The Relationship Between Price Stabilization and Cycles in the Canadian Wheat Market

J. Stephen Clark and K.K. Klein

In this study, moving average price stabilization schemes were analyzed under the assumption of rational expectations. It was shown that moving average price schemes may induce cyclical behaviour into market prices where no cyclical pattern previously existed. Moving average price stabilization schemes are important to Canadian agricultural policy analysis because they are a characteristic of stabilization programs in Canada. Indeed, the Agricultural Stabilization Act, introduced in 1975, and the Gross Revenue Insurance Program, introduced in 1991, use moving average prices to calculate returns to producers.

Stabilization of the agricultural industry has long been a priority of agricultural producers. In Canada, farmers have lobbied for more direct government intervention into what they believe is an inherently unstable industry. The government has responded to these pressures by enacting legislation such as the creation of the Canadian Wheat Board (with price pooling), the Agricultural Stabilization Act (ASA), the Western Grains Stabilization Act (WGSA), the National Tripartite Stabilization Act (NTSA) and, most recently, the Gross Revenue Insurance Program (GRIP) and the Net Income Stabilization Account (NISA).

The stabilization concept was given respectability by the publication of Massell's now famous article on the relationship between price stabilization and welfare. Most agricultural economists have studied Massell's paper and understand how, under the conditions described by Massell, price stabilization can increase total economic welfare. However, it has come to be realized that the manner in which expectations are formed by producers can have a big effect on potential welfare gains as a result of stabilization programs. Spriggs and Van Kooten demonstrated that, in the presence of rational expectations, "price stabilization may not provide unequivocal benefits to producers or consumers" (p. 291).

Most of the price stabilization schemes in Canada have been based on moving averages of prices. In the ASA, the moving average was five years in length. In recent years there has been concern that a five year period may be too short. A fifteen year moving average of prices was used in the GRIP to overcome the problem of protracted periods of low prices.

Luenberger (p. 164) shows that, if producers use long term moving averages to form price expectations, cyclical behaviour of prices and quantities can result. However, Luenberger does not explain why producers would choose moving average price schemes to form price expectations. Luenberger also ignores storage, an important component of the grains sector studied in this research.

In this study, a simple model of demand, supply and storage of wheat in Canada is developed to assess whether or not cycles could be expected to result from shocks in supply if producers form expectations rationally and price stabilization schemes are in effect. Two moving average price stabilization schemes are evaluated: five years and fifteen years.[1] Given the recent concern in Canada that a five year moving average may be too short to adequately stabilize prices in the wheat market,

The authors are Associate Professor, Department of Economics and Business Management, Nova Scotia Agricultural College and Professor, Department of Economics, The University of Lethbridge, respectively.
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[1] The lengths of moving average price stabilization schemes analyzed in this study correspond to the lengths of moving averages in the ASA (five years) and the GRIP (fifteen years). Other specific features of these programs are not addressed in this research.

this analysis will provide a comparison of impacts from supply shocks using a longer term as well as a shorter term moving average price stabilization scheme.

Price Behaviour With Moving Average Price Stabilization

Consider Muth's model of market storage and rational expectations (written in deviation form):

(1) Demand: $q_t^d = -\beta p_t$, $\beta > 0$,

(2) Supply: $q_t^s = \alpha E_{t-1}p_t + u_t$, $\alpha > 0$, $u_t \sim (0,\sigma^2)$,

(3) Stocks Demand: $s_t = \gamma(E_t p_{t+1} - p_t)$, $\gamma > 0$,

(4) Market Clearing: $q_t^s = q_t^d + s_t - s_{t-1}$.

The variable u_t is a white noise shock to supply representing, say, weather, and $E_t p_{t+1} = E(p_{t+1}/\Omega_t)$ is the conditional expectation of price given the information set Ω_t.[2] It is assumed that p_t is not known with certainty by producers when they make major supply decisions (e.g. planting decisions) and p_{t+1} is not known with certainty by agents when they make storage decisions. The assumption that the subjective expectation of price by farmers and storage agents is equivalent to the conditional expectation of price imposes rational expectations on the model.

