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A COMBINED ANNUAL/QUARTERLY APPROACH TO FORECASTING QUARTERLY WHEAT PRICES

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I - INTRODUCTION

In the process of modelling a commodity market one of the required decisions that must be made is the time period which should be used. Historically, there has emerged a dichotomy on this issue. Livestock models are typically constructed using quarterly or monthly data while crop models typically focus on an annual period, usually a crop year consisting of the twelve month period beginning at the time of harvest. An obvious factor underlying this dichotomy is that livestock production occurs continuously while crop production takes place in a relatively short period of time.

This dichotomy, while in one sense natural, is also inconvenient since it leads to models constructed using different periods of analysis. This makes it difficult to trace the impact of exogenous shifts in one sector through other sectors. Yet, it is frequently these inter-sectoral linkages in which one is interested. For example, one might wish to trace the impact of reduced grain production in a major importing country through the grain and livestock sectors to its ultimate impact on consumer prices and farm incomes. Interest in these inter-sectoral linkages has led to the construction of models of the livestock and grain sectors which can be linked together in order to quantify these impacts. Frequently, this has been achieved by estimating quarterly models of the grain sector. However, there are cogent reasons why satisfactory quarterly models of the grain sector would be difficult to construct. The most persuasive reason for the difficulty stems from the greater importance of inventories in the grain sector than in the livestock sector.

The existence of significant inventory holding complicates quantitative price analysis because it greatly increases the factors which can influence price in any particular period. Through their influence on inventory behaviour, expectations of market conditions in future periods can significantly influence the current price. When inventories are relatively small and hence all production must be consumed, price will be determined by the interaction of supply (production) and demand for consumption. Expectations of future market conditions may exist, but will have little impact on the current price.[1] However, when output is easily stored, expectations of future market conditions will influence the current price by inducing changes in inventories. As expectations of future prices change in response to new information, current prices are affected because of the influence of price expectations on inventory demand. As a result, if one is to adequately model short term price fluctuations one must account for the flow of information to the market. Failure to do so implies that one will be left with a regular seasonal pattern and spurious correlations between prices and commodity flows.

In light of this perceived difficulty, this paper will explore the possibility of generating quarterly price forecast which are required for various uses by applying what might be referred to as a crude "seasonal adjustment" formula to an annual price forecast developed using an annual model. For purposes of this investigation, the U.S. wheat sector has been singled out. The wheat sector was selected because of its importance to Canada. The U.S. sector was chosen because the U.S. is the world's leading exporter of wheat. Events there are consequently of great significance to Canada. In section II the structure of the annual model is described. In section III

[1]Where output can also be used for production in future periods, eg. heifer calves, production need not equal consumption. Expected future prices can influence current prices by influencing the amount of current output which is invested for future production. Investment, however, is more likely to be influenced by longer term expectations.

alternative seasonal adjustment formulae are discussed. In section IV the estimation results for both the annual and quarterly components of the model are presented. In section V the performance of the combined annual quarterly approach is examined over an historical sample period.

II - THE ANNUAL MODEL

The objective of this section is to present the annual model used to generate the annual price forecasts. Because U.S. agricultural policy is so inextricably involved with decisions to plant, to store or to export agricultural crops the model is specified to include major policy instruments such as support prices, export subsidies and storage policy as variables. The structure of the model follows closely that of the "U.S. Crops models" which is described in Baumes and Meyers (1979). The model divides the world into four regions: the United States, Centrally Planned Economies (i.e. the Soviet Union and China), other importers and other exporters.

The demand equation for domestic food use is quite conventional. The demand for wheat for food use is hypothesized to depend upon the price of wheat, disposable income and the general U.S. price level as measured by the wholesale price index.

The demand for wheat for feed use is hypothesized to depend upon the price of wheat and the price of corn, a competitive feed. Since most wheat is fed to cattle in feedlots, feed demand is also thought to depend upon the number of cattle on feed in 23 U.S. states in July, which is near the beginning of the U.S. crop year for wheat, and upon the price of slaughter steers.

The demand for wheat for seed use depends upon the acreage of wheat planted the following year and a trend variable to account for changes in seeding rates over time.

The inventory equation is perhaps the most interesting equation. Commercial inventories are distinguished from "policy inventories" held by the Commodity Credit Corporation (CCC) and in the Farmer-Owned Reserve (Reserve). Gardner (1979) has shown that the accumulation of policy stocks discourages (the so-called overhang effect) the holding of private stocks since their release tends to moderate expected future price increases and hence reduce the expected profitability of owning inventories. Policy inventories are, in the first instance, held to be exogenous. However, since market prices are constrained by the various price triggers in U.S. farm programs, policy inventories may be to some extent endogenized in order to maintain market prices in the price band implied by U.S. farm programs.

Production is hypthesized to influence the demand for commercial stocks in two ways. Current production is expected to stimulate private storage. However, expected production in the next crop year discourages stock holding since it will tend to depress prices in the next period and therefore reduce the profitability of holding stocks. Production in the following crop year can be regarded as a partial proxy for the expected price in that period. Ideally, a proxy for expected demand conditions in the next period should also be included in this equation. A suitable proxy was not discovered.

The demand for U.S. commercial exports (total exports less PL480 and aid shipments and exports to centrally planned economies - U.S.S.R., Eastern Europe and China) is hypthesized to depend upon prices of wheat, corn, and rice after adjustments are made for export subsidies paid by the U.S. government during the 1960's. Commercial export demand is also expected to be negatively impacted by PL480 and aid shipments and by wheat supplies outside the U.S. and centrally planned economies less exports by competitors (Canada, Argentina, Australia and the E.E.C.) to centrally planned economies. These latter exports are substracted since they reduce competitive export availabilities and therefore enhance U.S. commercial export demand.

To account for the impact of population growth, U.S. commercial exports, PL480 and aid shipments and rest of the world supplies are divided by world population less population in the U.S. and centrally planned economies. Finally a variable is added to account for the impact of the U.S. partial embargo of exports to the U.S.S.R. This variable is equal to one in 1979/80, 1/2 in 1980-81, 1/3 in 1981-82 etc. It is expected to have a positive impact on exports reflecting the increased trans-shipments of wheat from other primary destinations to the U.S.S.R.

