Market Delineation and Price Leadership in the World Wheat Market: A Cointegration Analysis

Atanu Ghoshray

Wheat types may be classified according to strength, a baking characteristic. Since the demand for wheat is derived demand, the baking characteristic is directly related to end use. Accordingly, the wheat classes that are used in this study are divided into sub-groups according to strength, that is, strong, medium, and weak wheats. Time-series methods are employed to determine how the different classes of wheats are related within each sub-group. The different wheats under the different sub-groups are found to be substitutes to various degrees, but form a robust cointegrating relationship, implying that the wheat prices in these markets are bound together by a long-term equilibrium relationship. Within each of the sub-groups, the U.S. wheats were found to act as a price leader, driving the prices of other wheats belonging in the same sub-group. These U.S. wheats were found to form no long-run relationship between each other given their distinct end uses. The study highlights the importance of differentiating wheat by end use to specify price linkages more accurately.

Key Words: cointegration, wheat, price leadership, market segmentation

The examination of price relationships is the essence of market analysis. A number of definitions are based on the relationship between prices. According to Marshall (1890) and Cournot (1971), prices are allowed to deviate from each other in the short run, but arbitrage and/or substitution allow the prices to be related in the long run. Stigler (1987) defines a market as the area within which the price of a good tends to uniformity, allowances being made for transportation costs. Within a country, the "extent of a market" (see Stigler and Sherwin 1985) may include regions linked by arbitrageurs. This market can also extend internationally when separate countries trade with each other. This definition has led to a growing literature on market delineation using time-series methods (see Benson and Faminow 1990, Asche, Salvanes, and Steen 1997, Asche, Bremnes, and Wessells 1999). If a single market for a good were to exist, this would imply that a price change in one good in that market would lead to a similar change in the price of other related goods in that market through arbitrage on the supply side and/or substitution on the demand side. However, if the goods are in different markets, then the price of the good can evolve independently over time without having any influence or causation on the other goods. In this way, the relevant market boundaries can be defined by examining the relationship among different prices of goods.

Wheat accounts for a substantial volume of trade in agricultural commodities and emanates from five principal exporters [the United States, Canada, the European Union (EU), Australia, and Argentina] that together account for over 80 percent of total wheat traded (Mohanty, Meyers, and Smith 1999). As the intensity of competition in the wheat market increases, so does the differentiation of important quality characteristics. The major wheat-exporting countries together account for several classes of wheat traded internationally. Different classes of wheat have different end uses and are not always considered as close substitutes (Antle and Smith 1999). For instance, the Canadian Western Red Spring wheat is considered to be a high quality wheat and generally commands a premium on the world market (Larue 1991). For

Atanu Ghoshray is Lecturer in Economics in the Department of Economics and International Development at the University of Bath in Bath, England. The author is grateful to the editors and three anonymous reviewers for their insightful comments. Special thanks are extended to the International Grains Council (IGC) for providing the data used in this study. The usual disclaimer applies.

any other class of wheat to be substitutable, the two classes of wheat would need to be perceived by the consumer as being of similar end use and closely priced. For example, if the price of Canadian Western Red Spring wheat is reasonably higher than the prices of other classes of wheat that have similar end uses, then consumers will switch their consumption to those other classes of wheat. As a result the price of Canadian Western Red Spring wheat will decline. This process will continue until the price gap between the two related commodities is reasonably narrowed down so that consumers will stop switching their consumption from Canadian Western Red Spring wheat to other classes of wheat. In other words, the prices of commodities with similar end uses should not diverge from each other to a great extent in the long run (Bose and McIlgrom 1996). From an econometric point of view this would imply that prices of wheats with similar end uses should be cointegrated.

A considerable body of research has been carried out on the structure of the international wheat market. McCalla (1966) concluded that the world wheat market could be characterized as a duopoly, with Canada assuming the role of price leader and the United States playing the role of a follower. With the emerging prominence of Australia as a major exporter of wheat, Alaouze, Watson, and Sturgess (1978) claimed that McCalla's duopoly model could be more accurately described as a triopoly. The conclusion of their study was that Canada acted as a price leader and the United States and Australia as price followers. More recent studies have concluded that the world wheat market can be characterized as an oligopoly (see Paarlberg and Abbott 1986, Kolstad and Burris 1986, Smith, Goodwin, and Holt 1995) as a result of the changes that have taken place in the world wheat market. Argentina's exports have steadily increased over time, thereby making it a major exporter. In addition, the EU has emerged as a major exporter of wheat. However, the increase from three to five major wheat exporters has not altered the oligopolistic nature of the world wheat market (Smith, Goodwin, and Holt 1995).

It has been suggested by Veeman (1987), Wilson (1989), and Larue (1991) that wheat should be differentiated according to end use when estimating econometric models. A major implication of these studies is that econometric models of wheat prices that assume product homogeneity generate estimates with no clear interpretation of market integration. Classes of wheat have genetic differences that make them more or less suitable for particular end uses. The different classes of wheat could influence international price linkages if these wheat types were imperfect substitutes for one another (Smith, Goodwin, and Holt 1995, Mohanty, Meyers, and Smith 1999). Past studies (Smith, Goodwin, and Holt 1995, Mohanty, Peterson, and Kruse 1995, Mohanty, Meyers, and Smith 1999, Bessler, Jian, and Wongcharupan 2003) have ignored this issue and have assumed that even in light of quality differences, individual wheat types are reasonably close substitutes in consumption. Given the number of possible combinations of wheat exporters and the differences in prices offered for the various classes of wheat, it is likely that some past studies on price dynamics in the international wheat market will be misspecified.

The question of price leadership is of interest as several economic studies of international trade in wheat have characterized the international wheat market as imperfectly competitive.[1] The issue of price leadership is of interest because the wheat market is perceived to be imperfectly competitive and the presence of single-desk sellers, asserted by the Canadian Wheat Board (CWB),[2] to be capable of exerting market power (Smith, Goodwin, and Holt 1995). Many studies have used time-series analysis to investigate the issue of price leadership role in the international wheat market. Applying a vector autoregression model and impulse response functions on monthly price data from July 1975 to December 1986, Goodwin and Schroeder (1991) find evidence of price leadership for the United States. Mohanty, Peterson, and Kruse (1995) used a Granger causality test to find that the U.S. price influences the export price of other wheat exporters. Both studies conclude that the United States is a price leader in the world wheat market. In contrast, Smith, Goodwin, and Holt (1995) employed Granger causality and impulse responses on monthly export prices over a thirteen-year period (1978–1991) to find

[1] See Paarlberg and Abbott (1986), Thursby and Thursby (1990), and Smith, Goodwin, and Holt (1995).