Substituting equations (1), (2) and (3) into the market clearing condition (4) and rearranging, yields

$$E_t p_{t+1} - \Phi E_{t-1} p_t + p_{t-1} = \frac{u_t}{\gamma},$$

$$\Phi = 2 + \frac{\alpha + \beta}{\gamma}. \tag{5}$$

The solution to equation (5) is outlined in Sargent (p. 270) and proceeds as follows. First, define the back-shift operator L as $L^i X_t = X_{t-i}$, where $i = \ldots, -2, -1, 0, 1, 2, \ldots$. Therefore equation (5) can be written as

$$(1 - \Phi L + L^2)\, E_t p_{t+1} = \frac{u_t}{\gamma}. \tag{6}$$

[2] There is no loss in generality in assuming that shocks to demand are zero whereas shocks to supply are not. One could easily add shocks to demand without affecting the results in a meaningful way.

Focusing on the quadratic expression in the parentheses on the left side of equation (6), the roots of this expression are sought such that

$$(1 - \lambda_1 L)(1 - \lambda_2 L) = (1 - \Phi L + L^2), \tag{7}$$

where λ_i^{-1}, $i = 1, 2$ are the roots of the quadratic expression. From equation (7), it is evident that

$$\lambda_1 + \lambda_2 = \Phi \; (8a) \qquad \lambda_1\lambda_2 = 1. \; (8b)$$

Substituting λ_2 from equation (8*b*) into equation (8*a*) results in

$$\lambda_1 + \frac{1}{\lambda_1} = \Phi. \tag{9}$$

One can see from equation (8*b*) that the roots are reciprocals of one another, that is, if λ_1 is a root, so is $\lambda_2 = 1/\lambda_1$. In addition, from equation (9), one root (say λ_1) msut lie between zero and one and the other must be greater than one. Therefore, the solution strategy for equation (6) is to solve stable roots backward (e.g. λ_1) and unstable roots forward (i.e., $1/\lambda_1 = \lambda_2$) (see Sargent). The solution to equation (6) is

$$E_t p_{t+1} = \lambda p_t - \frac{1}{\gamma} \sum_{i=0}^{\infty} \lambda^i E_t u_{t+i+1}, \tag{10}$$

where $\lambda = \lambda_1$. Under the assumption that u_t is white noise, then $E_t u_{t+i+1} = 0$ for all i, so that equation (10) reduces to

$$E_t p_{t+1} = \lambda p_t. \tag{11}$$

Since equation (11) holds at time $t + 1$, it also must hold at time t, so that

$$E_{t-1} p_t = \lambda p_{t-1}. \tag{12}$$

Substituting equation (11) and (12) into equation (5), and rearranging yields

$$p_t = \lambda p_{t-1} + \frac{u_t}{\lambda\gamma}. \tag{13}$$

Equation (13) is the price autoregression of the Muth model under market clearing and no government intervention. Notice that equation (13) does not display any cyclical behaviour. Autoregressive processes of degree one (AR(1)) like equation (13) with $0 < \lambda < 1$ are monotonically convergent series. For a one-time shock in supply, the series asymptotically approaches the steady state value of zero without any cyclical behaviour.

Indeed, no AR(1) process can generate a cycle. For cyclical behaviour in prices, at least an AR(2) process is required and at least one root must be imaginary (Sargent). Therefore, in the absence of government intervention, private markets for grains do not generate cyclical behaviour in the Muthian system.

Where cyclical behaviour could occur is from the stabilization rule introduced by a moving average. In this case, suppose producers are insured on the basis of a moving average in prices. This will affect the supply price that rational producers expect to receive. The supply equation given in equation (2) would become

$$(2') \qquad q_t^s = \frac{\alpha}{n}\left(\sum_{j=1}^{n} E_{t-1}p_{t-j}\right) + u_t,$$

where n is the length of moving average chosen to calculate producer returns. Substituting (1), (2′), and (3) into equation (4) and rearranging yields:

$$(1 - \Phi_1 L + (1 - \delta)L^2 - \delta L^3 - \ldots - \delta L^{n+1})\, E_t p_{t+1} = \frac{u_t}{\gamma},$$

$$(14) \qquad \delta = \frac{\alpha}{n\gamma}, \qquad \phi_1 + 2 + \frac{\beta}{\gamma} + \delta.$$

Equation (14) is a stochastic difference equation that involves $n + 1$ roots. The solution process for equation (14) is the same as in the previous case: solve stable roots backward and unstable roots forward. As in the previous case, the solution to feedforward roots is zero since u_t is assumed to be white noise. Therefore, the market clearing solution to the price autoregression is

$$(15) \qquad p_t = \Pi(L)p_{t-1} + e_t,$$

where $\Pi(L) = \pi_1 L^1, \cdots, \pi_k L^k$. The parameters of the $\Pi(L)$ are functions of the underlying structural parameters. The length of the autoregression (k) is the number of stable roots and e_t is a function of u_t and the structural parameters.

