Whole Farm Income Insurance in a Canadian Context

Calum G. Turvey

Department of Applied Economics and Management

Cornell University

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Abstract

This paper employs mean-variance and mean-skewness optimization to investigate farmers' crop choices under Gross Revenue Insurance (GRIP), Whole Farm Income Insurance, the Canadian Agricultural Income Stabilization program, and its modified 2008 program AgrInvest. To our knowledge this paper is the first to fully consider the endogenous optimization of whole farm insurance in a farm optimization model. The results indicate that farmers will alter farm plans significantly in response to the type of insurance offered and the level of subsidy. Farmers will take on production risks that they would not otherwise take and this risk taking behavior is exacerbated by subsidy.

Key Words: Agricultural Insurance, Skewness Maximization, Mean-Variance, Farm Income Insurance, GRIP, CAIS, AgrInvest

Introduction

The advent of modern risk management in agriculture is increasingly becoming focused on whole farm income insurance. By whole farm income insurance it is meant that a single policy is provided which covers the covariate risk of jointly produced farm crop and livestock enterprises. It is a separate and distinct approach to those farm safety nets that focus on crop specific insurance, price insurance and stabilization, or enterprise revenue insurance. Explorations into income insurance in Canada and the United States have been conducted by Turvey and Amanor-Boadu 1989; Hennessy, Babcock Hayes 1997, and Hennessy, Saak and Babcock (2003) and in a European context by Meuwissen, Huirne, and Skees (2003) but none, for a variety of reasons, are satisfactory from an economic point of view. The most serious deficiency, and that which is most explored in this paper, is the endogeneity of the insurance decision on crop choices. An exception is discussion of whole farm income insurance in the United States discussed in a very thorough review by Dismukes and Durst (2006). There they recommend a whole farm approach that does not require savings account balances such as Canada's CAIS program or income insurance savings in Australia but rather a whole farm approach that is based on portfolio indemnities and premiums. This is along the lines of the AGR and AGR-Lite programs in the United States which they describe as whole farm revenue insurance.

Nonetheless there has been scant research done on either the design of whole farm income insurance, how income insurance would affect enterprise selection, the effect of subsidy on crop choices, or the impact income insurance might have in terms of decoupling and World Trade Organization guidelines. With these problems in mind, the purpose of this paper is to investigate farm portfolio choice under whole farm income insurance plans. The particular plans include a gross revenue plan as a point of comparison, but the real focus is on a generalized indemnity-based whole farm plan stylized to the AGR program in the United States and the CAIS and AgrInvest policies in Canada. Canadian data is used for a typical farm in Manitoba. The next section is focused on policy design and model specification. This is followed by a discussion of the data sources, Monte Carlo simulations, and optimization results and conclusions.

Perhaps one of the most important outcome of this paper is a better understanding of endogenous choice in portfolio selection under a whole farm insurance regime. This is of course the fundamental problem facing policy makers and the consequence of choice have far reaching implications into matters of trade, market distortions, wealth accumulation, asset capitalization and so on. Yet our understanding to date is quite rudimentary. For example the portfolio models of Turvey and Amanor-Boadu (1989) or Hennessy, Saak and Babcock (2003) take the crop mix as exogenous. The notion that farmers will incorporate the parameters of insurance (allowable coverage and premium subsidy) into their crop planning strategy which in turn will simultaneously affect the cost of insurance and benefits of subsidy is not a trivial one, especially in the context of decoupling and the WTO (Baffes and de Gorter, 2004). The key factor is that the rules for eligibility and the criteria upon which payments are based upon originally (like the volume of production or use of input or status of a farmer) cannot change once the decoupled program is set in place (Baffes and de Gorter 2004)[1]. Care is required. At one level it would appear that if farmers paid fully an actuarial price, a production response would be decoupled because neither the policy or its benefits is targeted to any particular crop. Where the problem comes about is when tax payer funds are used to subsidize the insurance. If premiums are subsidized there will be an income effect that could favour the inclusion of crops in the final farm portfolio that would not have ordinarily been considered, even though the policy was not targeted to the favored crops. Examining how whole farm income insurance can affect farm enterprise selection is therefore important not only in the context of agricultural economics but in the practical matters of agricultural policy and trade.

A second problem this paper resolves is in modeling the complexity of whole farm income insurance. The problem of modeling whole farm income with endogenous premium determination has not to the writer's knowledge been solved previously. In this paper we show how to structure a mathematical programming model to account for this complexity. The third

[1] We will leave aside in this paper the implications of decoupled programs and government payments in general on other possible distortions such as land values. These effects are discussed elsewhere in Weersink et al, (1999); Goodwin et al (2003); However it is easy to understand how the expected wealth effect of subsidy can affect land values. Looking ahead to Table 7 the expected indemnity for Income insurance with a $185,000 target and a 50% subsidy implies an expected gain in wealth of $19,219 . Spread over 1,000 acres the simple capitalized value of $19.219/acre at 10% implies a land benefit of $192.19/acre.

problem we contribute to is related to the second and that deals specifically with how to price whole farm insurance. First we must distinguish whole farm insurance from say crop-specific gross revenue assurance applied to all crops in a portfolio because it explicitly includes cross-enterprise covariances and other dependencies (such as crop rotations).

A fourth problem arises in terms of expected utility. The concern here is that not all farmers will behave alike. Differing degrees of risk aversion or varying preference for reduced risk or positive skewness can affect crop decisions under a whole farm insurance plan. In this paper farm plans are optimized under the insurance policies using both a variance minimizing objective and a skewness maximizing objective. These models correspond to second degree stochastic dominance (see Hader and Russel 1969; Ogryczak and Ruszczynski 2001) and third degree stochastic dominance respectively (see Whitemore 1970 and Levy 1992). We rely on a theorem by Gotoh and Konno (2000) who show that an optimization model that maximizes the third moment of the probability distribution is also third degree stochastic dominant. This is of particular relevance for problems in risk management in which derivative products or insurance either skew probabilities towards more favourable outcomes, or truncate the lower partial moments entirely. This paper therefore explores the problem of income insurance with both a quasi mean variance approach (in the sense that multivariate normality is not imposed) that minimizes portfolio risk, and a mean skewness model that maximizes the skewness of the resulting portfolio. We are unaware of any other study that has actually maximized skewness in a portfolio problem as we do here. We find the solutions strikingly different and conclude that when it comes to incorporating risk contingencies in a portfolio model, mean variance cannot be assumed as a matter of course.

The remainder of this paper is as follows. In the next section we discuss expected utility and rationalize our use of mean-Variance (E-V) and mean-Skewness (E-S) optimizations. This is followed with mathematical descriptions of the income insurance and gross revenue insurance models. The data sources and use of Monte Carlo simulation of state-space is then provided, and the results of the models and conclusions follow.

Whole Farm Income, Expected Utility and Stochastic Dominance

The use of stochastic dominance to investigate agricultural crop insurance decisions is not foreign to the literature (Wilson et al 2009) and shows that crop insurance decisions are based on a number of factors related to risk including the price of insurance. In this section we examine first, second and third degree stochastic dominance (FSD,SSD, TSD) in the context of expected utility, choices under uncertainty, and the effect of insurance on these choices. The mean variance model excludes higher moments of utility beyond mean and variance and is generally restricted to the class of quadratic or negative exponential utility if the joint returns are at least approximately multivariate normal. It is naïve to assume that all farmers have homogenous preferences or are restricted to a particular quality of utility. Furthermore there is a lack of clarity in determining utility preferences when joint distributions are fully truncated or by the nature of insurance reduced in the lower partial moments. If we consider a more flexible class of utility with $U'(\pi) \geq 0, U''(\pi) \leq 0 \text{ and } U'''(\pi) \geq 0$ then we can provide further investigation when decision makers have a preference for positive skewness. This originates with a Taylor series expansion around the expected utility of profits, π, $E\left[U(\pi)\right]$;

$$(1)\; E\left[U(\pi)\right] = U(\bar{\pi}) + \frac{U''(\bar{\pi})}{2!} E\left[\pi - \bar{\pi}\right]^2 + \frac{U'''(\bar{\pi})}{3!} E\left[\pi - \bar{\pi}\right]^3 + \textit{higher order terms}$$

This also represents a much broader spectrum of utility in which risk aversion can be decreasing, constant or increasing in π, but more generally it is assumed that $U'''(\pi) \geq 0$ implies decreasing absolute risk aversion. (1) holds surely for negative exponential utility and weakly for power or logarithmic utility (Krause and Litzenberg 1976; Bawa 1975). It has also been suggested that $U'''(\pi) \geq 0$ implies a preference for positive skewness but how general this conclusion is has been questioned by Brockett and Kahane (1992). Nonetheless, the link between $U'''(\pi) \geq 0$ and skewness identified by Arditti (1967) and Tsiang (1972), experimentally by Alderfer and Bierman (1970) and empirically by Kraus and Litzenberger (1976) appears to be consistent with observed behavior, that is a preference for higher return ($U'(\pi) \geq 0$), and aversion to variance ($U''(\pi) \leq 0$) and a preference for skewness ($U'''(\pi) \geq 0$).

The general belief is that the three elements of (1) are not mutually exclusive; that it is normally assumed that the utility maximizer prefers more income to less AND prefers less variance to more AND prefers more skewness to less (or equivalently a smaller lower partial moment OR a larger higher partial moment). These combine to establish the necessary conditions for the ordering of risky prospects, and we label them accordingly: A manager who ignores risk and skewness is labeled as risk neutral; one who ignores skewness is a risk minimizer; one who includes all is a skewness maximizer. The precedence matters in the general expected utility model, for we would not ordinarily consider a preference for positive skewness if positive skewness comes at the expense of higher variance. This can be problematic for not all classes of probability distributions can preserve the ordering of mean and variance while altering skewness. The surgical removal of probabilities from the central core of the probability distribution and transplantation to the tails by Rothschild and Stiglitz (1970) and Kroll and Levy (1988) is illustrative of these complexities. Alternatively the SSD rule from Porter (1974) claims that among prospects with equal means a prospect with higher left-distribution semivariance will be least preferred as a necessary but not sufficient condition. It is not sufficient because it is entirely possible that the same distribution could be preferred if, for example, when measured relative to a target the right-distribution semivariance is considerably higher (see also Levy 1992).

