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PRICE DYNAMICS IN INTERNATIONAL WHEAT MARKETS

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Price Dynamics in International Wheat Markets

Abstract

Vector autoregressions are used to evaluate dynamic relationships among prices in six important international wheat markets. The effects of freight rates and exchange rates are also considered. The results indicate that Canada is the dominant market, supporting views that Canada is an oligopolistic price leader.

Key words: international trade, vector autoregressions, wheat markets

Price Dynamics in International Wheat Markets

Introduction

Considerable attention has focused upon price relationships in international grain markets. Issues of market power, government intervention, price instability, and pricing efficiency all have been addressed within the context of price behavior in international grain markets. In theory, prices of a homogeneous commodity in different international markets should be closely linked through trade and arbitrage activities. In competitive markets, arbitrage ensures that prices are perfectly linked across space, such that spatial price differentials are always less than or equal to transportation costs. In this case, markets are said to be perfectly integrated. However, in reality, such linkages may be influenced by a variety of factors, including information flows, transportation costs, exchange rates, barriers to trade, and the exercise of market power by large traders. In addition, because of the significant delivery lags associated with international commodity trade, markets are often slow to adjust to new information and to changes in local and global supply and demand conditions. In light of these factors, international price linkages may be imperfect and of a dynamic nature, evolving slowly over time in response to new information.

The process by which markets respond to new information is often termed "price discovery." In international markets, the commodity price discovery process may be quite complex. Trade linkages in commodity markets are influenced by financial variables, such as the exchange rate, as well as by information in related markets. In addition, transportation costs have a direct influence on international price linkages.

The objective of this analysis is to evaluate the causal and dynamic elements of spatial price linkages in international wheat markets. The analysis examines lead/lag relationships among monthly wheat prices in six important international wheat markets. The analysis also considers lead/lag relationships between these prices and exchange rates and transportation costs.

The exact nature of price relationships in international wheat markets has been addressed in several investigations. Roe et al. (1986) and Bredahl et al. (1979) evaluated price responsiveness in light of governmental interventions using price transmission elasticities. Binkley (1983) evaluated the effects of freight charges and other marketing costs on wheat price stability. Ardeni (1989), Jabara and Schwartz (1987), and Goodwin et al. (1990) addressed adherence to the law of one price in international wheat markets. Market power implications for international wheat price linkages have been investigated by McCalla (1966), Carter and Schmitz (1979), and Alaouze et al. (1978). Spriggs et al. (1982) examined price leadership roles for U.S. and Canadian markets. Bessler and Babula (1987) evaluated the relationship between exchange rates and wheat exports and prices. In nearly every case, attention has been directed toward reasons why prices may be imperfectly linked across space and, thus, why markets may be imperfectly integrated. However, relatively little attention has been focused upon the dynamic elements of price adjustments in international markets.[1]

International price linkages and the price discovery process may be better understood through an evaluation of the dynamic and causal elements influencing international commodity markets. Such an evaluation may also provide insights into price leadership roles for individual markets, often taken to be an important indicator of market power. Likewise, the dynamic price adjustment paths in individual markets in response to shocks to exogenous variables, such as transportation rates and exchange rates, may have important implications for the overall performance of international commodity markets.

The paper proceeds according to the following plan. The next section discusses an empirical methodology that uses a vector autoregressive (VAR) model to evaluate lead/lag relationships in the international wheat market. The third section applies this methodology to a consideration of causal and temporal relationships between prices, exchange rates, and transportation rates in the international wheat market. The final section contains a brief review of the analysis and offers concluding remarks.

Empirical Procedures

Multivariate vector autoregressive models are often utilized to examine dynamic relationships among a set of interrelated economic

[1]An exception is the work of Spriggs et al. (1982), who addressed lead/lag relationships between daily U.S. (Minneapolis) and Canadian (Thunder Bay) wheat prices. However, our work gives greater attention to the dynamics of international price adjustments over time and we consider a broader range of export markets and related variables.

variables. Such VAR models most often utilize a set of distributed lag equations to model each variable as a function of other variables in the system. Such an approach reduces spurious a priori restrictions on the dynamic relationships (Sims 1972).