[2] Commissioner Hehn of the Canadian Wheat Board was quoted: "…the CWB sells wheat and barley at different prices in different markets, depending on the competition it faces from other exporting countries" (CWB News Release No. 94-95015).

that Canada behaves as a price leader. More recently, Mohanty, Meyers, and Smith (1999) concluded that over the time period January 1981 to June 1993, no distinctive price leader existed among the five major wheat exporters. With the help of an error correction model using directed acyclic graphs over a time period January 1981 to June 1999, Bessler, Jian, and Wongcharupan (2003) find evidence that Canada is a price leader. The inconsistency in past studies regarding price leadership may be attributed to the restrictive assumption that the different classes of wheat are close substitutes in consumption. Clearly, the mixed empirical results suggest the need for further analysis.

This paper takes into account the implication of different classes of wheat, in that the end-use differences of wheat can affect international price linkages. The objective of this paper is to analyze the price relationships in the international wheat market by grouping different classes of wheat into sub-groups according to similar end use and to evaluate the possibility of whether a single market exists for these different classes of wheat. Under this framework, econometric evidence is presented about the potential roles of major wheat-exporting countries as price leaders or followers. The following section describes the characteristics of the major wheats traded on the world market, followed by the model specification, a description of the data, and the empirical analysis. Finally, the last section concludes the study.

The Different Classes of Wheat

Various types of wheat are produced around the world based on characteristics of the local climate. Environmental factors including rainfall, temperature, soil, and topography influence and cause wide variety in such wheat characteristics as protein content, test weight, and kernel size. Plant breeding programs differ greatly from one producing area to another, resulting in wide variations in inherited attributes. Differences in environment and genetics among wheat-producing areas of the world or within one country result in wide variations in the characteristics of wheats produced, even among those of the same general type.[3] The quantity and quality of protein is an important attribute of wheat in determining end-use suitability (Kent and Evers 1994). Table 1 displays the required protein levels of the major wheats exported internationally and the protein ranges of typical end uses of wheat. It can be seen in Table 1 that the overlapping protein ranges portray the possibilities of class substitutions. Differences between protein ranges and realization of protein quality differences between classes reveal the inability of wheat classes to be homogenous from a technical perspective.

A commonly used basis for classifying wheat is according to hardness or strength (Kent and Evers 1994). "Hardness" of wheat is a milling characteristic, whereas "strength" is a baking characteristic. Since the demand for wheat is derived demand, the baking characteristic is directly related to end use. Wheats yielding flour that is used for making bread of large loaf volume are classified as strong and usually have high protein content. Wheats yielding flour that is used in the production of flat bread and oriental noodles are classified as medium strength. Wheats yielding flour that is used for making confectionary products are classified as weak and are usually characterized by low protein content. It must be noted that protein content does not necessarily indicate the strength of the wheat noodles (Morris and Rose 1996). The Australian Prime Hard wheat, which is a hard wheat, mills flour that is of medium strength, whereas Australian Standard White, which has a relatively low protein content, mills flour that can be classified as medium-strong. Wheat is used in the preparation of countless food products. High-protein (that is, 13 percent or more) hard red spring wheats are the most preferred for making bread and rolls. For making flat breads, medium-strong wheats with 11 to 11.5 percent protein content are used. The Australian Standard White and Australian Prime Hard, which mill medium-strong flour, are particularly suitable in the production of oriental noodles (Morris and Rose 1996). In the case of weak wheat, the major end products tend to be biscuits and confectionary products. Weak wheats are not suitable for bread making. Following Kent and

[3] Grade-handling technologies can affect wheat quality. Hyberg et al. (1993) and Mercier (1993) have studied the economic costs and benefits of cleaner grain.

Table 1. Protein Content of Wheat

Uses		Sources	
Product	Protein Content	Wheat Class	Protein Content
Bread	13–14%	Canadian Red Spring	13.5–14.5%
Hard rolls	13–14%	U.S. Dark Spring	13–14%
Flat bread	10–11.5%	U.S. Hard Red Winter	11–12%
Crackers	10–11%	U.S. Soft Red Winter	8–11%
Biscuits	9–11%	U.S. Western White	7–11%
Cake	9–9.5%	EU Standard	10–11%
Cookies	8–9%	Australian Standard White	9–11.5%
		Australian Prime Hard	13–14%
		Argentinean Trigo Pan	11–12%

Source: Halverson and Zeleny (1988) and Morris and Rose (1996).

Evers (1994), the wheat classes employed in this study can be classified into groups according to their baking strength. Strong wheats include the Canadian Western Red Spring and U.S. Dark Northern Spring wheat; medium-strong wheats include the U.S. Hard Red Winter, Australian Prime Hard, Argentinean Trigo Pan, and Australian Standard White; and weak wheats include U.S. Soft Red Winter, U.S. Western White, and EU Standard wheat.

Model Specification

Goodwin and Schroeder (1991) and Goodwin (1992) have chosen the vector autoregressive (VAR) framework to estimate relationships between prices in the international wheat market. More recently, Smith, Goodwin, and Holt (1995), Mohanty, Peterson, and Smith (1996), Mohanty, Meyers, and Smith (1999), Lloyd et al. (2001), and Mohanty and Langley (2003) have extended the VAR analysis, employing advances in time-series methods to test for long-run relationships between agricultural commodity prices.

To briefly illustrate the Johansen (1988) methodology, the following vector error correction model (VECM) involving up to, say, k lags of $\mathbf{P_t}$ is specified:

$$(1) \qquad \Delta\mathbf{P_t} = \sum_{i=1}^{k-1} \mathbf{\Gamma_i} \Delta\mathbf{P_{t-i}} + \mathbf{\Pi P_{t-1}} + \mathbf{u_t}$$

$$\mathbf{u_t} \sim \text{i.i.d}\left(\mathbf{0}, \mathbf{\Omega}\right),$$

where $\Delta\mathbf{P_t}$ is an $n \times 1$ vector of first-differenced price series. This way of specifying the system contains information on both the short- and long-run adjustment to changes in $\mathbf{P_t}$ via the estimates of $\mathbf{\Gamma_i}$ and Π respectively. If $\mathbf{P_t}$ is $I(1)$ and has $r < n$ cointegrating vectors, then the rank of Π is equal to r. In this case Π can be factorized into $\alpha\beta'$, where α and β are two $n \times r$ matrices. The matrix α represents the speed of adjustment to equilibrium, while β is a matrix of long-run coefficients such that the term $\beta'\mathbf{P_{t-1}}$ represents a cointegrating relationship that is $I(0)$, which ensures that $\mathbf{P_t}$ converge to their long-run steady-state solutions. To investigate whether the different wheats compete in the same market, an investigation is made into the long-run relationship between the strong, medium-strong, and weak wheat prices. An economic interpretation is that arbitrage and substitution binds the prices together over time. If the multivariate cointegration test indicates one common trend in the system, it is that there exists a single market for each sub-market and that the wheats are perfect or close substitutes for another. The existence of more than one common trend indicates a lower substitutability between the wheats for each sub-market (Asche, Salvanes, and Steen 1997).

