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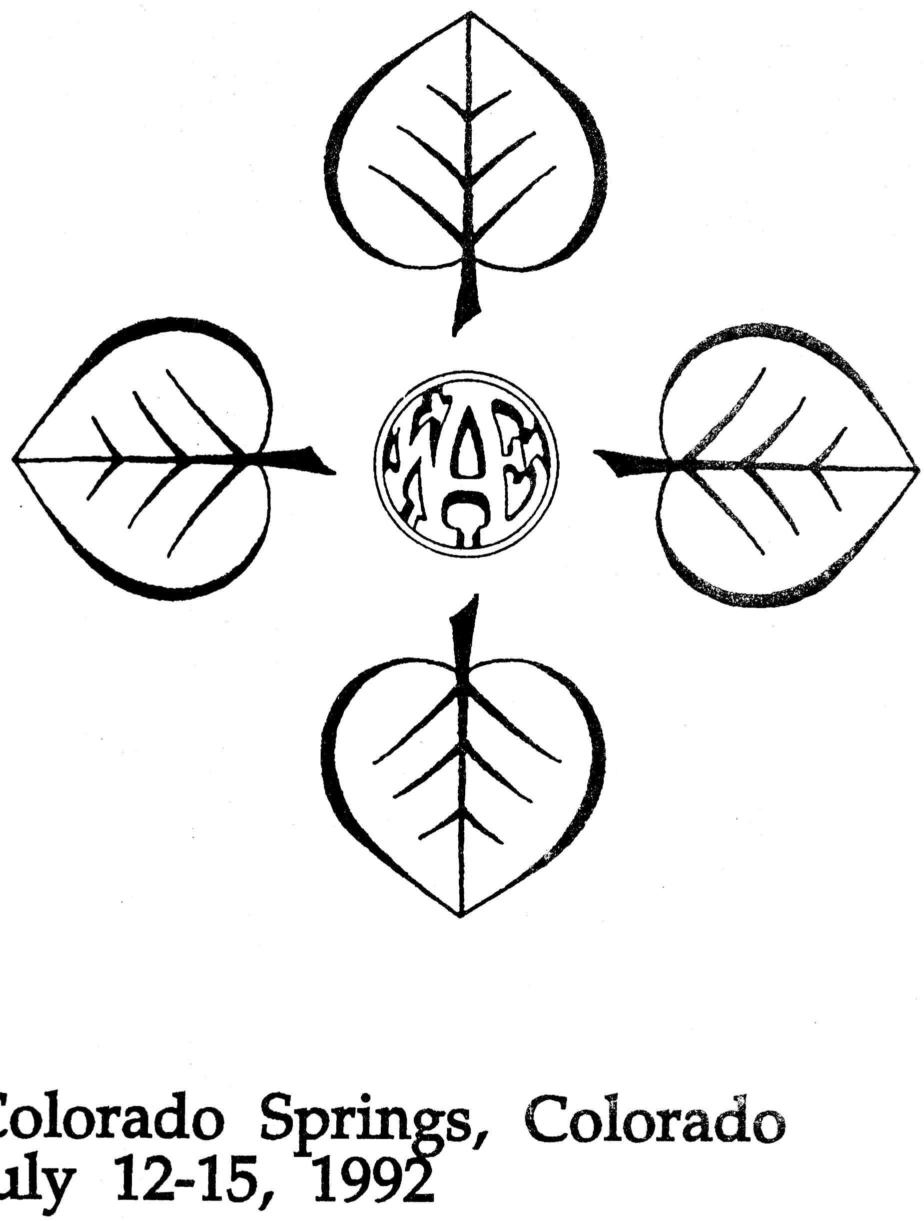

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An Analysis of the Canadian Gross Revenue Insurance Plan for Southern Saskatchewan

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Abstract

The Gross Revenue Insurance Plan (GRIP) is a program that allows farmers to insure their per hectare revenues of a select group of crops. A stochastic dynamic programming model of the profit maximizing farmer has been constructed to evaluate the moral hazard implications of the GRIP. The analysis finds that there is a very strong incentive to cut back the investment made in the crop. The net present value to the grower is in the range of $200 to $500 per hectare, most of which accumulates in the first four years of the program.