A VAR system for n variables can be defined as:

$$Y_t = \sum_{k=1}^{K} \begin{bmatrix} b_{11}(k) & \cdots & b_{1n}(k) \\ \vdots & & \vdots \\ b_{n1}(k) & \cdots & b_{nn}(k) \end{bmatrix} Y_{t-k} + E_t \qquad (1)$$

where t refers to time (t = 1,...,T), Y_t is an n x 1 vector of economic variables, K is the lag order of the system, the $b_{ij}(k)$'s are the parameters to be estimated, and E_t is a vector of random errors. Such VAR models have realized widespread usage in evaluations of dynamic relationships in economic systems (see for example, Bessler and Brandt 1982; Featherstone and Baker 1987; and Sims 1972).

To implement the VAR system, a technique for choosing the appropriate lag order (K) of the system is required. In the empirical applications that follow, the appropriate order of the VAR system was determined using the likelihood ratio test statistic for alternative lag orders. The final lag order chosen was the largest for which the null hypothesis was rejected (Nickelsburg 1985). To verify the final choice of lag length, the Ljung-Box Q statistic was used to test for significant residual autocorrelation in the residuals. In each equation, the Q statistic added support for the final specification in that no significant autocorrelation was detected. In the applications that follow, data were utilized in their levels.

Patterns of causality among the data were evaluated using standard Granger (1969) F-tests for causality. This procedure involves testing the null hypothesis that $b_{ij}(1) = \ldots = b_{ij}(K) = 0$ for each variable j in each equation i of the system. This procedure enables inferences to be drawn regarding which variables are significant causal determinants of other variables.

Inferences regarding the dynamic adjustments in each of the variables in response to unexpected shocks to the series are undertaken by converting the system to a moving-average representation using Choleski decomposition. This conversion allows us to use the VAR system to forecast the time path response to exogenous shocks to any one of the variables (Hakkio and Morris 1984). These time path responses, referred to as impulse responses, are used to examine the adjustments across different markets to unanticipated shocks to variables in the system. The standard errors of the impulse responses are calculated using the Monte-Carlo integration techniques outlined in Doan and Litterman (1987).

The Choleski decomposition of the VAR to a moving-average representation also allows us to evaluate the forecast error decomposition. The forecast error decomposition is used to evaluate the degree of exogeneity of a set of variables relative to another set of variables by computing the percentage of the k-steps ahead squared prediction error of a particular variable produced by an innovation in another variable (Hakkio and Morris 1984).

Empirical Results

The vector autoregressive model was applied to monthly price data covering the period from July 1975 through December 1986 for six important international wheat markets. The data were chosen to include major importing and exporting markets. In particular, export markets included the U.S. Gulf market for No. 2 Dark Northern Spring wheat (14% protein), the Canadian Pacific market for No. 1 Western Red Spring wheat (13.5% protein), the Argentine export market for Trigo Pan wheat, and the Australian export market for Australian Soft White wheat. Import markets included the Rotterdam and Japanese import markets for U.S. origin No. 2 Dark Northern Spring wheat. It is important to note that quality differences may exist in these individual wheat types across markets. Such quality differences could influence international price linkages, if these wheat types are imperfect substitutes for one another. However, even in light of possible quality differences, the markets should be interrelated to the extent that the individual wheat types are substitutes in consumption and, thus, respond to global supply and demand conditions.

The Japanese, Argentine, and Australian prices had a small number of missing observations. Because of the importance of the time series structure of the data series, deletion of missing observations was considered to be too strong a step. Instead, missing observations were replaced by the predicted values from a regression of the individual prices on prices in closely related markets.[2] Wheat prices were

[2]In particular, 11 missing Japanese prices were replaced by predicted values from a regression of Japanese prices on Rotterdam prices. A single observation of the Australian price was replaced by a regression of the Australian price on

collected from the International Wheat Council's World Wheat Statistics series.