More formally we are considering the class of third degree stochastic dominant solutions which minimally contain all orderings of first and second degree stochastic dominance in the set. By the general proofs of stochastic dominance (see for example Hadar and Russel (1971), Whitemore (1970), and Gotoh and Kanno (2000)) orderings that are second order stochastic dominant are also third order stochastic dominant, but not all third degree stochastic dominant orderings are second degree stochastic dominant. On this basis theorem 5.2 of Gotoh and Kanno shows that the third order moment

$$
\begin{aligned}
&Max \quad \sigma^3 = \int_{-\infty}^{\infty} \left(K_2 - E\left[K_2\right]\right)^3 f\left(K_2\right) dK_2 \\
&Subject \;\; to \\
&E\left[K_2\right] = K \\
&\sigma\left(K_2\right) \le \sigma\left(K_1\right)
\end{aligned}
\tag{2}
$$

has a solution that is TSD semi-efficient (that is, when evaluated at equivalent target income levels $E\left[K_2\right] = E\left[K_1\right]$) to the second moment problem

$$
\begin{aligned}
&Min \quad \sigma^2 = \int_{-\infty}^{\infty} \left(K_1 - E\left[K_1\right]\right)^2 f\left(K_1\right) dK_1 \\
&Subject \;\; to \\
&E\left[K_1\right] = K
\end{aligned}
\tag{3}
$$

What Gotoh and Kanno's theorem suggests is that if we substitute the standard definition of skewness (as a scalar adjustment of the third moment)

$$(4) \qquad Max \;\; skew = \frac{m}{(m-1)(m-2)} \sum_{i=1}^{m} \left(\frac{K_i - E[K]}{\sigma} \right)^3$$

for

$$(5) \qquad Min \;\; \sigma_p^2 = \frac{1}{m} \sum_{j=1}^{m} \left(K_j - E[K] \right)^2$$

in the optimization models to be presented below, the solutions are TSD efficient if the variance of the first is less than or equal to the variance of the second[2]. This rule has been established by Whitmore (1970) as being necessary but not sufficient. In our model we do not impose the constraint $\sigma(K_2) \le \sigma(K_1)$ because as a tautology it would place an unnecessary restriction on the upper bound of the positively skewed distribution we seek. By tautology we mean that having already established the minimum variance frontier the imposition of the constraint would do no more than ensure that the E-S skewness frontier lies on all points along the E-V frontier. Rather, it is far more interesting to optimize without the constraint and check to determine whether $\sigma(K_2) \le \sigma(K_1)$ occurs naturally. Importantly, while $\sigma(K_2) \le \sigma(K_1)$ is a necessary condition for the solution to (2) to be preferred to (3) it is not sufficient. Therefore a violation of $\sigma(K_2) \le \sigma(K_1)$ does not exclude the possibility that the portfolio (2) is preferred to portfolio (3)[3]. Skewness preference is therefore critical in terms of how farmers will respond to the income insurance policies. In an insurance world there are two things going on. First, insurance is purchased to eliminate downside risk, leaving upside risk intact. It may well be the case that

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[2] We are however cautious that Gotoh and Kanno's theorem does not explicitly consider skewness as defined by (4) (in comparison to the ordinary third moment in (2)) nor does their proof explicitly address the issue of truncated distributions, although their proof does assume that utility preference under the stochastic dominance criteria is distribution free. Levy (1982) does provide a set of dominance rules for the case of the normal distribution that hold also for lower partial moment truncation (Levy 1982, fn 1) that do not appear to contradict the theorem. Nonetheless our results are reassuring in that our model, even with the whole farm insurance structure, is consistent with their theorem. See fn 9 which shows that the σ^3 solution as defined by Gotoh and Kanno results in a slightly different solution than the one used in the optimization, and that the σ^3 solutions are identical to optimizations that maximize indemnity.

[3] In other words, by not restricting the set of feasible solutions to satisfy the necessary conditions we can expand the set to include higher order moments consistent with a utility preference for skewness. The reasoning is that the term can take on either positive or negative values. Maximization therefore places a preference on large positive deviations and this could occur at the expense of higher variance and downside risk. The choice is that in probability there is a greater chance of a large positive outcome than a variance measure might provide.

insurance premiums under a preference for skewness will be higher than for a risk minimizer. Second, if insurance is subsidized and it becomes less costly to insure greater amounts of downside risk, then farmers may well make choices accordingly. This is of course a purpose of insurance; that farmers can make choices with insurance that they would otherwise not make[4]. At full premium this would not constitute a moral hazard but with subsidized premiums a type of moral hazard can be expected which could lead to higher premiums.

But what of the current choices that farmers face between the mutually exclusive options of operating a farm without income insurance, or participating in an income insurance program? To start define $f(\pi)$ as the probability distribution of farm portfolio profit without participation in income insurance and $F(\pi)$ its cumulative distribution function. Likewise define $g(\pi)$ as the (ex post) distribution of farm profits with the insurance in place and $G(\pi)$ its cumulative distribution function. In this context $g(\pi)$ is a transformation of $f(\pi)$. Next, the common interpretation of FSD is a comparison of means. Thus

$$\begin{aligned}&\int_a^b \pi g(\pi)d\pi = \int_a^Z Zf(\pi)d\pi + \int_Z^b \pi f(\pi)d\pi \\ &\int_a^b \pi g(\pi)d\pi = \theta Z + \int_Z^b \pi f(\pi)d\pi > \int_a^b \pi f(\pi)d\pi\end{aligned} \tag{6}$$

where Z is an insurance coverage level and θ is the probability of receiving an insurance indemnity $Z-\pi$ for any $\pi < Z$. Note also that the integrals are of the Stieltjes-Lebesques class with $a \le Min(\pi)$ and $b \ge Max(\pi)$ for either $g(\pi)$ or $f(\pi)$. Now suppose that $\nu = \theta Z$ is an actuarial premium charge against the insurance. The subsidized cost is $(1-\delta)\nu$ where δ is a loading factor, $u > \delta \ge 0$. Then more generally

$$\theta Z + (1-\delta)\nu + \int_{Z+(1-\delta)\nu}^{b+(1-\delta)\nu} \pi f(\pi)d\pi \ge \int_a^b \pi f(\pi)d\pi \tag{7}$$

for $1 \ge \delta \ge 0$ and holding with strict equality when $\delta = 1$. Adjusting the integrand (e.g. $b+(1-\delta)\nu$) captures the fact that the distribution function shifts to the right when the premium is less than actuarially fair. If an administrative load is added so that $u \ge \delta > 1$ then (7) fails and the insurance policy will not dominate the base case by FSD. Of course in many industries an administrative load is added and insurance is still purchased because insurance reduces or

[4] This is also consistent with Baumol's (1963) argument that reducing the bounds of the lower confidence limits will expand the opportunity set .

eliminates the lower partial moments below base coverage. Thus $1 \geq \delta \geq 0$ is a necessary but not sufficient condition for SSD. The SSD claim is generally interpreted in terms of portfolio variance. We proceed accordingly. The variance without insurance is

(8) $$\sigma_f^2 = \int_a^b (\pi - \mu_\pi)^2 f(\pi) dx = \int_a^Z (\pi - \mu_\pi)^2 f(\pi) d\pi + \int_a^Z (\pi - \mu_\pi)^2 f(\pi) d\pi .$$

When income insurance $F(\pi)$ is truncated:

(9) $$\sigma_g^2 = \int_a^Z \left(Z - \left(\mu_x + (1-\delta)\nu\right)\right)^2 f(\pi) d\pi + \int_{Z+(1-\delta)\nu}^{b+(1-\delta)\nu} \left(\pi - \left(\mu_\pi + (1-\delta)\nu\right)\right)^2 f(\pi) d\pi$$

or

(10) $$\sigma_g^2 = \theta\left(Z - \left(\mu_x + (1-\delta)\nu\right)\right)^2 + \int_{Z+(1-\delta)\nu}^{b+(1-\delta)\nu} \left(x - \left(\mu_x + (1-\delta)\nu\right)\right)^2 f(x) dx \leq \sigma_f^2 .$$

Eq (10) will hold for all cases in which $1 \geq \delta \geq 0$ but there will be some $\delta^* > 1$ for which (10) does not hold. Generally we can assume that the public provision of agricultural insurance will be priced so that (9) holds to be true in most if not all instances. We can also see the insufficiency of the condition $1 \geq \delta \geq 0$; There will be some range, $\delta^* > \delta > 1$, for which (10) is true but for which (7) is false. That is, portfolio variance will be less than the base case while the expected profits are also less than the base case. Thus one cannot say that in all cases income insurance will dominate the base case by SSD as a matter of course, but as suggested above, the current policy regime of subsidized income insurance suggests that beyond the theoretical world whole farm income insurance will be preferred to no insurance.

With truncated (or significantly reduced) variance and expected profits equal to or better than the base case there will be a natural increase in the skewness of $f(x)$. This is most often represented by the distribution of the third moment. For the base case this is

(11) $$\sigma_f^3 = \int_a^b (\pi - \mu_\pi)^3 f(\pi) d\pi .$$

and with agricultural insurance (assuming for simplicity that $\delta = 1$) it is

(12) $$\sigma_g^3 = (Z - \mu_\pi)^3 \int_a^Z f(\pi) d\pi + \int_Z^b (\pi - \mu_x)^3 f(\pi) d\pi .$$

Assuming that $Z - \mu_\pi \leq 0$ (that is portfolio coverage is less than or equal to the mean) the reduction in σ_f^3 is

(13) $\Delta\sigma^3 = \left(Z-\mu_\pi\right)^3 \int_a^Z f(\pi)d\pi - \int_a^Z \left(\pi-\mu_\pi\right)^3 f(\pi)d\pi$.

If $Z=\mu_\pi$ then $\Delta\sigma^3 = -\int_a^{\mu_\pi} \left(\pi-\mu_\pi\right)^3 f(\pi)d\pi > 0$ but if $Z=a$, $\Delta\sigma^3=0$. Thus for any $Z>a$ the resulting distribution of $g\left(x\right)$ will always be more positively skewed than $f\left(\pi\right)$. With lower variance (Eq 10) and higher expected income (Eq 7) almost certain to be true with the public provision of income insurance, we can conclude with reasonable (but not perfect) certainty that the necessary conditions for whole farm insurance to dominate the base case by TSD will be satisfied. Importantly, since we have imposed no restrictions on the distribution of $f\left(\pi\right)$ then TSD dominance will hold for virtually any probability distribution that is continuous and locally differentiable or approximately so. This leads to the problem of endogeneity discussed in the introduction. It is understood that the distribution of profits is conditional on the choice and weighting of crops grown and this will impact both the range of indemnity and the cost of insurance. It is entirely feasible that the dominance of the insured distribution over the uninsured distribution will encourage some farmers to maximize skewness even if that comes at an increase in downside risk and insurance premium.

