stocks (t)	-41.1863	13.7747	-2.99
	Chicago Price (t-1)	-0.0504	0.1235	-0.41
	Kansas City Price (t-1)	1.0444	0.1288	8.11
	Minneapolis Price (t-1)	0.0112	0.0962	0.12
	Chicago Price (t-2)	0.0891	0.1237	0.72
	Kansas City Price (t-2)	-0.2491	0.1274	-1.96
	Minneapolis Price (t-2)	-0.0217	0.0952	-0.23
Minneapolis Price	Constant	65.5465	19.3841	3.38
	Protein Stocks (t)	-33.5678	14.9338	-2.25
	Chicago Price (t-1)	-0.2288	0.1339	-1.71
	Kansas City Price (t-1)	0.5022	0.1397	3.60
	Minneapolis Price (t-1)	0.6614	0.1043	6.34
	Chicago Price (t-2)	0.2000	0.1341	1.49
	Kansas City Price (t-2)	-0.4948	0.1381	-3.58
	Minneapolis Price (t-2)	0.1993	0.1032	1.93

Table 2. Threshold Switching Regime Model Parameter Estimates

Dependent Variable	Explanatory Variable	Outside Regime Parameter Estimate	Outside Regime Standard Error	Outside Regime t Ratio	Inside Regime Parameter Estimate	Inside Regime Standard Error	Inside Regime t Ratio
Chicago Price	Constant	22.7792	19.0585	1.20	85.9199	36.7720	2.34
	Protein Stocks (t)	-11.4098	14.6109	-0.78	-13.1946	37.1174	-0.36
	Chicago Price (t-1)	0.5035	0.1448	3.48	1.3042	0.2093	6.23
	Kansas City Price (t-1)	0.6560	0.1614	4.07	-0.3652	0.2183	-1.67
	Minneapolis Price (t-1)	-0.1935	0.1357	-1.43	-0.0265	0.1213	-0.22
	Chicago Price (t-2)	0.2188	0.1459	1.50	-0.2871	0.1926	-1.49
	Kansas City Price (t-2)	-0.4298	0.1633	-2.63	0.1911	0.1905	1.00
	Minneapolis Price (t-2)	0.1451	0.1309	1.11	-0.0358	0.1229	-0.29
Kansas City Price	Constant	58.2909	19.5316	2.98	144.7974	37.6848	3.84
	Protein Stocks (t)	-37.0815	14.9736	-2.48	-20.1873	38.0387	-0.53
	Chicago Price (t-1)	-0.2723	0.1484	-1.84	0.6244	0.2145	2.91
	Kansas City Price (t-1)	1.3526	0.1654	8.18	0.1662	0.2237	0.74
	Minneapolis Price (t-1)	-0.0438	0.1390	-0.31	0.0378	0.1243	0.30
	Chicago Price (t-2)	0.2971	0.1496	1.99	-0.0868	0.1974	-0.44
	Kansas City Price (t-2)	-0.5197	0.1673	-3.11	-0.0640	0.1952	-0.33
	Minneapolis Price (t-2)	0.0367	0.1341	0.27	-0.0371	0.1260	-0.29
Minneapolis Price	Constant	57.6586	21.6677	2.66	106.6062	41.8062	2.55
	Protein Stocks (t)	-24.4373	16.6112	-1.47	-22.7985	42.1989	-0.54
	Chicago Price (t-1)	-0.4385	0.1646	-2.66	0.2421	0.2380	1.02
	Kansas City Price (t-1)	0.8157	0.1835	4.45	-0.1928	0.2482	-0.78
	Minneapolis Price (t-1)	0.6917	0.1542	4.48	0.5412	0.1379	3.92
	Chicago Price (t-2)	0.3664	0.1659	2.21	0.0131	0.2190	0.06
	Kansas City Price (t-2)	-0.6722	0.1856	-3.62	-0.2158	0.2166	-1.00
	Minneapolis Price (t-2)	0.0958	0.1488	0.64	0.3566	0.1398	2.55
Threshold Parameter		0.1659					
Proportion of Observations		0.6278			0.3722		