Hathaway (1987, p. 14) notes that most agricultural trade in the major bulk commodities is priced in U.S. dollars because of the dominant position of U.S. agricultural exports and the U.S. dollar. Thus, all of the prices utilized in this analysis were quoted in U.S. dollar terms. To represent the influences of exchange rates on dollar prices in the markets, an aggregate measure of U.S. dollar exchange rates was desired. In the analyses that follow, the U.S. dollar / SDR (special drawing rights) exchange rate was utilized to provide a measure of exchange rate effects in each of the dollar-denominated commodity markets.[3]

Freight rates are also an important component of international price linkages for traded commodities. In a situation of perfect arbitrage, commodity prices in corresponding import and export markets should differ by no more than the transportation costs of trade between the two markets. Changes in freight rates thus should be reflected by equilibrating changes to prices in trading markets. An aggregate measure of transportation rates was constructed by taking a simple arithmetic average freight rate across alternative ship sizes for wheat trade between the U.S. Gulf ports and Japan; between the U.S. Pacific

U.S. prices. Five missing values of the Argentine prices were replaced by a regression of Argentine prices on U.S. prices. Details regarding the proxy measures of these missing prices are available from the authors on request.

[3]Monthly average U.S. Dollar / SDR exchange rates were collected from the International Monetary Fund's International Financial Statistics series.

ports and Japan; between the U.S. Gulf ports and Rotterdam; and between the U.S. Atlantic ports and Rotterdam.[4]

The VAR system was estimated using OLS. The likelihood ratio statistics initially indicated that a lag order of 2 months was most appropriate. The Ljung-Box Q-statistics indicated that no significant residual autocorrelation was present in any equation, except the freight rate equation. To purge this autocorrelation, time trends and 3-, 4-, and 12-month lags of freight rates were added to the system of equations.

Contemporaneous correlations of the residual errors of the VAR system are presented in table 1. Of the 28 correlation coefficients, 24 are significantly different from zero at the 5% level. This indicates that a significant portion of information is reflected in price adjustments between the markets within the current month. The correlation coefficients for prices range in magnitude from .22 to .77, with most being around .50.[5] Residual correlation coefficients appear to be highest between individual markets and Canada and the U.S., indicating important roles for these two markets in global wheat price discovery.

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[4]Monthly freight rates for wheat trade between these markets were collected from the International Wheat Council's World Wheat Statistics.

[5]Strong contemporaneous correlation in conjunction with the absence of any significant lead/lag relationships can have two implications for price discovery. First, this may indicate that markets respond rapidly (i.e., within the one-month sampling interval) to new information. Secondly, this result may imply the absence of significant information flows across markets. In the lead/lag relationships that follow, it is important to recognize this limitation of the empirical analysis.

Table 1. Contemporaneous Correlation Coefficients of Residuals for VAR System, July 1975 through December 1986.

	Variable							
Variable	SDR	Canada	U.S.	Australia	Argentina	Rotterdam	Japan	Shipping
SDR	1.00	0.20 (0.02)[a]	0.15 (0.08)	0.26 (0.00)	0.17 (0.05)	0.13 (0.13)	0.33 (0.00)	0.07 (0.42)
Canada		1.00	0.65 (0.00)	0.71 (0.00)	0.31 (0.00)	0.71 (0.00)	0.67 (0.00)	0.25 (0.00)
U.S.			1.00	0.57 (0.00)	0.29 (0.00)	0.77 (0.00)	0.51 (0.00)	0.21 (0.02)
Australia				1.00	0.45 (0.00)	0.48 (0.00)	0.51 (0.00)	0.26 (0.00)
Argentina					1.00	0.22 (0.01)	0.25 (0.00)	0.11 (0.23)
Rotterdam						1.00	0.56 (0.00)	0.26 (0.00)
Japan							1.00	0.18 (0.05)
Shipping								1.00

[a] Significance levels are reported in parentheses

Causal relationships among the individual markets were investigated using the Granger F-tests. The summary F-statistics are presented in table 2. A surprising result is the overall degree of price independence exhibited in the world wheat markets. This is reflected in the relatively low values of the Granger F-statistics for causal comparisons between alternative variables. Causality appears to be unidirectional, in that little feedback is revealed between any two series. In all, 13 of the 64 tests indicate significant causality at the 5% level, and an additional 6 tests are marginally significant at the 15% level.

