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Assessment of the Effect of the Policy Environment on Farm Decision-Making: Aggregate Acreage Response in the Canadian Prairies Under the Western Grains Stabilization Program

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Abstract

An aggregate acreage supply model for the Canadian prairie provinces is estimated under the assumption that farmers base acreage allocation decisions on the rational ex-ante expectationa and variance of net per hectare revenue. In order to account directly for the effects of government intervention during the period of estimation, a structural model of the Western Grains Stabilization Program is incorporated into the estimation framework. Results indicate that the revenue enhancement and revenue stabilization effects of the program both contributed nearly equally to modest increases in cropped acreage between 1976 and 1990.

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Aggregate Acreage Response in the Canadian Prairies Under the Western Grains Stabilization Program

In this paper we estimate an aggregate acreage supply model for the western Canadian prairie provinces of Alberta, Manitoba, and Saskatchewan. Estimation of acreage supply in this region is complicated by the incidence of several substantive shifts in government agricultural policy during the period of estimation. Western Canadian grain producers operated mainly free of government intervention up to 1976, when the Western Grains Stabilization Program (WGSP) was introduced. The WGSP was designed to disburse payments to participating farmers from a buffer fund maintained by farmer and Government co-contributions. During its first six years of operation, WGSP payments were triggered whenever aggregate net cash flow fell below its five-year moving average. In 1982, a second payout trigger mechanism, based on shortfalls of net cash flow per tonne of grain marketed, was implemented. In 1990, the WGSP was abandoned in favor of an expanded crop insurance program.

Several econometric studies have examined western Canadian acreage response under the WGSP (Coyle and Brink; Mielke and Weersink; Cameron and Spriggs).[1] These studies, however, employed *ad hoc* autoregressive expectations frameworks that ignore the basic structural features of the WGSP.[2] Lucas, in his well-known critique of econometric policy evaluation models, argued that autoregressive formulations represent reduced forms whose parameters are stable only in the absence of substantial policy shifts. An autoregressive formulation is thus inappropriate for the study of the western Canadian grain producing sector, which has experienced three major shifts in policy regime over the last two decades. At the very least, autoregressive expectation models estimated from WGSP era data lack validity now that the WGSP has been abandoned.

To overcome lack of robustness inherent in an autoregressive formulation, we estimate an aggregate acreage supply model for western Canada under the alternative assumption that farmers base acreage allocation decisions on the rational ex-ante expectation and variance of net per hectare revenues. In order to account directly for the effects of government intervention, a detailed structural model of the WGSP is incorporated into the estimation framework. The resulting nonlinear rational expectations model lacks a closed form solution and is estimated using a combination of maximum likelihood methods and Monte Carlo numerical integration techniques. In the next section, the estimation model is presented. In the subsequent two sections, the estimation results and the revenue stabilization and acreage supply impacts of the WGSP are discussed.

Structural Estimation Model

Our ultimate goal is to estimate the log-linear aggregate acreage supply equation:

$$\log A_t = \alpha_0 + \alpha_1 \log E_t R_t + \alpha_2 \log V_t R_t + \alpha_3 \log A^*_{t-1} + \tilde{\varepsilon}_t. \tag{1}$$

Here, A_t is millions of hectares planted in western Canada, prior to the beginning of marketing year t, to six major grain crops: wheat, barley, oats, rye, flax, and canola.[3] R_t is the marketing year production-weighted average revenue from the six crops, in real 1986 Canadian dollars per hectare, net of production costs and WGSP levy contributions and inclusive of WGSP payments. E_t and V_t are the expectation and variance operators conditional on information known at planting time. A^*_{t-1} is millions of hectares of tillable acreage available the previous year, including summer fallow and acreage devoted to minor crops; its presence in the estimation equation captures the high adjustment costs of increasing the tillable base in the short-run and the mainly exogenous growth in the tillable base in the long-run.[4]

The primary obstacle to estimating (1) is that the ex-ante expectation and variance of per hectare revenue are unobservable and thus must be derived from an auxiliary theory of expectation formation. For the reasons previously discussed, we endogenize the ex-ante expectation and variance of revenue by assuming that producers are rational in the sense of Muth. Ex-ante expectations and variances are derived directly from an explicitly posited behavioral sub-model of the western Canadian grain market and an explicitly posited structural sub-model of the WGSP.

