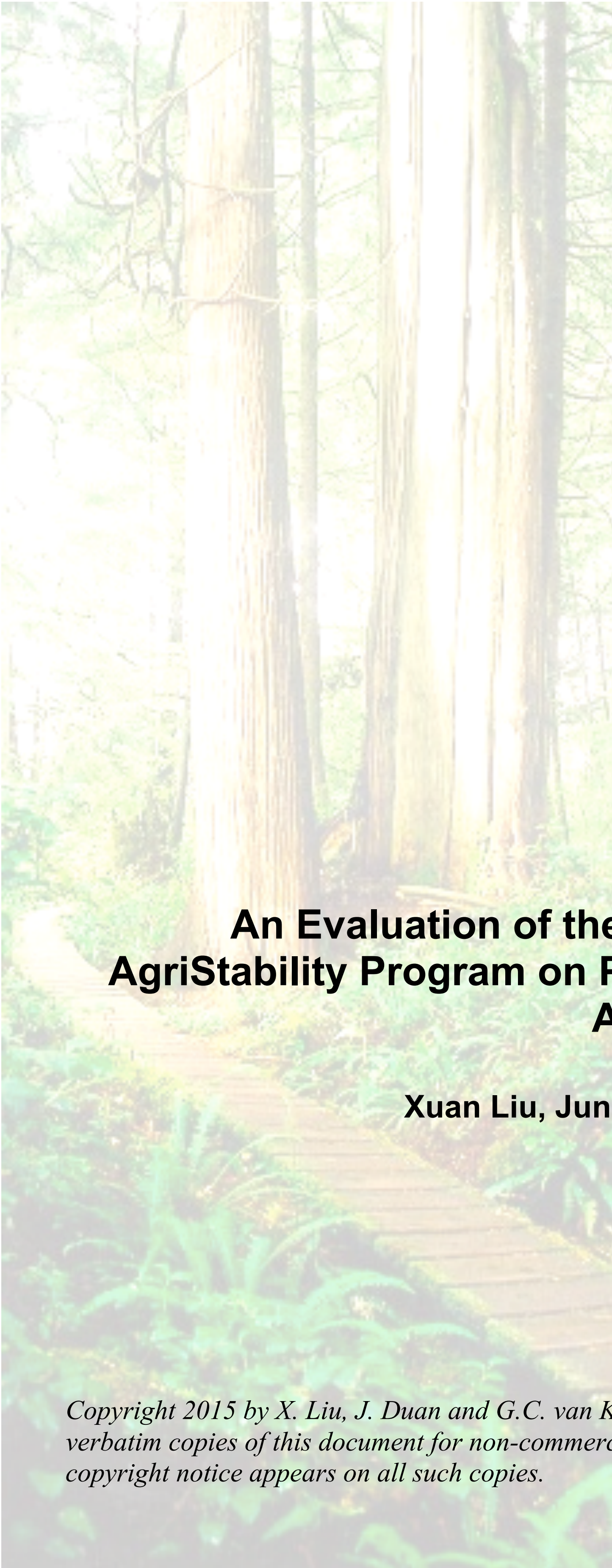

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An Evaluation of the Effects of Changes in the AgriStability Program on Producers' Crop Activities: A Farm Modeling Approach

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An Evaluation of the Effects of Changes in the AgriStability Program on Producers' Crop Activities: A Farm Modeling Approach

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Abstract

In this paper, we examine the impacts of changes in Canada's AgriStability program on crop allocation, particularly the change in the payment trigger associated with the shift from Growing Forward (GF) to Growing Forward 2 (GF2). To examine whether this change could affect production decisions, and thereby potentially violate the WTO's 'green box' criteria, we construct farm management models for representative farms in six different Alberta regions. To incorporate risk and uncertainty into the farm model, we assume that, instead of maximizing overall gross margin, a farmer varies her crop activities to maximize expected utility subject to technological and market constraints. The models are calibrated using positive mathematical programming (PMP), which then facilitates their use for policy analysis; however, PMP is not straightforward in the case of expected utility maximization because a risk parameter also needs to be calibrated. Possible ways to address this issue are examined. Results indicate that the initial introduction of the AgriStability program tilted farmers' planting decisions towards crops with higher returns and greater risk, but that a change in the AgriStability payout trigger (going from GF to GF2) would not further alter land-use decisions. However, the latter shift does reduce indemnities and farmers' expected profits; increases in farmers' aversion to risk will lead to changes in crop allocations, although it is not clear to what extent it impacts trade.

Key words: Agricultural business risk management; AgriStability program; positive mathematical programming and risk aversion

JEL Categories: Q14, Q17, Q18, C61

Introduction

Governments support the incomes of farmers partly to protect them from income volatility but also to prevent the demise of rural communities (and protect a particular lifestyle), earn foreign exchange through exports, address concerns about food safety and self-sufficiency, and, importantly, respond to lobbying from a large political constituency. In the United States, farm programs began with the Agricultural Adjustment Act of 1933; by the time of the 2014 Farm Bill, programs allocated $89.8 billion to crop insurance, $56.0 billion for soil conservation programs, $44.4 billion for commodity programs and $8.2 billion for other farm programs, as well as $756.0 billion for urban welfare (food stamps and nutrition). However, the recent spending on agriculture represented a shift away from price and income support towards greater reliance on crop insurance.

The Conference of Stressa (1958) signalled the beginning of the European Union's Common Agricultural Policy (CAP), which provided high levels of price and income support to agricultural producers. Recent reforms of the CAP reduced support prices while 'modulating' funds from direct farm support towards rural development. Initially, the CAP accounted for more than three-quarters of the EU's budget, but, by 2014, only 40.5% of the budget (or €57.8 billion) went to agriculture, split roughly 75-25 as direct support to farmers and rural development. Nonetheless, spending on agriculture is expected to remain the largest item in the EU's long-term budget for 2014-2020.

Other countries followed the U.S. and the EU in providing support to their agricultural sectors, including Japan, Norway, Canada and Australia.[1] However, it has been the extent of support and the size of their agricultural sectors that has made American and European farm policies an obstacle in international trade negotiations. During the Uruguay Round (1986-1994) of the GATT, an Agreement on Agriculture was negotiated with great difficulty and it entered into force only with the establishment of the World Trade Organization (WTO), which replaced the GATT in January 1995. The WTO's Doha Development Round of trade negotiations was launched

[1] Along with New Zealand, Canada and Australia are the only developed countries comprising the 19-nation Cairns group that sought to negotiate reductions in U.S. and EU agricultural subsidies (Coppens 2014, p.33).

in November 2001, but progress on agriculture continues to be slow, with only "some limited agricultural differences" having been resolved to date as part of the "Bali package" reached on December 2013 (Coppens 2014, p.35).

The WTO's Agreement on Agriculture (AoA) permits some farm subsidies, classifying them according to three 'pillars': domestic support, market access and export subsidies. Domestic support is categorized according to three boxes: 'amber' (production-enhancing programs that distort trade), 'blue' (production-limiting programs, such as supply restrictions that adversely affect trade) and 'green' (subsidies that have only a minor distortionary impact on trade). Countries have agreed to reduce or eliminate amber box subsidies, while green box programs were exempt from trade reduction commitments. Blue box programs were tolerated but could be targeted by other countries for modification (e.g., Canada's dairy and poultry marketing regimes have been singled out). However, governments are still in the process of replacing crop-specific subsidies with ones that provide income support and target income volatility but no longer distort trade – programs that decouple support payments from output. Europe's single farm payment and the use of base acres and base yields in the most recent (2014) U.S. Farm Bill (Babcock 2014) are examples of attempts at decoupling. As noted above, governments are also turning to crop and income insurance as these will likely be considered green box programs.