Optimization Models for Whole Farm Insurance

This study uses two variants of the mean-variance and mean-skewness models. The first model is used to optimize a base case with no insurance as well as the enterprise specific gross revenue insurance. The second is a more complex model that shows the normative response to whole farm insurance policies in Canada (CAIS and AgrInvest) and the U.S. (AGR). Here the payout is based on the choice of ALL crops rather than on individual crops.

*The base Mode*l

As a point of comparison the base model excludes all forms of insurance. The objective function is to minimize portfolio risk across all states of nature using a discrete state-spaced framework. This is distinctively different from the quadratic programming approach used by Turvey and Amanor-Boadu that requires the full specification of a positive-definite variance covariance matrix as the objective function. The use of state-spaced programming is required because later, when we build the gross revenue and whole farm models, the payouts are contingent on the particular states that emerge and not on the means. Furthermore it is assumed that only revenue is uncertain, and although the revenue states, R, represent gross margins, the cost structure is deterministic. The base E-V model is as follows:

$$
\begin{aligned}
& Min \;\; \sigma_p^2 = \frac{1}{m}\sum_{j=1}^{m}\left(\pi_j - E[\pi]\right)^2 \\
& Subject \;\; to \\
& \sum_{i=1}^{n} x_i = 1{,}000 \\
& \sum_{i=1}^{n} E[R_i] x_i = K \\
& \sum_{i=1}^{n} R_{1,i} x_i - \pi_1 = 0 \\
& \sum_{i=1}^{n} R_{2,i} x_i - \pi_2 = 0 \\
& \vdots \\
& \sum_{i=1}^{n} R_{j,i} x_i - \pi_j = 0 \\
& \vdots \\
& \sum_{i=1}^{n} R_{m,i} x_i - \pi_m = 0
\end{aligned} \tag{14}
$$

Here the subscripts i and j represent crop enterprise and risky state respectively. $R_{j,i}$ represents the state specific revenue for crop i in state j, and $E[R_i]$ represents the mean net revenue across all random states. K represents a target income level while π_j represents the income associated with random state j. The parameter m indicates the number of random states included in the model (in our case $m = 1{,}000$) while the parameter n represents the number of crop choices or farm enterprises ($n = 7$ for Manitoba).

The critical component to the analysis is the generation of the crop revenues $R_{j,i}$. One thousand possible revenue outcomes were generated using Monte Carlo simulation. The revenues are based on joint price and yield correlations and are net of any price, yield or revenue indemnities and the net cost of the indemnities.

Gross Revenue Insurance

Because of the historical interest in gross revenue insurance we also build an optimization model to investigate it. In this model all crops have available a gross revenue option. Although each of the revenue states are identical to the base model, any shortfalls receive payments. Because premiums are marginal each state of nature is net of variable costs, state contingent indemnities, crop specific revenue insurance premiums and subsidy.

$$
\begin{aligned}
& Min\ \ \sigma_p^2 = \frac{1}{m}\sum_{j=1}^{m}\left(\pi_j - E\left[\pi\right]\right)^2 \\
& Subject\ \ to \\
& \sum_{i=1}^{n} x_i = 1{,}000 \\
& \sum_{i=1}^{n} E\left[R_i\right] x_i = K \\
& \sum_{i=1}^{n}\left(R_{1,i} + Max\left[Z_i - R_{1,i}, 0\right] - \delta E\left[Max\left[Z_i - R_{1,i}, 0\right]\right]\right) x_i - \pi_1 = 0 \\
& \sum_{i=1}^{n}\left(R_{2,i} + Max\left[Z_i - R_{2,i}, 0\right] - \delta E\left[Max\left[Z_i - R_{2,i}, 0\right]\right]\right) x_i - \pi_2 = 0 \\
& \vdots \\
& \sum_{i=1}^{n}\left(R_{j,i} + Max\left[Z_i - R_{j,i}, 0\right] - \delta E\left[Max\left[Z_i - R_{j,i}, 0\right]\right]\right) x_i - \pi_j = 0 \\
& \vdots \\
(15)\qquad & \sum_{i=1}^{n}\left(R_{m,i} + Max\left[Z_i - R_{m,i}, 0\right] - \delta E\left[Max\left[Z_i - R_{m,i}, 0\right]\right]\right) x_i - \pi_m = 0
\end{aligned}
$$

The term $Max\left[Z_i - R_{j,i}, 0\right]$ is the crop specific revenue indemnity for state j and $E\left[Max\left[Z_i - R_{1,i}, 0\right]\right] = E\left[Max\left[Z_i - R_{j,i}, 0\right]\right] = E\left[Max\left[Z_i - R_{m,i}, 0\right]\right]$ is the revenue insurance premium

Whole Farm Income Insurance and the AGR Model

The whole farm insurance model is more complex. The first whole farm model is a straight forward portfolio insurance policy that closely resembles the AGR program in the United States. The program provides an indemnity if farm income from all sources falls below a pre-specified coverage level. The indemnity, which is priced to be actuarially sound, is equal to the expected value of the indemnities across all states of nature. In comparison with the enterprise specific models described above and in which portfolio choice is based on insurance outcomes known prior to selecting a crop mix, the whole farm approach requires first the selection of the crop mix and only then can whole farm insurance premiums be calculated and indemnities enumerated. In other words the payouts and premiums are endogenous to the optimization problem, whereas with the enterprise approach the payouts and premiums are exogenous. The whole farm model is structured as follows:

$$Min\ \ \sigma_p^2 = \frac{1}{m}\sum_{j=1}^{m}\left(\pi_j - E\left[\pi\right]\right)^2$$

$$Subject\ \ to$$

$$\sum_{i=1}^{n} x_i = 1,000$$

$$\sum_{i=1}^{n} E\left[R_i\right] x_i = K$$

$$\sum_{i=1}^{n} R_{1,i}x_i + Max\left[Z - \sum_{i=1}^{n} R_{1,i}x_i, 0\right] - \delta E\left[Max\left[Z - \sum_{i=1}^{n} R_{j,i}x_i, 0\right]\right] - \pi_1 = 0$$

$$\sum_{i=1}^{n} R_{2,i}x_i + Max\left[Z - \sum_{i=1}^{n} R_{2,i}x_i, 0\right] - \delta E\left[Max\left[Z - \sum_{i=1}^{n} R_{j,i}x_i, 0\right]\right] - \pi_2 = 0$$

$$\vdots$$

$$\sum_{i=1}^{n} R_{j,i}x_i + Max\left[Z - \sum_{i=1}^{n} R_{j,i}x_i, 0\right] - \delta E\left[Max\left[Z - \sum_{i=1}^{n} R_{j,i}x_i, 0\right]\right] - \pi_j = 0$$

$$\vdots$$

$$\sum_{i=1}^{n} R_{m,i}x_i + Max\left[Z - \sum_{i=1}^{n} R_{m,i}x_i, 0\right] - \delta E\left[Max\left[Z - \sum_{i=1}^{n} R_{j,i}x_i, 0\right]\right] - \pi_m = 0 \qquad (16)$$

All notation corresponds to the revenue insurance model described above, except here we include Z, which represents the income coverage level to be protected by income insurance. Then, $Max\left[Z - \sum_{i=1}^{n} R_{j,i}x_i, 0\right]$ represents the whole farm indemnity payout in any given state of nature and $\delta E\left[Max\left[Z-\sum_{i=1}^{n}R_{j,i}x_i,0\right]\right]=\frac{\delta}{m}\sum_{j=1}^{m}Max\left[Z-\sum_{i=1}^{n}R_{j,i}x_i,0\right]$ is the premium to be paid given loading factor δ. If $\delta=1$ the whole farm insurance premium is actuarially fair. If $\delta=0.50$ the premium is subsidized by 50%..

The Canadian Agricultural Income Stabilization Program (CAIS)

The CAIS program was introduced by the Government of Canada as part of the Agricultural Policy Framework and as a replacement for the Net Income Stabilization Account program. The CAIS program expired in 2007 and a new program comprised of AgriInvest+AgStabilize+AgInsure is in place for 2008 and 2009. The newer program is a derivative of the CAIS program but with differentiating features that can be economically meaningful.

The CAIS program is a whole farm insurance program which differs only in the measurement of payouts and in the premium setting. It is whole farm insurance in the sense that all eligible farm enterprises are included in the mix, and payouts are based on the income as a whole. This is in comparison to GRIP type programs which provide insurance on its parts. CAIS pays out on accrued income (after adjustments for inventory, receivables and payables) and is defined by a margin equal to the accrued difference between revenues and eligible expenses. Ineligible expenses include capital costs, depreciation, wages, salaries and so on.

CAIS is a three-tiered program to protect against income losses below a targeted margin. The targeted margin is normally the average margin over the past 5 years although in the present formulation the margin is based upon current market risks on a mark-to-market basis. The three tiers are mathematically defined as follows:

$$
(17) \quad
\begin{aligned}
&tier\ 1 = 0.50 \times Min\left[0.15K, K - \sum_{i=1}^{n} R_{j,i}x_i\right] \ \ for\ 0.85K \le \sum_{i=1}^{n} R_{j,i}x_i \le K \\
&tier\ 2 = 0.70 \times Min\left[0.15K, 0.85K - \sum_{i=1}^{n} R_{j,i}x_i\right] \ \ for\ 0.70K \le \sum_{i=1}^{n} R_{j,i}x_i < 0.85K \\
&tier\ 3 = 0.8 \times Min\left[0.7K, 0.70K - \sum_{i=1}^{n} R_{j,i}x_i\right] \ \ for\ \sum_{i=1}^{n} R_{j,i}x_i < 0.70K \\
&I = Min\left[0.65\left(K - \sum_{i=1}^{n} R_{j,i}x_i\right), tier\ 1 + tier\ 2 + tier\ 3\right] \ for\ \sum_{i=1}^{n} R_{j,i}x_i < K
\end{aligned}
$$

In words, if income falls to within 85% of the elected margin the farmer will receive 50% of the shortfall in tier 1. If the margin is below 85% of the elected margin but above 70%, then tier 2 indemnities pay 70% of the shortfall, and if the margin is less than 70% of the shortfall then the farmer will receive an indemnity of 80% of the shortfall. In other words, the more severe is the loss the greater weight is put on the indemnity. The final indemnity is equal to the sum of the three tiered payouts, but the total payout cannot exceed 65% of the total shortfall below the elected margin.