Grain Market Sub-Model

The grain market sub-model consists of four estimable log-linear equations describing price formation, grain marketings, on-farm grain dispositions, and aggregate yield:

$$\log P_t = \beta_0^P + \beta_2^P \log P_{t-1} + \beta_3^P \log U_t + \tilde{\eta}_t^P \tag{2}$$

$$\log M_t = \beta_0^M + \beta_2^M \log P_t + \beta_3^M \log S_t + \beta_4^M \log M_{t-1} + \tilde{\eta}_t^M \tag{3}$$

$$\log D_t = \beta_0^D + \beta_2^D \log P_t + \beta_3^D \log N_t + \tilde{\eta}_t^D \tag{4}$$

$$\log Y_t = \beta_0^Y + \beta_2^Y t + \beta_3^Y t^2 + \tilde{\eta}_t^Y \tag{5}$$

Here, P_t is the marketing year production-weighted average price for the six crops, in real 1986 Canadian dollars per tonne.[5] M_t and D_t are gross grain marketings and on-farm dispositions, respectively, in millions of tonnes, and

Y_t is production-weighted average yield in tonnes per hectare. S_t is available supply at the beginning of the marketing year, the predetermined sum of old crop carryin and new production, in millions of tonnes. Exogenous variables include U_t, the global stock-utilization ratio expressed as a percentage, and N_t, a cattle-equivalent index of cattle and hog numbers in western Canada.

Equation (2) embodies the assumption that Canada is a price taker on the international grain market.[6] Equation (3) presumes that grain marketings will respond positively to price increases, subject to the availability of pre-determined supplies; a lagged endogenous variable captures the high short-run adjustment costs associated with rapid expansion or contraction of established marketing channels. Equation (4) presumes that on-farm dispositions will respond negatively to price increases but, like grain marketings, are subject to the availability of pre-determined supplies; the inclusion of an animal numbers index reflects the large proportion of on-farm dispositions devoted to livestock feed. Equation (6) assumes that the aggregate yield is exogenous, and subject to predictable growth over time.

WGSP Sub-Model

The WGSP sub-model consists of nine deterministic structural equations describing WGSP payouts under the three policy regimes that existed between 1970 and 1990:[7]

$$(6) \qquad PAY_t = \begin{cases} 0 & t \leq 1975 \\ PAY1_t & 1976 \leq t \leq 1981 \\ \max\{PAY1_t, PAY2_t\} & 1982 \leq t \leq 1990. \end{cases}$$

From its introduction 1976 to 1981, WGSP payouts were triggered whenever the aggregate net cash flow NCF_t fell below its simple average over the preceding five years $\overline{NCF}_t$. The so-called potential payout under the aggregate net cash flow trigger was computed as

$$(7) \qquad PAY1_t = WPR_t \cdot \max\{0, \overline{NCF}_t - NCF_t\}$$

where WPR_t, the weighted participation ratio, is the proportion of western Canadian producers participating in the WGSP.

In 1982, a second payout trigger mechanism was incorporated into the WGSP. Under the second mechanism, payouts were triggered whenever the per-tonne net cash flow $NCFPT_t$ fell below its simple average over the preceding five years $\overline{NCFPT}_t$. The potential payout under the per-tonne net cash flow trigger was computed as

$$(8) \qquad PAY2_t = M_t \cdot ER_t \cdot WPR_t \cdot \max\{0, \overline{NCFPT}_t - NCFPT_t\}$$

where ER_t, the eligibility ratio, is the proportion gross grain proceeds eligible for coverage under the WGSP and M_t is grain marketings. With the introduction of the per-tonne trigger, actual WGSP payout became the larger of the payouts calculated using the aggregate and per-tonne triggers.

For the purposes of WGSP payout calculations, aggregate net cash flow, in billions of nominal Canadian dollars, and per-tonne net cash flow, in nominal Canadian dollars per tonne, were computed as follows:

$$(9) \qquad NCF_t = ER_t \cdot (GGP_t - MPR_t \cdot GGE_t)$$

$$(10) \qquad NCFPT_t = (GGP_t - MPR_t \cdot GGE_t)/M_t.$$

Here, gross grain proceeds GGP_t, in billions of nominal Canadian dollars, is the simple product of the market price P_t and grain marketings M_t:

$$(11) \qquad GGP_t = P_t \cdot M_t.$$

GGE_t is gross grain expenses, in billions of nominal Canadian dollars. MPR_t, the marketing-production ratio, is the proportion of grain production actually marketed as approximated by

$$MPR_t = 1 - \frac{D_t}{A_t \cdot \overline{Y}_t} \tag{12}$$

where $\overline{Y}_t$ is the average yield over the preceding five years.