Figure 1. Estimated Seasonality in Protein Stocks Variable

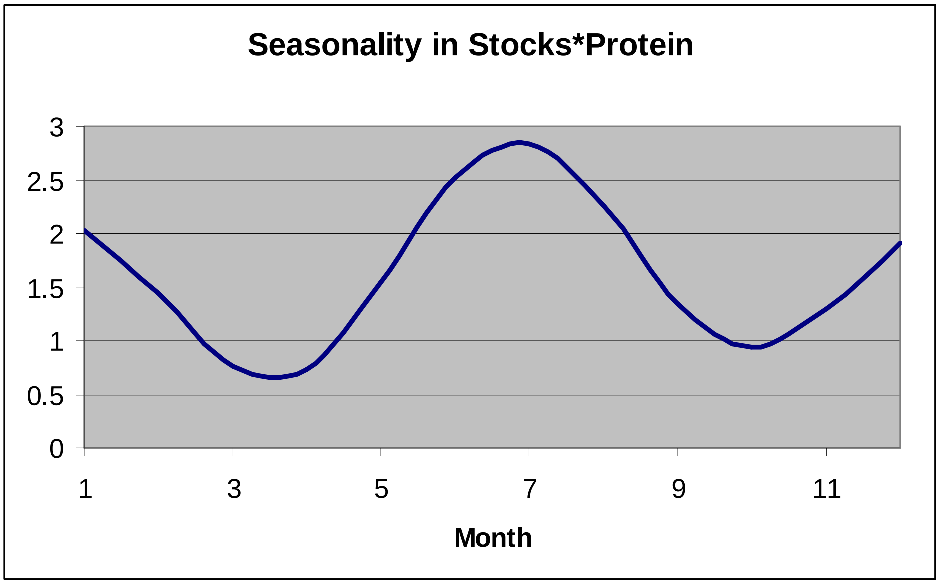


Figure 2. Actual and Interpolated Protein Stocks Variable

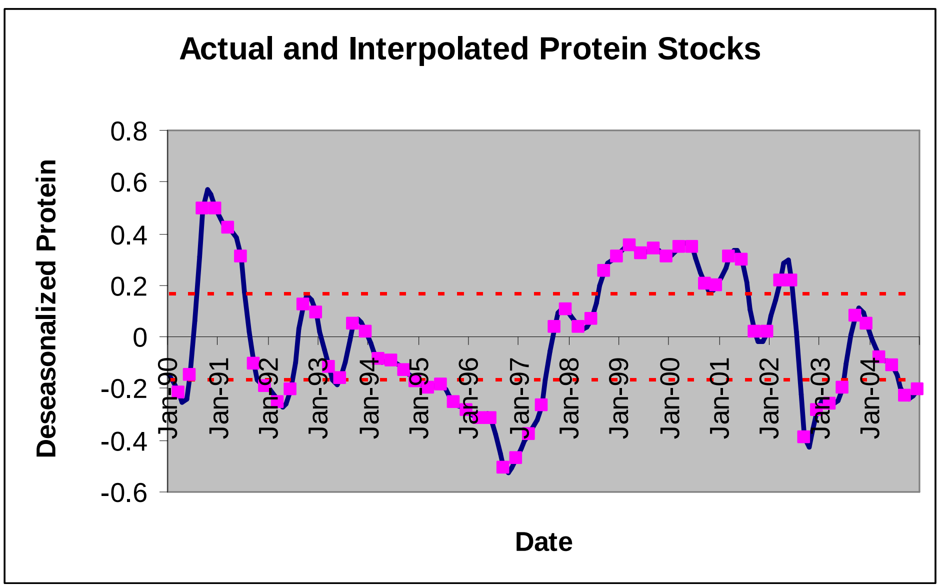


Figure 3. Standard Impulse Responses to Protein Shocks