Planted acreage of wheat (equation A6) is determined by the expected farm price of wheat and by wheat diversion payments. The expected farm price, PE, is hypothesized to depend on a weighted average of the lagged market price and the effective support price (SP) provided by U.S. farm programs (see Houck et al. (1976) for the description of the procedure used to calculate these prices). When the lagged price, PM(-1) is less than SP, the support price, the expected price equals the support price. However, when the lagged market price exceeds the support price, the expected price is a weighted sum of both prices. Specifically,

(1) $PE = k*PM(-1) + (1-k)SP$

Since the expected price cannot fall below the support price, it is hypothesized that as the market price falls toward the support price, the weight placed on the support price (1-k) increases. Gallagher (1978) has derived the following specification which incorporates this characteristic.

(2) $PE = SP + b* ((PM(-1) - SP + C)* \log (PM(-1) - SP + C) - (PM(-1) - SP))$

where C is an arbitrary constant required to avoid attempting to calculate the logarithm of a negative number. If we hypothesize a simple relation for planted acreage

(3) A(t) = a + f*PE(t)

then the estimating form becomes

(4) A(t) = a + f*SP + fb*Z

where Z is defined as the entire second term in equation (2).

The response of expected price to changes in market prices or support prices is given by

(5) dPE/dPM(-1) = b*log(PM(-1) - SP + C) and

(6) dPE/dPS = 1 - b*log(PM(-1) - SP + C)

The corresponding elasticities can be written

(7) E(A, PM(-1)) = PM(-1)*fb*log(PM(-1) - SP + C)/A

(8) E(A, SP) = SP*f*(1 - b*log(PM(-1) - SP + C))/A

There are two concerns about this formulation. First, the expected price is not homogeneous of degree 1 in prices and therefore the derived behavioural parameters depend upon the unit in which prices are measured. A more general concern about the entire equation is that it does not allow for competition for land by alternative crops. Prices of alternative crops were tested but were not found to improve the performance of the equation.

Since the required variables are either lagged market price or policy variables known in advance (support prices), acreage can be estimated the crop year before it occurs. This is done to facilitate the estimation of seed use and expected production which is an explanatory variable in the commercial inventory demand equation.

Wheat production is derived as a product of yield and planted acreage multiplied by a constant to reflect the difference between harvested and planted acreage.

III - ANNUAL/QUARTERLY LINKAGES

We now turn to the problem of deriving quarterly forecasts. The basic premise upon which this suggestion is based is that three factors determine the seasonal price pattern. The first of these is the input into the market of new information. The difficulty of modelling this aspect was discussed earlier. The second factor influencing the seasonal price pattern is the cost of storage. This includes the cost of operating the storage facility, quality deterioration, and the opportunity cost of funds invested in grain stocks. Other things being equal, storage costs will cause prices to increase through the year in order to encourage market participants to acquire inventories. This influence would be expected to be relatively stable over time except perhaps for the cost of funds which could vary due to interest rate fluctuations. The final aspect influencing the seasonal pattern of price is the price in the previous and following crop years. If the current annual price is greater than the price in the previous year one would expect that an upward trend would be superimposed on any stationary seasonal pattern. The opposite would be the case if the current price is less than the previous price. Similarly if the price in the next period is expected to be less (greater) than the current price, a downward price trend would be expected to be superimposed on the seasonal pattern particularly in the last half of the crop year. These two factors give rise to four possible combinations identified in Figure 1.

An equation incorporating the effect of next period's annual price is cumbersome to use in a single model since it requires the model to solve for price in the next crop year before determining the price in each quarter of the current crop year. For this reason, only the impact of the previous period's annual price is used in estimating the seasonal pattern.

Two seasonalization models are tested. Both models allow the seasonal price pattern to depend upon the direction of change in the seasonal average price. Model A can be written as:

$$(9) \quad P^Q_{T,t} = \sum_{t=1}^{4} a_t d_t P^A_T \quad \text{for} \quad P^A_T > P^A_{T-1}$$

$$= \sum_{t=1}^{4} b_t d_t P^A_T \quad \text{for} \quad P^A_T \leq P^A_{T-1}$$

where P^A_T is the season average price in season T, $P^Q_{T,t}$ is the price in quarter t of season T and d_t is a binary variable equal to 1 in quarter t, and 0 in all others. The price in each quarter is a proportion of the season average price.

A potential difficulty with this model is that where the change in the season average price between two years is large, there is implied a large change in price in the third quarter (the first quarter of the new season) followed by smaller price fluctuations. One might suspect that the size of seasonal price fluctuations would depend upon the amount of change in the season average prices. To test this hypothesis, model B was specified such that the price in each quarter is equal to last year's annual average price plus a proportion of the difference between the current and lagged annual price.

Specifically,

$$(10) \quad P^{Q}_{T,t} = P^{A}_{T} + \sum_{t=1}^{4} c_t d_t D_t \quad \text{for} \quad D_t > 0$$

$$= P^{A}_{T} + \sum_{t=1}^{4} c_t d_t D_t \quad \text{for} \quad D_t \leq 0$$

Under this formulation, the quarterly fluctuations would be wider in years when the annual price changes sharply from the previous year. This could allow a smooth transition between crop years. It also, however, implies that when there is no change in the annual price, there is no seasonal price variation. In neither case are the parameters constrained to sum to unity. Since the U.S. uses a June/May crop year for wheat and since the season average price is a weighted average the season average price is not a simple average of four quarters. Because the data is partitioned according to the direction of change in the annual price, each model requires estimation of eight parameters.

IV - EMPIRICAL RESULTS

The annual portion of the model was estimated over the period 1962 to 1980. The quarterly linkage equation was estimated over the period from the third quarter of 1966 to the second quarter of 1981[2].

The demand for wheat for food use is quite stable. The price elasticity of demand is estimated to be -0.01 while the income elasticity is estimated at 0.09. The equation explains food demand quite well and all of the coefficients have the expected signs. The standard errors of the coefficient for the price of wheat and the wholesale price index are quite large however.

[2]Detailed estimation results are presented in Appendix I.