Government sponsored multi-peril crop insurance is never actuarially sound, and there is always a risk that such programs violate WTO rules. Rules for determining the reference yield that triggers a payout are important: Are farmers incentivized to increase production to increase the reference yield, and to what degree? For example, there are many variations as to how a reference margin is determined, including the average of a farmer's historical yield for a base period (e.g., 2001-2006), the average regional yield for the base period, or some hybrid of a farmer's own yield and average regional yield. The use of a base period prevents farmers from increasing yields used to determine the reference margin, although in practice it would be difficult to implement programs where the base period does not change. One variant of this approach used in Europe is to provide a fixed payment ($/ha) that varies by crop and is based on average prices, yields and costs for some reference period – a single farm payment (Sckokai and Moro 2006, 2009).

A more recent suggestion is to employ whole farm insurance (WFI), where it is the total farm income that is insured and not returns to individual crops (Coble et al. 2013; Turvey 2012). As a result of an OECD report on agricultural risk management (OECD 2011), countries appear willing to accept WFI as a green box subsidy under the WTO as long as income falls by at least 30% from a reference level of income before indemnities are triggered, and then no more than 70% of the lost income is compensated. Yet there remain concerns that the whole farm approach may still distort crop production decisions due to both an insurance effect, which provides an effective lower bound on income, and a wealth effect, which reduces the farmer's aversion to risk (Boere and van Kooten 2015; Finger and Lehmann 2012; Hennessy 1998). The objective of the current paper is to examine this issue in the context of Canada's changing agricultural programs.

In 2007, Canada replaced its agricultural support programs with Growing Forward (GF), which consisted of four business-risk management components: AgriInvest, AgriStability, Agri-Recovery and AgriInsurance (see Vercammen 2013; Trautman et al. 2013). AgriInvest subsidized farmers' savings accounts to provide flexible coverage for small income losses and some protection against investment risk. AgriStability protects farmers against larger income losses while AgriRecovery provides disaster relief. Finally, AgriInsurance continues to provide production insurance. When GF expired on March 31, 2013, it was replaced by Growing Forward 2 (GF2), which left much of GF intact with the exception of AgriInvest and AgriStability. With regard to the former, producer contributions were raised and the size of savings accounts greatly increased. The major change of relevance to the current research concerned AgriStability, where the margin necessary to trigger a payout changed from 85% of the reference margin to 70%, and the method for calculating the reference margin was revised so that farmers could choose the lesser of the historic average program margin (as in GF) or a margin based on historical average of allowable expenses (determined for the same three years used to calculate the reference margin).

In this study, we analyze the effect of the Agristability program on farmers' decisions of land allocation and the influence of the change in the payout trigger from 85% to 70% of the reference margin using data on Alberta producers from six regions. We construct representative farm models for each region to show how producers are likely to adjust their crop allocation in going from GF to GF2. We conclude that the AgriStability program distorts production decisions slightly. The change in the AgriStability payout trigger (from 0.85 to 0.7) does not further distort farmers' land allocation decisions while the amount of saved indemnity is higher than the amount of the reduction in farmers' expected profit at the average level. In this regard, our results are similar to those of Trautman et al. (2013) who simulated the impact on net present value of changes in going from GF to GF2.

We begin in the next section by constructing crop allocation models for six representative farms in different regions within the province of Alberta. The models are calibrated using positive mathematical programming, which then facilitates their use for policy analysis. We then use the calibrated models to examine the impacts of Canada's AgriStability program on crop allocation, with particular focus on the change in the payment trigger associated with the shift from GF to GF2.

Farm Management Model and Calibration

Given data on prices, yields and average costs of planting and harvesting different crops, a linear programming model that maximizes expected gross margin will fail to identify crop allocations that are as diverse as those observed in practice. To replicate observed plantings, ad hoc constraints can be added to the model to mimic the benefits of crop rotations, long-term soil conservation and other factors, but such models are unduly constrained and not usually suitable for policy analysis. Another approach is to maximize expected utility rather than expected gross margin, but this assumes that all of the variability in land uses can be attributed to the decision maker's risk aversion. A third option is to use positive mathematical programming (PMP) to calibrate the individual crop cost functions so that marginal cost is upward sloping rather than constant (Howitt 1995, 2005; Heckelei et al. 2012). By calibrating farm management models to a base period, the

PMP calibrated models take into account farmers' risks, crop rotations, crop impacts on soil quality, and any other factors that cause costs to rise as more of the same crop is planted. The calibrated model can then be used to compare the effects of agricultural policies (e.g., payments to specific crops and various agricultural insurance programs) on farmers and the agricultural sector as a whole (Arfini et al. 2003).

The PMP method is more complicated when the objective is to maximize expected utility, which would be more applicable in the study of farm insurance. To incorporate risk and uncertainty into the farm model, we assume that a farmer varies land uses or crop activities to maximize her expected utility subject to technological and market constraints, instead of simply maximizing the total gross margin. In that case, one should also calibrate the absolute risk aversion parameter (denoted φ). However, the PMP method for calibrating both the cropping cost functions and the risk aversion coefficient is not straightforward. One can iteratively choose values of φ so that the observed crop allocation is almost exactly replicated, but then it is no longer necessary to use PMP to recover the crop-specific cost functions. But what if φ has very little impact on land use?

Petsakos and Rozakis (2011, 2015) provide a more complete model in which observed plantings and a variance-covariance matrix of gross margins are needed to calibrate the model. Rather than assuming an exponential utility function which leads to a constant absolute risk aversion (CARA) parameter, Petsakos and Rozakis (2015) assume a logarithmic function and thus a decreasing absolute risk aversion (DARA) parameter that is a concave function of wealth. Specification of an initial level of wealth is required so that DARA changes in response to the farmer's cropping choice. In their application, the authors choose an initial wealth given by the (small) fixed payment available to EU farmers in Greece.

Our own experience suggests that a farmer's wealth does not change dramatically from one crop year to the next – the probability distribution of gross margins from the available planting decisions in any given year does not represent a lottery with a large windfall. As a result, the farmer's risk aversion is best characterized by CARA rather than DARA. Nonetheless, a method for specifying the CARA parameter, φ, is still required.[2] One approach would be to vary φ in iterative fashion until we came close to duplicating the observed crop allocation; we would then use that value of φ to calibrate the cost function. But, as noted above, a problem arises if the observed crop allocation is precisely duplicated, in which case risk aversion completely explains why all of the available land is not planted to the crop with the greatest gross margin – aversion to risk is the only reason why farmers plant a variety of crops. Alternatively, since the standard PMP approach takes risk into account (albeit it in a general sense because we deal with representative farms), we could simply use the calibrated cost functions obtained when expected margins are maximized and then investigate risk further by specifying expected utility maximization while retaining the calibrated marginal cost functions. In that case, φ can only be interpreted as risk aversion relative to the risk embodied in the calibrated cost functions.

As usual, we began by specifying constant but crop-specific marginal costs, which equal respective average costs. When the expected-utility objective was then employed, iteration across the risk aversion parameter did not lead to a crop allocation that came close to approximating the observed land uses. Therefore, we decided to calibrate quadratic crop-specific cost functions using the standard PMP approach, based on an LP model where the objective is to maximize overall gross margins. We then re-specified the objective to maximize expected utility, but including the calibrated marginal cost functions. Before we settled on the final model, we considered values of φ and chose one that would not trigger a change in the replicated (observed) crop allocation. Finally, in the policy analysis phase, we examined various values of φ to examine how, in addition to changes in AgriStability, different attitudes to risk might change the optimal crop allocation.

Since the policy to be analyzed is delivered at the farm level, we employ the common method of modeling a representative farm. For example, Turvey (2012) uses one representative farm for Manitoba, because the farming area he considered is quite homogeneous. He investigated

[2] Attempts to implement Petsakos and Rozakis's (2015) procedure fell short, perhaps due to the values of initial wealth that we chose. We sought to calibrate φ after we calibrated the cost functions, because attempts first to calibrate φ did not come anywhere close to a reasonable approximation of the observed land use.

the change to a producer's optimal crop choices in moving from the Canadian Agricultural Income Stabilization (CAIS) program (the precursor of GF's AgriInvest and AgriStability) to a whole farm insurance scheme, finding that producers are likely to alter their strategies in response to the introduction of a new or altered insurance product. On the other hand, Coble et al. (2013) use a total of four representative farms (two corn-soybean farms and two corn-wheat farms) from four different states in the U.S. to "develop and analyze customizable area whole farm insurance" (p.1). They find that expected indemnity payouts differ significantly by crop mixes. Given the diversity of the agricultural landscape in Alberta, it is necessary to develop several representative farms (as discussed in the next section).