The speed of adjustment towards the long-run relationship is given by the size of the coefficients in α. Johansen and Juselius (1992) developed a test based on the notion that variables that do not respond to disequilibrium in the system of which they are a part may be considered weakly exogenous to that system. If the null hypothesis that one of the rows of the α matrix, say, α_i, equals zero cannot be rejected, then the equation for the corresponding $\Delta\mathbf{P}_{\mathbf{it}}$ contains no information about the long-run β since the cointegration relationships do not enter into this equation, and therefore it is valid to condition on the weakly exogenous variable $\Delta\mathbf{P}_{\mathbf{it}}$ and proceed with the following conditional parsimonious version of the VECM in (1) by

$$(2) \qquad \Delta\mathbf{P}'_{\mathbf{t}} = \mathbf{\Phi}\Delta\mathbf{P}_{\mathbf{it}} + \mathbf{\Gamma}\Delta\mathbf{P}_{\mathbf{t-1}} + \boldsymbol{\alpha}_{11}\boldsymbol{\beta}'\mathbf{P}_{\mathbf{t-1}} + \mathbf{v}_{\mathbf{t}}\,,$$

where $\Delta\mathbf{P}'_{\mathbf{t}}$ is an $(n-1) \times 1$ vector of first-differenced $I(0)$ price series and α_{11} is equal to α with $\alpha_i = 0$.[4] The weak exogeneity test indicates which of the prices in the system adjusts to maintain the cointegrating relationship, and thereby offers evidence of "price leadership."

Finally, if there are a large number of variables, n, then using the multivariate approach, one is exposed to what Hendry labels the "curse of dimensionality" in dynamic models (Hendry 1995, p. 313). Under this problem, the number of parameters, p, grows as the square of the number of variables n, times the maximum lag l, so that $p = n^2l$. Hence, the more variables included in the system, the more quickly the available degrees of freedom will dissipate. This issue reinforces the point that in order to measure the price linkages accurately, we need to divide the wheat prices into smaller groups.

Description of Data

The data used for the analysis are monthly average export price quotations from July 1989 to December 1999. Border prices are used instead of internal prices since the latter are not available for all the countries and classes of wheat to be covered in this study.[5] The prices include Argentinean Trigo Pan (ATP), Australian Standard White (ASW), Australian Prime Hard (APH), Canadian Western Red Spring (CWRS), U.S. Dark Northern Spring from the Pacific port (USDS), U.S. Hard Red Winter (USHRW), U.S. Soft Red Winter from the Gulf port (USSRW), U.S. Western White (USWW), and EU Standard Winter (EUSW) wheat. The data source was the *World Grain Statistics*, published by the International Grains Council. All prices are quoted in U.S. dollars. The subsequent analysis of the data is carried out on the logarithm of prices. Figure A1 in the Appendix illustrates wheat export prices. Figure A1 consists of Panels, A, B, and C, which show the price movements of strong, medium-strong, and weak wheat prices, respectively. In each of the sub-markets, it seems that the wheat prices co-move.

It has been controversial to use quoted prices for econometric analysis. First, there has been criticism about the use of quoted prices on the grounds that they do not reflect actual prices. However, according to Mohanty, Peterson, and Kruse (1995) and Mohanty, Meyers, and Smith (1999), quoted prices may be used to reflect demand and supply. Failure to reflect supply and demand conditions would imply that the market does not clear. Further, Goodwin (1992) has argued that though the relationship between actual and quoted prices is not perfect, quoted prices may be used to represent actual prices.

Second, data frequency could make an important impact on the results of the test for cointegration. Spriggs, Kaylen, and Bessler (1982) employed daily prices to examine the relationship between Canadian and U.S. wheat prices on the prior belief that any lead lag relationship in prices would be observed in one or two days at the most. However, complete data on a daily basis for the range of wheats (which includes the five major exporters and the different classes of wheat) analyzed in this study is not available. Past studies have not employed weekly data as there are a large number of missing observations for all the major wheat exporters, except the United States. Von Cramon-Taubadel and Loy (1996) have used weekly wheat prices for the United States and Australia only, but do not explain how they treat the missing observations for Australia. This makes it difficult to decide how much weight to attach to those results.

Third, it has been argued that subsidies could contribute to a divergence between actual and

[4] The number of lags has been set equal to 1 for notational convenience.

[5] Border prices are more appropriate for the Law of One Price than internal prices because they better represent arbitrage opportunities (see Goodwin, Grennes, and Wohlgenant 1990). Internal prices may differ because of domestic transportation costs, processing costs, and sales taxes, without providing any opportunity for profitable arbitrage. For instance, Officer (1989, p. 17) found that the largest deviations from the LOP were due to special indirect taxes and monopoly distribution. The use of border prices avoids this problem.

quoted prices. The Export Enhancement Program (EEP) subsidy is a case in point. However, in an oligopolistic wheat market, export subsidies such as the EEP are the result of a country's response to another country (Mohanty, Peterson, and Kruse 1995). It has been argued by Brooks, Devadoss, and Meyers (1990) that the subsidy levels of major exporters are positively correlated, so that if a major wheat-exporting country raises its subsidy, other major exporters of wheat respond by raising their subsidies. For instance, Mohanty, Peterson, and Kruse (1995) conclude that the EEP bonuses were based on the EU export prices. Besides, there is no complete data available on actual market prices.[6] Past studies such as Goodwin and Schroeder (1991), Mohanty, Peterson, and Kruse (1995), Smith, Goodwin, and Holt (1995), Mohanty, Meyers, and Smith (1999), Ghoshray (2002), Bessler, Jian, and Wongcharupan (2003), and Mohanty and Langley (2003) have used quoted prices on the basis that there is likely to be some relationship between quoted and realized wheat prices. However, caution needs to be exercised in interpreting the results of the analysis.

Empirical Analysis

The price series were initially tested for their order of integration. Table 2 presents the results of the Augmented Dickey Fuller (ADF) tests for each of the price series expressed in log levels and in growth form (first difference of log levels). The lag length was determined by the Schwartz Bayesian Criterion (SBC). From the results of Table 2 it is clear that unit roots cannot be rejected for the price series in levels at the 5 percent significance level but can be rejected in growth form. The results conclude that the log level of each price series is integrated of order one, that is, $I(1)$.