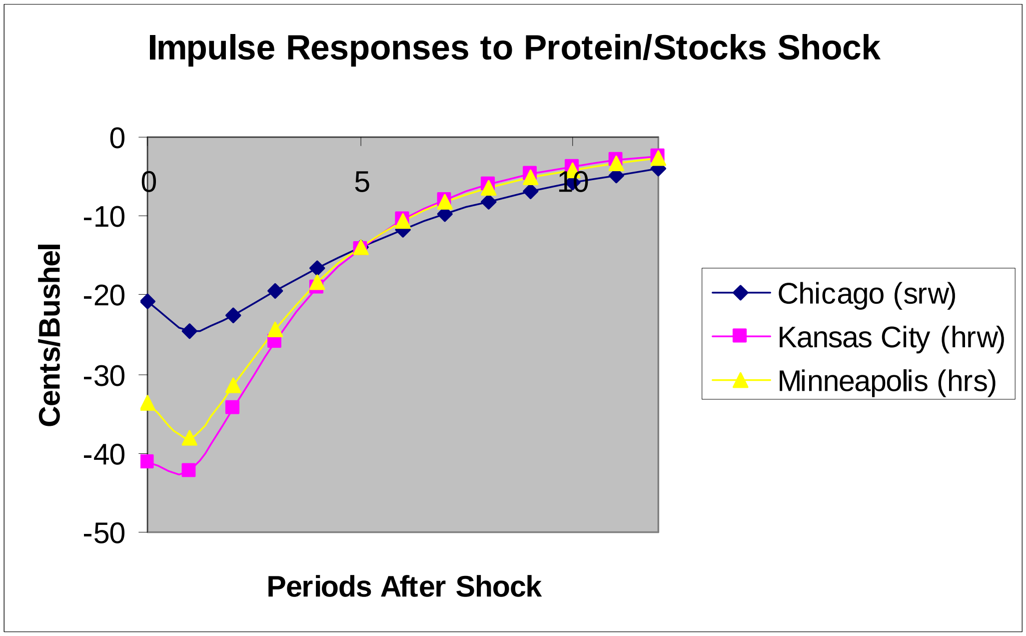


Figure 4. Standard Impulse Responses to Chicago Price Shocks

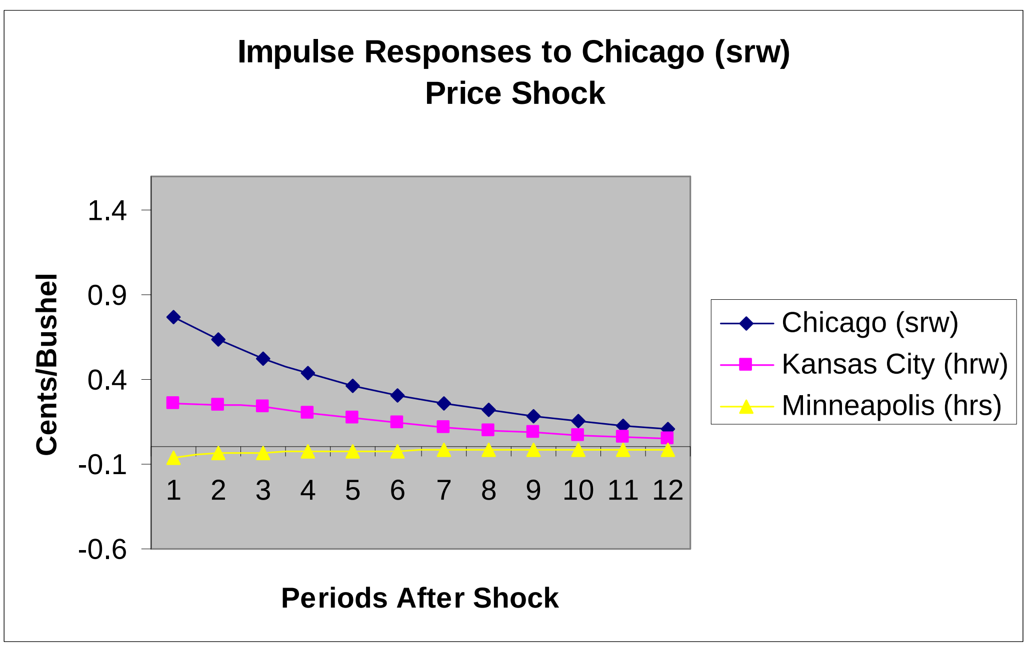


Figure 5. Standard Impulse Responses to Kansas City Price Shocks

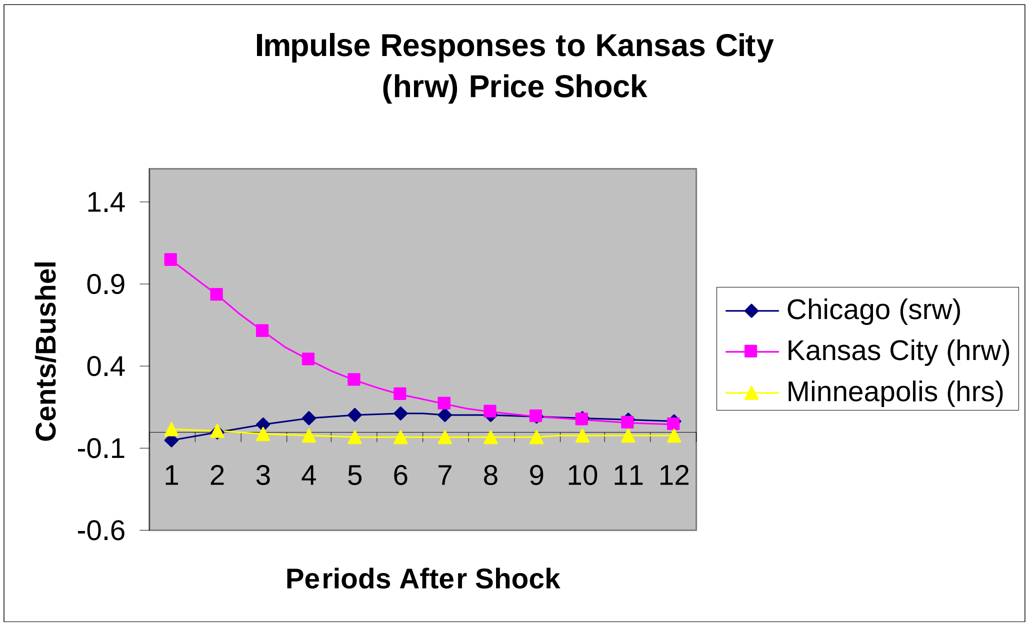