Canada appears to be the dominant market. Canada's price is not significantly influenced by any variable other than lagged values of its own price. The Canadian export price appears to be a significant determinant of import prices in Japan and export prices in Australia, in that Canadian prices lead prices in each of these markets. This is reasonable because Canada is a major supplier of wheat to Japan, and Australia is an important competitor with Canada for the Japanese market. These results are consistent with oligopoly views (see McCalla 1966 and Alaouze et al. 1978) of the world wheat market, which assume a role of price leadership for Canada.

U.S. export prices also exhibit a high degree of independence. However, causality from exchange rates to U.S. prices is indicated in the F-tests. Trade theory indicates that domestic prices of traded goods will rise as the domestic currency depreciates. This effect is verified in the empirical analyses, in that the coefficients on exchange

Table 2. Granger Blockwise F-Statistics, July 1975 through December 1986.

Dependent Variable	Variable Causing Dependent Variable							
	SDR	Canada	U.S.	Australia	Argentina	Rotterdam	Japan	Shipping
SDR	123.12 (0.00)[a]	1.27 (0.29)	0.95 (0.39)	0.08 (0.92)	0.92 (0.40)	0.67 (0.51)	2.27 (0.11)	0.59 (0.56)
Canada	0.92 (0.40)	35.33 (0.00)	0.22 (0.80)	0.34 (0.71)	0.73 (0.48)	1.68 (0.19)	0.14 (0.87)	1.11 (0.33)
U.S.	3.07 (0.05)	0.94 (0.39)	21.59 (0.00)	0.23 (0.80)	1.38 (0.26)	0.07 (0.93)	1.40 (0.25)	2.09 (0.13)
Australia	0.22 (0.80)	4.07 (0.02)	1.24 (0.30)	18.86 (0.00)	0.29 (0.75)	2.28 (0.11)	0.48 (0.62)	1.11 (0.33)
Argentina	1.04 (0.36)	0.66 (0.52)	0.57 (0.57)	2.81 (0.06)	61.23 (0.00)	0.00 (0.99)	0.49 (0.61)	0.83 (0.44)
Rotterdam	1.39 (0.25)	1.25 (0.29)	5.73 (0.00)	0.06 (0.94)	1.17 (0.31)	3.73 (0.03)	0.15 (0.86)	2.10 (0.13)
Japan	3.15 (0.05)	7.95 (0.00)	0.94 (0.39)	0.58 (0.56)	0.02 (0.98)	0.89 (0.42)	4.21 (0.02)	0.94 (0.39)
Shipping	0.81 (0.45)	0.04 (0.96)	0.43 (0.65)	0.28 (0.76)	0.40 (0.67)	0.46 (0.63)	2.23 (0.11)	85.37 (0.00)

[a] Significance levels are reported in parentheses.

rates are positive in the equation for U.S. prices. U.S. prices are significant determinants of prices in Rotterdam for imported U.S. wheat.

Wheat prices in Australia have a significant (at the 6% level) influence on Argentine export prices. Australian prices are also marginally influenced (at the 11 % level) by price changes in Rotterdam. A surprising result is that the index of freight rates does not appear to be a strong determinant (from the F-tests) of wheat price relationships between importing and exporting markets. This index has a marginally significant effect (at the 13% level) on U.S. and Rotterdam prices. However, freight rates do not appear to exhibit a significant influence on wheat prices in Japan, Australia, Canada, or Argentina. Finally, with the exception of the U.S. and Japanese prices, exchange rates do not exhibit strong causal influences on the wheat prices.

The Granger causality results offer insights into price linkages in these selected international wheat markets. In general, a large degree of price independence is suggested by the results. Freight rates and exchange rates appear to exhibit a limited influence on wheat prices, significantly affecting only the Japanese and U.S. prices. Price linkages in these markets can be further investigated by considering the forecast error decompositions. These allow us to consider which of the variables are exogenous or endogenous relative to one another in the short run. Note that the forecast error decompositions are not invariant to the ordering of variables in the system.