The multivariate analysis using Johansen's Maximum Likelihood method of testing for the presence of multiple cointegrating vectors is employed. The results of the test are given in Table 3. The multivariate cointegration test finds one common trend in the strong wheat market, thereby implying that there exists a single market for strong wheat. In other words, both strong wheats in the above analysis can be classified as close substitutes for one another. The finding of a single market for the strong wheat prices is not surprising, as the wheats included in this sub-market have similar end uses. Interestingly, the competition for export share between the United States and Canada has been intense for the strong wheats (Sumner and Boltuck 2001). Given that a single common trend was found for the strong wheat market, a test for homogenous coefficients on the cointegrating vector was made to find out whether perfect price transmission exists. The likelihood ratio statistic obtained was $\chi^2(1)$ = 11.01[0.00]. Thus we can reject perfect price transmission for the strong wheat market.

In the medium-strong wheat market, the multivariate cointegration test finds a single cointegration vector and thus three common trends in the system. We can still conclude that interdependencies exist among the price series, given that the cointegration test indicates the existence of a long-run relationship. However, one implication that arises from the results is the lower substitutability between the wheat prices in the medium-strong wheat market. A similar result is found for the weak wheat market. A single cointegrating vector (or alternatively two common trends) is found, implying that a long-run relationship holds between the different wheat prices classified as weak wheats. However, the results indicate that in the weak wheat market, the wheats are imperfect substitutes for each other.

Given that there exists a long-run relationship between the wheat prices in each of the separate sub-markets, it might be of interest if we investigate whether the price of a single class of wheat drives or leads the prices for all other wheats belonging to the same sub-market. This amounts to a test for each of the prices in the sub-markets for weak exogeneity, and can be tested by making restrictions on the α matrix. The tests are distributed as χ^2 statistics. The results for the strong, medium, and weak wheat markets are given in Table 4.

An interesting result emerges from the results of the weak exogeneity tests. In the strong wheat

[6] However, the actual transaction prices are not available as they are usually tightly held secrets of trade (Smith, Goodwin, and Holt 1995). The prices used in this paper are average monthly export price quotations, which, according to Smith, Goodwin, and Holt (1995), are likely to overstate actual transaction prices. This is because quoted prices do not include the discounts that are often associated with exports.

Table 2. Augmented Dickey Fuller (ADF) Tests

Variables	Levels	Differences
ATP	-2.24	-7.30*
ASW	-1.82	-8.03*
APH	-2.33	-7.44*
CWRS	-2.58	-9.03*
USHRW	-1.95	-8.78*
USSRW	-1.81	-8.26*
USDS	-2.18	-7.06*
USWW	-1.98	-6.97*
EUSW	-2.41	-6.43*

Note: * indicates rejection of the null hypothesis of non-stationarity or null unit roots at the 5 percent significance level. Critical value is -2.88.

market, the null hypothesis of weak exogeneity is clearly rejected for the CWRS wheat at the 5 percent significance level. It may be concluded that in the long run, the price of USDS wheat drives the prices in the strong wheat market. In the case of the medium-strong wheat market it can be concluded that the USHRW wheat is weakly exogenous, thereby evolving independently, and that the other wheats are adjusting to any deviations in the long-run relationship between the medium-strong wheat prices. Similarly, in the case of the weak wheat market, it was found that we could not reject the null hypothesis that the USWW wheat is weakly exogenous, implying that the USWW wheat drives the price of all the wheats in the weak wheat market. The upshot is that in all three sub-markets it is the U.S. wheat prices that are driving the prices of the other wheats.

The above results call for a dynamic analysis of the relationships between prices in each sub-market. To investigate this issue, Figures A2, A3, and A4 in the Appendix illustrate the impulse response analysis for each of the sub-markets. The impulse response analysis incorporates the error correction term and is represented as accumulated responses. The impulse response function in the strong wheat market generated by a one-unit orthogonalized shock is illustrated by Panels A and B in Figure A2. There is a significant impact to an own-price shock for the CWRS price. In the following months the effect of the shock starts to diminish, and then stabilizes in approximately nine months to a new equilibrium. The response by the USDS price is initially lower, but continues to increase before stabilizing and settling down to a new and higher equilibrium. The shock in the USDS price produces a much higher response in the own price and a relatively lower initial response from the CWRS price. Both prices reach a plateau above zero in approximately four months, indicating that they reach new and higher equilibrium levels.

In Figure A3, Panel A, a one-unit orthogonalized shock in the ATP price brought about a significant response of a 0.08-unit increase in its own price. The shock diminishes and then stabilizes in approximately five months. The initial responses in the ASW and APH prices were lower, at 0.015 and 0.009, respectively. There was no initial response from the USHRW price. In the following months the impact on all three prices increases, and then stabilizes after 5 months. In Panel B the effect of a one-unit orthogonalized shock in ASW is illustrated. The initial own-price response is significantly high at around 0.037. A positive initial response is found for the APH and ATP prices, whereas there is no initial response of the URHRW price. All prices eventually stabilize after 7 months. In Panel C we observe the effect of a one-unit orthogonalized shock in APH. The initial own-price response is significantly high at around 0.025, whereas there is no initial response of the ATP, ASW, and USHRW prices. All prices eventually stabilize after 5 months. In Panel D, the effect of a one-unit orthogonalized shock in USHRW is shown. The initial own-price response is significantly high at around 0.04. A positive initial response is found for all the other prices. All prices eventually stabilize after 5 months.

Finally, the effects of shocks in the weak wheat market are depicted in Figure A4. Panel A traces the response to a one-unit orthogonalized shock in the USSRW price. Both USSRW and the EUSW price respond in a cyclical fashion, first responding strongly to the price shock and then declining and gradually stabilizing. In Panel B, when the USWW price is shocked, there is a positive price response from both the USSRW and EUSW price. In Panel C, the effect of a one-unit orthogonalized shock in EUSW is shown. The initial own-price response is significantly high at around 0.055. No initial response is found for all the other prices; however, in the following

Table 3. Multivariate Johansen Test

	Strong Wheat	Medium-Strong Wheat	Weak Wheat
Rank	Trace Statistic	Trace Statistic	Trace Statistic
$p = 0$	29.08*	52.6**	35.67*
$p \leq 1$	5.98	25.3	14.44
$p \leq 2$		6.86	2.52
$p \leq 3$		1.46	

Note: * indicates significant at the 5 percent level and ** indicates significant at the 10 percent level.