For each farm, we calibrate cost functions using the PMP approach. Implementation of the PMP approach requires three steps. First, the following linear programming model is specified for each representative farm, with calibration constraints included to ensure that the model solves closely for the observed crop allocations:

Maximize $\sum_{k=1}^{K} R_k = \sum_{k=1}^{K} \left(p_k y_k - c_k\right) x_k$, (1)

Subject to

$$\sum_{k=1}^{K} x_k \leq \overline{X} \quad (2)$$

$$x_k \leq x_k^o + 0.001, \forall k \quad (3)$$

$$x_k \geq 0, \forall k \quad (4)$$

Here R_k represents the total gross margin from planting x_k acres of crop k (= 1, …, K); $\overline{X}$ is the total area available for crop production at the representative farm; p_k is the price and y_k the per-acre yield of crop k; c_k is the per-acre variable cost of planting and harvesting; and the superscript 'o' indicates the observed amounts of the variable in question. Objective function (1) is linear because the per-acre variable cost of preparing the ground, seeding, fertilizing, harvesting, et cetera, is fixed, varying only by the crop that is planted. Constraint (2) imposes an upper limit on the producer's seeded area, which cannot exceed the total available area. Calibration constraints (3) are applied based on the assumption that the observed land allocation is the optimal choice. The small positive adjustment 0.001 is used to prevent linear dependency between constraint (2) and (3). Constraint (4) ensures that all allocations are strictly positive.

Upon solving the model, we recover the shadow prices (λ_k) for all crops. Then, in the second step, we assume a quadratic cost function: $\alpha_k x_k + ½\, \beta_k x_k^2$. For each crop, the shadow price $\lambda_k = \mathrm{MC}_k - \mathrm{AC}_k = (\alpha_k+\beta_k x_k) - (\alpha_k+½\beta_k x_k) = ½\beta_k x_k$. Using the shadow prices derived in the first step, and equations $\beta_k = 2\lambda_k/x_k^{o}$ and $\alpha_k = c_k^{o}-\lambda_k$, we can find the corresponding cost-function parameters, α_k and β_k, given the observed crop allocations x_k^{o} and observed average costs c_k^{o}.

Once the cost function parameters are obtained, the objective function is set to maximize a farm's expected utility. We assume the utility function takes an exponential form and maximizing utility with normally distributed consumption results in a standard mean-variance objective as follows (McCarl and Spreen 2004, p.14-8):

$$\text{Maximize EU } = \sum_{k=1}^{n}\left(p_k x_k y_k - \alpha x_k - 0.5\beta x_k^2\right) - \frac{\varphi}{2}\sum_{k=1}^{K}\sum_{i=1}^{K}\left[x_k \times CV(R_k, R_i) \times x_i\right] \qquad (5)$$

$$\text{Subject to } \sum_{k=1}^{K} x_k \leq \overline{X} \text{ and } x_k \geq 0,\ \forall k. \qquad (6)$$

where $CV(R_k,R_i)$ refers to the variance-covariance matrix between crops with R_k and R_i as the realized net return to crop k. The risk aversion coefficient is then calibrated iteratively to determine the greatest value of φ that reproduces the land allocations of the base run without the calibration constraints for each crop. Then the calibrated model is subsequently used for policy analysis.

Study Area, Representative Farms and Data

The current application focuses on arable farms in Alberta with a mixed crop portfolio. We begin by identifying geographic locations and soil types to determine the characteristics of the representative farms. Alberta has 69 counties and municipal districts. According to the regional economic indicator reports provided by Government of Alberta, 69 districts are grouped into 14 regions, with economic information available for each including average farm size based on the 2011 Canada census (see also Government of Alberta 2014). Some districts in northern and northeastern Alberta were subsequently excluded from further consideration because they had insignificant area in crops.

Alberta's Agricultural Financial Services Corporation (AFSC) provided data on average yields, number of farms and total insured acres of cropland for each municipal district. The five most important crops in Alberta in terms of plantings are wheat, barley, canola, peas and durum, with more than 95 percent of cropland in the AFSC database planted to these crops. Although the preliminary plan was to set up representative farms for each of the five major soil types, we used the municipal level data to identify the 12 districts with the largest total crop production as candidates for further analysis, of which five were then chosen. Although not among the top 12 districts, the county of Smoky River, which ranks 29th in production, was also included to obtain representative province-wide coverage, giving us six farms representative of the province (Figure 1). These are summarized in Table 1, where the average proportions of land in various crops for the period 2011-2013 are provided based on insured acres for each crop within each municipal district.

After setting up representative farms, four types of information are needed to calibrate a base farm-level crop allocation model: product prices, yields, production costs and the variance-covariance matrix of realized returns per acre among crops. By assuming that shipping and handling costs are relatively uniform across the province, we apply the same crop prices to all six representative farms. Data on monthly crop prices are available from Statistics Canada for all crops for the period August 1993 through September 2014, except that the data for durum for the period August 2012 to July 2013 are missing. The price data are plotted in Figure 2. A stationary mean-reverting, Ornstein-Uhlenbeck (OU) stochastic process is then used to obtain estimated long-term mean prices for all crops for calibration.[3] The general stochastic differential equation for an OU process is:

[3] We use the R package {sde} is used to simulate the parameters of the discrete Ornstein-Uhlenbeck process.

$$dx_t = \theta(\mu - x_t)dt + \sigma\, dW_t, \quad (7)$$

where $W(t)$ is a Wiener process, θ is a parameter that captures the speed of reversion back to the mean price μ, and σ represents the degree of volatility.

Since there was an obvious change in trend as prices rose to a higher level after 2007, which would distort the estimate of mean prices, only monthly data for the period January 2008 to March 2014 are used in the estimation. Table 2 presents the average prices directly calculated from the original data and the estimated mean prices based on the OU model for five agricultural products. Except for canola, the estimated mean prices are clearly lower than the observed average prices. From Figure 2, it appears that the mean prices estimated from the stochastic process are perhaps more reasonable to use than the original averages; thus, we employ the estimated mean prices in what follows.

Per-acre average crop yield data were also obtained from AFSC. For illustrative purposes, the data for Vulcan County are plotted in Figure 3. The figure indicates that yields have increased in recent years, and that yields are positively correlated across all five crops. The correlation matrix for yields in this county is given in Table 3. Five-year Olympic average yields (2009-2013) are used for the model calibration and are provided in Table 4.

In this study, only variable costs are considered, and these include costs of seed, fertilizer, herbicides, machinery repairs, et cetera. Total variable cost of production per acre is obtained from Alberta Agriculture & Rural Development (2014a, 2014b) and calculated based on sector averages. Given the available yield and price data, net revenues are calculated for all cropping activities. An overview of net revenues, costs, yields and prices by crop and representative districts is also found in Table 4.

The variance-covariance matrix of realized returns per acre among crops is estimated based on 1000 simulated outcomes (as discussed in the next section), rather than a few historical observations, since the simulated data represent the potential outcomes that farmers anticipate, which are not necessarily observed, when they plant crops. We are assuming rational expectations on the part of farmers.

PMP Results

For the first step of the PMP approach, we use the data in Tables 1 and 2 to maximize the gross margin of each representative farm subject to observed land-use calibration constraints. The associated shadow prices are then used to derive a quadratic cost function for each crop at each representative farm. The observed allocations of land to crops are reproduced based on the model constructed in the above step. For each representative farm, the marginal cost of barley land remains constant since its calibration constraint was not binding (λ=0). Table 5 shows the estimates of the representative farm in Vulcan County as an example.