Table 3 reports error decompositions for 1-, 3-, and 10-month ahead forecasts from an ordering scheme implied by the Granger causality

Table 3. Error Decompositions Attributed To Innovations in Respective Series, July 1975 through December 1986.

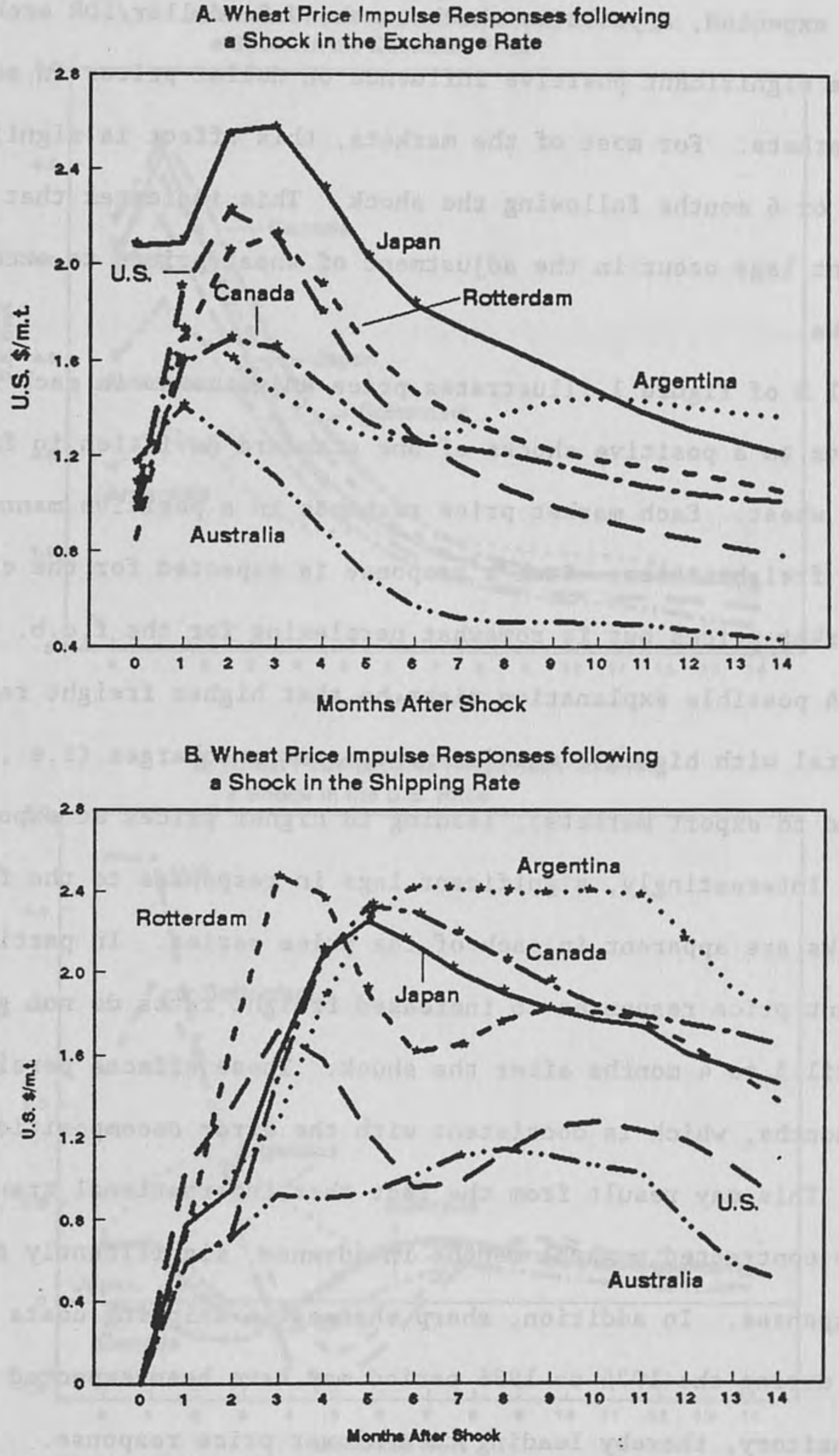
Variable	Months Ahead	Standard Error	Percentage of Forecast Error Explained by: SDR	Canada	U.S.	Australia	Argentina	Rotterdam	Japan	Shipping
SDR	1	0.013	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3	0.022	96.5	0.4	0.3	0.0	0.5	0.3	1.0	1.0
	10	0.029	89.5	1.9	0.6	0.7	1.6	0.6	4.4	0.7
Canada	1	4.34	4.2	95.8	0.0	0.0	0.0	0.0	0.0	0.0
	3	8.37	7.6	89.4	0.2	0.1	0.5	0.8	0.0	1.4
	10	12.11	11.0	59.6	0.7	5.0	1.3	0.6	0.1	21.7
U.S.	1	5.84	2.4	40.4	57.2	0.0	0.0	0.0	0.0	0.0
	3	10.18	8.1	42.5	42.6	0.1	2.1	0.0	1.5	3.0
	10	12.45	14.3	37.9	30.1	3.6	2.5	0.3	1.5	9.8
Australia	1	4.34	6.6	44.6	1.8	47.1	0.0	0.0	0.0	0.0
	3	7.33	8.2	54.3	1.3	30.4	0.1	3.5	0.4	1.7
	10	9.04	9.0	49.2	1.4	25.8	0.3	3.7	0.6	10.2
Argentina	1	5.96	3.0	8.1	1.2	8.2	79.5	0.0	0.0	0.0
	3	9.21	7.1	13.2	4.4	8.8	64.0	0.0	0.8	1.6
	10	12.11	12.1	13.0	4.6	5.9	38.9	0.5	1.4	22.7
Rotterdam	1	5.67	1.8	48.4	16.0	1.1	0.0	32.7	0.0	0.0
	3	9.97	6.6	53.8	20.5	0.4	1.6	12.9	0.4	3.7
	10	13.29	13.0	42.2	12.6	4.3	1.9	7.5	0.6	17.9
Japan	1	6.32	10.6	38.6	0.8	0.0	0.0	0.7	49.3	0.0
	3	9.80	14.4	58.5	0.7	0.2	0.0	0.7	23.7	1.7
	10	13.25	21.6	41.1	0.9	4.2	0.8	0.6	13.3	17.4
Shipping	1	0.91	0.5	6.0	0.3	0.9	0.0	1.4	0.0	90.9
	3	1.58	0.9	13.1	0.4	2.7	0.4	0.9	1.2	80.4
	10	2.53	6.9	11.1	1.1	6.0	1.7	0.7	0.6	72.0