Under the WGSP, participating producers were required to contribute a fixed proportion of their gross grain proceeds to the WGSP fund. Adjusted for eligibility and participation rates, aggregate levy contributions to the WGSP fund, in billions of nominal Canadian dollars, were

$$LEVY_t = PLR_t \cdot ER_t \cdot WPR_t \cdot GGP_t \tag{13}$$

where PLR_t is the producer levy rate.

Adjusted for inflation, WGSP payouts, WGSP levy contributions, and expenses, the net per hectare revenue received by farmers, in real Canadian dollars per hectare, was

$$R_t = \frac{GGP_t - GGE_t + PAY_t - LEVY_t}{A_t \cdot CPI_t} \tag{14}$$

where CPI_t is the Canadian consumer price index with $CPI_{1986} = 1$.

Estimation Method and Results

Estimation of behavioral equations (1)-(5) is complicated by the nonlinear and discontinuous restrictions (6)-(14) that must be satisfied by the rational expectations equilibrium. Specifically, the complete model lacks a closed-form solution for the ex-ante revenue expectations and variances, and thus cannot be estimated using conventional linear rational expectations econometric techniques (Hansen and Sargent). As an alternative, we use the maximum likelihood estimation technique developed by Fair and Taylor for nonlinear rational expectations models. This technique calls for the nonanalytic restrictions implied by rationality to be imposed using numerical methods, including Monte Carlo integration.[8] We substantially reduce the otherwise extreme computational complexity of the Fair-Taylor algorithm by assuming that the error term of the acreage supply equation (1) is uncorrelated with the error terms of the grain market sub-model equations (2)-(5).[9] Under this assumption, the model can be straightforwardly estimated in a three step sequence.

In step one of the estimation, equations (2)-(5) of the grain market submodel were estimated jointly using maximum likelihood techniques, allowing for first order autocorrelation and contemporaneous correlation among the equation error innovations.[10] The parameter estimates, together with asymptotic t-statistics, are presented in Table 1.[11]

All parameter estimates for the price formation equation (2) are of the expected sign and significant at the five percent level, with the exception that the shock exhibits no appreciable autocorrelation. An increase of one percent in the global stock-utilization ratio would lower price by about 3.5 percent.

All parameter estimates for the grain marketing equation (3) are of the expected sign and significant at the five percent level, with the exception of the autocorrelation coefficient which is negative though not statistically significant. The price elasticity of grain marketings was approximately 0.2. A one percent increase in available supply raises marketings by about the one percent. A highly significant coefficient on lagged marketings confirms the presence of significant adjustment costs in grain marketing.

All parameter estimates for the on-farm dispositions equation (4) are of the expected sign and significant at the five percent level, with the exception of the price elasticity, which is positive though small and statistically insignificant. A one percent increase in available supply raises on-farm dispositions by about 0.8 percent. A one percent increase in the livestock population raises on-farm dispositions by about 0.8 percent, confirming the importance of grains as livestock feed. Strong positive autocorrelation was detected.

The parameter estimates for the yield equation (5) suggest a steady but slightly declining annual rate of growth in yields of three percent. Autocorrelation was not detected in the yield shocks.

In the second step of the estimation procedure, Monte Carlo integration methods were used to compute the rational ex-ante expectation and variance of per hectare revenues.[12] For each year between 1970 and 1990, the combined grain market and WGSP model (2)-(14) was simulated 10,000 times. Each of these replications required one pseudo-random draw from the joint normal probability distribution of the shock innovations in (2)-(5). For each replication, the net per hectare revenue that would have prevailed under the drawn random shock was calculated. For each year, the first and second moments of the per hectare revenue were accumulated over all the replications and used to compute the ex-ante mean and variance of real per hectare revenues.

In the third and final step of the estimation procedure, the rational ex-ante means and variances of real per hectare revenues generated in the second step are used to estimate the acreage response equation (1) using ordinary least squares. As seen in Table 2, all parameter estimates for the acreage response equation are of the expected sign and significant at the five percent level, with the exception of the autocorrelation coefficient which is not statistically significant. The elasticity of acreage supply with respect to expected per hectare revenue is approximately 0.29, which is typical of short-run revenue elasticities for grains. The elasticity of acreage supply with respect to revenue variance is approximately -0.12, indicating that a doubling of the revenue variance would reduce acreage supply by about 12 percent.

Simulation Analysis

Using the estimated model (1)-(14), we assessed the effects that the WGSP had on the distribution of revenues and on planted acreage during its operational years of 1976-1990. To make the assessment, we first had to compute the ex-ante expectations and variances of per hectare revenues that would have prevailed under the counterfactual scenario that the WGSP had never been implemented. This was accomplished by simulating the grain market sub-model (2)-(5) alone, setting the WGSP payouts and levy contributions to zero.