To obtain the shadow price for barley, we include the elasticity of land supply with respect to the output price of barley, $\eta_s = (\partial q/\partial p)\ (p/q)$, to adjust the estimates of all λ_k as (see Howitt 2005, pp.88-91): $\hat{\lambda}_k = \lambda_k + Adj$. Meyers et al. (1993) estimate supply elasticities for U.S. crops for the period 1985-1989, with the own-price supply elasticity of barley estimated to be between 1.084 and 1.215. Jansson (2007) employs an own-price supply elasticity of 1.109 for barley, while Barr et al. (2011) find that it is 1.038 for the 2007-09 period although somewhat lower than it has been in previous periods. Lacking further information including information about the supply elasticity of land in barley, we simply assume it to be 1.04.

The calibration results once the shadow prices are adjusted for the assumed supply elasticity of land in barley are reported in Table 6. These indicate that the six groups of parameters are quite distinct from each other. The marginal cost curves for wheat for the six representative farms are provided in Figure 4, and illustrate the distinctiveness of the representative farms. Although the marginal cost functions of wheat are similar for the farms in the counties of Vulcan and Smoky River, differences across the other farms are significant. After calibrating the parameters of the quadratic cost functions for all representative farms, we iterate the value of risk aversion coefficient to find a range for each farm to reproduce the land allocations of the base run without the calibration constraints for each crop. Eventually, φ is set at 0.0000005 for all farms, which is the maximum value that reproduces the base outcome for all farms.

AgriStability Program Analysis

The purpose here is to examine how changes in Canada's AgriStability Program affect producers' land use decisions. Clearly, participation in AgriStability itself will change producers' crop choices to some extent. However, the premium subsidy rate should not affect producers' land use decisions if they decide to participate, but, rather, it might affect producers' decision about whether to participate. As in other countries, Canada continues to adapt its agricultural policies. Thus, for example, the Canadian Agricultural Income Stabilization (CAIS) program was replaced by GF, which was "designed to be more responsive, predictable and bankable" (AAFC 2014b).Yet, in a survey conducted by the Canadian Federation of Independent Business (CFIB) from November 2009 to January 2010, 65 percent of respondents categorized the predictability of financial support under AgriStability to be poor, while 56 percent replied that the paperwork and the calculations were complicated (Labbie 2010; see also Vercammen 2013). Compared to GF, the current GF2 simplifies the AgriStability payment calculation by harmonizing multi-tier compensation rates under GF to a single level (70%). Meanwhile, GF2 lowers the payment trigger from 85% to 70% of the reference margin, as required by the OECD (2011) for AgriStability to qualify as a green box program; in this way, the program also covers losses rather than simply declines in profit. Although discussion about the impacts of changes on farmers appeared before and after the launch of GF2, including arguments about the estimated reduction in indemnities and reduced attractiveness to farmers, there has been little research on the effect that changes in the policy parameters, including the compensation rate and the payment trigger, have on farmers' production decisions and overall wellbeing.

Extending the Farm-level Model

The farm model given by (5) and (6) is now modified to account for the AgriStability program. Constraints in the model include exogenous input and output prices and fixed land. A farmer is assumed to

$$\text{Maximize } U = E[R] - \frac{\varphi}{2}\sigma^2, \tag{8}$$

where φ is the Arrow-Pratt coefficient of absolute risk aversion and σ^2 represents the variance or risk associated with the chosen crop portfolio. The constraints are given by:

$$\begin{aligned} R_t = \sum_{k=1}^{K}\left[p_{k,t}y_{k,t} - c_k(x_k)\right]x_k + Z \times Max\left(0,\ \alpha\left[\beta M - \sum_{k=1}^{K}\left(p_{k,t}y_{k,t} - c_k\right)x_k\right]\right) \\ - \frac{\delta}{T}\sum_{t=1}^{T} Max\left(0,\ \alpha\left[\beta M - \sum_{k=1}^{K}\left(p_{k,t}y_{k,t} - c_k\right)x_k\right]\right), \end{aligned} \tag{9}$$

$$E[R] = \frac{1}{T}\sum_{t=1}^{T} R_t \tag{10}$$

$$\sigma^2 = \sum_{k=1}^{K}\sum_{i=1}^{K}\left[x_k \times CV(R_k, R_i) \times x_i\right] \tag{11}$$

$$CV(R_k, R_i) = \frac{1}{T}\sum_{t=1}^{T}\left(R_{k,t} - E[R_k]\right)\left(R_{i,t} - E[R_i]\right), \forall k, i \tag{12}$$

$$E[R_k] = \frac{1}{T}\sum_{t=1}^{T} R_{k,t}, \forall k \tag{13}$$

R_t is the gross margin in state of nature *t* and E[*R*] represents the expected whole farm gross margin. $M = \sum_{k=1}^{K}\left[p_k y_k x_k - c_k x_k\right]$ is used to calculate the reference margin, while β describes the payment trigger level as a proportion of the reference margin. Only when a farm's realized gross margin declines by more than (1–β) of *M* will the farmer get a payment from the AgriStability program. The compensation rate α represents the proportion of qualified losses that will be covered by the program, and dummy variable *Z*, with *Z*=1 when $R_t < \beta \times M$ and Z=0 when $R_t \geq \beta \times M$, is used to trigger a payout equal to $Max\left(0,\ \alpha(\beta M - \sum_{k=1}^{K}\left[p_{k,t}y_{k,t} - c_k(x_k)\right]x_k)\right)$ in a given state of nature *t*. To ensure the insurance scheme is actuarially sound, the premium is calculated by the formula

$\frac{1}{T}\sum_{t=1}^{T} Max\left(0,\ \alpha(\beta M - \sum_{k=1}^{K}\left[p_{k,t}y_{k,t} - c_k(x_k)\right]x_k)\right)$, which is multiplied by (1–δ) to determine the cost to the public purse. E[R_k] is the farmer's expected net return ($/acre) from planting crop *k*. *K* crops are planted in any given period and *T* refers to the number of simulated outcomes or states of nature. To simulate the per acre gross margin across scenarios, crop prices, yields and production costs are key elements for the crop-specific quadratic cost functions across representative farms.

Monte Carlo simulation is used to generate *T*=1,000 sets of prices and yields, and thus gross margins, for each crop and representative farm. Prices are determined using the Ornstein-Uhlenbeck process discussed above; a graph of the distributions of 1,000 simulated wheat and canola prices is provided in Figure 5. Since crop yields are positively correlated (Table 3), we assume they are characterized by a multivariate normal distribution. AFSC yield data for the period 1997-2013 are used to calculate the covariance matrix for simulation. To do so, we first de-trend the yield data to remove the influence of technology so that we can get proper estimates of the underlying probability distribution (Cooper 2010). Then we use the de-trended data to derive the covariance matrix and generate 1,000 sets of yield data from this matrix (Luis 2011). Each representative farm has a distinctive covariance yield matrix so crop scenarios will differ across regions of the province.

Growing Forward (GF) versus Growing Forward 2 (GF2)

Under both GF and GF2, the AgriStability indemnity or payout is determined by the extent to which a farmer's gross margin declines, but the elements used to calculate final payments have changed. Under GF, a payout is triggered once a farmer's gross margin falls below 85% of her reference margin, with AgriInvest meant to cover any reduction between the reference margin and the gross margin for that year (see left-hand panel in Figure 6). The farmer would then receive an indemnity that covered 70% any reduction in gross margin below the 85% trigger; if the gross margin fell below 70%, she would receive 80% of any difference in realized gross margin and 0.7 of the reference margin. Under GF2, government support is triggered only when a farmer's margin falls below 70% of the reference margin and a harmonized compensation rate of 70% is applied to the payment calculation as indicated in the right-hand panel of Figure 6 (AFSC 2014a, 2014b). When comparing the AgrStability program between GF and GF2, for simplicity and without loss of generality, we set the margin coverage (*β*) at 85% and the compensate rate (*α*) at 80% for GF, while both *α* and *β* are set equal to 70% for GF2.