results.[6] The variables were ordered as presented in table 3. The forecast error decompositions reconfirm a relatively large degree of price independence in most of the series. Again, Canada seems to be a dominant market. Innovations in the Canadian price have a significant effect on Canadian, U.S., Australian, Rotterdam, and Japanese prices. This is verified by the relatively large percentages of the forecast errors for each of these series that are attributable to innovations in the Canadian price. A similar result occurs for the U.S. price, which appears to be responsible for a large degree of the forecast errors in these series, particularly in Rotterdam. However, the forecast errors for Argentine prices do not appear to depend upon innovations in any of the other series. Adjustments to innovations in freight rates appear to take place over a significant length of time, as evidenced by larger percentages of forecast error decompositions that are explained by freight rates in the 10-month-ahead forecasts relative to the 1- and 3-month-ahead forecasts. This may imply that adjustments to shocks in freight rates are quite slow to occur.

Calculation of impulse responses enables us to evaluate the dynamic paths of adjustment of prices to shocks in the data series. Impulse responses for prices in the six markets generated by separate shocks of one standard deviation to the exchange rate and freight rates are presented in figure 1.[7] Panel A illustrates price adjustments for the six wheat markets in response to a shock to the SDR exchange rate. As

[6]Results for the forecast error decompositions for alternative orderings of the variables were very similar and are available from the authors upon request.