Equation (15) is the new market clearing price autoregression that would result from imposing an nth order moving average price stabilization rule on a Muthian system. Although the generality of such a moving average stabilization rule of unspecified length makes analytic results such as those of the unconstrained Muthian model very difficult, it is reasonable to expect that at least one pair of the feedback roots are complex conjugates of one another. If this is the case, cyclical behaviour in prices would result from a shock to the system.

The cyclical behaviour of the system can be studied once the roots of the price autoregression given by equation (15) are known. That is, suppose a pair of complex conjugates of equation (15) are given by $\lambda_i = a + bi$ and $\lambda_j = a - bi$, where a is the real part of the root, b is the imaginary part, and $i = (-1)^{1/2}$. Define $r = (a^2 + b^2)^{1/2}$; then r is the dampening factor. It is this value that controls how fast the system returns to equilibrium after a shock for complex conjugate pair λ_i and λq_j^3. In general, the larger the dampening factor, the slower the rate at which the system returns to equilibrium following a shock. In addition, the periodicity (i.e., the number of periods from peak to peak) of the cycle represented by a complex conjugate pair is given by $2\pi/(\cos^{-1}(a/r))$. Therefore, the speed of convergence to long run equilibrium as well as the periodicity of each cycle can be deduced.

Additional insights into the possible effects of a moving average price stabilization rule on the grain sector can be discovered by studying the so-called "dominant root" of the system given by equation (15). Dominant roots are important because, as their name suggests, they govern the time series behaviour of the system in the long run. Therefore, a comparison can be made of the properties of these roots with those of the roots from the unconstrained system given by equation (13).

Define one of the complex conjugate pair of the dominant root to be $\lambda^* = a^* + b^* i^4$. Therefore $r^* = (a^{*2} + b^{*2})^{1/2}$ is the dampening factor associated with the dominant root. Comparing this value with that of the market clearing root given in equation (13), then convergence is

$$\begin{pmatrix} \textit{slower} \\ \textit{the same} \\ \textit{faster} \end{pmatrix} \textit{as } r^* \begin{pmatrix} > \\ = \\ < \end{pmatrix} \lambda.$$

Stabilization of the Canadian Wheat Price

This section examines the impacts of a shock in the Canadian wheat market when five and fifteen year moving average stabilization programs are in effect. The price received by producers is the average of the previous five or fifteen years, whichever is appropriate.

Equations (1) through (3) are estimated for Canada using data from 1946 to 1989. Variable descriptions and sources of the data are provided in the Appendix. The parameters of the model are

[3] It must be true that $|r| < 1$ since this means that the root is stable. As mentioned above, the solution to equation (15) is in terms of the stable roots only.

[4] There is no loss of generality in assuming the dominant is complex and not real. If the dominant root is real, then $b = 0$.

estimated under the assumption of rational expectations. The ex-post realizations of prices are used as proxies for the expected price variables in equations (1) through (3). The use of ex-post proxies for expected price variables means that an instrumental variable technique is needed since these regressors are not independent of the error terms (Eckstein). However, given the assumption of rational expectations, any variable in the producers' information sets is uncorrelated with the error terms of each equation and thus these provide a ready set of instruments that can be used to derive consistent estimates of the parameters (Hansen and Sargent).

The estimation procedure employed is Hansen's generalized method of moments (GMM) estimator, which takes into account serial correlation among the error terms of the estimating equations. The actual algorithm that is used to estimate the parameters is outlined in Gallant.

In order to identify the parameters of the model, it is necessary to specify demand and supply shifters. The demand for wheat is estimated as the sum of two wheat demand functions: 1) domestic human consumption demand and 2) export plus feed use demand. The shifter chosen for domestic human consumption demand is real per capita income (Y_t). The shifter chosen for export plus feed demand is total world wheat production, excluding Canadian production (Q_t^w). The domestic price of wheat (P_t^d) was different from the export price of wheat (P_t) during the years between 1973 and 1989 because of the two-price wheat policy instituted by the federal government. The price of barley (P_t^b) is chosen as the shifter in the supply of wheat equation.