1) Introduction

The Gross Revenue Insurance Plan (GRIP) was adopted by several Canadian governments in the spring of 1991. It allows farmers who grow one of a select list of crops to ensure their per-hectare revenue from that crop. The crops covered are primarily those grown in the drier prairie regions of Canada, such as wheat, barley, canola, and several of pulse crops. Perennial crops such as alfalfa and pasture, and specialty crops like grass seed are not insurable under GRIP.

The program is meant to provide income stability and support to prairie farmers during times of unusually low grain prices. A support price is set at seventy percent of an inflation corrected fifteen year price history. The program responds to differences between producers. The level of support a farmer can receive is the product of the growers long term average yield, represented as an index factor of the area average production, and the support price. The GRIP is "not intended to mask price trends," only provide stability in the face of price fluctuations (Alberta Hail and Crop, 1991).

Superficially the program seems to offer a number of attractive features. Principle among these is the attempt to maintain some degree of market responsiveness. However, there are a number of potentially undesirable outcomes that may result from the incentives created. By providing a guaranteed income for land grown to any of the insurable crops, the farmer's production decision does not need to be guided by the market. When prices are low, the marginal value product of the crop will be zero until production is well above average. Unless the farmers production index is very low, there is little incentive to produce high yields. One would expect the farmer to cut back on the level of input use and 'milk' the GRIP.

When deciding which crop to produce and how to produce it, the farmer must take into account the impact of this periods decision on both the expected returns in this period and in future periods. Normally, these dynamic effects are carried by the states of the system, such as the levels of soil moisture, soil nitrogen, pest population, *et cetera*. Many authors have chosen to model such a system using dynamic programming (DP). Burt and Allison (1963) used DP to look at the optimal choice between fallowing or planting to wheat, given one of five different soil moisture levels. The level of soil moisture, and thus the yield, in the next period was modeled as a stochastic function of the decision taken in this period.

B. S. Fisher and R. R. Lee (1981) used a deterministic DP model to investigate the optimal control of weed and disease infestations of wheat in Australia. Three constraining states, the level of crown root rot in the soil, the density of wild oats, and the available soil moisture were included. They allowed five different decisions, wheat, wheat with herbicide, sorghum, winter fallow, and summer fallow.

C. Robert Taylor and Oscar R. Burt (1984) investigated the optimal control of wild oats in spring wheat for North Dakota. They used a stochastic model, and estimated the transformation probabilities using data gathered under the Wild Oats Pilot Project conducted by the U.S. Department of Agriculture. Five state variables were maintained in their complete model, wild oat seed density, the land use history, soil moisture level, grain price, and the density of wild oat plants. These states, and the empirically determined relationship between crop yield, herbicide effectiveness, and these states were used to determine a threshold level for application of post-emergent herbicide.

This paper follows the general approach of using biological and physical state variables to model the dynamic aspects of the cropping decision facing a grain grower on the Canadian prairies. The effects of the GRIP on the input use decision of the farmer will be the main target of this investigation. The next two sections are a presentation of the DP model. The results are then presented. This is followed by a discussion of their interpretation and a consideration of the incentives generated by the GRIP in light of some of the stated goals of Canadian agricultural policy.'

2) Theoretical Model

The economic actor is normally seen as trying to maximize an objective function subject to a set of constraints. In dynamic programming, the objective function is evaluated over a number of stages or periods, and the constraints in the next stage are a function of the decision made during this stage. The standard form is:

$$V_t(y_t) = \max_{x_t}\left[r_t(x_t, y_t) - c_t(x_t) + \alpha V_{t+1}(y_{t+1})\right]$$

where y_t is the state of the system at stage n, x_t the decision made, and α the discount factor. $V_t(y_t)$ represents the present value of the income stream resulting from the decision made in stage n, $r_t(x_t, y_t)$ the revenue, and $c_t(x_t)$ the cost for the decision in that stage. The recursive nature of the equation allows backwards induction to be used to find a solution.