Table 4. Weak Exogeneity Tests

Strong Wheat		Medium-Strong Wheat		Weak Wheat	
Prices	Statistic	Prices	Statistic	Prices	Statistic
CWRS	5.43	ATP	5.97	USSRW	6.32
	[0.02]		[0.01]		[0.01]
USDS	0.35	ASW	3.15	USWW	0.11
	[0.55]		[0.07]		[0.73]
		APH	4.77	EUSW	2.81
			[0.02]		[0.09]
		USHRW	0.05		
			[0.81]		

Note: The numbers in square brackets denote p-values.

7 months there is an immediate decline in USSRW prices. While the long-run effect for USWW price is negative, the difference from zero is relatively insignificant. Apart from the shocks in the EUSW price, all shocks generate time paths which are positive and stabilize between four to nine months. This observation to a large degree is expected, and consistent with the weak exogeneity tests. In the strong wheat market the shocks for the CWRS wheat take relatively longer to disappear than the USDS price. In the weak wheat market the EUSW and USSRW wheats take longer to stabilize than for the USWW wheat. In the medium-strong wheat market the shocks to all prices stabilize around the same time, between four to seven months; however, there is no initial impact on the USHRW wheat in response to a shock in the other wheat prices belonging to the same sub-market.

Having obtained the long-run cointegrating relations using the Johansen approach, tested for weak exogeneity, and generated impulse response functions, we can obtain further information about the short-run dynamics of the prices by modeling a parsimonious conditional vector error correction model (VECM). The results are reported in Table 5.

In the strong wheat market the weakly exogenous price—that is, the USDS—has a coefficient equal to 0.64. This implies that the impact of current changes in the USDS price is fairly high, that is, approximately 64 percent of changes in prices are incorporated in the CWRS prices within a month. The error correction coefficients in the strong wheat market (denoted by ECM1) indicate that the speed of adjustment to equilibrium is slow but significant, that is, approximately 9 percent of the deviation is corrected in one month. In the medium-strong wheat market, the weakly exogenous price, USHRW, indicates that the impact of current changes on the other wheat prices is considerably different. The impact on the ATP wheat price is quite high at around 0.71, but relatively low on the APH price equal to 0.32. The error correction coefficients in the medium-strong wheat market (denoted by ECM2) show that the speed of adjustment is slow and significant for the Australian prices but relatively high for the ATP wheat price. In comparison with the strong wheat market, the speed of adjustment coeffi-

Table 5. Conditional Vector Error Correction Model

	Strong Wheats		Medium-Strong Wheats		Weak Wheat	
	ΔCWRS	ΔATP	ΔASW	ΔAPH	ΔUSSRW	ΔEUSW
ΔUSDS(t)	0.64 (11.59)					
ΔCWRS(t-1)	0.22 (2.49)					
ΔUSDS(t-1)	-0.14 (1.81)					
ECM1(t-1)	-0.09 (2.74)					
ΔUSHRW(t)		0.71 (4.88)	0.49 (5.29)	0.32 (3.64)		
ΔATP(t-1)		0.36 (3.71)	0.002 (0.04)	-0.01 (0.17)		
ΔATP(t-2)		0.08 (0.84)	-0.02 (0.36)	0.02 (0.45)		
ΔASW(t-1)		-0.62 (2.65)	-0.08 (0.55)	-0.38 (2.73)		
ΔASW(t-2)		-0.29 (1.25)	-0.15 (1.02)	0.13 (0.95)		
ΔAPH(t-1)		0.16 (0.74)	-0.05 (0.35)	0.53 (3.85)		
ΔAPH(t-2)		-0.07 (0.32)	-0.12 (0.86)	-0.28 (2.06)		
ΔUSHRW(t-1)		0.12 (0.75)	0.26 (2.54)	0.10 (1.06)		
ΔUSHRW(t-2)		0.07 (0.59)	-0.01 (0.14)	-0.04 (0.55)		
ECM2(t-1)		0.18 (2.72)	-0.07 (1.65)	-0.06 (1.54)		
ΔUSWW(t)					0.93 (10.2)	0.70 (6.72)
ΔUSSRW(t-1)					0.04 (0.51)	0.26 (2.58)
ΔEUSW(t-1)					0.09 (1.35)	0.22 (2.77)
ΔUSWW(t-1)					-0.31 (2.24)	-0.02 (0.12)
ECM3(t-1)					0.15 (3.92)	-0.12 (2.85)
Serial Correlation	1.39 [0.24]	1.14 [0.34]	0.78 [0.60]	0.39 [0.90]	1.85 [0.16]	1.27 [0.16]
ARCH	1.04 [0.40]	0.05 [0.99]	2.00 [0.06]	0.73 [0.64]	1.11 [0.36]	0.79 [0.59]
Heteroskedasticity	1.54 [0.15]	0.45 [0.97]	1.29 [0.20]	1.12 [0.33]	0.77 [0.65]	1.06 [0.39]
Functional form	1.28 [0.22]	0.91 [0.62]	0.83 [0.74]	0.71 [0.89]	0.61 [0.89]	0.90 [0.58]

Note: The numbers in parentheses indicate the t-ratios. For the diagnostics, the numbers in square brackets represent p-values.

cients in the weak wheat market (denoted by ECM3) is slightly higher and significant for both the USSRW and EUSW wheat prices. The impact of current changes in the USWW price is fairly high, that is, 0.93 in the case of the USSG short-run equation and 0.70 in the case of the EUSW. This implies that around 93 percent of changes in prices are incorporated into the USSRW price and 70 percent in case of the EUSW price. A battery of diagnostic tests were conducted that revealed that the model passes the test for autocorrelation in residuals and squared residuals, functional form, and heteroskedasticity.

Finally, a test is made to investigate the long-run relationship of wheats across the different sub-markets. Having found that the USDS, USHRW, and USWW wheats are driving the other wheat prices in their respective sub-markets, it may be assumed that these three U.S. wheats can be chosen as representative wheats for each sub-market. The Johansen maximum likelihood method of testing for cointegration was employed to determine whether the three different U.S. wheats were cointegrated. The results are shown in Table 6.

The trace statistics indicate that the null hypothesis of no cointegration cannot be rejected. This result implies that the U.S. wheats are not bound together by any long-run relationship and are thus not considered to be near substitutes. This finding is consistent with the contention that there are increasing market demands for specific wheat classes and end-use performance.

Table 6. Multivariate Johansen Test Across Sub-Markets

Rank	Trace Statistic	95% Critical Value	90% Critical Value
$p = 0$	31.56	35.06	32.09
$p \leq 1$	10.03	20.10	17.95
$p \leq 2$	3.61	9.09	7.56

Conclusion

This paper examines the price relationships for different classes of wheat divided into three sub-markets according to the end use. The number of cointegrating vectors (or number of common trends) reflects the extent of substitution between the different "strong" and different "weak" wheats. The wheats under the sub-group "strong wheat market" are perfect substitutes given the finding of a single common trend. The different wheats under the sub-groups "medium-strong wheat market" and "weak wheat market" are not perfect substitutes, but are substitutes to a certain degree and form a robust cointegrating relationship, implying that the wheat prices in these markets are bound together by a long-term equilibrium relationship.