The changes in land allocations of the representative farms under GF2 compared to the base year are given in Tables 7(a) and 7(b). Table 7(a) reports the changes in acres while Table 7(6) report the changes in percentage. For example, after joining the AgriStability program under GF2 and compared to the model base outcome, which assumes the farmer does not participate in AgriStability, a farmer in Forty Mile County reduces the acres allocated to dryland wheat by 45 acres (14.15%) while increasing acres planted to dryland wheat by 44 acres (4.37%). Since producers' land-use decisions are very similar under GF and GF2 compared to the base case, the changes in land allocations under GF are not reported. The results indicate that farmers' land use decisions will change if they join the AgriStability program. Although the impact varies by region (weather, soil and other environmental conditions), all of the representative farms reduce production of canola while choosing to produce more wheat.

A comparison between GF and GF2 is provided in Tables 8(a) and 8(b). We find that the change in going from GF to GF2 affects the number of triggered payouts, the actuarially sound premium for the program, and the farmers' expected gross margin. With the reduction of the margin coverage (*β*), number of payouts, premiums and expected gross margins all decline to some extent. There are two important findings worth noting: First, both the number of payouts and the premiums are significantly reduced in percentage terms. For example, the actuarially sound premium for the program in Forty Mile County under GF2 is about 17% of that under GF. Second, although farmers suffer some loss in terms of the expected gross margin, the value of benefits that other agents in society get is larger than the value of the farmers' losses. The reason relates to the reduction in the actuarially sound premium, which is partly subsidized by government. Further, given that the real cost of public funds is often 1.3 to 1.5 times that of the net subsidy, the total benefit to taxpayers of the premium reductions exceeds those of our representative farmers. Since moving from GF to GF2 does not alter producers' production decisions, we focus on analysing GF2 in the next subsection.

Premium Subsidization Rate

Thus far we have not examined the effect of a premium subsidy. A change in the proportion of the subsidy paid by government (δ) does not alter the farmer's production decision once the farmer has decided to participate in the AgriStability program. The premium paid by a farmer for a \$100,000 hedge against the reference margin is \$315 (AAFC 2014a, p.11). Even including a \$55 administrative fee, the amount is small compared to a representative producer's gross margin. Therefore, the effect of a premium subsidy on crop allocation decisions is not obvious. However, to incentivize a farmer to participate in the program and protect her from large losses with small probabilities in the long term, a subsidy is necessary (see Chambers 2007; Moshini and Hennessey 2001). The subsidization rate should be determined by comprehensively considering other factors, like the opportunity cost of public funds.

Risk Aversion Coefficient

To explore how farmers' risk attitudes affect their crop portfolio, we also solve the model for various φ values. McCarl and Bessler (1989) discuss three approaches to develop an upper bound for the risk aversion coefficient. The non-negative certainty equivalent approach finds the bound of φ equals 2× the mean divided by the variance (σ^2). The confidence interval method yields the bound as 2× the number of standard deviations divided by σ. If Chebyshev's inequality is applied, an extreme value of φ is found as 28 divided by σ. The third approach comes from MOTAD studies and specifies the bound as 5 divided by σ.[4]

We apply three methods to find three bound values of φ for sensitivity analysis. Solutions at those values of φ for representative farms in Forty Mile and Vulcan counties are provided in Tables

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[4] Recall that, because the calibrated cost functions already account for some risk, these bounds are likely much larger than is the case. Although the risk accounted for as a result of the PMP adjustment is unknown, it might be small since maximizing expected utility when marginal (=average) costs are constant fails to replicate the observed crop allocation for various values of φ.

9 and 10, respectively. The land allocations in the base case are provided for comparison. The results indicate a clear trend: the number of triggered payments and the premium are monotonically increasing with increases in the risk aversion coefficient. Farmers in different regions will respond to changes in their risk attitudes in different ways since the variance of crop yields is not the same across the province. For a farmer in Forty Mile County, land allocated to barley, canola and irrigated wheat increases with φ at the cost of durum, peas and dryland wheat. For a farmer in Smoky River County, however, more barley and peas are planted as the producer becomes more risk averse (φ rises) at the expense of canola and wheat.

Concluding Discussion

The objective of this paper was to analyse how a farmer's land-use decisions vary in response to changes in the AgriStability program and their risk aversion level. For this, a mathematical programming model that aims to maximize a farmer's expected utility is employed to determine crop allocation. We conclude that the AgriStability program slightly alters production decisions. However, the change in the AgriStability payout trigger does not further affect farmers' land allocation decisions. Meanwhile, as a result of a reduction in the trigger mechanism and the coverage proportion of the income difference, the number of payouts and the actuarial sound premium are significantly reduced in percentage terms. In this regard, our findings are similar to those of Trautman et al. (2013), who employed net present value analysis to examine the differences between GF and GF2. Further, farmers in different regions will respond to changes in their risk attitudes in different ways.

In this study, we employed what is now a standard approach for analyzing changes in agricultural policy related to business risk management. However, there remain several research questions that need to be addressed. First, positive mathematical programming was initially proposed as a means of calibrating LP models to an observed crop allocation because the use of ad hoc constraints was unsatisfying and not useful for analyzing policy, while modeling attempts to replicate observed land uses by maximizing expected utility as opposed to expected returns fell short of the mark (Howitt 1995, 2005). However, while PMP could identify crop-specific cost functions that enabled the analyst to replicate precisely observed land use, it was not clear what the adjustment entailed. The calibrated functions could apparently account for many unseen factors that went into crop production, including risk perceptions. This interpretation was a focal point of criticism (e.g., Heckelei et al. 2012), which has not yet been clarified although research continues into this issue.

Second, when analyzing policy related to agricultural insurance and risk, it is necessary to calibrate not only crop-specific cost functions but also the risk aversion parameter. Although Petsakos and Rozakis (2015) provide one means for doing so, there remain problems implementing their approach. In the current application, we recognize this problem and used an ad hoc procedure to incorporate farmers' risk attitudes. Even though we could not replicate the observed land uses only on the basis of farmers' risk aversion, attitude toward risk does in our model turn out nonetheless to be more important than changes in the AgriStability program between GF and GF2. Further research is needed to address the simultaneous calibration of cost functions and risk aversion within a PMP framework, while also finding a better way to measure farmers' risk attitudes. These steps are necessary to improve economists' abilities to analyze agricultural business risk management and related public policy.

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Table 1: Representative Farms in Alberta

County	Region	Soil Zone	Farm Size (acres)	Crop Land Allocation				
				Barley	Canola	Durum	Peas	Wheat
Forty Mile *	South	Brown	3089	7%	10% / 3%	23%	20%	32% / 6%
Red Deer	West	Black	785	35%	37%		2%	27%
Smoky River	North	Dark Gray	1265	2%	53%		3%	42%
Vermilion River	East	Black	1166	15%	43%		5%	38%
Vulcan	South	Dark Brown	1569	19%	28%	7%	15%	31%
Westlock	Central	Dark Gray	743	14%	50%		2%	34%
Average of Alberta			1168	14%	33%	8%	10%	35%

* For the representative farm of Forty Mile County, dryland/irrigated canola and wheat are treated as separate crops.

Table 2: Crop Prices

	Barley	Canola	Durum	Peas	Wheat
Estimated Mean Price ($/bu)*	3.87	11.42	6.16	6.90	6.07
Original Average Price ($/bu)**	4.04	11.36	7.42	7.31	6.67

* Estimated mean prices are derived from the Ornstein–Uhlenbeck model.
** Average prices are directly calculated from the original data.