The actual legislated premium assigned to CAIS is not actuarially sound. In actuality it is defined as $v = 0.85 \times \frac{Z}{1,000} + \$55$. In other words the legislated premium is tied to the target income and not the underlying risk. In addition to evaluating portfolio choice with this premium I also investigate portfolio choice if premiums are actuarially sound and subsidized at 50% of the actuarial rate.

The Canadian AgrInvest Policy

The 2008 program is to some extent similar to the CAIS program but differs in several respects. First, there is no tier 1 payout under the new program. Instead, under AgrInvest, farmers can set aside 1.5% of eligible sales into a savings account and this will be matched by the Government. Under AgriStability tier 2 and tier 3 payouts are combined such that any shortfall below 85% of margin will be indemnified up to 70% and any negative shortfall would be indemnified to 65%. Finally AgrInsure provides for multiple peril crop insurance so that crop insurance payouts can be received even if final margins exceed the target margin, but are added to the margin in the event of a whole farm loss to decrease AgriStability payouts. Mathematically we have:

$$AgrInvest = 0.015\sum_{i=1}^{n} \hat{R}_{j,i} x_i$$

$$AgStability = 0.70 \times Min\left[0.85K, 0.85K - \sum_{i=1}^{n} R_{j,i} x_i\right] \quad 0 \le \sum_{i=1}^{n} R_{j,i} x_i < 0.85K$$

$$+ 0.65 \times ABS\left[0 - \sum_{i=1}^{n} R_{j,i} x_i\right] \quad \sum_{i=1}^{n} R_{j,i} x_i < 0$$

(18) $$I = AgrInvest + AgStability$$

Where $\hat{R}_{j,i} x_i$ represents net eligible sales. The indemnity can also include crop insurance if there is a crop insurance payout but not an AgriStability payout, however in this paper we exclude AgrInsure (the optional addition of crop insurance) to focus exclusively on the whole farm income component. Note that we do not exclude AgrInvest as a passive benefit. Even though the amount invested is contingent on the gross revenue item it is still a benefit tied to production and production decisions. It is entirely possible that a variable (random) payout on revenues is not neutral and needs to be investigated separately. This is especially true if money is considered fungible between savings and investment.

The critical element with the AgrInvest program is the cost to farmers. In essence, for the maximum coverage farmers will pay $4.50 per $1,000 of margin plus a $55 administrative fee. For example a margin of $100,000 will cost the farmer only $450 plus $55 = $505, which is extraordinarily low for the insurable and investment benefit. (Crop insurance under AgrInsure is sold as a separate risk management product.)

Optimizing the CAIS and AgrInvest programs are however, a simple modification of the model presented above.

$$Min\ \ \sigma_p^2 = \frac{1}{m}\sum_{j=1}^{m}\left(\pi_j - E\left[\pi\right]\right)^2$$

$$Subject\ \ to$$

$$\sum_{i=1}^{n} x_i = 1,000$$

$$\sum_{i=1}^{n} E\left[R_i\right] x_i = K$$

$$\sum_{i=1}^{n} R_{1,i} x_i + I_1 - \delta E\left[I\right] - \pi_1 = 0$$

$$\sum_{i=1}^{n} R_{2,i} x_i + I_2 - \delta E\left[I\right] - \pi_2 = 0$$

$$\vdots$$

$$\sum_{i=1}^{n} R_{j,i} x_i + I_j - \delta E\left[I\right] - \pi_j = 0$$

$$\vdots$$

$$\sum_{i=1}^{n} R_{m,i} x_i + I_m - \delta E\left[I\right] - \pi_m = 0 \qquad (19)$$

Where I_j are the CAIS benefits as defined above and $\delta E\left[I\right]$ is the cost to the farmer with $E\left[I\right]$ representing the actuarial value of the cost and δ represents a discount or subsidy.

Rotational Constraints

In addition to the land and income constraints identified in the models constraints were also imposed on production. Crop rotational constraints in Manitoba are designed to mitigate the emergence of plant diseases. For Manitoba the constraints are a) canola acres can be no more than 250 acres and no less than 200 acres; b) flaxseed acres can be no greater than canola acres; c) the total of field peas plus lentil acres must equal canola acres; and d) acres planted to hard red wheat must exceed acres planted to durum wheat. No constraints were imposed on barley beyond the marginal effects of the explicit constraints. Varying target income levels (e.g. $175,000) results in different farm portfolios with different risk profiles. Ultimately we seek to understand how and to what extent the various agricultural risk management policies could affect portfolio choices and management practices.

Data and Assumptions

The representative farm models for Manitoba requires data from multiple sources. The approach used in this study differs from most optimization approaches in its use of generating random crop price, yield and revenue outcomes with Monte Carlo techniques. The first step was to generate correlated prices and yields from distributions ‘consistent’ with observed price dynamics (a random walk) and crop yield distributions (normally distributed) for a representative Manitoba cash crop farm. Prices reflect actual conditions in the spring of 2008 and were obtained from common media sources and the Winnipeg Commodity Exchange. Drift and Volatility measures were obtained from studies conducted by the author as well as from data provided at the Winnipeg Commodities Exchange and the Chicago Mercantile Exchange. It was assumed in all cases that the price path over 180 days followed a geometric Brownian motion (a random walk). Crop yields were obtained from historical data (Statistics Canada; Manitoba Agriculture;). In all cases crop yields were based on provincial averages which were tested using Palisades’s Best Fit computer program. Despite findings of non-normality in some studies the assumption of normality as an approximation to any of the crop yields could not be ruled out and so for convenience, and with no loss in generality, we assumed normally distributed yields for all crops. Crop yields represent provincial averages, and while the averages are consistent with actual individual farm yields, the standard deviations were not. A study by the author showed that on average individual farm yields ranged from about 66% to 125% higher than an ‘average’ yield metric. Hence, while keeping mean yields at their historical provincial average all standard deviations were increased by 75% [5] .The data are reported in Table 1.

Costs of production (Tables 1) were obtained from cost of production and enterprise budgets prepared by the agricultural ministry in Manitoba and are based on an acre basis. Price and yield correlations used are reported in Table 2. The costs of Gross Revenue Insurance were obtained using Monte Carlo simulation. These are reported in Table 3 and are based on 20,000 Monte Carlo replications to ensure convergence under the law of large numbers. In the

[5] These two assumptions, the normality of yields and the adjustment in standard deviation may be questioned by some researchers. While a variety of researchers report that crop yield distributions follow normal or beta or some other distribution, in reality no two crop distributions are alike (Turvey and Islam 1995). The use of a beta distribution is as questionable as a gamma or for that matter a normal. What we seek here is a representative distribution. Altering the assumptions will not alter the storyline of this paper. Nonetheless, to ensure validity of the data used, the author met with a group of Western Canadian farmers in 2008 who were provided the adjusted data as well as images of the probability distribution. The farmers examined the distributions and confirmed agreement with them as being appropriate and representative.

optimization models that follow, only the first 1,000 Monte Carlo iterations were used. Every Monte Carlo simulation used the same initial seed so that the all models can be compared directly.

Table 1: Manitoba Yields and Prices

Crop		Mean Yield	Std Dev Yield	Mean Price	Std Dev Price	Annualized Drift	Variable Costs
				Manitoba			
Hard red	Tonne	2.38	0.34	6.62	0.24	0.02	149.02
Durum wheat	Tonne	2.23	0.40	9.78	0.24	0.02	141.72
Barley	Tonne	3.03	0.42	4.06	0.19	0.02	139.07
Dry field peas	Tonne	2.11	0.45	6.22	0.22	0.02	150.73
Flaxseed	Tonne	1.24	0.20	18.12	0.22	0.02	123.60
Canola (rapeseed)	Tonne	1.49	0.23	13.89	0.21	0.02	192.17
Lentils	Tonne	1.25	0.32	14.02	0.20	0.02	168.24

Table 2: Yield and Price Correlations: Manitoba

	Hard red Yield	*Durum wheat Yield*	*Barley Yield*	*Dry field peas Yield*	*Flaxseed Yield*	*Canola Yield*	*Lentils Yield*	*Hard red Price*	*Durum wheat Price*	*Barley Price*	*Dry field pea Price*	*Flaxseed Price*	*Canola Price*	*Lentils Price*
Hard Red Yield	1.000													
Durum wheat Yield	0.521	1.000												
Barley Yield	0.846	0.598	1.000											
Dry field peas Yield	0.135	-0.102	-0.275	1.000										
Flaxseed Yield	0.797	0.321	0.627	0.445	1.000									
Canola Yield	0.296	0.486	0.557	-0.254	0.100	1.000								
Lentils Yield	0.801	0.234	0.517	0.464	0.679	0.280	1.000							
Hard red Price	0.174	0.316	0.101	-0.109	0.280	-0.190	-0.023	1.000						
Durum wheat Price	0.174	0.316	0.101	-0.109	0.280	-0.190	-0.023	1.000	1.000					
Barley Price	0.267	0.357	0.213	-0.150	0.362	-0.112	0.017	0.976	0.976	1.000				
Dry field peas Price	-0.192	0.462	-0.101	-0.218	-0.195	0.149	-0.249	0.595	0.595	0.547	1.000			
Flaxseed Price	0.128	0.177	0.154	-0.339	0.117	-0.122	-0.069	0.847	0.847	0.879	0.526	1.000		
Canola Price	0.127	0.114	-0.069	0.285	0.377	-0.236	0.142	0.800	0.800	0.802	0.522	0.762	1.000	
Lentils Price	0.132	0.134	0.101	-0.188	0.060	-0.213	-0.026	0.557	0.557	0.501	0.017	0.399	0.185	1.000

Table 3: Manitoba Computed Insurance Cost at 80%

Manitoba Premiums	Hard red	Durum wheat	Barley	Dry field peas	Flaxseed	Canola (rapeseed)	Lentils
Manitoba Revenue Insurance 80%	10.16	18.02	7.70	14.23	17.74	17.37	26.14
Manitoba Revenue Insurance 90%	17.63	28.97	14.37	21.07	29.40	29.34	35.87

Results

We will discuss the results in two steps. First we will use tables 4 and 5 to discuss the crop plans and illustrate how different assumptions about farmer behaviour (risk aversion, skewness preference) and differing attributes in policy design can affect crop choices. The tables themselves obscure some interesting results one of which is the relationship between skewness preference and indemnity. We then discuss more broadly the various relationships between risk and return and dominance in the context of the E-V and E-S models as well as expected utility maximization.