Under the GRIP, the guaranteed revenue is based on the average production history of the farmer and the support price. The average production level is calculated for the entire farm, so the farm average yield must be maintained as a state. To model the whole farm, more than one field must be considered. The decision vector over which the farmer maximizes includes decisions for each field. The farmer receives the maximum of the market revenue and the insurance. Therefore

$$r_t(x_t, y_t) = \max\left[p_M\, g(x_t, N_t, M_t),\ p_G h(I_t)\right]$$

is the revenue function, where x_t contains the decisions for each field, N_t and M_t hold the soil nitrogen and soil available moisture respectively for each field, and I_t is the average production index for the farm. $y_t = [N_t, M_t, I_t]'$ is a vector containing all state conditions.

The production resulting from the farmers decision,

$$g(x_t, N_t, M_t) = \sum_{i=1}^{G} P(g_i | x_t, N_t, M_t) g_i$$

is the sum of the conditional probabilities $P(g_i | x_t, N_t, M_t)$ for the G different yield levels g_i. Multiplying by the market price p_M gives the revenue from the crop produced. The GRIP insurance level, $h(I_t)$ is a function of the producer index I_t. When multiplied by the support price p_G, this gives the insurance level. The farmer receives the maximum of these two sources of revenue in the current period.

The stochastic nature of the model forces the expected revenue from future decisions to be the integral over the probability distribution of the state transformation function. The maximization problem then becomes

$$V_t(y_t) = \max_{x_t}\left\{r_t(x_t, y_t) - c(x_t) + \alpha \sum_{y} P(y_{t+1} | x_t, y_t) V_{t+1}(y_{t+1})\right\}.$$

where $P(y_{t+1}|x_t, y_t)$ is the conditional probability density function resulting from the initial state conditions and the decision made.

As the number of periods contained in the yield index increase, the dispersion of the index decreases. The state transformation function can best be written as follows:

$$I_{t+1} = \frac{(n-1)I_t + (1/\bar{g})\sum_{i=1}^{G} P(g_i|x_t, N_t, M_t)g_i}{t}.$$

where $\bar{g}$ is the average yield for the area. The probability distribution resulting from this transformation function changes with each stage. Since the returns function is not preserved across stages, an infinite stage solution cannot be found (Kennedy, 1986).

The yield probability distribution is assumed to be independent of the field being considered, and of the state condition and decision in any other field. The probability distributions for the different state variables are also assumed to be independent. It is further assumed that the probabilities are independent regarding the field being looked at. The probability distribution for the index value is a scaled version of the probability density function for the yield. These assumptions allow the probability distribution of the state transformations for all the fields to be generated by expanding the probability distribution for one field, with no reference to the covariances between the fields and state conditions. It is also assumed that the returns from stage T+1 are zero.

3) Empirical Model

To allow a solution to be calculated, the continuous state variables were made discrete. The nitrogen and moisture states were divided into five intervals per field. The average yield index state was broken into three intervals. This produces a total of 1875 states per stage over two fields. If the outcome of a calculation fell between two discrete positions, it was divided by weight based on its relative position.

Five controls were allowed for each field, one fallow option and four different fertilizer levels. With two fields there were twenty-five controls for each state. The variable costs included were the cost of purchasing the nitrogen and phosphate fertilizers, and a small allowance for harvesting costs. The fixed costs included seed purchase, chemical purchase and application, crop and hail insurance, labour, *et cetera*. Several of these may not really be fixed, but such an omission would only strengthen the effect. The numbers are derived using Alberta Agriculture information for the Medicine Hat area (1991).

The probability distributions were generated using data gathered through the Innovative Acres program in south-western Saskatchewan. The data was arranged in pairs for two years, and then split into the decision categories. For each category a relationship between the states across periods, and between yield and state conditions was determined using OLS. A Monte-Carlo procedure was then used to generate a distribution for the joint probabilities of nitrogen and moisture. Normality was assumed, where the standard error of the dependent variable provided the dispersion.

4) Results

The empirical DP model produced output in the form of a profit maximizing decision and an expected return for each state and index combination, over all the stages considered. Since a stochastic procedure was used, the state conditions in the next period are not known with certainty when this periods decision has been made. However, by relying on the normality assumption, a 'most probable path' can be produced. The cumulative fertilizer usage over the planning horizon and the expected values resulting from this optimal path have been tabulated (table 3).