Within each of the sub-markets, the United States was found to act as a price leader, driving the prices of other wheats belonging in the same sub-group. The USDS wheat in the strong wheat market, the USHRW wheat in the medium-strong wheat market, and the USWW in the weak wheat market were found to be price leaders. Overall, the U.S. wheats seem to lead the prices of other major wheat exporters. This result supports the popular belief that the United States is the price leader (Goodwin and Schroeder 1991 and Mohanty, Peterson, and Kruse 1995) and is in contrast to the studies that suggest that Canadian prices influence U.S. prices (Smith, Goodwin, and Holt 1995, Bessler, Jian, and Wongcharupan 2003) or that no distinct price leader exists (Mohanty, Meyers, and Smith 1999). These past studies could be compared with this study because of similarity in data and method. Results from other studies that are not consistent with this study might be due to the different wheat class or shipping port used in those studies. For example, Mohanty, Meyers, and Smith (1999) and Bessler, Jian, and Wongcharupan (2003) use USHRW and CWRS, which are not close substitutes. Smith, Goodwin, and Holt (1995) chose USDS from the Gulf port and CWRS from the St. Lawrence port, which are close substitutes but are shipped from different port terminals. This study chooses the wheats exported from the Pacific ports. The reason is that over half of USDS wheat exports and three-quarters of CWRS wheat exports are exported from the Pacific port (U.S. Department of Agriculture 1999), which clearly dominates the volume of wheat shipped from the Gulf and St. Lawrence ports.

From the conditional error correction model the USDS is found to have a considerable impact on the CWRS wheat. This result does not support the contention that Canadian export prices have undermined the U.S. wheat price support program (Mohanty, Peterson, and Smith 1996). Rather, the finding that Canada responds to U.S. wheat price changes might be an indication that Canada sets its export price in relation to the price of its close substitute wheat, that is, USDS, exported by the United States. The USHRW wheat is considered as the reference price for wheat in the world market (MacLaren 1999). The finding that it has a significant impact on its substitute wheats is not surprising. The ATP wheat is affected most, as both wheats compete for the same markets, that is, the Middle East countries, particularly Iran. The Australian wheats are affected to a lesser extent, as they are primarily exported to the South East Asian and Far East countries. The USWW wheat seems to have a significant impact on the USSRW wheats and the EUSW wheat. The finding that the EU wheat responds to changes in U.S. wheats goes against the conventional belief that U.S. wheat prices are based on the EU export subsidies (Mohanty, Meyers, and Smith 1999). The results suggest that the United States might have started the Export Enhancement Program (EEP) in response to the EU export subsidies; however, since the EEP's introduction, the EU might be setting its export subsidies in relation to the U.S. prices. Finally, the finding of no cointegration between the three representative wheats belonging to each sub-market indicates that the wheats from each sub-market form no long-run relationship given their distinct end uses. This finding supports the contention that wheat should be differentiated according to end use in econometric modeling (Veeman 1987, Wilson 1989, Larue 1991).

This study highlights the importance of differentiating wheat by end use to specify price linkages more accurately. While wheats belonging to the same market may be amenable to aggregate analysis, wheats that are independent should be modeled in a disaggregate manner (Diakosavvas 1995). Broader implications can be drawn from this study. End-use responses are greater when wheats are more substitutable. As the magnitude of end-use response to an agricultural policy change increases, the errors in the estimates of price, quantity, and welfare effects of the policy caused by using the model of a homogenous commodity increase. Agricultural commodity markets are becoming more differentiated and segmented. Even for the most generic categories of commodities, there can be different quality grades that may lead commodities in the same generic group to form different sub-markets. Market segmentation significantly increases the stakes for market position and policy in agriculture.

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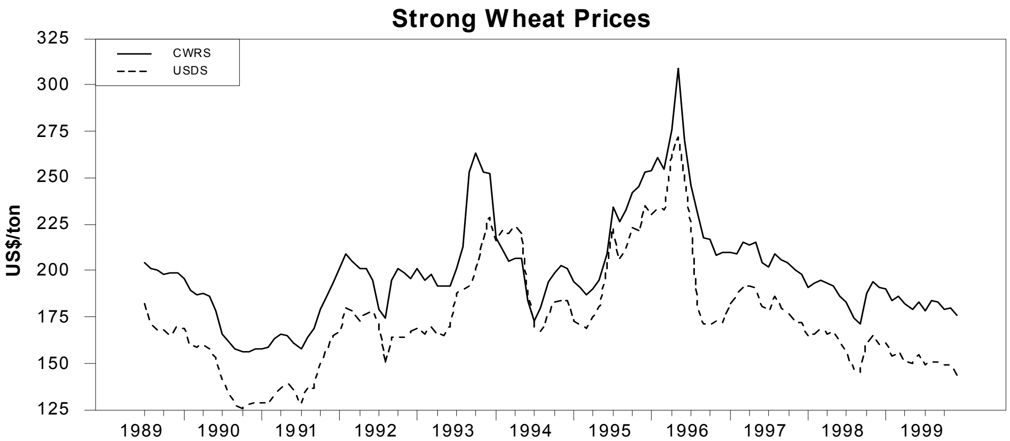
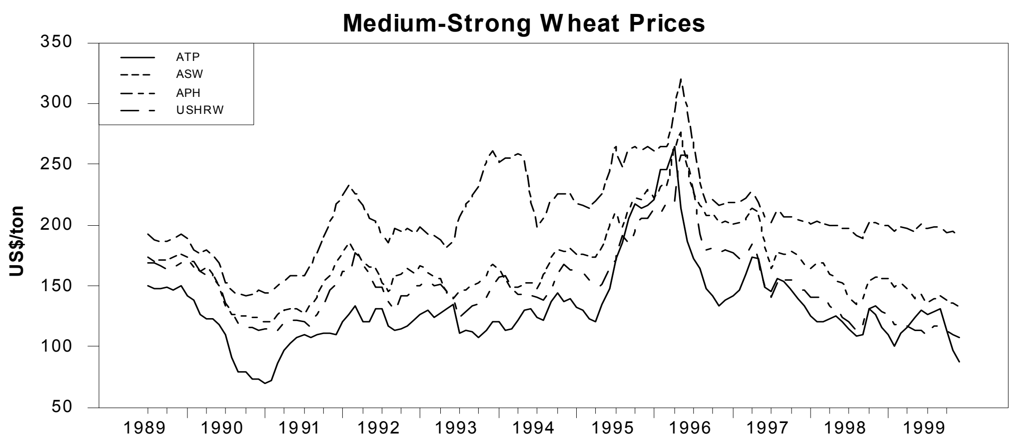
APPENDIX