Table 4 provides the mean-variance results for portfolios ranging from $125,000 to $185,000, with and without the subsidy. Here the policy interest is the extent by which farmers could alter their farm plan and crop mix in response to targeted income levels and policy parameters. All categories are considered relative to the uninsured base case. Without subsidy Income Insurance, CAIS and AgrInvest are production neutral in the sense that these plans are virtually identical to the base plan. For example at a Target of $145,000 the optimum strategy is to grow 38 acres each of hard red and durum wheat, 174 acres of barley, 250 acres of peas, flax, and canola and 0 acres of lentils. The specific mix reflects the income and skewness preferences as well as the production constraints. The commodity specificity of GRIP in contrast grows 51 acres of hard red winter wheat, 51 acres of durum, 196 acres of barley, 203 acres of peas, 234 acres of flax and canola and 0 acres of lentils[6]. The E-V frontiers for base, CAIS and AgrInvest models are provided in Figure 1

The effect of subsidy can also be seen. With a 50% subsidy on premiums the GRIP solution includes no wheat, 309 acres of barley, 230 acres of peas, flax and canola and no lentils.. The CAIS program reduces flax from 250 to 187 acres while barley increases from 173 acres to 413 acres. Peas and canola are reduced from 250 acres to 200 acres. Similarly Whole farm income insurance grows 416 acres of barley, 200 acres each of field peas and canola and 184 acres of flax. When the legislated premium is charged for CAIS, a further shift is observed with 545 acres of winter wheat, 4 acres of durum wheat, 200 acres of peas, 51 acres of flax, and 200

[6] To place commodity specificity in context we ran the GRIP model with only wheat and barley targeted for insurance. At $145,000 the final solution was 200.00, 200.00, 0.00, 113.36, 200.00, 200.00, 86.64 acres for hard red, durum, barley, field peas, flax, canola and lentils respectively. With GRIP and insurance targeted to grains alone, the portfolio effects are evident.

Table 4: Optimum Farm Plans, Manitoba with Constrained Crop Choice. Optimization minimized risk subject to a land, growing constraints, and income constraint. The base case excludes all farm programs. GRIP is a revenue insurance plan that provides indemnities if the individual crop margin falls below 80% of specified expected crop margin. Income Insurance is a whole farm insurance plan with whole farm coverage at 80% of target income. AgrInvest and CAIS are constructed according to the Canadian Agricultural Income and Stabilization program and its 2008 modification respectively. Optimization based on 1,000 jointly determined random outcomes.

Mean	Winter Wheat	Durum Wheat	Barley	Peas	Flax	Canola	Lentils	Indemnity	Premium	STD	Max	Min	Skew
125,000	0	0	450	200	150	200	0			90,960	476,289	-123,626	0.402
145,000	38	38	174	250	250	250	0			100,360	533,503	-132,776	0.385
165,000	125	125	0	17	250	250	233			117,077	629,072	-152,300	0.402
						GRIP 50%							
125,000	0	0	491	200	109	200	0	12,031	6,016	74,128	446,895	14,249	1.033
145,000	0	0	309	230	230	230	0	13,748	6,874	79,253	487,489	38,739	1.072
165,000	97	97	56	136	250	250	114	16,856	8,428	88,514	537,863	63,525	1.137
						GRIP 100%							
125,000	0	0	451	200	149	200	0	12,441	12,441	75,568	453,148	15,308	1.045
145,000	51	51	196	203	234	234	30	14,852	14,852	82,647	499,419	40,623	1.101
165,000	125	125	0	25	250	250	225	18,542	18,542	93,989	552,288	59,574	1.168
						Income 50%							
125,000	0	0	548	200	52	200	0	29,042	14,521	57,573	421,097	85,479	1.802
145,000	0	0	416	200	184	200	0	29,949	14,974	62,737	475,402	101,026	1.748
165,000	78	78	93	250	250	250	0	32,642	16,321	69,853	526,519	115,679	1.727
185,000	125	125	0	0	250	250	250	38,082	19,041	79,967	615,661	128,959	1.756
						Income 100%							
145,000	38	38	174	250	250	250	0	26,353	26,353	72,300	507,150	89,647	1.543
155,000	125	125	0	209	250	250	41	28,164	28,164	77,369	538,616	95,836	1.556
165,000	125	125	0	17	250	250	233	31,168	31,168	84,155	597,978	100,832	1.572
						CAIS Legislated							
145,000	545	4	0	200	51	200	0	37,744	708	57,378	474,702	-20,889	1.622
165,000	0	0	440	200	160	200	0	39,379	798	57,543	468,247	1,859	1.597
185,000	17	17	216	250	250	250	0	42,820	888	62,040	506,496	10,265	1.603
205,000	125	125	0	144	250	250	106	47,663	978	69,261	551,657	13,069	1.632
215,000	125	125	0	8	250	250	242	50,627	1,023	73,934	572,337	11,701	1.620
						CAIS 50%							
125,000	0	0	541	200	59	200	0	27,092	13,546	60,903	423,932	-41,330	1.351

Mean	Winter Wheat	Durum Wheat	Barley	Peas	Flax	Canola	Lentils	Indemnity	Premium	STD	Max	Min	Skew
145,000	0	0	413	200	187	200	0	29,446	14,723	64,648	462,461	-26,650	1.404
165,000	79	79	92	250	250	250	0	32,700	16,350	71,433	507,734	-22,936	1.421
184,000	132	132	0	0	245	245	245	37,349	18,674	82,171	555,072	-28,882	1.417
						CAIS 100%							
125,000	0	0	449	200	151	200	0	23,336	23,336	67,346	442,715	-50,359	1.265
145,000	39	39	173	250	250	250	0	25,897	25,897	73,979	487,268	-45,362	1.277
165,000	125	125	0	16	250	250	234	30,118	30,118	86,594	542,082	-53,906	1.285
						AgrInvest Legislated							
145,000	0	0	524	200	76	200	0	31,571	610	61,617	451,224	38,070	1.518
165,000	0	0	393	202	202	202	0	32,982	686	66,535	491,176	50,172	1.491
185,000	102	102	62	245	245	245	0	36,009	763	73,840	537,519	57,996	1.497
205,000	125	125	0	12	250	250	238	40,655	839	83,582	582,847	62,855	1.498
						AgrInvest 50%							
125,000	0	0	536	200	64	200	0	25,713	12,856	65,125	434,925	13,882	1.369
145,000	0	0	405	200	195	200	0	27,017	13,509	70,313	475,666	25,551	1.347
165,000	96	96	59	250	250	250	0	29,683	14,841	78,452	523,973	31,889	1.348
180,000	161	161	0	0	226	226	226	33,239	16,620	88,256	564,686	32,945	1.372
						AgrInvest 100%							
125,000	0	0	449	200	151	200	0	22,876	22,876	71,428	452,411	4,142	1.249
145,000	39	39	173	250	250	250	0	24,866	24,866	78,964	498,276	11,080	1.231
165,000	125	125	1	15	250	250	235	28,842	28,842	92,127	554,294	11,134	1.251

Table 5: Optimum Farm Plans, Manitoba with Constrained Crop Choice. Optimization maximizes skewness subject to a land, growing constraints, and income constraint. The base case excludes all farm programs. GRIP is a revenue insurance plan that provides indemnities if the individual crop margin falls below 80% of specified expected crop margin. Income Insurance is a whole farm insurance plan with whole farm coverage at 80% of target income. AgInvest and CAIS are constructed according to the Canadian Agricultural Income and Stabilization program and its 2008 modification respectively. Optimization based on 1,000 jointly determined random outcomes.

Mean	Winter Wheat	Durum Wheat	Barley	Peas	Flax	Canola	Lentil	Indemnity	Premium	STD	Max	Min	Skew
						base							
125,000	453	147	0	0	0	200	200			103,769	506,812	-149,135	0.469
145,000	226	226	0	200	147	200	0			103,843	543,938	-136,810	0.450
165,000	138	138	0	0	241	241	241			117,488	629,914	-152,317	0.409
						GRIP 50%							
125,000	532	68	0	0	0	200	200	15,334	7,667	81,427	480,613	40,062	1.230
145,000	407	60	0	0	133	200	200	16,281	8,140	85,419	501,383	56,778	1.205
165,000	245	128	0	0	209	209	209	17,600	8,800	91,312	541,577	62,403	1.185
						GRIP 100%							
125,000	475	87	0	0	38	200	200	15,769	15,769	83,415	482,257	35,593	1.219
145,000	360	40	0	0	200	200	200	16,628	16,628	86,835	502,517	57,817	1.197
165,000	138	112	0	0	250	250	250	18,735	18,735	94,448	552,091	61,238	1.175
						Income 50%							
125,009	505	95	0	200	0	200	0	31,464	15,732	60,849	455,246	84,269	1.901
145,010	317	283	0	200	0	200	0	33,672	16,836	67,715	511,544	99,166	1.874
165,000	271	271	0	0	58	200	200	37,410	18,705	75,938	546,644	113,293	1.833
185,000	125	125	0	0	251	250	250	37,240	18,620	80,003	615,922	128,975	1.755
						Income 100%							
125,000	349	251	0	200	0	200	0	27,203	27,203	70,861	491,528	72,797	1.678
145,000	277	277	0	0	45	200	200	30,729	30,729	80,513	530,862	85,271	1.647
165,000	138	138	0	0	241	241	241	31,302	31,302	84,490	598,611	100,698	1.579
						CAIS Legislated							
145,000	523	77	0	200	0	200	0	38,219	708	58,548	481,555	-23,574	1.629
165,000	361	239	0	200	0	200	0	42,047	798	63,099	514,312	-12,399	1.683
185,000	244	244	0	200	111	200	0	44,654	888	65,420	539,459	4,533	1.709
205,000	200	200	0	60	200	200	140	48,392	978	70,515	559,115	13,149	1.681
215,000	132	132	0	0	245	245	245	50,705	1,023	74,065	572,711	11,718	1.625
						CAIS 50%							
125,000	599	1	0	0	0	200	200	29,570	14,785	69,560	459,863	-63,595	1.352