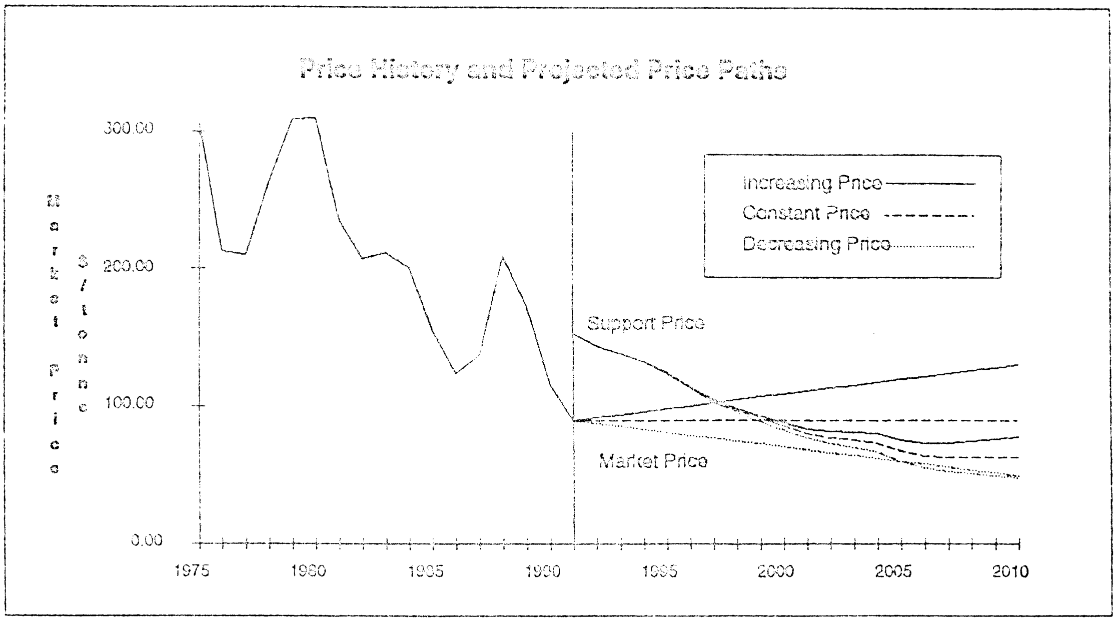

Figure 1. Historical price and projected price paths used in the analyses.

This study was meant to asses the impact of the GRIP on the input use decisions of the farmer. The difference between the amount of fertilizer used in the presence and absence of the GRIP will be the main indicator of the effect of the moral hazard. The expected values will indicate how long the program will be beneficial to the farmer, relative to the situation without the GRIP. The basic case considered involved a constant market price, a ten percent discount rate, and a twenty year planning horizon. The impact of the GRIP was then measured when these three conditions were varied. First three price paths were considered: a fifty percent increase in the market price over twenty years, the constant price, and a fifty percent decline (figure 1). Secondly four different discount rates were used, zero, five, ten, and twenty percent. Lastly the difference in projected fertilizer usage was assessed by changing the planning horizon to fifteen, ten, five, and two years.

The results table contains the expected value, the cumulative fertilizer usage over the planning horizon, and the number of stages until the expected value with the GRIP is the same as the situation without the GRIP. In all cases, the expected value is higher with the GRIP in place than when there is no GRIP. This situation is reflected by the cumulative fertilizer usage also. In every case, the amount of fertilizer is lower with the GRIP in place than when it is absent. There is some variation between the years until the expected value with the GRIP is equal to the value without the GRIP. In general, these variations are consistent with the expectations one would have.

5) Discussion of Results

The primary assumption being made in this analysis is that farmers are risk neutral profit maximizes. Given this assumption, the model chooses the decision that maximizes the expected profit at each stage within the planning horizon.

The optimal decision in all cases was to reduce inputs under the GRIP. When different index levels are looked at, the expected value increases with the level of coverage. Similarly, the total amount of fertilizer used over the planning horizon declines as the index increases. It also takes longer for the grower to become indifferent between having or not having this revenue insurance. However, the reported 'Stages to Indifference' can be deceptive. By cutting back on inputs today, the future income stream is affected. Without the GRIP, the grower would not cut back as much when prices are low.