Panel A



Panel B



Panel C

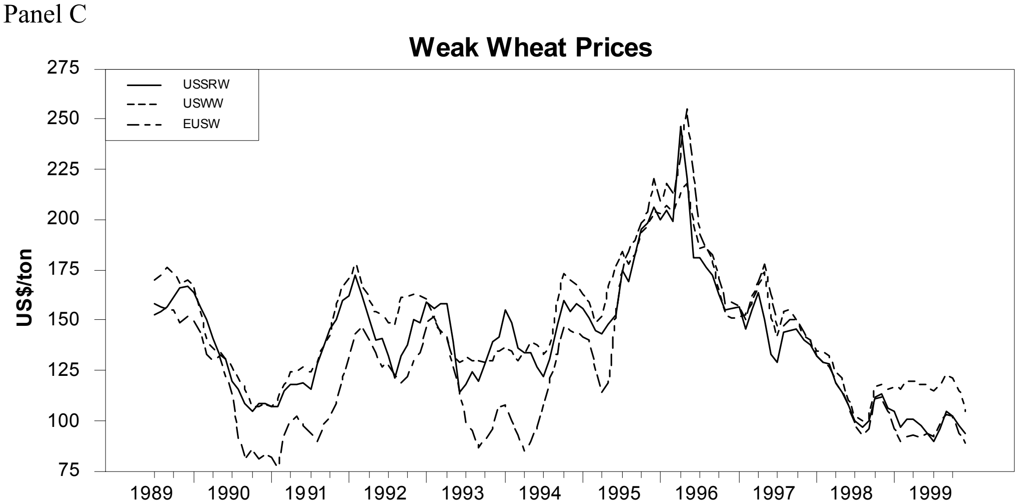
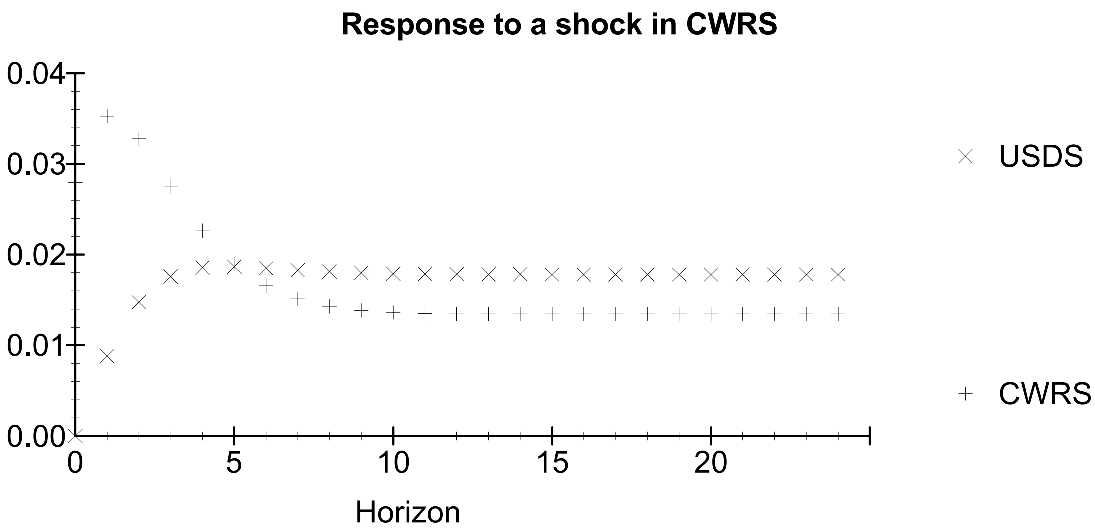


Figure A1. Wheat Prices

Panel A



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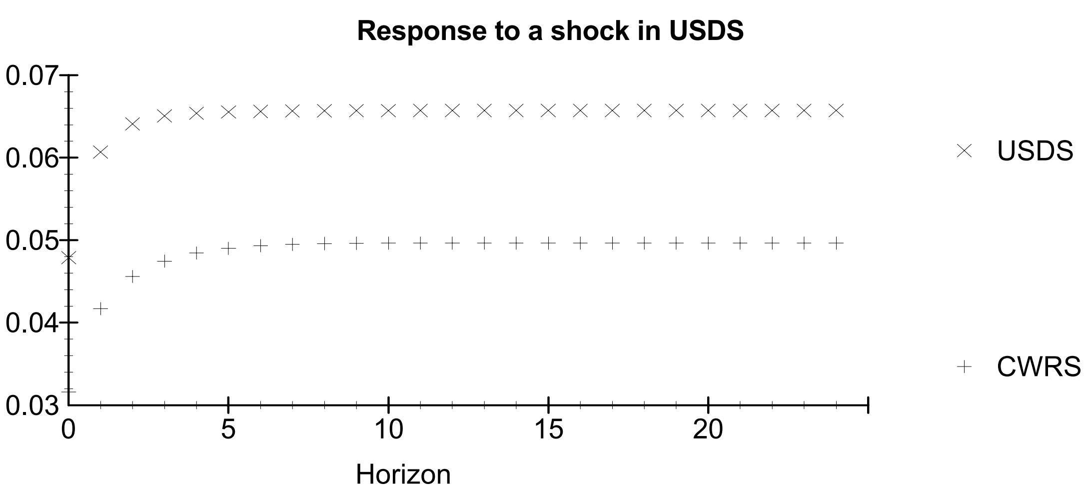
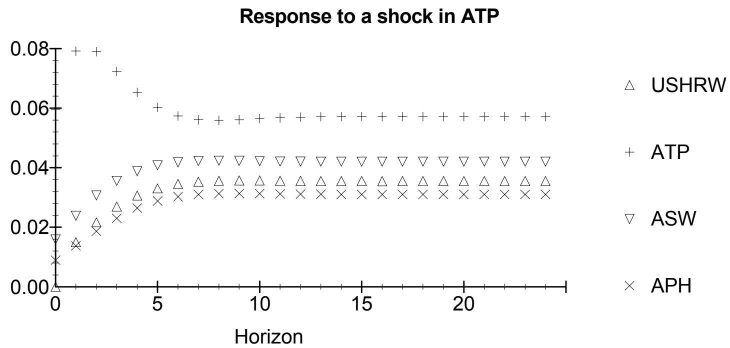