Mean	Winter Wheat	Durum Wheat	Barley	Peas	Flax	Canola	Lentil	Indemnity	Premium	STD	Max	Min	Skew
145,000	307	293	0	200	0	200	0	31,689	15,845	71,529	514,813	-43,421	1.483
165,000	210	210	0	200	181	200	0	33,317	16,658	73,149	528,378	-23,807	1.488
184,000	132	132	0	0	245	245	245	37,349	18,674	82,171	555,072	-28,882	1.417
CAIS 100%													
125,000	452	148	0	0	0	200	200	26,017	26,017	78,413	480,896	-78,042	1.280
145,000	226	226	0	200	148	200	0	26,753	26,753	77,169	516,078	-49,751	1.353
165,000	137	137	0	0	242	242	242	30,208	30,208	86,936	542,979	-54,126	1.292
AgrInvest Legislated													
145,000	480	120	0	200	0	200	0	33,784	610	65,505	500,136	33,612	1.651
165,000	304	296	0	200	0	200	0	36,150	686	72,017	541,421	43,818	1.633
185,000	272	272	0	0	56	200	200	39,778	763	80,070	566,264	51,065	1.580
205,000	136	136	0	0	243	243	243	40,749	839	83,792	583,461	62,852	1.504
AgrInvest 50%													
125,000	596	4	0	0	0	200	200	28,952	14,476	72,837	470,346	3,649	1.459
145,000	300	297	0	198	3	200	2	29,635	14,817	76,747	528,371	17,760	1.470
165,000	259	259	0	0	82	200	200	32,563	16,282	85,473	552,568	23,994	1.421
180,000	161	161	0	0	226	226	226	33,239	16,620	88,256	564,686	32,945	1.372
AgrInvest 100%													
125,000	452	148	0	0	0	200	200	26,296	26,296	81,687	490,631	-9,493	1.342
145,000	277	277	0	0	46	200	200	27,958	27,958	88,415	538,413	-55	1.325
165,000	137	137	0	0	242	242	242	28,925	28,925	92,454	555,214	11,006	1.258

E-V Efficiency Frontiers for CAIS and AgrInvest

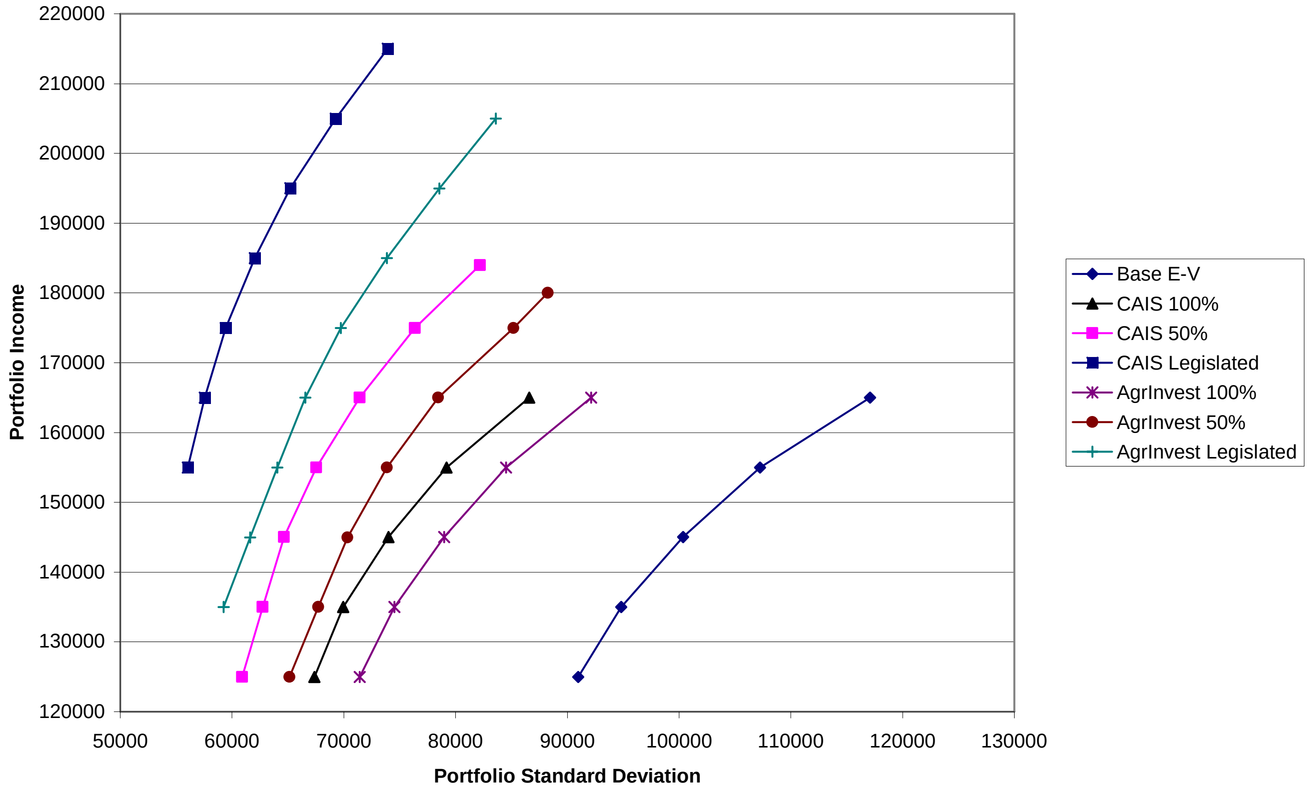

Figure 1: E-V Efficient Frontiers. The figure shows the E-V frontiers for the CAIS and AgrInvest programs in comparison to the base. The two most leftward frontiers represent the current policy with legislated premiums far below actuarial values. The 2nd and 3rd curve from the right represent efficiency frontiers with the farmer paying 100% of the actuarial premium. The combined risk reduction and income effects discussed in the text are evident. As subsidy increases farmers can accept lower risk portfolios in order to achieve the same target income.

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acres of canola. The skewness impact is evident. The base case solution has skewness of 0.385. The GRIP program has an unsubsidized skewness of 1.101 and with the subsidy it is 1.072, Downside risk which reaches a minimum of $-167,255 for the base model, increases to $40,623 with unsubsidized GRIP and $38,739 when subsidized. Likewise, AgrInvest has skewness of 1.23 with a range of $11,080 to $498,276 when unsubsidized, 1.347 with a range of $25,551 to $475,666 when subsidized by 50% and skewness of 1.518 with a range from $38,070 to $451,224 when subsidized at the legislated rate. In general, subsidy increases the skewness of the distribution while increasing the lower bound loss. Note that Income Insurance has the highest minimum value. Income insurance is the only policy that truly truncates the risk at the 80% coverage level. The three-tiered design of CAIS and AgriInvest allows some slippage of downside risk. Figure 2 shows the cumulative distribution functions for whole farm income insurance and GRIP, and illustrates the relationship between risk reduction and premium subsidization.

There are several explanations for these results. The first is when the objective is to satisfy a target income, that is a solution constrained by money rather than risk aversion, the insurance offsets risk to some degree. On an actuarial basis the mean return with and without insurance are the same, but the reallocation of risk permits a different solution. The reduction in variance shifts lower moments to higher moments with a concomitant increase in expected income, but this shift is offset exactly by the actuarial premium. When the premium is subsidized the income effect plays a more dominant role. In order to achieve the stated income the farmer can balance insurance payouts against natural risk, but with the subsidy the degree of risk will be lower. On the basis of higher risk- higher return a risk-free addition to expected income requires that less risk be taken in order to achieve the target. In contrast there are more opportunities to exploit risk at the margin with GRIP type programs. That is the tradeoff between enterprise risk is stronger with the income effect higher for higher risk crops rather than averaged across all crops.

Table 5 provides the solutions for the skewness model[7]. As expected an objective that maximizes skewness results in solutions that are quite different from those in Table 4 that minimize risk[8].

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[7] The reader might be interested in the minimize skewness option. Using the base model for $155,000 we get $x^* = (167, 70, 0, 152, 264, 250, 98)$ with $\sigma = \$109,859$, skewness 0f 0.39, and a range from -$211,238 to $575,832. In comparison the maximize solution is $x^* = (231, 231, 0, 0, 138, 200, 200)$ with $\sigma = \$115,300$, skewness of 0.449 and a range from -$167,255 to $600,003. The equivalent income E-V solution is $x^* = (187, 187, 27, 98, 200, 200, 102)$, $\sigma = \$110,492$, skewness of 0.428 and a range from -$151,957 to $561,848. Minimizing skewness does not necessarily imply a reduction in downside risk. As can be seen the potential loss of $211,238 is far greater than the maximum loss for either the skewness maximization model or the E-V model. Repeating the optimization for Income insurance with a 50% subsidy we find the skewness minimization model solution is $x^* = (0, 0, 352, 200, 247, 200, 0)$ and $\sigma = \$97,139$, skewness of 1.68 and a range from $108,640 to $495,297. The skewness maximization solution is $x^* = (344, 256, 0, 0, 0, 200, 200)$, $\sigma = \$74,531$, skewness of 1.828 and a range from $105,437 to $549,098. Although the skewness max problem