Figure 6. Standard Impulse Responses to Minneapolis Price Shocks

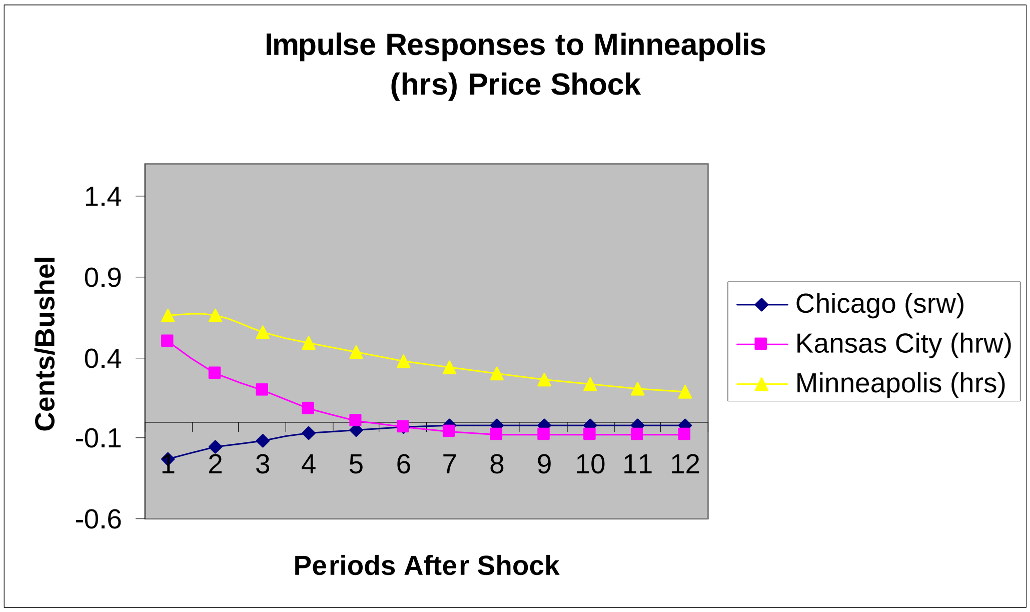


Figure 7. Outside Regime Impulse Responses to Protein Shock

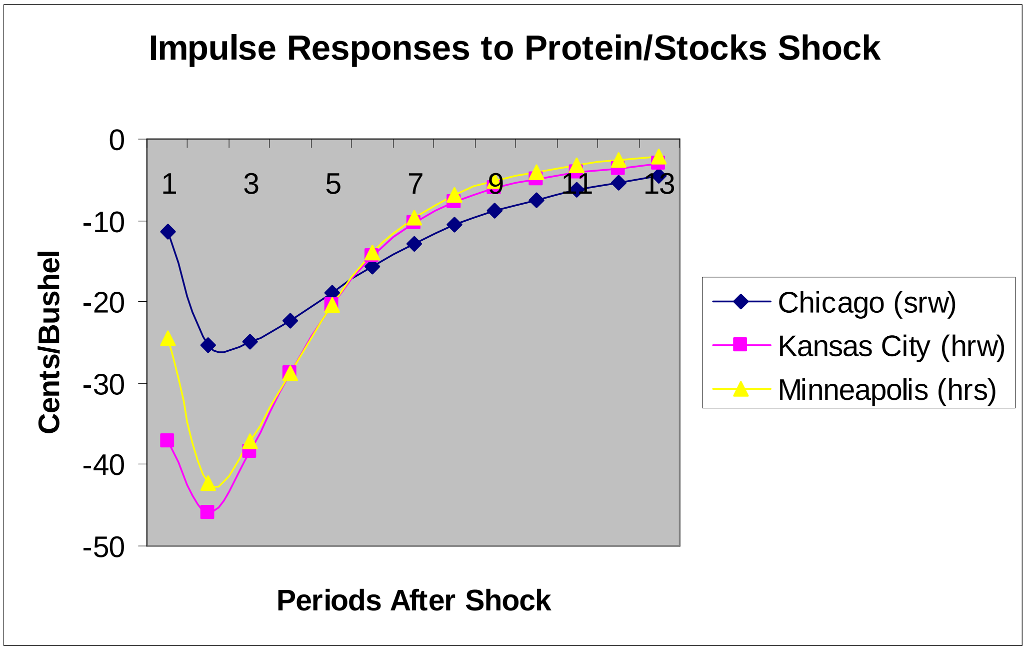


Figure 8. Inside Regime Impulse Responses to Protein Shock