Table 1. Results for the different situations tested in the DP model

Situation Being Tested	Expected Value		Cum. Fertilizer Usage		Stages to
	No GRIP	GRIP	No GRIP	GRIP	Indiff.
Different Index Positions					
0.70 Index	649.92	854.70	640	565	2
1.00 Index	649.92	982.42	640	415	4
1.30 Index	649.92	1199.10	640	370	8
Changing Market Price					
Decreasing Price	344.53	825.30	385	295	14
Constant	649.92	982.42	640	415	4
Increasing	964.51	1207.96	625	490	3
Changing Discount Rates					
0% Discount Rate	2479.68	3003.62	640	490	4
5%	1125.01	1497.02	565	475	4
10%	649.92	982.42	640	415	4
20%	315.15	603.57	595	490	5
Changing Length of Planning Horizon					
2 year	31.04	201.02	55	25	3
5	268.63	606.30	126	78	6
10	504.71	857.07	230	200	11
15	606.15	942.99	443	323	4
20	649.92	982.42	640	415	4

When the two expected values become equal, to opt out of the program would probably reduce the income relative remaining in, since the physical state values have been reduced.

When the different price paths are considered (figure 1), the largest difference in the cumulative fertilizer usage occurs for the constant price. When the price increases, the marginal value product (MVP) of using additional fertilizer becomes positive again at an earlier stage, so that it to becomes profitable to use fertilizer. When the price falls, the MVP of fertilizer becomes very low, and it is no longer profitable to use fertilizer even without the GRIP. The largest difference in expected values, $480.77, occurs when the price falls (figure 2). When this is the expected price path, the revenue insurance is beneficial to the grower for fourteen years as a result of the lag between the support price and the market price.

The expected values for the increasing price show a trend that was also seen when the discount rate was between zero and five percent. Between years four and fourteen the expected value with the GRIP is below that of path without the GRIP. The effect is especially pronounced after year nine. This corresponds to the point when the cumulative fertilizer path begins to parallel the no GRIP path. With GRIP in place, the premium payment and the physical state effects reduce the expected value. This creates an incentive to opt out of the program after a few years.

When the discount rate was varied, in almost all cases only four years were needed until the grower was indifferent. Therefore almost all the benefit to the grower, assuming constant price expectations, will occur in the first few years. The largest difference in cumulative fertilizer usage occurs for the ten percent discount rate. Here the discounted future revenue is small enough to make collecting the insurance revenue optimal relative to the lower discount rates.

When the length of the planning horizon is varied, periods of less than or equal to ten years show a positive difference in the expected values for all stages. After ten years, the benefit to the grower is exhausted in the first four years. The ten year planning horizon also shows the greatest amount of fertilizer used under the GRIP. For the shorter planning horizons, it is beneficial to the grower to