Figure A2. Impulse Response Functions in the Strong Wheat Market

Panel A



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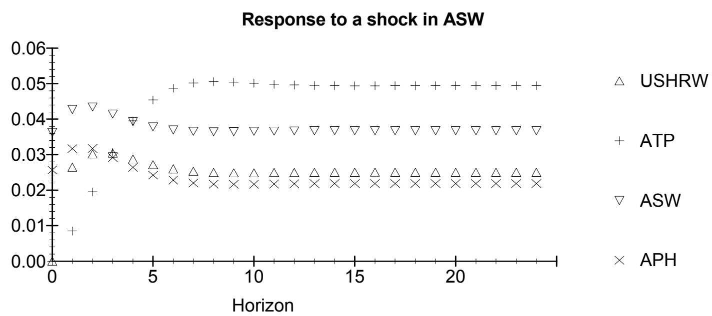

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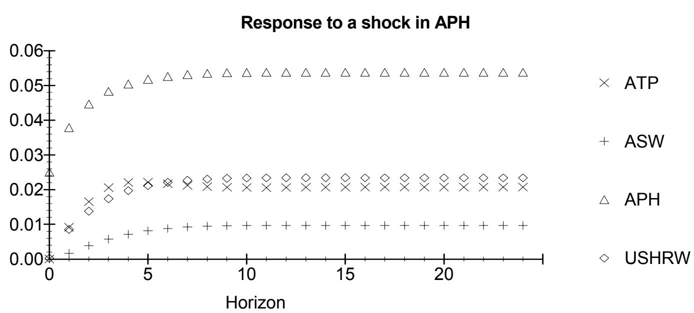


Panel D

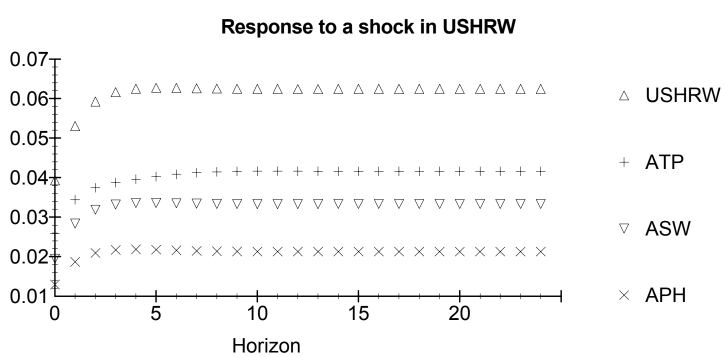
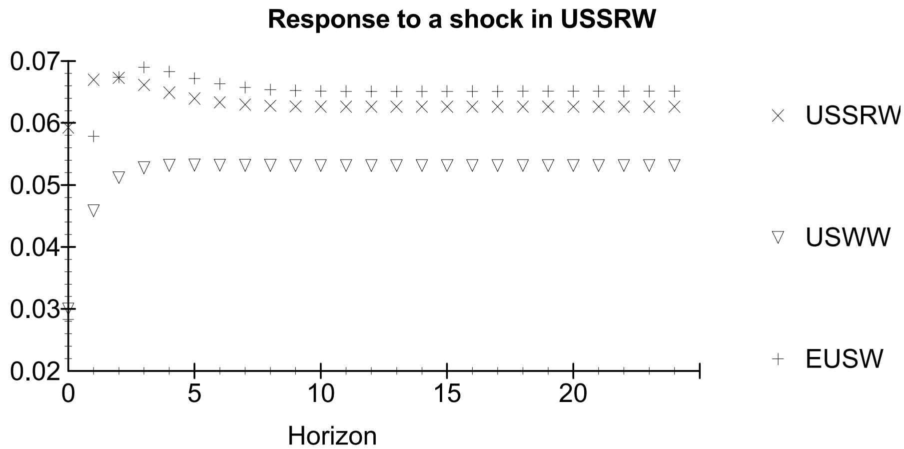


Figure A3. Impulse Response Functions in the Medium-Strong Wheat Market

Panel A



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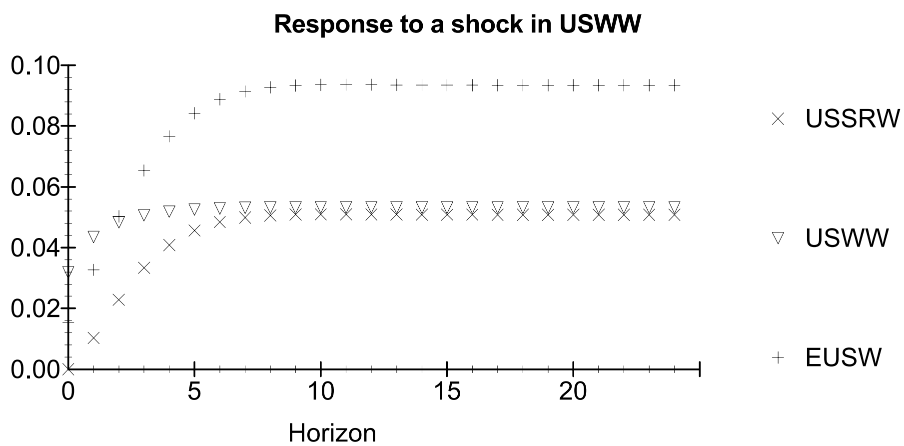

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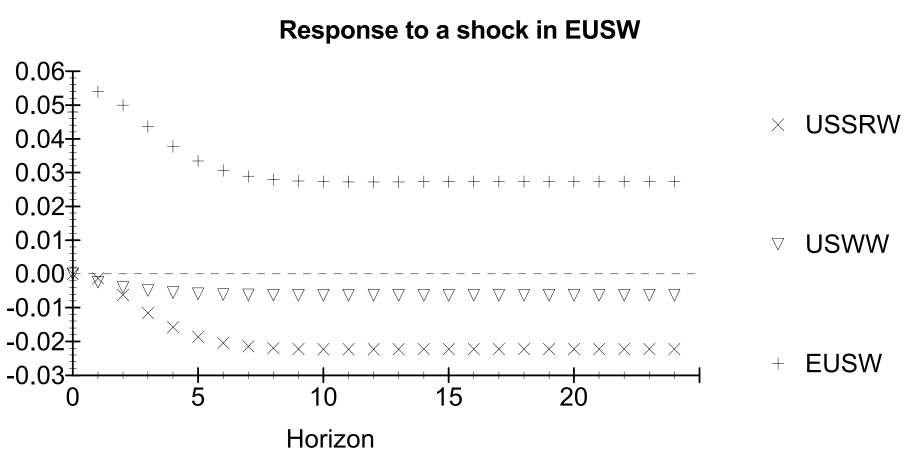

Figure A4. Impulse Response Functions in the Weak Wheat Market