Table 3 presents the ex-ante mean and standard deviation of real per hectare revenues under the factual scenario (with WGSP) and counterfactual scenario (without WGSP). The level and volatility of per-hectare revenues mirror the shifts that took place in international grain prices during the period: low prices at the beginning of the 1970s, following the collapse of existing international grains arrangements; rapid increases in grain prices in the early 1970s, following major Soviet grain purchases; and sharp declines in grain prices in the early 1980s, with 1987 the low point. Year-to-year changes in expected revenues per hectare often exceeded one-third both in the period of rising prices in the mid-1970s and in the period of sharp price declines of the early 1980s.

As seen in Table 3, the WGSP typically increased the expected per hectare revenue, though in some years, when expected levy contributions exceeded expected payout, the WGSP actually reduced expected per hectare revenue. The WGSP, on the other hand, reduced the ex-ante standard deviation of revenue in every year it operated. The major increases in revenue level and the major reduction in revenue instability occurred in the 1980s as swiftly declining grain prices triggered the first of a series of substantial payments from the WGSP fund. From 1982 to 1987, under dual trigger mechanism, the buffering activity of the WGSP reduced the standard deviation of revenue by one-third to one-half.

To assess the effects of the WGSP on acreage supply, we multiplied the WGSP-induced percent changes in revenue expectation and variance by their respective acreage supply elasticities. As seen in Table 4, the WGSP raised acreage planted to the six major crops in every year except 1989. Over its fifteen years of operation, the WGSP raised acreage by an average of 1.477 million hectares annually, or about 6.85 percent. Of this increase, 3.14 percent is attributable to the increases in the general revenue level—a slightly higher percentage, 3.71 percent, is attributable to the risk reduction induced by the WGSP. The WGSP had a greater impact on acreage between 1982 and 1990, under the dual trigger mechanism, than between 1976 and 1981, under the single trigger mechanism. In particular, about one-half of the overall acreage increase attributable to the WGSP occurred during three years: 1985, 1986 and 1987.

Our assessment of the acreage supply impacts of the WGSP differs from earlier studies. Fulton, whose observations preceded the major WGSP payouts of the late 1980s, concluded that the WGSP had no effect on acreage response. Similarly, Coyle and Brink concluded that the WGSP had little or no effect on cropped acreage. Meilke and Weersink estimated a slight (1.59 percent) increase in acreage due to increases in expected revenue, but found no significant supply response to decreases in revenue variability. Cameron and Spriggs also reported some acreage response, though less than that reported here, and attributed a lesser portion of the acreage increase to the revenue stabilization effects of the WGSP.

Conclusion

We have combined maximum likelihood techniques and Monte Carlo methods to estimate a nonlinear rational expectations model of aggregate acreage response in western Canada. In order to account directly for the effects of government intervention during the period of estimation, a structural model of the Western Grains Stabilization Program was incorporated into the estimation framework.

Our results suggest that during its fifteen years of operation, the WGSP raised acreage planted to eligible crops by close to 7 percent. Slightly more than half of this increase was attributable to the risk reduction effects of the program, the remainder to the increases in expected returns. The most significant impact of the program occurred in the mid and late 1980s, when changes in WGSP rules and rapidly declining grain prices led to large payouts.

More generally, we have shown that the effects of government agricultural stabilization programs can be assessed empirically in a rational expectations framework, even when the underlying equilibrium possesses no analytic solution. Expanding the methods developed here to deal with large country cases or multiple commodities, would appear possible directions for future work. The existing framework, however, appears capable of assessing a wide range of concerns associated with agricultural stabilization and support programs.

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Footnotes

1. Spriggs; Spriggs and Van Kooten; and Spriggs, Gould, and Koroluk used Monte Carlo simulation methods to analyze proposed changes in the WGSP, but did not attempt systematic econometric estimation of the underlying structural model.

2. Cameron and Spriggs recognize the weaknesses of an autoregressive expectations formulation and encourage future work using a rational expectations framework (page 444).

3. Due to the absence of stockholding data, we ignore a seventh crop covered under the WGSP, mustard, which on average accounted for a negligible 0.2 percent of total production under the program.

4. Between 1970 and 1990, tillable acreage grew steadily at rate of one-half percent per year, despite wildly fluctuating and ultimately downward trending prices. Government subsidization of homesteading and technical developments that made the cultivation of previously marginal lands feasible, processes that are exogenous to our short-run acreage response model, accounted for most of the long-term growth in tillable acreage.