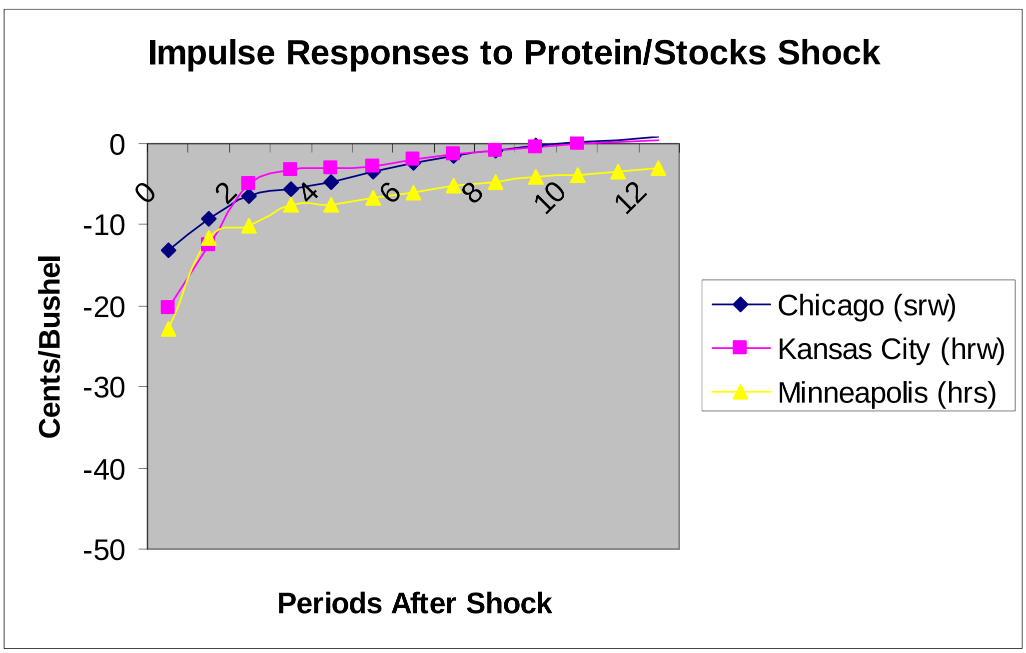


Figure 9.A. Outside Regime Price Responses to Chicago Price Shocks

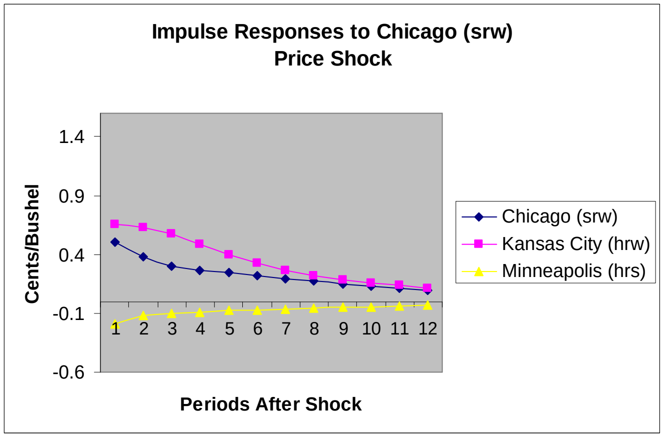


Figure 10.A. Outside Impulse Responses to Kansas City Price Shocks