[7]A complete set of impulse response functions for all of the variables in the system is available from the authors upon request.



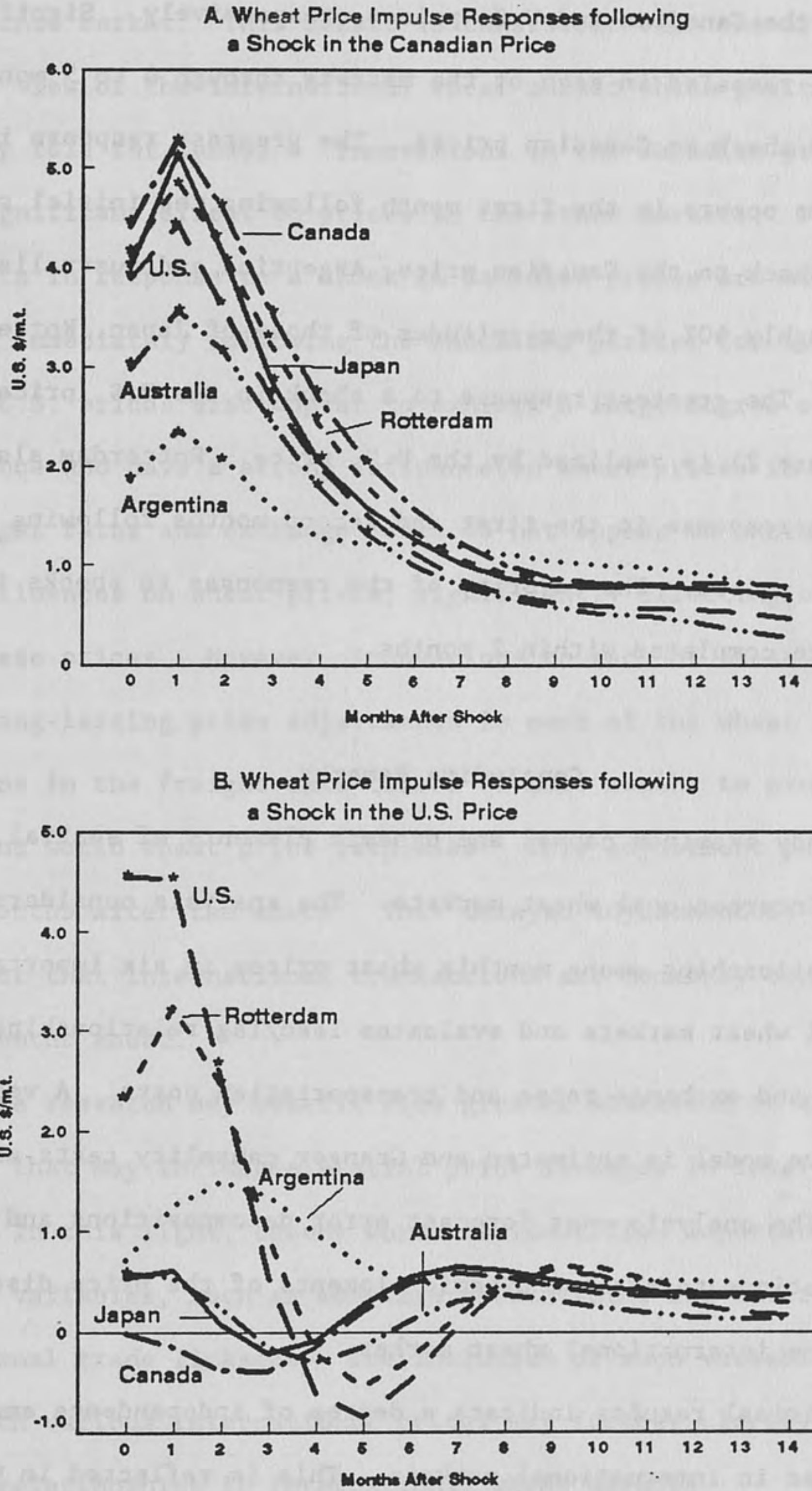
* indicates response twice its standard error

Figure 1. International Wheat Price Impulse Responses to One Standard Deviation Shocks in Exchange Rates and Shipping Rates

would be expected, a positive shock to the U.S. dollar/SDR exchange rate has a significant positive influence on dollar prices in each of the six markets. For most of the markets, this effect is significant through 5 or 6 months following the shock. This indicates that significant lags occur in the adjustment of wheat prices to exchange rate shocks.