The feed demand euqation is somewhat less satisfactory. This is not surprising given the wide (proportional) fluctuations in feed use. The elasticity of feed demand with respect to the price of wheat is estimated to be -1.7. The cross elasticity with respect to the price of corn was constrained to a value of -0.9 at the mean. The results indicate that an increase in cattle on feed by 1 million head results in an increase on the feed demand for wheat of 0.73 million tonnes. Similarly, a 1-percent increase in the price of slaughter steers results in a 0.52-percent increase in the demand for wheat for feed.

The demand for seed is closely related to planted acreage in the following crop year. A one acre increase in wheat plantings leads to an increase in seed demand of 0.038 tonnes. This relationship indirectly introduces a positive elasticity into the demand for seed: when price rises, expected acreage next crop year rises and this causes an increased demand for seed. This indirect elasticity is estimated to be +0.22.

The commercial inventory demand equation was estimated in log-linear form. The empirical results indicate a relatively high price elasticity of demand for private stocks of -1.05. Baumes and Womack have estimated that a one unit increase in CCC stock of wheat results in a .09 unit decrease in private stocks. Stocks in the Farmer-Owned Reserve are expected to discourage private stock holding more than CCC stocks since the latter are available to the market only at higher prices. Since the Reserve program is relatively new[3] the data series is too short for precise estimation. Sharples and Holland (1980) have estimated that a one unit increase in the Reserve program reduces private stocks by .13 units. Based on these results, the substitution effect of Reserve stocks was constrained to a value of 1.5 times that of CCC stocks. Our estimates indicate the substitution effects are considerably stronger than the results cited above. They indicate that a one unit change in the CCC stocks reduces

[3]The Farmer Owned Reserve program was initiated in 1977-78.

stocks reduces private stocks by 0.26 units and that private stocks are reduced by 0.40 units following a one unit increase in Reserve stocks. These results consequently imply that policy stocks are a weaker (although still quite effective) tool for influencing the price of wheat than do previous estimates. It is of some interest that when the upper end of the estimation range for this equation is extended from 1978 to 1980 that the estimated replacement effect increases from -0.18 to -0.30. Over this same period both the proportion of total stocks in policy reserves and the size of the policy reserves have increased. This would suggest that there is some reduction in the price-enhancing ability of these reserves as they get larger.

A 1 million tonne increase in wheat production results in an estimated 0.44 million tonne increase in private inventory demand. This greatly moderates the impact on prices of changes in production levels. A one million tonne increase in expected wheat production in the following year is estimated to reduce inventory demand by 0.19 tonnes. This response to expected production indirectly adds additional elasticity to the inventory equation: when price falls, expected production also falls, stimulating inventory demand. This indirect elasticity is estimated to be -0.18. The equation explains variations in commercial stocks well. Moreover, the signs of the coefficients are consistent with expectations and have relatively small standard errors.

The estimation results for the commercial export equation indicate a relatively strong replacement effect of food aid shipments on commercial exports. A one unit increase in food aid shipments is estimated to reduce commercial exports by 0.68 units. The estimated price elasticity of export demand, -.44, is significantly larger than the estimate of -0.35 reported by Baumes and Womack. The cross price elasticities for the prices of corn and rice are 0.61 and 0.42 respectively. The results also indicate tht an increase in the rest of the world supplies by 1 million tonnes reduces U.S. commercial exports by 0.15 million tonnes.

The results indicate that wheat acreage depends both on market prices for wheat as well as price support levels. Moreover, as market prices rise relative to support levels, its importance grows. Nevertheless, the empirical results indicate that even when market prices exceed support prices by significant amounts, the support price is an important determinant of wheat acreage. To illustrate how the responsiveness of wheat acreage to support and market prices can vary, expected price weights and elasticities were calculated for two periods, 1970-1972 when market prices were low relative to support prices and 1974-1976 when market prices were high relative to support prices. The results of these calculations are presented in Table 1 and illustrate two points. First, the importance of the support price in determining wheat acreage varies significantly depending upon the strength of market prices. Second, even though its importance does decline in periods of relatively strong market prices, it is still an important determinant of wheat acreage. In fact, even in the 1974-76 period, a $1 increase in the support price would increase wheat acreage by more than a $1 increase in the lagged market price.

The price elasticities reported here of planted acreage with respect to the market price are similar to those reported by Gallagher for corn. However our results indicate that support prices play a much larger role in determining wheat acreage than in the case for corn. Finally, the estimated elasticity of wheat acreage with respect to diversion payments is quite low (0.01) suggesting they do not have a large influence on wheat acreage.

TABLE 1. IMPACTS OF SUPPORT AND MARKET PRICES ON U.S. WHEAT ACREAGE

	LAGGED MARKET PRICE RELATIVE TO SUPPORT PRICE (1974-1976) high	(1970-1972) low
dPE/dPM(-1)	0.489	0.348
dPE/dPS	0.511	0.652
dA/dPM(-1)	0.181	0.129
E(A, PM(-1)	0.342	0.114
E(A, PS)	0.184	0.255

In evaluating the empirical model, it is useful to look at the estimated elasticity of the model as a whole. Since supply is pre-determined, we must therefore look at the aggregate demand elasticity of the model. This aggregate elasticity can be calculated as the average of the individual elasticities weighted by their share of total disposition. The mean values of the required variables are presented in Table 2. A number of points are worth noting. First, about 27 percent of disposition (policy and aid exports and policy stocks) is exogenous and therefore in the context of the model is not responsive to price. A further 22 percent is consumed as food which has a very low estimated price elasticity. It is, therefore, not surprising that the aggregate elasticity of the model is quite low (-0.44). This raises two serious implications. First, even though individual equations may forecast quite well, small errors in quantity estimates will result in significant errors in the corresponding price forecast. Second, the aggregate demand elasticity of the model is near the supply elasticity in relatively high price periods. This raises questions about the stability of the model in such periods.