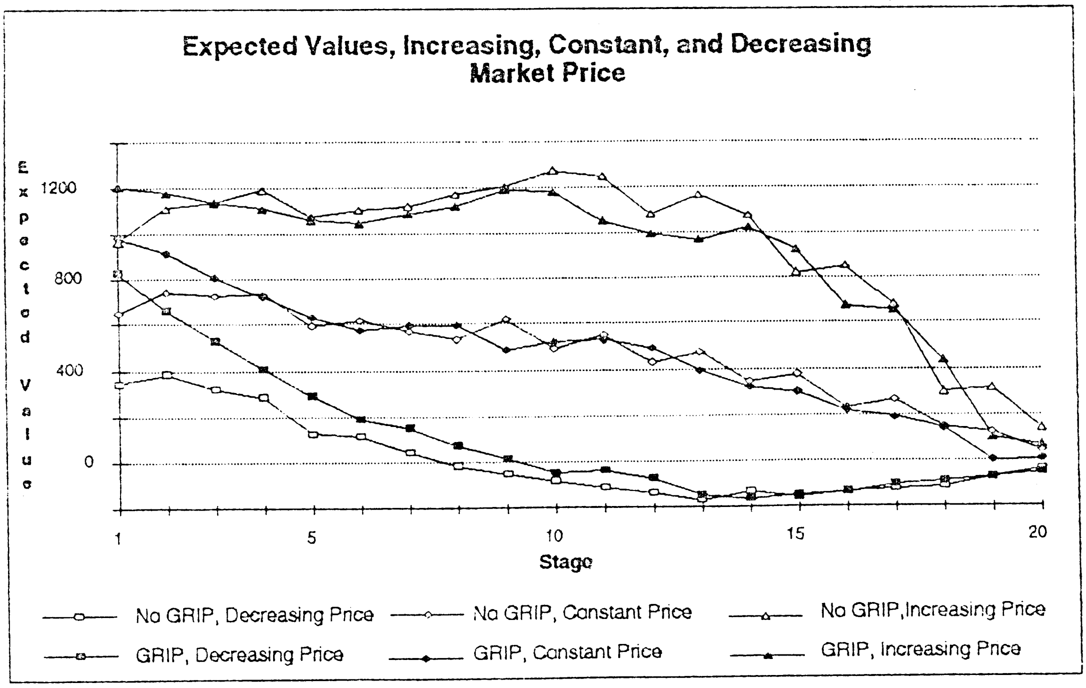

Figure 2. Expected values for the different price paths considered.

maintain a high index level. However, with longer planning horizons, the reduction in the support price makes the benefit of keeping the index up insufficient to offset the future revenues.

There are several further issues that have not been explicitly addressed here. Total government transfers to the farmer were not estimated, but they will be sizable. The net present value of the program to the farmer is in the range of $200 to $500 per hectare above the returns from the market. These funds may be replacing other transfers, so that the net increase in government expenditures may not be this great. However, there is likely to be a very large transfer to growers in the first years of the program.

The final model had the restriction imposed that one of the two fields must be planted in each stage. The impact on land use was not directly addressed. However, when this restriction is dropped, the model suggests planting both fields and applying the minimum level of input. This indicates that there will be upward pressure on the area of the insurable crops grown. Statistics Canada has reported that in 1992 the expected area planted to spring wheat will be much greater than in 1991 (CBC, 1992). Also, in 1991 there was a large increase in the acres of soft wheat grown in southern Alberta after the support price was announced (ASWPA, 1991). There is a restriction in the GRIP that the land area planted to an insurable crop can be increased be only fifteen percent of the average area grown in the last three years, so the pressure to increase acreage will be contained somewhat (Ag Canada, 1991).

Grey *et al* expressed concern that, since not all crops are covered, the GRIP will encourage farmers to switch into those crops that can be ensured (Grey, 1991). Although other crop options were not included, the analysis supports this concern. With the large benefit to the grower in the first years of the program, the price relations between insured and uninsured crops will be altered. One would expect resources to be shifted into growing those crops that can receive the higher insurance revenue.

The GRIP appears to have several shortcomings. Two explicit goals of future Canadian agricultural policy, as expressed in 'Growing Together,' include improved market responsiveness and greater self-reliance in the agri-food sector.(Ag Canada, 1991).With the assumptions made, these objectives are not being met. By shielding the grower, the cropping decisions are decoupled from the market, impairing market responsiveness. The large transfers expected in the first years of this program indicate that, at least for the short term, the agri-food sector will be even more reliant on government for its well being.

The desire to maintain a safety net for the farm sector has some laudable qualities, especially if ones' values include aspects of equity and fairness. However, the incentives of a program must be carefully investigated so that they don't work against the very principles they are meant to support. The GRIP suffers from this problem. Some suggested improvements include shifting to an income insurance, so that the farm family has financial security but the growing decisions are unaffected; expanding the list of crops covered so that incentives to change crops are not altered, and requiring certain practices in exchange for premium reductions, especially for environmental protection.

5) Conclusion

The Gross Revenue Insurance Program generates some very strong incentives for the grower to optimize the insurance revenue instead of optimizing the market revenue. This runs directly counter to the objective of the government policy statement that agriculture should become more market responsive. The size of the incentive to optimize the insurance revenue is in the range of $200 to $500, as revealed through the difference in the expected value between the GRIP and no GRIP cases. In almost all the situations considered, the producer will be indifferent between the presence or absence of the GRIP after less than five years. This indicates that there will likely be sizable transfers to the agricultural sector in the first years of the program, after which the transfers will be minimal.

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