Table 1 presents the estimated parameter values and other statistics associated with the GMM estimator of the parameters of the Canadian wheat market. The instruments chosen to estimate the model include one year lagged value of the price of barley (P_{t-1}^b), the rest of the world wheat production (Q_{t-1}^w) and per capita income (Y_{t-1}). The sum of squared errors (SSE) is distributed as a χ^2 random variable with 1 degree of freedom (Hansen). This χ^2 value is a test of fit for the over-identifying restrictions of the model (e.g., Gallant). The results indicate that the over-identifying restrictions on the model are not rejected at the 10% level of significance.

The parameter estimates conform to a priori expectations. Both estimates on own price in the export and domestic demand functions are negative. Also, the own price coefficient in the export demand function is approximately six times higher than the own price coefficient on domestic demand. The coefficient on the storage function and own price in the wheat supply equation are both positive, as suggested by economic theory.

The estimation also yielded three other impor-

Table 1. Generalized Method of Moments Estimators of Structural Parameters for Canadian Wheat Market (1946–1989)[a]

Regressor	Demand Equations: Domestic Human Consumption	Demand Equations: Export + Feed	Stocks	Supply Equation
Intercept	1608.77	8616.31	13530.58	17087.34
	(7.05)	(1.90)	(6.46)	(1.68)
Farm/Export Wheat Price (P_t)	—	−13.754	—	172.508
		(−1.21)		(1.44)
Domestic Wheat Price (P^d_t)	−1.899	—	—	—
	(−2.59)			
Differenced Price ($P_{t+1} - P_t$)	—	—	238.943	—
			(1.57)	
Per Capita Income (Y_t)	0.081	—	—	—
	(12.14)			
World Wheat Production (Q^w_t)	—	0.034	—	—
		(5.84)		
Price of Barley (P^b_t)	—	—	—	−289.586
				(−1.91)
Model Sums of Squared Errors = 0.34 (1 Over-Identifying Restriction)	χ^2 (.05, 1) = 3.84			

Asymptotic t-values in parentheses. Key: The domestic human demand equation is of the form $Q^d_t = a_0 + a_1P^d_t + a_2Y_t + e_{1t}$ where Y_t is real per capita income. The export plus feed demand function is of the form $Q^x_t = b_0 + b_1P_t + b_2Q^w_t + e_{2t}$ where Q^w_t is world wheat production excluding Canada. The supply equation is of the form $Q^s_t = c_0 + c_1P_t + c_2P^b_t + e_{3t}$, where P^b_t is the price of barley. The stocks demand equation is of the form $S_t = d_0 + d_1(P_{t+1} - P_t) + e_{4t}$.

tant results. First, per capita income is an important variable in explaining domestic wheat consumption. Second, world wheat production is an important variable in explaining wheat exports. Third, barley price is an important variable in explaining wheat production. The coefficients on all of these variables are significant to approximately the 5% level of statistical significance.

Table 2 presents the values of the market clearing price autoregressions with no price stabilization, as well as five and fifteen year moving average prices. It can be seen that under no stabilization, the market clearing price is an AR(1) process with the lag coefficient (which is also the market clearing root) being 0.423. The market clearing price autoregressions for the five and fifteen year moving average stabilization schemes are AR(5) and AR(15), respectively.

Table 3 presents the roots of the price autoregressions with five year and fifteen year moving average stabilization rules, along with the dampening factors and cycle lengths. It is clear that the system will converge to long run equilibrium more slowly when moving average stabilization schemes are imposed on the system and, in the case of the fifteen year moving average stabilization scheme, much more slowly. The dampening factor for the dominant eigenvalue under the five year moving average stabilization scheme is 0.611, which is higher than the 0.423 eigenvalue for no stabilization, indicating slower convergence for the five year moving average stabilization scheme. For the fifteen year moving average stabilization scheme,

Table 2. Marketing Clearing Price Autoregressions

Year Lag	No Stabilization	5 Year Moving Average Stabilization	15 Year Moving Average Stabilization
1	0.423	0.373	−0.556
2		−0.040	0.086
3		−0.038	0.086
4		−0.034	0.086
5		−0024	0.086
6			0.085
7			0.085
8			0.084
9			0.082
10			0.080
11			0.077
12			0.072
13			0.063
14			0.051
15			0.118

Source: Estimated using the parameters presented in Table 1.