Table 3: Correlation Matrix for Average Crop Yields

	Wheat	Barley	Canola	Peas	Durum
Wheat	1.00				
Barley	0.77	1.00			
Canola	0.91	0.83	1.00		
Peas	0.93	0.69	0.85	1.00	
Durum	0.91	0.79	0.83	0.85	1.00

Table 4: Summary of Returns and Costs for Six Representative Farms

Item	County	Barley	Canola	Durum	Peas	Wheat
Mean Price ($/bu)		3.87	11.42	6.16	6.90	6.07
Yields (bu/acre)	**Forty Mile** *	59.0	27.9 / 46.5	48.3	36.4	39.5 / 83.3
	Red Deer	69.4	38.1		43.8	59.8
	Smoky River	62.0	34.1		38.3	47.3
	Vermilion River	60.0	35.4		36.8	47.1
	Vulcan	67.9	38.8	48.2	49.5	46.6
	Westlock	74.0	44.3		51.6	65.2
Costs ($/acre)	**Forty Mile** *	71.8	99.4 / 140.5	87.5	91.2	84.4 / 195.0
	Red Deer	120.2	150.9		120.1	125.7
	Smoky River	105.5	129.2		108.5	109.5
	Vermilion River	120.2	150.9		120.1	125.7
	Vulcan	99.0	118.2	104.0	105.0	101.5
	Westlock	117.6	140.3		115.5	121.0
Marginal Contribution ($/acre)	**Forty Mile** *	156.2	219.4/390.4	209.8	160.1	155.3/310.5
	Red Deer	148.1	284.6		181.8	237.4
	Smoky River	134.3	260.5		155.6	177.7
	Vermilion River	111.7	253.4		133.4	159.8
	Vulcan	163.4	325.1	192.6	236.5	181.0
	Westlock	168.5	366.0		240.7	274.7

* For the representative farm of Forty Mile County, dryland/irrigated canola and wheat are treated as separate crops.

Table 5: Parameters for the Vulcan Representative Farm

District	Crop	λ	α	β
Vulcan	Barley	0.00	99.00	0.00
	Canola	161.32	-43.12	0.75
	Durum	29.31	74.69	0.52
	Peas	72.90	32.10	0.62
	Wheat	17.81	83.69	0.07
Total Land Use		1569.00		

Table 6: Calibration Results for Six Representative Farms

District	Crop	λ	α	β
Forty Mile	Barley	116.42	-44.62	1.07
	Canola (Dry)	179.38	-79.98	1.13
	Canola (Irr)	350.42	-209.92	6.64
	Durum	169.92	-82.42	0.48
	Peas	120.20	-29.00	0.44
	Wheat (Dry)	115.29	-30.89	0.23
	Wheat (Irr)	270.59	-75.60	2.90
Red Deer	Barley	129.16	-8.93	0.96
	Canola	265.45	-114.54	1.84
	Peas	162.75	-42.69	18.84
	Wheat	218.28	-92.59	2.09
Westlock	Barley	138.75	-21.15	2.68
	Canola	332.47	-192.17	1.79
	Peas	208.29	-92.79	23.58
	Wheat	244.47	-123.47	1.95
Vulcan	Barley	126.18	-27.18	0.86
	Canola	287.50	-169.30	1.33
	Durum	155.49	-51.49	2.73
	Peas	199.08	-94.08	1.69
	Wheat	143.99	-42.49	0.58
Vermilion River	Barley	111.63	8.57	1.31
	Canola	253.00	-102.10	1.01
	Peas	133.45	-13.35	4.89
	Wheat	159.83	-34.13	0.73
Smoky River	Barley	115.41	-9.96	10.41
	Canola	241.37	-112.15	0.71
	Peas	136.60	-28.10	6.97
	Wheat	158.59	-49.09	0.60

Table 7: Land-use Changes with AgriStability Program

(a) GF2 versus Base Outcome (acre)

County	Planted area						
	Barley	Canola		Durum	Peas	Wheat	
		Dryland	Irrigated			Dryland	Irrigated
Forty Mile	20	-45	-6	-32	13	44	6
Red Deer	-4	-3		-	0	8	
Smoky River	0	-13		-	-2	15	
Vermilion River	-3	-12		-	-2	17	
Vulcan	-11	-12		-2	6	18	
Westlock	-2	-5		-	-1	8	

(b) GF2 versus Base Outcome (percentage)

County	Planted area						
	Barley	Canola		Durum	Peas	Wheat	
		Dryland	Irrigated			Dryland	Irrigated
Forty Mile	9.13%	-14.15%	-5.66%	-4.52%	2.38%	4.37%	3.23%
Red Deer	-1.48%	-1.18%		-	-1.73%	3.70%	
Smoky River	-1.71%	-1.97%		-	-5.61%	2.83%	
Vermilion River	-1.64%	-2.45%		-	-2.75%	3.78%	
Vulcan	-3.73%	-2.67%		-1.41%	2.55%	3.66%	
Westlock	-2.02%	-1.43%		-	-3.41%	3.24%	

Table 8: Changes under GF2 compared to GF

(a) GF2 versus GF (dollar)

County	# of payments	Premium ($)	Expected gross margin ($)
Forty Mile	-186	-8,931	-2,679
Red Deer	-177	-3,646	-1,094
Smoky River	-193	-4,183	-1,255
Vermilion River	-118	-8,137	-2,441
Vulcan	-186	-6,541	-1,962
Westlock	-172	-4,002	-1,201

(b) GF2 versus GF (percentage)

County	# of payments	Premium	Expected gross margin
Forty Mile	-73.5%	-83.3%	-0.6%
Red Deer	-61.0%	-75.5%	-0.7%
Smoky River	-72.6%	-82.2%	-0.5%
Vermilion River	-30.3%	-45.8%	-1.2%
Vulcan	-70.5%	-81.2%	-0.6%
Westlock	-62.8%	-76.8%	-0.6%

Table 9: Forty Mile Representative Farm's Optimal Choice for Different Risk Attitudes

Forty Mile	Risk aversion coefficient	Actuarial sound premium	# of Triggerred payment	Barley	Canola (Dry)	Canola (Irr)	Durum	Peas	Wheat (Dry)	Wheat (Irr)
28/(standard deviation)	0.000227	7074	207	15.1%	22.5%	4.6%	16.5%	5.6%	26.6%	9.2%
2 (expected value)/variance	0.000054	3326	101	10.9%	13.5%	3.9%	19.4%	12.8%	32.0%	7.4%
5/(standard deviation)	0.000040	2940	94	10.3%	12.4%	3.8%	19.9%	14.0%	32.5%	7.2%

Table 10: Smoky River Representative Farm's Optimal Choice for Different Risk Attitudes

Smoky River	Risk aversion coefficient	Actuarial sound premium	# of Triggerred payment	Barley	Canola	Peas	Wheat
28/(standard deviation)	0.000528	8165	382	7.3%	45.8%	7.8%	39.0%
2 (expected value)/variance	0.000189	2671	184	4.1%	49.0%	5.1%	41.8%
5/(standard deviation)	0.000094	1608	124	3.0%	50.4%	4.0%	42.5%