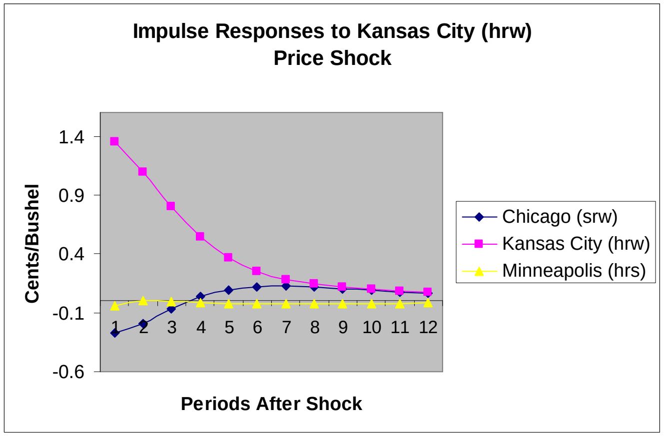


Figure 9.B. Inside Regime Price Responses to Chicago Price Shocks

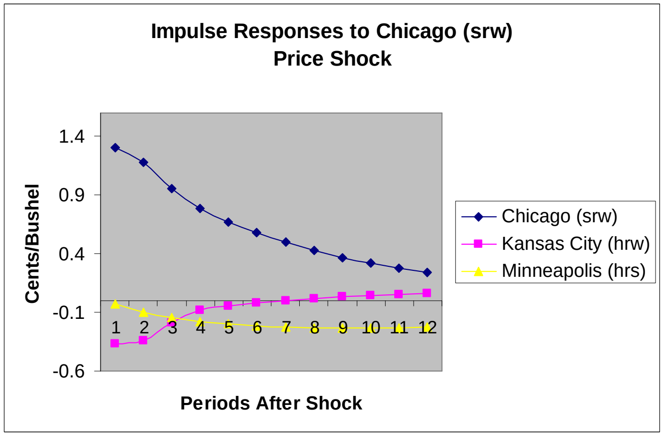


Figure 10.A. Inside Impulse Responses to Kansas City Price Shocks

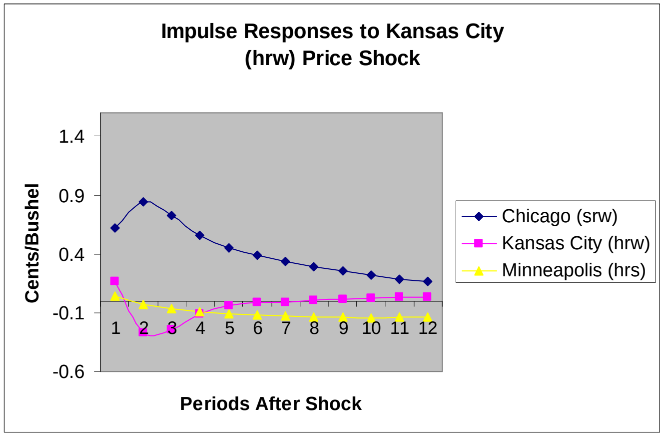