Panel B of figure 1 illustrates price adjustments in each of the six markets to a positive shocks of one standard deviation in freight rates for wheat. Each market price responds in a positive manner to increased freight rates. Such a response is expected for the c.i.f. import market prices but is somewhat perplexing for the f.o.b. export prices. A possible explanation might be that higher freight rates were coincidental with higher domestic transportation charges (i.e., from hinterland to export markets), leading to higher prices at export markets. Interestingly, significant lags in responses to the freight rate shocks are apparent in each of the price series. In particular, significant price responses to increased freight rates do not generally occur until 3 to 4 months after the shock. These effects persist until 9 or 10 months, which is consistent with the error decomposition results. This may result from the fact that international transactions are often contracted several months in advance, significantly slowing price responses. In addition, sharp changes in shipping costs that occurred during the 1975 to 1986 period may have been expected to be only transitory, thereby leading to a slower price response.

Panels A and B of figure 2 illustrate price adjustments for each of the six markets in response to separate exogenous shocks of one standard



* indicates response twice its standard error

Figure 2. International Wheat Price Impulse Responses to One Standard Deviation Shocks in Canadian and U.S. Export Wheat Prices

deviation in the Canadian and U.S. prices, respectively. Significant responses are revealed in each of the markets through 4 to 5 months following the shock to Canadian prices. The greatest response in each of the markets occurs in the first month following the initial shock. Following a shock to the Canadian price, Argentina and Australia have responses roughly 40% of the magnitudes of those of Japan, Rotterdam, and the U.S. The greatest response to a shock in the U.S. price series (panel B figure 2) is realized by the U.S. price. Rotterdam also shows a significant response in the first and second months following the shock to U.S. prices. The majority of the responses to shocks in the U.S. price are completed within 2 months.

Concluding Remarks

This study examines causal and dynamic elements of spatial price linkages in international wheat markets. The analysis considers lead/lag relationships among monthly wheat prices in six important international wheat markets and evaluates lead/lag relationships between these prices and exchange rates and transportation costs. A vector autoregressive model is estimated and Granger causality tests are performed. The analysis uses forecast error decompositions and impulse response functions to examine dynamic elements of the price discovery process in the international wheat market.

The empirical results indicate a degree of independence among monthly prices in international markets. This is reflected in Granger causality F-tests that reveal limited causality between prices in the individual markets. The Canadian price appears to be dominant in the international market. This result is consistent with the often-assumed oligopoly view of the international wheat market which posits a price leadership role for Canada . Innovations in the Canadian price seem to have a significant effect on prices in the other markets. Price adjustments in response to a shock in Canadian prices are strongest in the month immediately following the shock and persist for 4 or more months. U.S. prices also appear to exhibit a large degree of independence and have a strong influence on wheat prices in Rotterdam.

Freight rates and exchange rates do not appear to exhibit strong causal influences on wheat prices, significantly affecting only the U.S. and Japanese prices. However, innovations to each of these series produce long-lasting price adjustments in each of the wheat markets. Innovations in the freight rate take 3 or more months to produce significant world wheat price responses. This adjustment persists for 9 or more months after the shock. This delayed adjustment is likely due to the fact that international transactions are commonly contracted several months ahead.

Future research may benefit from greater attention to alternative variables that may influence spatial price linkages in international markets. In this light, recent work has identified important roles for financial variables, such as monetary growth rates and interest rates in international trade linkages. The inclusion of such variables in a VAR system with various international prices may further clarify causal and temporal relationships in international wheat markets.

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