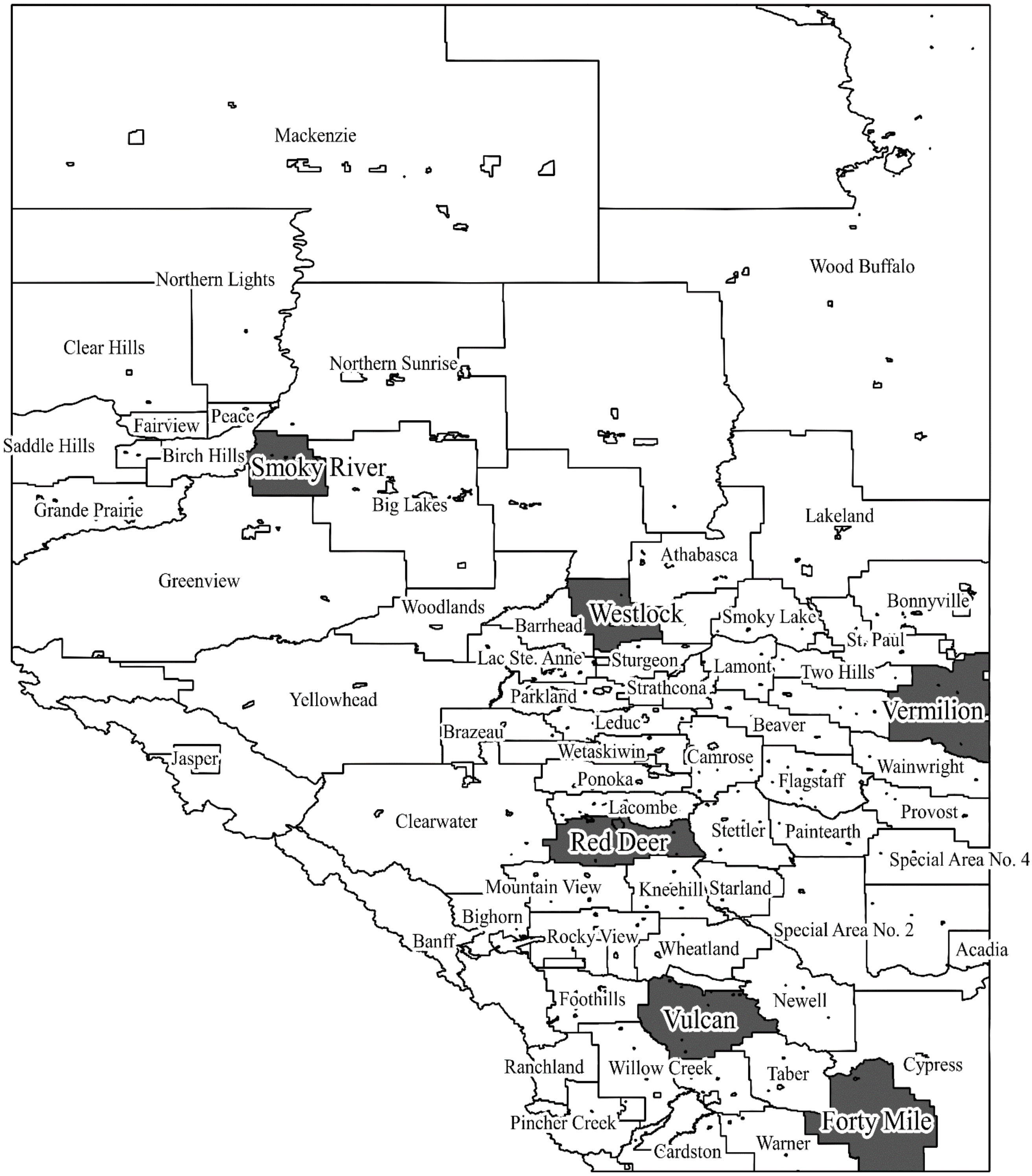

Figure 1: Map of Alberta: The six municipal districts and counties with representative farms are shaded – Forty Mile, Vulcan, Red Deer, Vermilion River, Westlock, and Smoky River.