Figure 11.A. Outside Impulse Response to Minneapolis Price Shocks

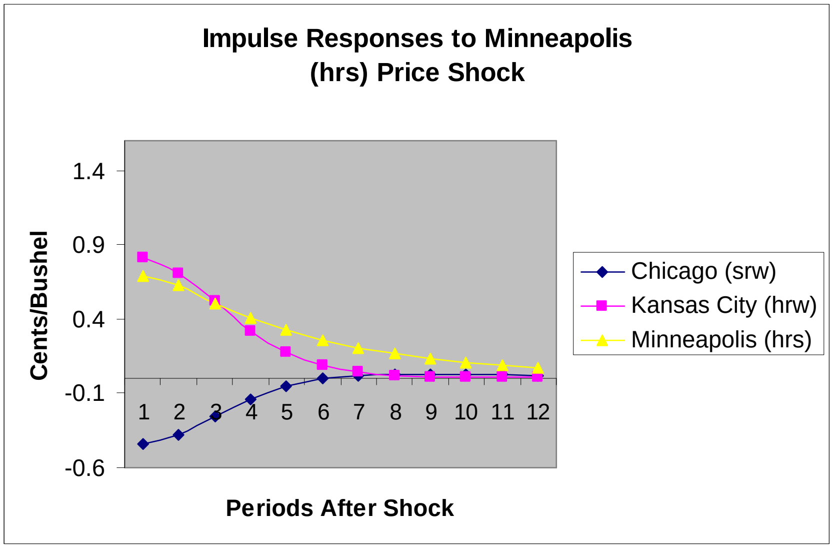
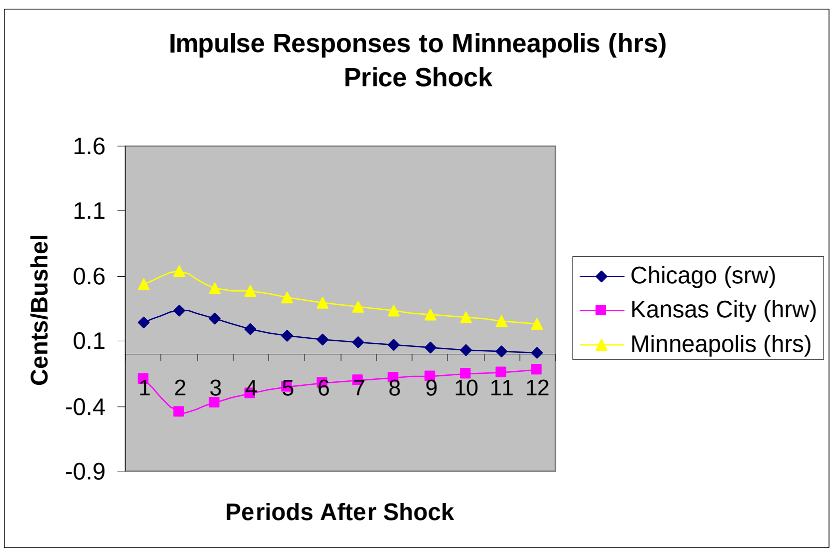


Figure 11.B. Inside Impulse Response to Minneapolis Price Shocks



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