TABLE 2. COMPONENT AND TOTAL ELASTICITIES FOR WHEAT MODEL

Component	Elasticity (mean)	Quantity (mean)	Share (mean)
Exports			
Commercial	-0.44	14.9	0.22
Policy	0	3.9	0.06
PL480 and Aid	0	6.9	0.10
Food	-0.01	14.9	0.22
Feed	-1.7	3.1	0.05
Seed: indirect	+0.22	2.1	0.03
Stocks			
CCC	0	5.4	0.08
Farmer Reserve	0	2.0	0.03
Commercial: direct	-1.05	14	0.21
: indirect	-0.18		
Total	-0.44	67.1	1.0

The seasonal price patterns implied by the estimated parameters are presented in Table 3. Both models imply that when the season average price increases the quarterly price reaches the season average price for the year by the fourth quarter (the second quarter of the crop year). Model A implies that the season price peak will occur in the fourth quarter while Model B implies that the peak will occur in the first quarter. When the season average price declines, however, Model A implies that the quarterly price reaches the season average price by the fourth quarter while Model B implies that the transition does not take place until the first quarter. Both Model A and Model B imply that the price will reach its lowest point in the second quarter. Model A was selected since it implies some seasonal variation when season average prices do not change.[1]

[1]One reviewer suggested that the choice between models A and B might be made in a more regorous manner by using a test reported by Davidson and MacKinnon (1981). The test, in fact, indicated that model B was superior to model A. Some the forecasts results are similar over the period examined, the simulations are not repeated. However, the results of the test are reported in Appendix V.

For years when the annual price increases, the quarterly price pattern has price increasing from 1 percent below the annual price in the third (calendar year) quarter to 9 percent above the annual price in the fourth quarter, falling slightly in the third quarter and then falling to 3 percent below the annual price in the final quarter of the crop year. When the annual price falls the quarterly price patterns shows a gradual decline in prices from 2 percent above the season average price in third calendar quarter to 3 percent below in the second quarter.

TABLE 3. ESTIMATED SEASONAL PRICE PATTERNS FOR WHEAT

	Calendar Quarter			
	3	4	1	2
<u>Model A</u>		Proportion of Season Average Price		
P_T^A GT P_{T-1}^A	.992	1.092	1.075	.969
P_T^A LT P_{T-1}^A	1.023	1.007	.999	.971
<u>Model B</u>		Proportion of Annual Price Change Achieved		
P_T^A GT P_{T-1}^A	.944	1.229	1.490	.943
P_T^A LT P_{T-1}^A	.756	1.081	1.100	1.278
		ESTIMATED SEASONAL PRICES FOR WHEAT		
P_T^A GT P_{T-1}^A		ASSUMES P_{T-1}^A = 100	P_T^A = 120	
Model A	119.04	131.04	129.0	116.28
Model B	118.90	124.58	129.8	125.56
P_T^A LT P_{T-1}^A		ASSUMES P_{T-1}^A = 100	P_T^A =80	
Model A	81.84	80.56	79.92	77.68
Model B	84.88	88.38	78.00	74.44

V - HISTORICAL SIMULATION

To evaluate its forecasting ability, the annual model was simulated over the period 1963 to 1980. Two simulation were performed. In the first, estimated values of lagged endogenous variables were used by the model in solving for current values of the endogenous variables. A summary of the result of this simulation are presented in Table 4. As measured by the root mean square percentage error, the forecast accuracy of the model is quite good. It is particularly interesting that the model tends to forecast price more accurately in later periods. The root mean square percentage error for price over the period 1975 to 1980 is 4.1.

Even if it makes significant errors, a model may be useful if it accurately predicts the direction of change or turning points. Over the simulation period, the model forecasts accurately the direction of change in 13 of 17 years. Moreover, in one of the years when the direction of change was predicted incorrectly, the actual and predicted change in price was very small.

Using the estimated values of the season average farm price the seasonal adjustment model was simulated over the period 1975 3 to 1981 2. At 11%, the root mean square percentage error is more than twice that for the annual model in the same period. The bulk of the error is accounted for by two years - 1976/77 and 1978/79.

A second simulation was performed in which the model uses actual values of lagged endogenous variables in solving for current values of all endogenous variables. In the context of this model, actual value for production (but not expected production or expected acreage) and beginning stocks would be used. The results of this type of simulation are of interest since the forecaster often possesses accurate

TABLE 4. SIMULATION ERRORS BY COMPONENT - WHEAT

Year	Food	Feed	Exports	Stocks	Production	Price
1963	0.5	1.1	-0.3*	2.3	3.8*	-15.0
1964	-0.2	0.4*	0.8*	-0.4	-1.8*	4.8
1965	-0.2*	-1.1	0.0	1.4	0.6*	-0.7
1966	0.2	0.5	-1.0*	2.2	0.3*	-6.7
1967	-0.1	1.9*	-1.9	-2.2	-4.6*	5.1
1968	-0.1	-0.3	1.1*	-5.0	-0.2*	2.3
1969	0.0	0.0	-0.4	-2.5	-2.4*	0.4
1970	0.2	0.2	-0.3*	1.3	4.1	-0.3
1971	0.1	-1.2*	1.5	4.1	3.3*	-7.4
1972	0.0	0.8	1.0	4.7*	2.4	3.2
1973	-0.1*	-0.4*	1.1	0.8	-3.1	-4.2
1974	0.0	0.3	1.6	-0.7	0.3*	-3.8
1975	-0.1	-0.3	-0.9	-1.5	-2.3*	0.4
1976	0.1*	0.5*	-1.7	-3.5	-3.3*	7.5
1977	-0.3	-1.6	-1.7	-3.6	-3.8*	4.8
1978	-0.1	-0.4	-0.5	-1.3	1.2	3.3
1979	0.2	-0.2	-0.1	-1.2	0.0	3.0
1980	0.0	1.0	-0.2*	2.7	4.7*	-1.2
SUMMARY STATISTICS						
RMSE	0.2	0.9	1.1	2.7	2.9	5.4
RMSPE	1.3	61.7	9.2	18.9	6.6	8.2

*Denotes when quantity error for demand component is in some direction as price error or when the production error is an opposite direction to price error.

**Root mean square error.

***Root mean square percentage error.

knowledge of these values which he can utilize when making short term (1-2 years) forecasts. One would expect that this additional information would improve the accuracy of the forecast.