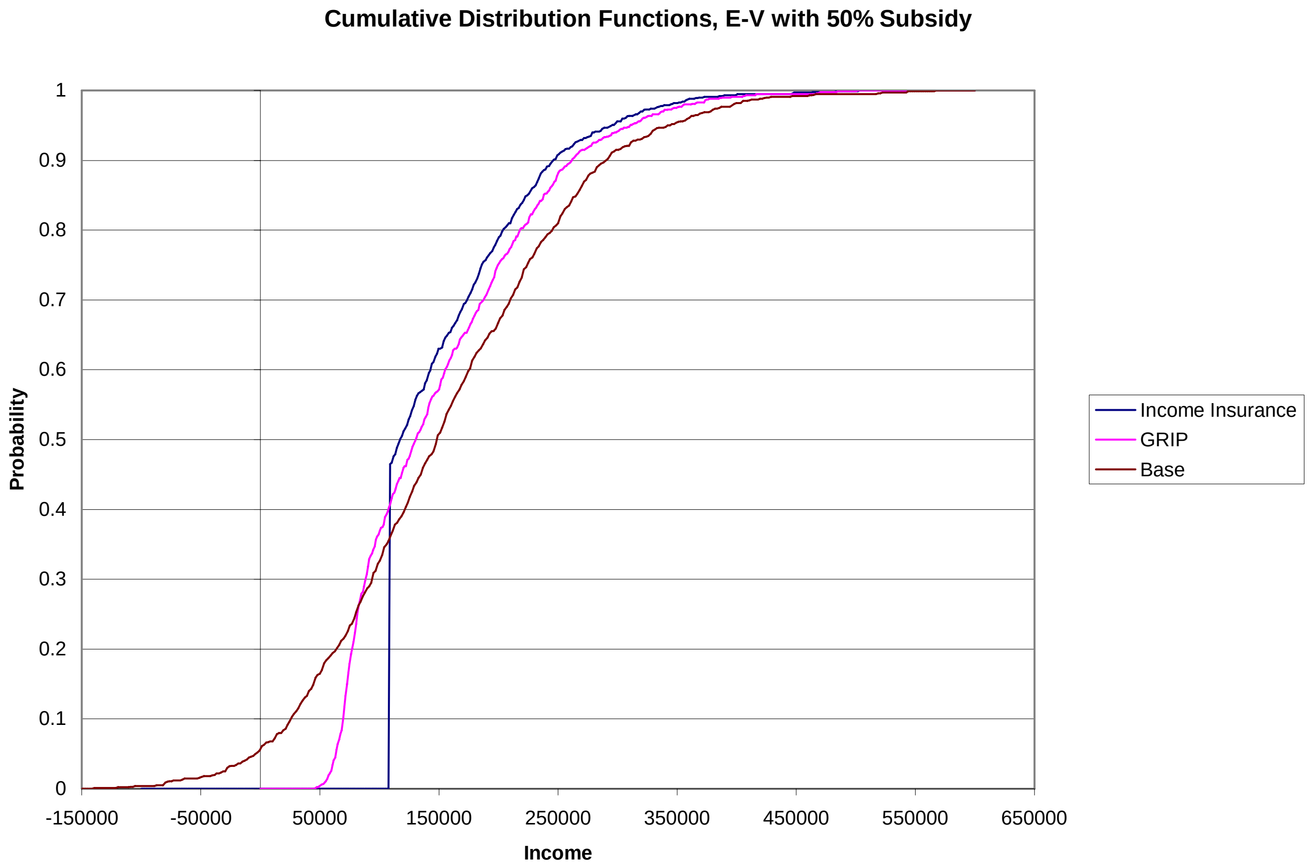

Figure 2: Cumulative Distribution Functions for base Model, Income Insurance and GRIP at Target Income of $155,000. The nature of optimization affects the probability distributions of outcomes. The effect of GRIP relative to the base is to reduce the downside risk and because of the subsidy on insurance the GRP CDF lies mostly above the base model. Whole Farm Income provides greater risk reduction, with the distribution truncated at the 80% of target coverage level. With greater risk reduction the actuarial premium is higher for Whole Farm Income Insurance. The subsidy effect is evident with the Whole Farm Income insurance CDF lying above the GRIP CDF.

The base model at $145,000 grows 226 acres each of hard red and durum wheat, 0 acres of barley, 200 acres of field peas and canola, 147 acres of flax and 0 acres of lentils. The standard deviation of this portfolio is $103,843 with an income range from $-136,810 to $543,938. . Skewness is 0.450. With AgrInvest the mix without subsidy is 277 acres of hard red

has a lower downside outcome, its (truncated) standard deviation is lower and the upside is more than $54,000 higher.

[8] We have also run a set of solutions without the constraints in place. Using the variance minimizing model the unconstrained choices in Manitoba include a combination of flaxseed and barley only. For example a target income of $175,000 has a minimum risk portfolio comprised of 461 acres of barley and 539 acres of flax. The standard deviation of this portfolio is $103,424.

and durum wheat, 0 acres of barley and field peas, and 200 acres of canola and lentils. The standard deviation is $88,415 with an income range from $-55 to $538,413 and skewness of 1.325. When subsidized at the legislated rate the solution is 480 acres of winter wheat, 120 acres of durum, 200 acres of peas and canola and 0.00 acres of barley, flax and lentils. The standard deviation is lower at $65,505 and the range of income, with skewness of 1.651 is from $33,612 to $500,136 .A similar pattern is found for the other safety net programs.

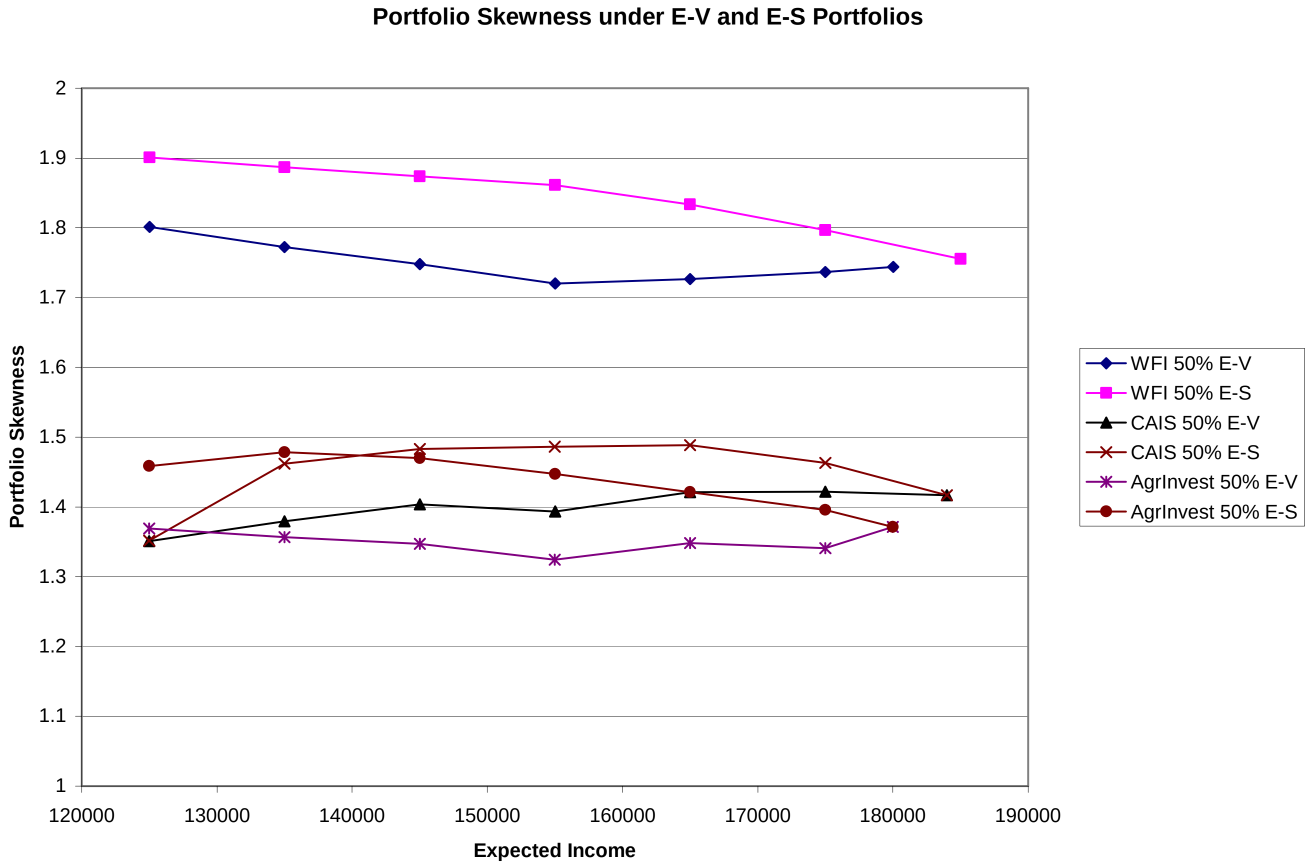

Figure 3: Portfolio Skewness With E-S and E-V Solutions. The Figure compares skewness between the E-S and E-V models for whole farm income insurance (WFI) , CAIS and AgrInvest. By design the maximization of skewness results in higher skewness in all portfolios except the minimum and maximum feasible solutions at which E-S and E-V skewness are equal. Skewness is highest for WFI because the income distribution is truncated at 80%, whereas the three-tiered design of CAIS and AgrInvest provide indemnities on a different scale. There is greater potential for maximizing skewness under the CAIS program than AgrInvest.

Of interest is the general observation that skewness preference has an impact on portfolio selection. Optimizing according to skewness tends to increase (in many instances) standard deviation over the mean variance approach and also affects the range with greater clustering towards favourable outcomes, even at the expense of accepting some downside risk[9].These relationships are shown in Figures 3 and 4.A final point of interest is that all E-V solutions lie on the base E-V frontier while all E-S solutions lie neither on the base E-V nor the base E-S frontier. For example under the 50% GRIP E-V solution for $145,000, the equivalent income of that plan without revenue insurance is $137,967 with standard deviation $96,337.67, a range from $513,872 to -$127,744 and skewness of 0.386. Running the base model for $137,967 provides an identical outcome. However, for the 50% GRIP E-S solution, the base income for that portfolio without the insurance was $136,522 with standard deviation $105,177 , a range $537,858 to -$143,755 and skewness of 0.441. The base skewness model optimized to $136,522 (standard deviation $109,434; range $541,814 to -$153,075; skewness 0.472) did not provide the same solution nor did the base E-V model when optimized to the same income level (standard deviation $95,588; range $509,506 to -$126,615; skewness 0.389). This is due to certain convexity properties which hold under the E-V rule but not under the E-S rule (see Figure 4).

[9] As discussed in the text the necessary conditions for $g(\pi)\rangle f(\pi) \Rightarrow \mu_g = \mu_f \;\; and \;\; \sigma_g \le \sigma_f$ (see for example Eq 2). Our skewness model did not impose this restriction. However, for completeness we ran several optimizations on the base model that included the restriction in the skewness model. No interior solution resulted that would have confirmed a dominant TSD solution. Imposing the constraint resulted in solutions identical to the base E-V solutions, which is no more than a confirmation that all SSD solutions are part of the TSD set. Likewise for the whole farm insurance models. The E-S models with standard deviation constrained was identical to the E-V solution.