Table 3. Roots, Dampening Factors and Cycles for Wheat Price Model Under Five and Fifteen Year Moving Average Stabilization Schemes*

Real Part (a)	Imaginary Part (b)	Dampening Factor (r)	Cycle (years)
1) Five Year Moving Average Stabilization Program			
0.489	0.367	0.611	9.76
−0.116	0.397	0.414	3.39
−0.373	0.000	0.373	n.a.
2) Fifteen Year Moving Average Stabilization Program			
0.951	0.000	0.951	n.a.
0.716	0.413	0.826	12.01
0.454	0.642	0.786	6.58
0.149	0.752	0.766	4.57
−0.165	0.740	0.758	3.51
−0.794	0.136	0.805	2.11
−0.666	0.401	0.778	2.42
−0.448	0.616	0.726	2.86

* Deduced using the parameters presented in Table 2.
n.a. = not applicable.

the dominant eigenvalue rises to 0.951, indicating much slower convergence than under no stabilization.

In addition, there are two overlapping cycles that result from a five year moving average stabilization scheme, ranging from approximately three years to ten years in duration. There are five overlapping cycles induced by the fifteen year moving average stabilization scheme, with the longest approximately twelve years and the shortest just over two years. Therefore, not only is convergence slower under fifteen year moving average stabilization than under five year moving average stabilization, the length of the longest cycle is approximately two years longer.

The (impulse) response from a positive one-time change in price (i.e., $u_t = 5$ in equation (13) or a one-time price shock of $5/tonne) is presented in Figure 1. The response under the price autoregression with no stabilization scheme is the expected monotonically convergent series. No cyclical behaviour is evident. The price returns to its long-run equilibrium level rather quickly, within the first 5 years.

The (impulse) response on the market clearing price autoregression under the five year moving average stabilization scheme from the same one-time price shock is presented in Figure 2. Figure 2 displays a different pattern from that of no stabilization. Fluctuations that result from a one-time shock in price are still noticeable at year sixteen, as opposed the situation depicted in Figure 1, where shocks are no longer evident after five years. This

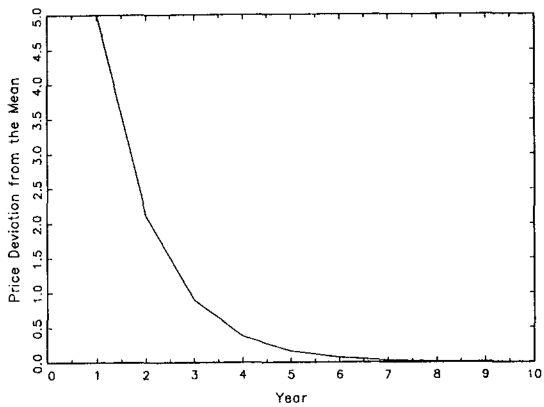

Figure 1. Price Deviations from a One-Time Shock with no Price Stabilization

indicates slower system convergence under a five year moving average stabilization scheme than under no stabilization.

The (impulse) response on the market clearing price autoregression under the fifteen year moving average stabilization scheme from the same one-time price shock is presented in Figure 3. The lengthening of the longest cycle and the slower convergence as compared to the five year moving average stabilization scheme, as presented in Figure 2, is clearly evident. The positive one-time price shock has pronounced price deviations approximately every fifteen years whereas this pattern occurs once every five years for the five year moving average stabilization scheme. A noticeable response to the price shock is still evident after even sixty years under fifteen year moving average stabilization, long after the effects of the price shock have dissipated under the five year moving average stabilization and no stabilization.

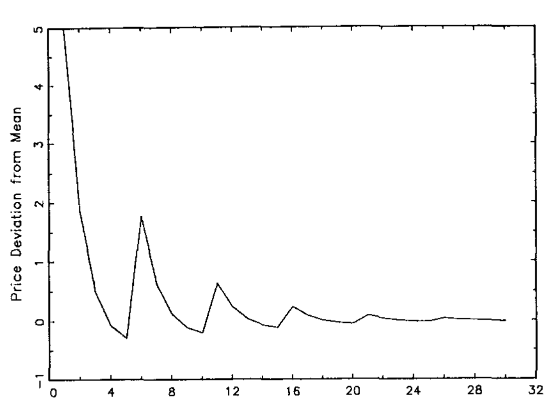

Figure 2. Price Deviations from a One-Time Shock with Five year Moving Average Stabilization

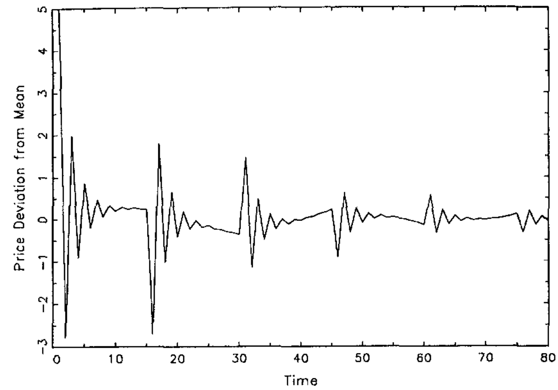

Figure 3. Price Deviations from a One-Time Shock with Fifteen year Moving Average Stabilization