The results of this simulation are summarized in Table 5. A comparison of the results of the two simulations reveals that the additional information available to the model in the second simulation does little to improve the performance of the model in forecasting price. Moreover, as illustrated by Figure 3, the estimated pattern of prices is aslo very similar for both simulations. The explanation to this would appear to be in the positive correlation of the errors in the inventory equation. Because of this positive correlation errors in estimates of lagged commercial stocks, which are a component of supply, offset errors in estimates of current commercial stocks. Thus, even though the model's ability to forecast commercial inventories is enhanced by the additional information, its ability to forecast price is not. Although the additional information does not improve the accuracy of forecast of the level, it does improve the ability of the model to predict turning points, reducing the number of errors from four to two.

VI- CONCLUSIONS

The annual model would appear to have a good capability for forecasting the annual U.S. farm price of wheat. Given the dominant position of the United States in the world wheat economy, such forecasts should prove useful in forecasting Canadian wheat prices. Moreover, the fact that a number of U.S. policy variables are included in the model should make the model useful for analyzing the impact of U.S. farm programs on Canadian producers. In estimating quarterly prices the model performs on average reasonably well. However it does make relatively large errors in two of the six years examined. This may stem from the fact that the seasonal adjustment equations are rather crude. Although the price in period t + 1 was excluded from the model because of the difficulties this would pose for solving the annual and quarterly parts of the model simultaneously, the performance of the quarterly portion might be improved if its specification included some information concerning the next year's prospects. In the content of the general model being used, the expected size of next year's crop could be included in the quarterly specification.

TABLE 5. SIMULATION ERRORS BY COMPONENT - WHEAT (Actual Lagged Endogenous Variables)

Year	Food	Feed	Export	Stocks	Price
1963	0.4	0.5	-1.0*	0.1	-5.2
1964	-0.2	0.3*	0.7*	-0.7	7.1
1965	-0.2*	-1.1	0.1	1.2	-0.6
1966	0.2	0.3	-1.1*	1.0	-3.4
1967	-0.1	2.0*	-1.7	0.0	3.5
1968	-0.1*	0.0	1.4	-1.4*	-2.2
1969	0.0	0.4	0.0	-0.6*	-5.0
1970	0.2	0.2	0.3	-0.3*	-0.3
1971	0.1	-1.5	1.2	0.0	-3.6
1972	0.0	0.1*	0.2*	-0.4	13.5
1973	-0.2	-0.9	0.3*	0.5*	4.8
1974	0.0	0.0	1.2	-1.3	0.0
1975	-0.1*	0.0	-0.4*	0.7	-5.4
1976	0.1	0.8*	-1.3	0.6*	3.2
1977	-0.3*	-0.9	0.7	2.0	-6.5
1978	-0.1*	0.2	0.2	-0.2*	-5.1
1979	0.2	0.0	0.3	-0.6*	-1.3
1980	0.0	0.4*	-1.1	0.6*	7.9
SUMMARY STATISTICS					
RMSE	0.2	0.8	0.9	0.9	5.4
RMSPE	1.3	52.1	8.8	6.3	7.9

*Denotes when error was in same direction as price error.
**Root mean square error.
***Root mean square percentage error.

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APPENDIX I: SPECIFICATION OF THE ANNUAL MODEL

MODEL: FORAWHT

SYMBOL DECLARATIONS

ENDOGENOUS:

- CIWH4A - COMMERCIAL WHEAT INVENTORIES: U. S. (MMT),
- DDWH4A - WHEAT USED FOR HUMAN CONSUMPTION: U. S. (MMT)
- DFWH4A - WHEAT USED FOR FEED: U.S. (MMT)
- DSWH4A - WHEAT USED FOR SEED : U.S. (MMT)
- EAWH4A - ACRES PLANTED TO WHEAT NEXT CROP YEAR: U.S. (MILL. ACRES)
- EQWH4A - EXPECTED PRODUCTION NEXT CROP YEAR: U. S. (MILL. ACRES)
- EXWH46Y - WHEAT EXPORTS EXCEPT TO USSR AND CHINA AND EXCEPT PL480 AND AID:U.S. (MMT)
- FPWH4A - FARM PRICE OF WHEAT: U.S. ($ US/TONNE)
- QWH4A - WHEAT PRODUCTION: U.S. (MMT)

EXOGENOUS:

- AVWROW - WHEAT SUPPLIES IN LDC,CDA,AUST,EEC AND OTHER W. EUROPE (MMT)
- CCCWH4A - COMMODITY CREDIT CORPORATION WHEAT STOCKS: U.S. (MMT)
- CTLOFY - CATTLE ON FEED IN 23 STATES:U.S. (M.HEAD)
- DU7576 - BINARY VARIABLE:=1 IN 1975 AND 1976,ELSE 0
- DY4A - DISPOSABLE INCOME:U.S. (BILLIONS OF $US)
- D76 - BINARY VARIABLE:=0 IN 1976,ELSE 0
- D79Y - DUMMY VARIABLE FOR USSR EMBARGO:=1 IN 1979 .5 IN 1980,.33 IN 1981 ETC,ELSE 0
- EDPWWH4Y - WINTER WHEAT DIVERSION PAYMENT FOR NEXT CROP YEAR: U.S. ($ US/TONNE)
- ESPWH4A - EFFECTIVE SUPPORT PRICE FOR WHEAT: U.S. ($ US/TONNE)
- EXWHCCP - WHEAT EXPORTS TO USSR CHINA AND E. EUROPE:U.S. COMPETITORS (MMT)
- EXWH48Y - WHEAT EXPORTS TO USSR AND CHINA:U.S. (MMT)
- EYWH4Y - WHEAT YIELD/HARVESTED ACRE:U.S. (TONNES)
- FPCO4Y - FARM PRICE OF CORN: U.S. ($ US/TONNE)
- FPRIC4A - FARM PRICE OF RICE:U.S. (US$/TONNE)
- IMWH4A - WHEAT IMPORTS:U.S. (MMT)
- PL480 - PL480 AND AID SHIPMENTS OF WHEAT :U.S. (MMT)
- PL480CP - PL480 AND AID SHIPMENTS TO USSR,CHINA AND E. EUROPE (MMT)
- POPIM - POPULATION,WORLD LESS USSR CHINA E. EUROPE AND U.S. (BILLIONS)
- PSS4A - PRICE OF SLAUGHTER STEERS:OMAHA,U.S. ($ US/CWT)
- TIMEY - LINEAR ANNUAL TIME TREND
- WPI4A - WHOLESALE PRICE INDEX: U.S.
- XIWH4A - WHEAT IN FARMER OWNED RESERVE : U.S. (MMT)
- XSURIC4A - RICE EXPORT SUBSIDY:U.S. (US$/TONNE)
- XSUWHT4A - WHEAT EXPORT SUBSIDT:U.S. (US$/TONNE)