5. One tonne is equal to one thousand kilograms.

6. Canada is most clearly a price-taker in markets for feedgrains and oilseeds, where it is a minor part of the international market. Even for wheat, where Canada has a higher international market share, but a very low share of world output, there is widespread evidence that demand is extremely elastic. Tyers and Anderson report long-term

price elasticities in the -10 to -20 range for Canadian wheat, and in the vicinity of -40 for Canadian coarse grains.

7. Except for a few minor notational differences, the WGSP simulation sub-model presented below is essentially the same as the one employed by Spriggs, Gould, and Koroluk.

8. Holt and Johnson were the first to use the Fair-Taylor technique to estimate an agricultural policy model.

9. Without this assumption, the expectations and variances of revenue become dependent on the parameters of the acreage supply equation and thus must be recomputed every time the parameters are perturbed during the estimation procedure. Computational complexity would increase by several orders of magnitude, requiring the use of a supercomputer.

10. The log-likelihood function was maximized using a quadratic hill-climbing algorithm (Goldfeld and Quandt).

11. R-square measures of goodness-of-fit are not meaningful in a multi-equation maximum likelihood estimation framework and therefore are not reported.

12. Law and Kelton is an authoritative reference on Monte Carlo techniques, including the generation of correlated normal pseudo-random variates.

Table 1. Parameter Estimates for Western Canadian Grain Market Sub-Model.

Dependent Variable	Independent Variable	Parameter Estimate	Asymptotic T-Statistic
Log P_t	Const	2.149	3.39
	Log P_{t-1}	0.731	6.30
	U_t	-3.510	-4.70
	Auto	0.069	0.30
Log M_t	Const	-9.407	-5.14
	Log P_t	0.196	2.34
	Log S_t	0.993	6.64
	Log M_{t-1}	0.781	10.15
	Auto	-0.180	-1.01
Log D_t	Const	-7.010	-2.14
	Log P_t	0.065	0.54
	Log S_t	0.808	5.94
	Log N_t	0.760	3.00
	Auto	0.736	4.85
Log Y_t	Const	7.304	92.87
	Year	0.030	2.07
	$Year^2$	-0.001	-1.54
	Auto	0.020	0.10

Table 2. Parameter Estimates for Western Canadian Aggregate Acreage Response Equation.

Dependent Variable	Independent Variable	Parameter Estimate	Asymptotic T-Statistic
Log A_t	Const	-30.064	-7.09
	Log E_tR_t	0.290	2.94
	Log V_tR_t	-0.120	-2.49
	Log A^*_{t-1}	3.785	9.61
	Auto	-0.272	-1.14

Table 3. Ex-Ante Mean and Standard Deviation of Per-Hectare Revenue under Alternative Scenarios, Real 1986 Canadian Dollars.

	Factual Scenario (With WGSP, 1976-90)		Counterfactual Scenario (Without WGSP)	
Year	Mean	Std. Dev.	Mean	Std. Dev.
1970	253	74	253	74
1971	262	70	262	70
1972	274	74	274	74
1973	385	100	385	100
1974	625	151	625	151
1975	493	129	493	129
1976	342	89	336	99
1977	305	70	279	87
1978	271	63	239	81
1979	319	83	307	96
1980	381	105	381	110
1981	340	104	343	106
1982	221	65	208	79
1983	238	64	219	81
1984	221	65	210	78
1985	189	43	136	62
1986	159	35	94	51
1987	122	29	74	47
1988	137	55	143	58
1989	239	78	246	80
1990	178	48	167	61

Table 4. Increases in *Planted* Acreage Attributable to the Western Grains Stabilization Program, 1976-1990.

	Absolute Increase (Thousand Hectares)	Percent Increase		
Year	Total	Total	Expectation Effect	Variance Effect
1976	438	2.41	0.46	1.96
1977	1122	6.16	2.18	3.97
1978	1481	7.67	3.13	4.54
1979	721	3.73	0.95	2.78
1980	151	0.79	-0.03	0.82
1981	7	0.04	-0.24	0.28
1982	1027	4.90	1.48	3.42
1983	1386	6.50	2.04	4.45
1984	983	4.47	1.20	3.27
1985	3449	15.39	8.52	6.88
1986	4888	21.45	13.94	7.51
1987	5101	23.04	13.43	9.61
1988	16	0.07	-0.97	1.04
1989	-74	-0.32	-0.74	0.41
1990	1458	6.45	1.77	4.68
Average	1477	6.85	3.14	3.71