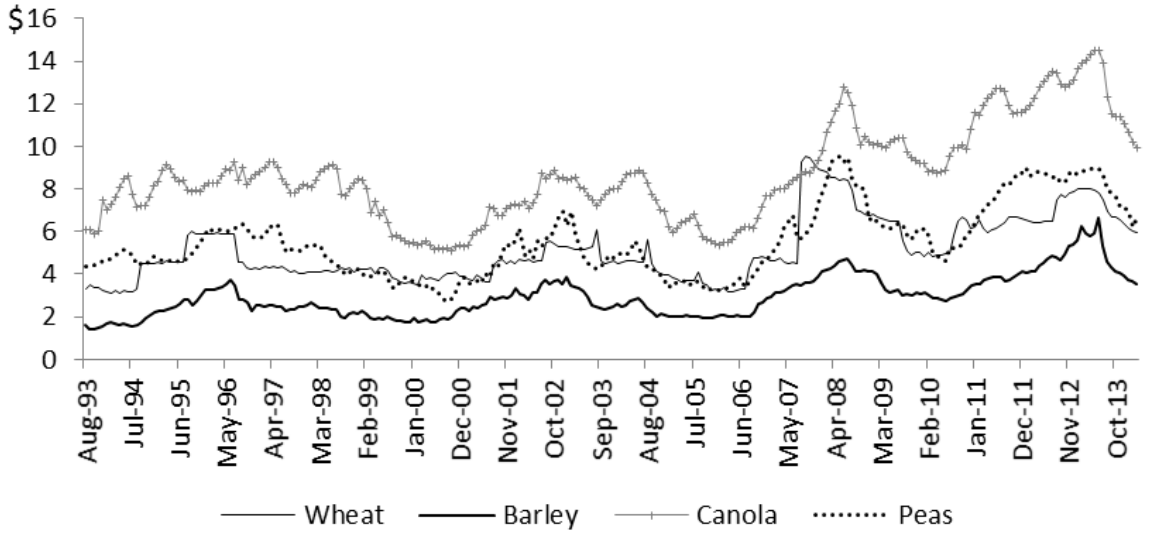

Figure 2: Volatility in crop prices, 1993–2014

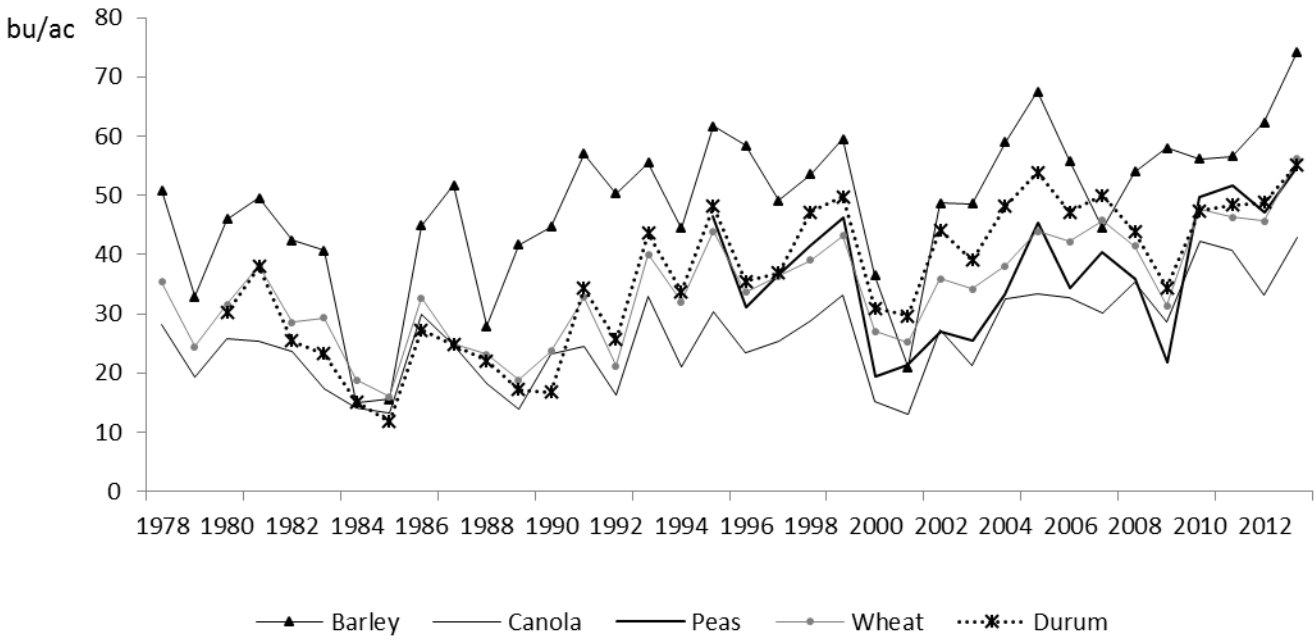

Figure 3: Average yields for five crops in Vulcan County, Alberta

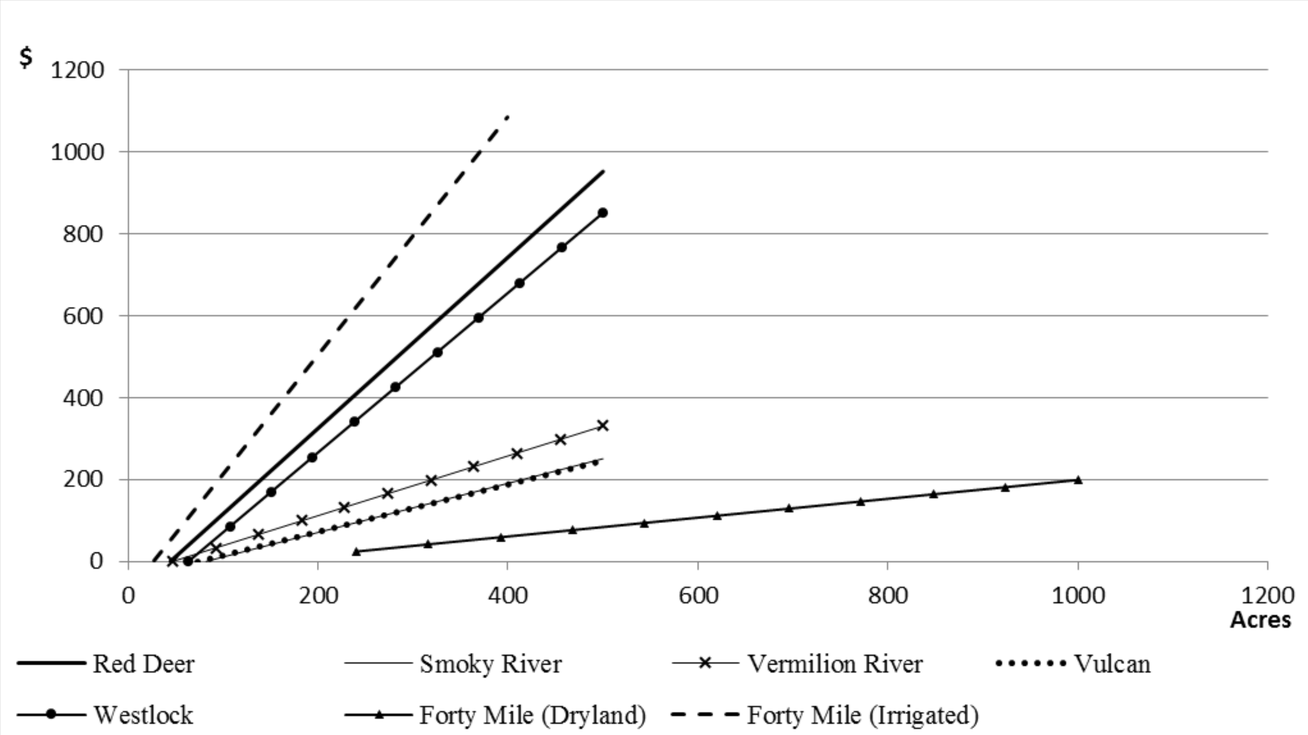

Figure 4: Marginal cost curves for wheat for six representative farms in Alberta

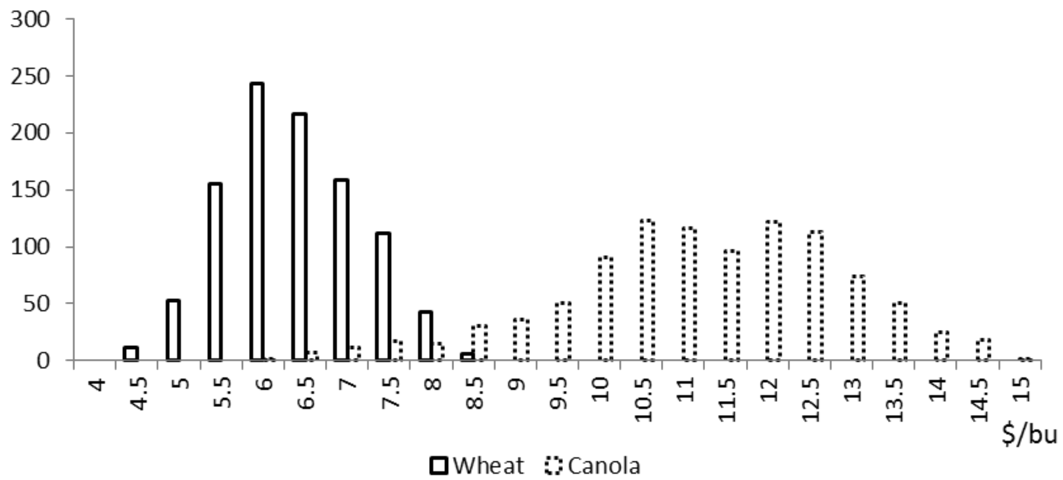

Figure 5: Distributions of Simulated Prices of Wheat and Canola

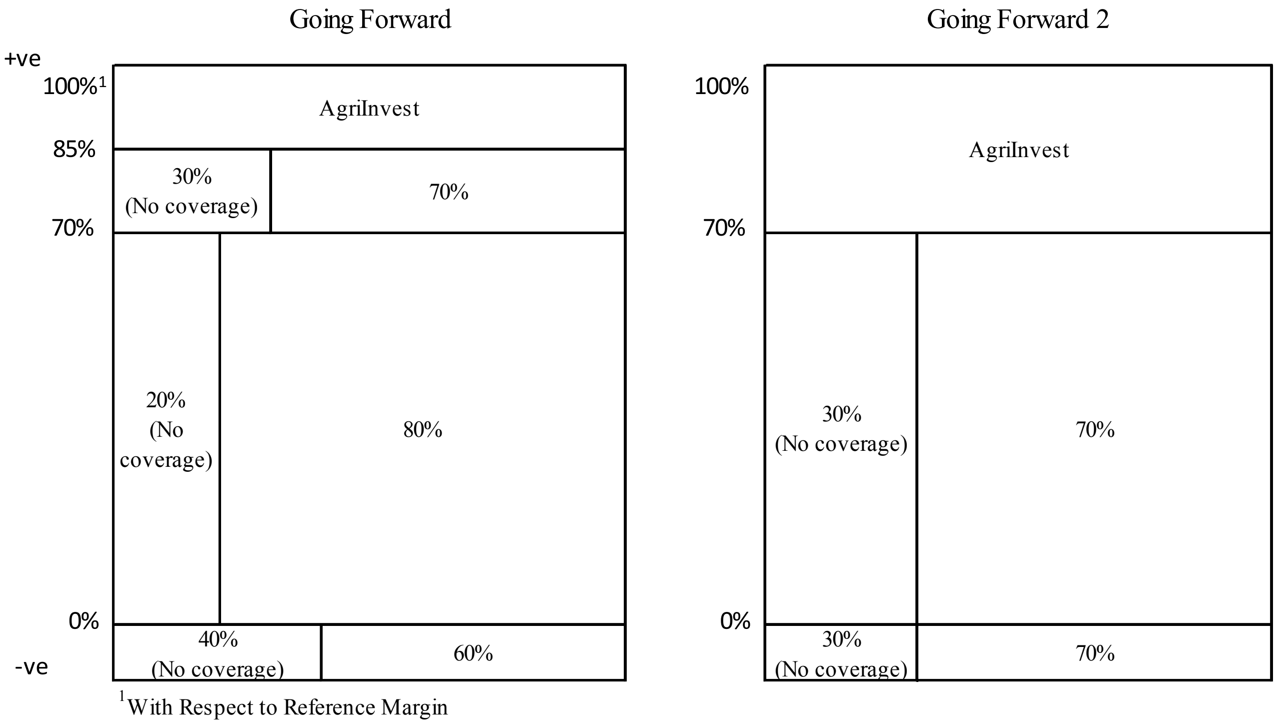

Figure 6: AgriStability Payment Structure under GF and GF2
Sources: AgriStability Program Handbook, Revised August 2011 (AAFC 2014b)
AgriStability Program Handbook, Effective for Program Years commencing 2013 (ASFC 2014b)