COEFFICIENT:

AA.0 AA.1 AA.2 AA.3 AB.1 CIWH4A.0 CIWH4A.1 CIWH4A.2 CIWH4A.3 CIWH4A.4 CIWH4A.5
CIWH4A.6 DDWH4A.0 DDWH4A.2 DDWH4A.3 DDWH4A.4 DDWH4A.5 DFWH4A.0 DFWH4A.1 DFWH4A.2
DFWH4A.3 DSWH4A.0 DSWH4A.1 DSWH4A.2 EXWH4A.0 EXWH4A.1 EXWH4A.2 EXWH4A.3 EXWH4A.4
EXWH4A.5 EXWH4Y.6

EQUATIONS

U.S. FOOD DEMAND FOR WHEAT:

1: DDWH4A = DDWH4A.0+DDWH4A.2*FPWH4A+DDWH4A.3*DY4A+DDWH4A.4*WPI4A(1)+DDWH4A.5*
DU7576

U. S. FEED DEMAND FOR WHEAT:

2: DFWH4A = DFWH4A.0+DFWH4A.1*FPWH4A+0.03*FPCO4Y+DFWH4A.2*CTLOFY+DFWH4A.3*PSS4A

U. S. SEED DEMAND FOR WHEAT:

3: DSWH4A = DSWH4A.0+DSWH4A.1*EAWH4A+DSWH4A.2*TIMEY

U. S. COMMERCIAL INVENTORY DEMAND FOR WHEAT:

4: LOG(CIWH4A) = CIWH4A.0+CIWH4A.1*LOG(FPWH4A/WPI4A)+CIWH4A.2*LOG(QWH4A)+
CIWH4A.3*LOG(EQWH4A)+CIWH4A.4*LOG(CCCWH4A+XIWH4A*1.5+1)+CIWH4A.5*D76+CIWH4A.6
*LOG(CIWH4A(-1))

COMMERCIAL EXPORT DEMAND FOR U.S. WHEAT:

5: EXWH46Y/POPIM = EXWH4A.0+EXWH4A.1*(FPWH4A-XSUWHT4A)+EXWH4A.2*FPCO4Y+EXWH4A.3*
(FPRIC4A-XSURIC4A)+EXWH4A.4*(AVWROW-EXWHCCP)/POPIM+EXWH4A.5*(PL480-PL480CP)/
POPIM+EXWH4Y.6*D79Y

U. S. PLANTED WHEAT ACREAGE NEXT CROP YEAR:

6: EAWH4A = AA.0+AA.1*ESPWH4A+AA.2*((FPWH4A-ESPWH4A+36.74)*LOG(FPWH4A-ESPWH4A+
36.74)-(FPWH4A-ESPWH4A))+AA.3*EDPWWH4Y

U. S. WHEAT PRODUCTION NEXT CROP YEAR:

7: EQWH4A = AB.1*EYWH4Y*EAWH4A

CURRENT U. S. WHEAT PRODUCTION:

8: QWH4A = EQWH4A(-1)

IDENTITY EQUATION:

9: QWH4A+CCCWH4A(-1)+XIWH4A(-1)+CIWH4A(-1)+IMWH4A = DFWH4A+DDWH4A+DSWH4A+CIWH4A+
CCCWH4A+XIWH4A+EXWH46Y+PL480+EXWH48Y-PL480CP

APPENDIX II: ANNUAL ESTIMATION RESULTS

1: DDWH4A = DDWH4A.0+DDWH4A.2*FPWH4A+DDWH4A.3*DY4A+DDWH4A.4*WPI4A(1)+DDWH4A.5*DU7576

NOB = 19 NOVAR = 5
RANGE = 1962 TO 1980
RSQ = 0.97042 CRSQ = 0.96197 F(4/14) = 114.838
SER = 0.2031 SSR = 0.577 DW(0) = 2.40 COND(X) = 75.75
LHS MEAN = 14.77660 SR = 0.00003

COEF	VALUE	ST ER	T-STAT	MEAN
DDWH4A.0	12.70590	0.22879	55.53410	1.00000
DDWH4A.2	-0.00221	0.00243	-0.90816	84.85860
DDWH4A.3	1.39604E-06	1.04925E-06	1.33052	9.20993E+05
DDWH4A.4	0.00584	0.00842	0.69368	152.11100
DDWH4A.5	0.79418	0.16051	4.94792	0.10526

2: DFWH4A = DFWH4A.0+DFWH4A.1*FPWH4A+0.03*FPCO4Y+DFWH4A.2*CTLOFY+DFWH4A.3*PSS4A

NOB = 19 NOVAR = 4
RANGE = 1962 TO 1980
RSQ = 0.77802 CRSQ = 0.73362 F(3/15) = 17.525
SER = 1.0187 SSR = 15.567 DW(0) = 2.54 COND(X) = 16.96
LHS MEAN = 3.08381 SR = -0.00003

COEF	VALUE	ST ER	T-STAT	MEAN
DFWH4A.0	-2.14102	1.32722	-1.61316	1.00000
DFWH4A.1	-0.06356	0.00964	-6.59317	84.85860
DFWH4A.2	0.73374	0.15896	4.61600	9.50263
DFWH4A.3	0.04178	0.02958	1.41235	37.85500

3: DSWH4A = DSWH4A.0+DSWH4A.1*EAWH4A+DSWH4A.2*TIMEY

NOB = 19 NOVAR = 3
RANGE = 1962 TO 1980
RSQ = 0.99439 CRSQ = 0.99369 F(2/16) = 1417.330
SER = 0.0362 SSR = 2.101E-02 DW(0) = 1.03 COND(X) = 20.35
LHS MEAN = 2.09178 SR = 0.00003

COEF	VALUE	ST ER	T-STAT	MEAN
DSWH4A.0	-0.46478	0.04875	-9.53353	1.00000
DSWH4A.1	0.03775	0.00119	31.58900	64.61240
DSWH4A.2	0.00453	0.00244	1.85270	26.00000