Conclusions

In this study, it is shown that stabilization programs that are based on moving average prices may well cause a cyclical pattern in prices over time. Thus a "grain cycle" may emerge in the grains sector from such a stabilization scheme. The intuition behind this result can perhaps best be explained by comparison to animal price cycles. The fundamental reason why cycles are thought to exist in animal markets (such as beef and hogs) is because there is a lag in the production of animals due to the time it takes to change production plans and sell the output. Moving average stabilization schemes in the grains sector means that lags in production will influence prices farmers expect to receive in the future. These government induced lags therefore can induce cyclical behaviour in prices.

The results indicate that a one-time shock to either the demand or supply sides of the market could cause several cycles, ranging from approximately three to ten years for a five year moving average price stabilization scheme and from two to twelve years for a fifteen year moving average price stabilization scheme. It is also shown that the system reacts to price shocks quite sluggishly with the moving average price regimes, resulting in a long period of time before steady state prices are re-established.

The model used in this study was very simple and may not provide the precision that would normally be required by agricultural program administrators. Thus, the length and magnitude of the cycles as well as the time taken to converge to an equilibrium may not be as precisely estimated as would be the case with a more sophisticated model. In addition, of course, governmental programs have a habit of periodic change, introducing another form of instability not addressed in this study. Nevertheless, this simple model illustrates how a grain cycle could develop if producers face moving average price stabilization programs. More research needs to be undertaken into this and other aspects of agricultural stabilization programs, preferably before moving average price schemes become entrenched in producers' expectations.

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Appendix

The Data and its sources are given in Table A.1

Variable	Symbol	Time Period	Source
Domestic Wheat Prodution (000's tonnes)	Q_t^s	1946–1974	Urquhart et al. *Hist. Stat. of Canada (1926–76)*
		1975–1988	Stat. Can. Grains & *Oilseeds Rev.* #22-007.
Wheat Exports + Domestic Feed (000's tonnes)	Q_t^x	1946–1974	Urquhart et al. *Hist. Stat. of Canada (1926–76)*
		1975–1988	Stat. Can. *Grains & Oilseeds Rev.* #22-007.
Dom. Wheat Human Consumption (000's tonnes)	Q_t^d	1946–1974	Urquhart etal. *Hist. Stat. of Canada (1926–76)*
		1975–1988	Stat. Can. *Grain Trade of Canada.* #22-201.
Wheat Stocks (000's tonnes)	S_t	1946–1974	Urquhart et al. *Hist. Stat. of Canada (1926–76)*
		1975–1988	Stat. Can. *Grain Trade of Canada.* #22-201.
Wheat Price (Excl. Domest. Price $/tonne)	P_t	1946–1988	*Agric. Stats. of Sask. 1988.* Regina. Saskatchewan.
Dom. Wheat Price ($/tonne)	P_t^d	1946–1972	*Agric. Stats. of Sask. 1988.* Regina,
		1973–1989	Saskatchewan. *CWB Annual Rep.* (#1 Hard Red Spring) Winnipeg, Man.
Barley Price ($/tonne)	P_t^b	1946–1989	*Agric. Stats. of Sask. 1988.* Regina, Saskatchewan.
Tot. Labor Income (millions of $)		1946–1974	Urquhart et al. *Hist. Stat. of Canada (1926–76)*
		1975–1988	*Can. Stat. Review,* Stat. Can. #11-003E.
Population (millions)		1946–1974	Urquhart et al. *Hist. Stat. of Canada (1926–76)*
		1975–1988	*Can. Stat. Review,* Stat. Can. #11-003E.
Per Capita Income	Y_t	1946–1988	Tot. Labor Income/Population
World Wheat Prod. (000's tonnes)	Q_t^w	1946–1988	*CWB Annual Rep.* Winnipeg Man.
Consumer Price Index (1988–100)		1946–1988	Stat. Can. *Prices and Price Indexes.* #62-002.

All wheat prices, the barley price and per capita income were deflated by the consumer price index. Variable symbol names are given in the text, or at the bottom of Table 1. All dollar amounts are in Canadian dollars.