4: LOG(CIWH4A) = CIWH4A.0+CIWH4A.1*LOG(FPWH4A/WPI4A)+CIWH4A.2*LOG(QWH4A)+CIWH4A.3*LOG(EQWH4A)+
CIWH4A.4*LOG(CCCWH4A+XIWH4A*1.5+1)+CIWH4A.5*D76+CIWH4A.6*LOG(CIWH4A(-1))

NOB = 19 NOVAR = 7
RANGE = 1962 TO 1980
RSQ = 0.96962 CRSQ = 0.95443 F(6/12) = 63.836
SER = 0.1006 SSR = 0.121 DW(0) = 1.94 COND(X) = 158.31
LHS MEAN = 2.54328 SR = 0.00008

COEF	VALUE	ST ER	T-STAT	MEAN
CIWH4A.0	-0.78662	0.44696	-1.75991	1.00000
CIWH4A.1	-1.05429	0.11848	-8.89875	-0.55076
CIWH4A.2	1.37062	0.30971	4.42555	3.77728
CIWH4A.3	-0.65258	0.27348	-2.38619	3.82593
CIWH4A.4	-0.20121	0.02466	-8.15942	1.82264
CIWH4A.5	0.11810	0.11786	1.00199	0.05263
CIWH4A.6	0.16956	0.06580	2.57705	2.53163

5: EXWH46Y/POPIM = EXWH4A.0+EXWH4A.1*(FPWH4A-XSUWHT4A)+EXWH4A.2*FPC04Y+EXWH4A.3*(FPRIC4A-
XSURIC4A)+EXWH4A.4*(AVWROW-EXWHCCP)/POPIM+EXWH4A.5*(PL480-PL480CP)/POPIM+EXWH4Y.6*D79Y

NOB = 19 NOVAR = 7
RANGE = 1962 TO 1980
RSQ = 0.96488 CRSQ = 0.94732 F(6/12) = 54.945
SER = 0.5868 SSR = 4.132 DW(0) = 1.98 COND(X) = 78.33
LHS MEAN = 6.14637 SR = 0.0003

COEF	VALUE	ST ER	T-STAT	MEAN
EXWH4A.0	15.64660	3.28889	4.75741	1.00000
EXWH4A.1	-0.03437	0.01834	-1.87373	80.32170
EXWH4A.2	0.05432	0.02340	2.32168	68.81160
EXWH4A.3	0.00921	0.00278	3.30809	284.12900
EXWH4A.4	-0.15335	0.03999	-3.83422	73.14030
EXWH4A.5	-0.68395	0.14136	-4.83833	3.15991
EXWH4Y.6	3.58087	0.95452	3.75149	0.07895

6: EAWH4A = AA.0+AA.1*ESPWH4A+AA.2*((FPWH4A-ESPWH4A+36.74)*LOG(FPWH4A-ESPWH4A+36.74)-(FPWH4A-ESPWH4A))+AA.3*EDPWWH4Y

NOB = 20 NOVAR = 4
RANGE = 1962 TO 1981
RSQ = 0.9031 CRSQ = 0.88494 F(3/16) = 49.708
SER = 4.1321 SSR = 273.194 DW(0) = 1.48 COND(X) = 7.56
LHS MEAN = 65.68180 SR = 0.00011

COEF	VALUE	ST ER	T-STAT	MEAN
AA.0	31.54290	3.19577	9.87019	1.00000
AA.1	0.37250	0.03397	10.96620	74.31410
AA.2	0.03867	0.00833	4.63981	189.30300
AA.3	-0.20204	0.13569	-1.48895	4.27513

7: EQWH4A = AB.1*EYWH4Y*EAWH4A

NOB = 19 NOVAR = 1
RANGE = 1962 TO 1980
RSQ = 0.99109 CRSQ = 0.99109 F(0/18) = 2002.640
SER = 1.0991 SSR = 21.743 DW(0) = 1.64 COND(X) = 1.00
LHS MEAN = 47.14870 SR = -0.69846

COEF	VALUE	ST ER	T-STAT	MEAN
AB.1	0.88843	0.00462	192.27000	53.11090

APPENDIX III: QUARTERLY/ANNUAL PRICE LINKAGE SPECIFICATIONS

MODEL: QWHT

QUARTERLY-ANNUAL PRICE LINKAGE:MODEL A

SYMBOL DECLARATIONS

ENDOGENOUS:

FPWH4 - U.S. QUARTERLY FARM PRICE OF WHEAT (US$/TONNE)

EXOGENOUS:

FPWH4AQ - U.S. SEASON AVERAGE PRICE OF WHEAT (US$/TONNE)
JS1 - BINARY VARIABLE: 1 IN QTR 1,ELSE 0
JS2 - BINARY VARIABLE: 1 IN QTR 2,ELSE 0
JS3 - BINARY VARIABLE:1 IN QTR 3,ELSE 0
JS4 - BINARY VARIABLE:1 IN QTR 4,ELSE 0

COEFFICIENT:

FPWH4.0 FPWH4.1 FPWH4.2 FPWH4.3 FPWH4.4 FPWH4.5 FPWH4.6 FPWH4.7

EQUATIONS

QUARTERLY-ANNUAL WHEAT PRICE LINKAGE:

```
1:   FPWH4 = IF FPWH4AQ-FPWH4AQ(-4) GT 0 THEN FPWH4.0*JS1*FPWH4AQ+FPWH4.1*JS2*
     FPWH4AQ+FPWH4.2*JS3*FPWH4AQ+FPWH4.3*JS4*FPWH4AQ ELSE FPWH4.4*JS1*FPWH4AQ+
     FPWH4.5*JS2*FPWH4AQ+FPWH4.6*JS3*FPWH4AQ+FPWH4.7*JS4*FPWH4AQ
```

MODEL: QWHTB

QUARTERLY-ANNUAL PRICE LINKAGE:MODEL B

SYMBOL DECLARATIONS

ENDOGENOUS:

FPWH4 - U.S. QUARTERLY FARM PRICE OF WHEAT (US$/TONNE)

EXOGENOUS:

FPWH4AQ - U.S. SEASON AVERAGE FARM PRICE OF WHEAT (US$/TONNE)
JS1 - BINARY VARIABLE 1 IN QTR. #1,ELSE 0
JS2 - BINARY VARIABLE 1 IT QTR #2,ELSE 0
JS3 - BINARY VARIABLE 1 IN QTR.#3,ELSE 0
JS4 - BINARY VARIABLE 1 IN QTR.#4,ELSE 0

COEFFICIENT:

PF.0 PF.1 PF.2 PF.3 PF.4 PF.5 PF.6 PF.7

EQUATIONS

QUARTERLY-ANNUAL WHEAT PRICE LINKAGE #2:

```
1:      FPWH4 = IF FPWH4AQ-FPWH4AQ(-4) GT 0 THEN FPWH4AQ(-4)+PF.0*JS1*(FPWH4AQ-
        FPWH4AQ(-4))+PF.1*JS2*(FPWH4AQ-FPWH4AQ(-4))+PF.2*JS3*(FPWH4AQ-FPWH4AQ(-4))+
        PF.3*JS4*(FPWH4AQ-FPWH4AQ(-4)) ELSE FPWH4AQ(-4)+PF.4*JS1*(FPWH4AQ-FPWH4AQ(-4)
        )+PF.5*JS2*(FPWH4AQ-FPWH4AQ(-4))+PF.6*JS3*(FPWH4AQ-FPWH4AQ(-4))+PF.7*JS4*(
        FPWH4AQ-FPWH4AQ(-4))
```

APPENDIX IV: QUARTERLY ESTIMATION RESULTS

MODEL A

1: FPWH4 = IF FPWH4AQ-FPWH4AQ(-4) GT 0 THEN FPWH4.0*JS1*FPWH4AQ+FPWH4.1*JS2*FPWH4AQ+FPWH4.2*JS3*FPWH4AQ+FPWH4.3*JS4*FPWH4AQ ELSE FPWH4.4*JS1*FPWH4AQ+FPWH4.5*JS2*FPWH4AQ+FPWH4.6*JS3*FPWH4AQ+FPWH4.7*JS4*FPWH4AQ

NOB = 52 NOVAR = 8
RANGE = 1969 3 TO 1982 2
RSQ = 0.94209 CRSQ = 0.93288 F(7/44) = 102.254
SER = 10.6878 SSR = 5026.090 DW(0) = 1.71 COND(X) = 1.00
LHS MEAN = 106.12900 SR = 9.25569

COEF	VALUE	ST ER	T-STAT	MEAN
FPWH4.0	1.07479	0.03272	32.84480	17.23430
FPWH4.1	0.96875	0.03272	29.60430	17.23430
FPWH4.2	0.99184	0.03272	30.30990	17.23430
FPWH4.3	1.09159	0.03272	33.35830	17.23430
FPWH4.4	0.99928	0.04643	21.52170	8.70550
FPWH4.5	0.97077	0.04643	20.90770	8.70550
FPWH4.6	1.02295	0.04643	22.03160	8.70550
FPWH4.7	1.00739	0.04643	21.69650	8.70550

MODEL B

1: FPWH4 = IF FPWH4AQ-FPWH4AQ(-4) GT 0 THEN FPWH4AQ(-4)+PF.0*JS1*(FPWH4AQ-FPWH4AQ(-4))+PF.1*JS2*(FPWH4AQ-FPWH4AQ(-4))+PF.2*JS3*(FPWH4AQ-FPWH4AQ(-4))+PF.3*JS4*(FPWH4AQ-FPWH4AQ(-4)) ELSE FPWH4AQ(-4)+PF.4*JS1*(FPWH4AQ-FPWH4AQ(-4))+PF.5*JS2*(FPWH4AQ-FPWH4AQ(-4))+PF.6*JS3*(FPWH4AQ-FPWH4AQ(-4))+PF.7*JS4*(FPWH4AQ-FPWH4AQ(-4))

NOB = 52 NOVAR = 8
RANGE = 1969 3 TO 1982 2
RSQ = 0.95381 CRSQ = 0.94646 F(7/44) = 129.790
SER = 9.5454 SSR = 4009.000 DW(0) = 1.68 COND(X) = 1.00
LHS MEAN = 106.12900 SR = 40.21

COEF	VALUE	ST ER	T-STAT	MEAN
PF.0	1.48993	0.10537	14.13990	3.13031
PF.1	0.94285	0.10537	8.94794	3.13031
PF.2	0.94370	0.10537	8.95596	3.13031
PF.3	1.22908	0.10537	11.66430	3.13031
PF.4	1.09981	0.23977	4.58699	-1.39203
PF.5	1.27816	0.23977	5.33085	-1.39203
PF.6	0.75634	0.23977	3.15448	-1.39203
PF.7	1.08076	0.23977	4.50752	-1.39203

APPENDIX V

Test of Seasonal Adjustment Specifications

The test used to discriminate between the two seasonal price equations is referred to by Davidson and MacKinnon as a "J test". Applying the test to models A and B we have supposed that one has two hypotheses:

Model A: $P^{Q}_{T,t} = f\ (P^{A}_{T}, P^{A}_{T-1})$

Model B: $P^{Q}_{T,t} = g\ (P^{A}_{T}, P^{A}_{T-1})$

where f and g are linear functions.

To inplement the tests, each of the equations was fitted using ordinary least squares. The residuals from model B were then added to model A and then from moded A were added to model B to yield:

Model A^{*}: $P^{Q}_{T,t} = (1-c)* f\ (P_{T}, P^{A}_{T-1}) + C* P_{2}$ and

Model B^{*}: $P^{Q}_{T,t} = (1-d)* g\ (P_{T}, P^{A}_{T-1}) + d* P_{1}$

where P_1 and P_2 are the predicted values of $P^{Q}_{T,t}$ from model A and model B respectively. The validity of model A is rejected if using the "t statistic", the coefficient c is found to be significantly different from 0. Similarly the validity of model B is rejected if the coeffcient d in model B* is found to be significantly different from 0.

Test results

When model A* and B* were fitted the following test result were obtained:

Coefficient	Estimate	T-Statistics
c	1.04	4.05
d	0.4	1.2

The estimated "t statistics" indicate that c is significantly different from 0 but d is not. This indicates that model B is the more appropriate of the two models.

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