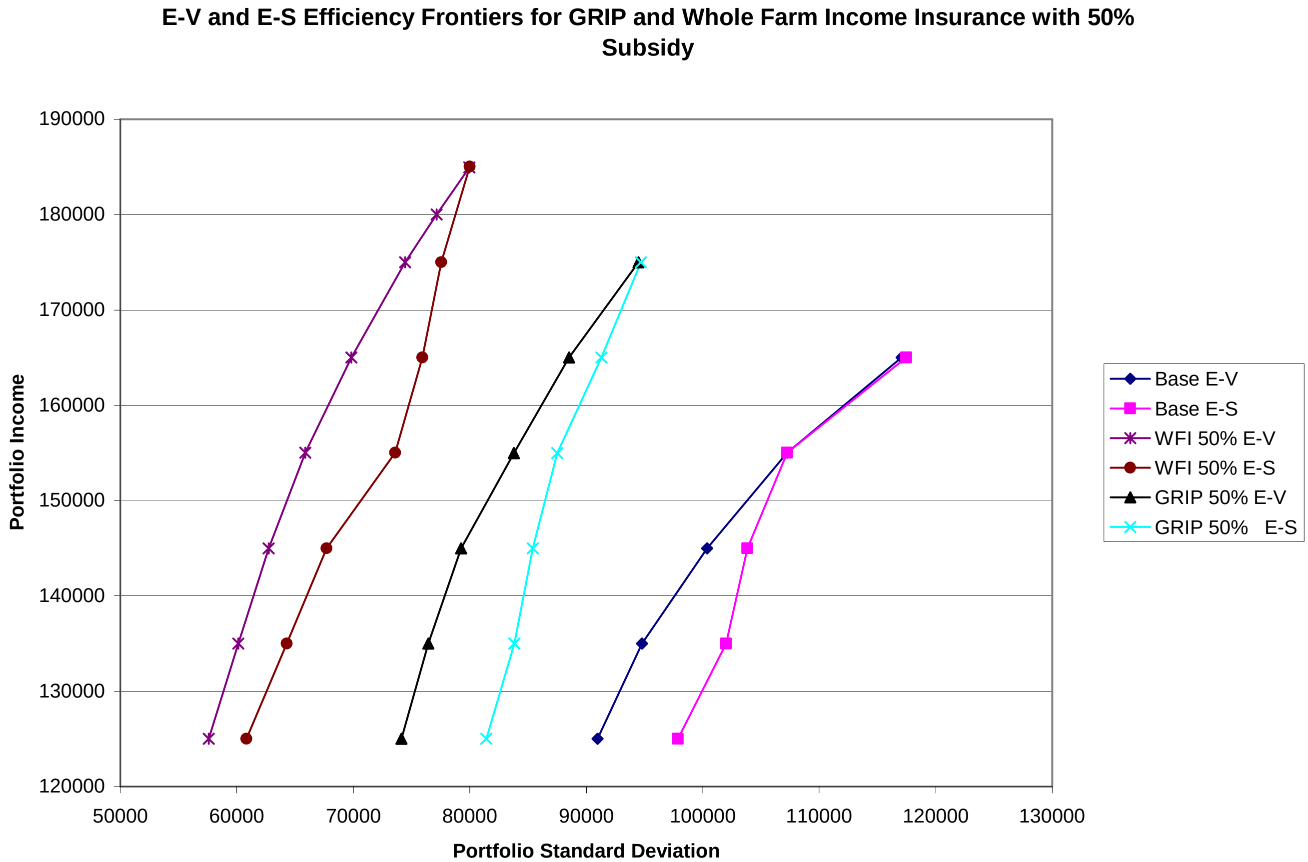

Figure 4: E-V and E-S Efficiency Frontiers. The figure compares the efficiency frontiers in mean-standard deviation space for GRIP and Whole Farm Income Insurance (WFI). These relationships are typical of all E-V and E-S comparisons. The E-S frontier lies everywhere below the E-V frontier, except at the maximum and minimum feasible solutions at which they are equal. Because the E-S frontier lies below the E-V frontier portfolio standard deviations are higher, which indicates that the necessary conditions for the skewness maximization model to dominate the mean variance model by TSD is not satisfied. Because the condition is not sufficient we cannot conclude that the E-S solutions between the minimum and maximum feasible solutions either dominate or do not dominate the E-V solutions by TSD. What is clear is that in order to optimize positive skewness and hence a higher potential gain in the upper partial moments, decision makers will have to accept considerably greater risk. However, because downside risk is reduced or truncated with insurance a source if increased variability can be attributed to the spread between the higher upper bound of the income distribution that comes with skewness preference. Thus, although portfolio standard deviation is higher this does not necessarily imply that the incremental variability is undesirable. What is evident is that comparisons across models do satisfy the necessary conditions. Thus we can state that E-S portfolios under GRIP or WFI dominate the base model by TSD and that WFI dominates GRIP by TSD but we cannot conclude that E-S decisions for GRIP (as an example) dominates E-V decisions by TSD.

Constant Absolute Risk Aversion and Expected Utility Maximization

In the discussion above we observed that in order to meet a fixed target under the E-V rule farmers will select lower risk portfolios. How this translates into an expected utility framework is discussed in this section. We do this with a simple modification of the objective function by substituting the standard utility maximization objective, $EU\left[K\right] = K - \frac{\alpha}{2}\sigma^2$, for variance and removing the income constraint. It is well known that the coefficient of constant absolute risk aversion in the expected utility maximization model can be extracted from the shadow price of the income constraint from the variance minimization model. For example the implied constant absolute risk aversion coefficient extracted from the inverse of the shadow price on the income constraint from the base model with a $145,000 income target is 0.000031757. Applying this coefficient to the expected utility maximizing objective will provide an identical result. However when applied to the appropriately modified GRIP model the solution yields a utility maximizing income of $160,579 with (skewed) standard deviation $90,789. When GRIP is subsidized by 50% the solution is at $173,809 with a (skewed) standard deviation of $93,678. Likewise, optimizing utility with the whole farm income insurance model yielded expected income of $152,874 and a (truncated) standard deviation of $78,057 without the subsidy, and $162,544 with (truncated) standard deviation $79,520 with the 50% subsidy applied. In all cases the expected utility model with insurance yielded solutions that were higher on the base E-V frontier (i.e higher risk and higher income) than the base solution of $145,000 with equivalent risk aversion. Furthermore the riskiness of the portfolios got larger as the subsidy increased. This leads us to conclude that agricultural insurance, in general, inhibits risk aversion and encourages farmers to take production risks that would not ordinarily be taken in the absence of insurance.

Portfolio Choice and Expected Indemnity

Tables 4 and 5 also provide the expected indemnities premiums for the income insurance models when the insurance is charged an actuarial rate, subsidized by 50% and in the cases of CAIS and AgrInvest the much lower legislated rate (between approximately $600 and $900 total). These are illustrated in Figure 5. The indemnities reported are the mean insurance payouts that would have occurred under each of the programs across the 1,000 states of nature used in the model build. Under the indemnity columns the reported values are equal to the actuarial premiums by definition. Under the premiums columns the numbers reported are the total premiums charged with 100% indicating that the farmer pays the full premium, 50% for half the actuarial premium and then the legislated rate. For example the premium for Income insurance with coverage at 80% of $145,000 under the risk minimization model would be $26,353 in premium to receive $26,353 of expected indemnity. At 50% the premium is $29,949 but the farmer pays only $14,974 .The premiums under the legislated plans are, as discussed previously, low and unrelated to the actuarial structure of risk. For CAIS at $145,000 the farmer would pay only $708 to receive $37,744 in expected indemnity and with AgrInvest they would pay only $610 to receive $31,571 of expected indemnity.

The table confirms the various propositions discussed. First, farmers will respond to the premium structure. The greater the subsidy the greater will be the willingness of farmers to accept strategies with lower downside risk and hence will receive higher expected indemnities[10]. For example under the EV strategy for CAIS at a target income of $145,000 the expected indemnities are $25,897 when the farmer pays the actuarial premium, $29,446 when the premium is subsidized by 50% and $37,744 when the much lower legislated premium is charged. Second, as target income increases so does the expected indemnity. This is an expected result since higher income implies greater risk. For example under AgrInvest with the actuarial rate the EV solution shows expected indemnities increasing from $22,876 to $28,842 as target income increases from $125,000 to $165,000. Third, at equivalent income levels farmers with skewness preference will tend towards solutions that have higher downside risk. But examining Table 5 this is a tendency and not a generality. Indeed, at least two feasible solutions, that with the lowest feasible expected income and that with the highest will result in exact solutions for either risk

[10] Maximizing skewness does not necessarily mean the same as maximizing the indemnity, although they are closely related. Altering the model to maximize indemnity payouts alters the farm plan. In general maximizing indemnity increases the standard deviation and decreases skewness. In other words, one cannot make the claim that maximizing skewness is the same as maximizing indemnity. For example with a 50% subsidy maximizing indemnity with a target income of $155,000 results in an expected payout of $37,996 compared to $37,090 for the E-S solution, but skewness is lower (1.844 vs. 1.861) and portfolio standard deviation is higher ($74,236 vs. $73,610). Across all target income levels alternative strategies could be implemented to increase indemnities by as much as 9.3% (for $135,000) with an increase in standard deviation of 4.7% and a decrease in skewness of 1.14%. Under rational assumptions of expected utility maximizations one could dismiss the idea of indemnity maximization, but in more practical terms indemnity maximization could be a feasible strategy for non utility maximizers. Of additional interest is the discovery that solutions based on the σ^3 measure provide solutions identical to the indemnity maximization models for WFI. The reasoning behind the differences, we conjecture, is that the skewness measure moderates σ^3 by the standard deviation. For the base model using σ^3 rather than skewness resulted in identical strategies.

minimizers or skewness maximizers. The interesting results are with the GRIP solution. In all cases, the lower income of the skewness portfolio is significantly higher than the E-V portfolio. With a 50% subsidy and a target of $145,000 the lowest income outcome under E-V is $38,739 but for the skewness portfolio it is $56,778. This is a differentiating characteristic of commodity specific programs which are better able to target risk management in terms of marginal risk reduction rather than the portfolio approach which targets risk management to the portfolio average.

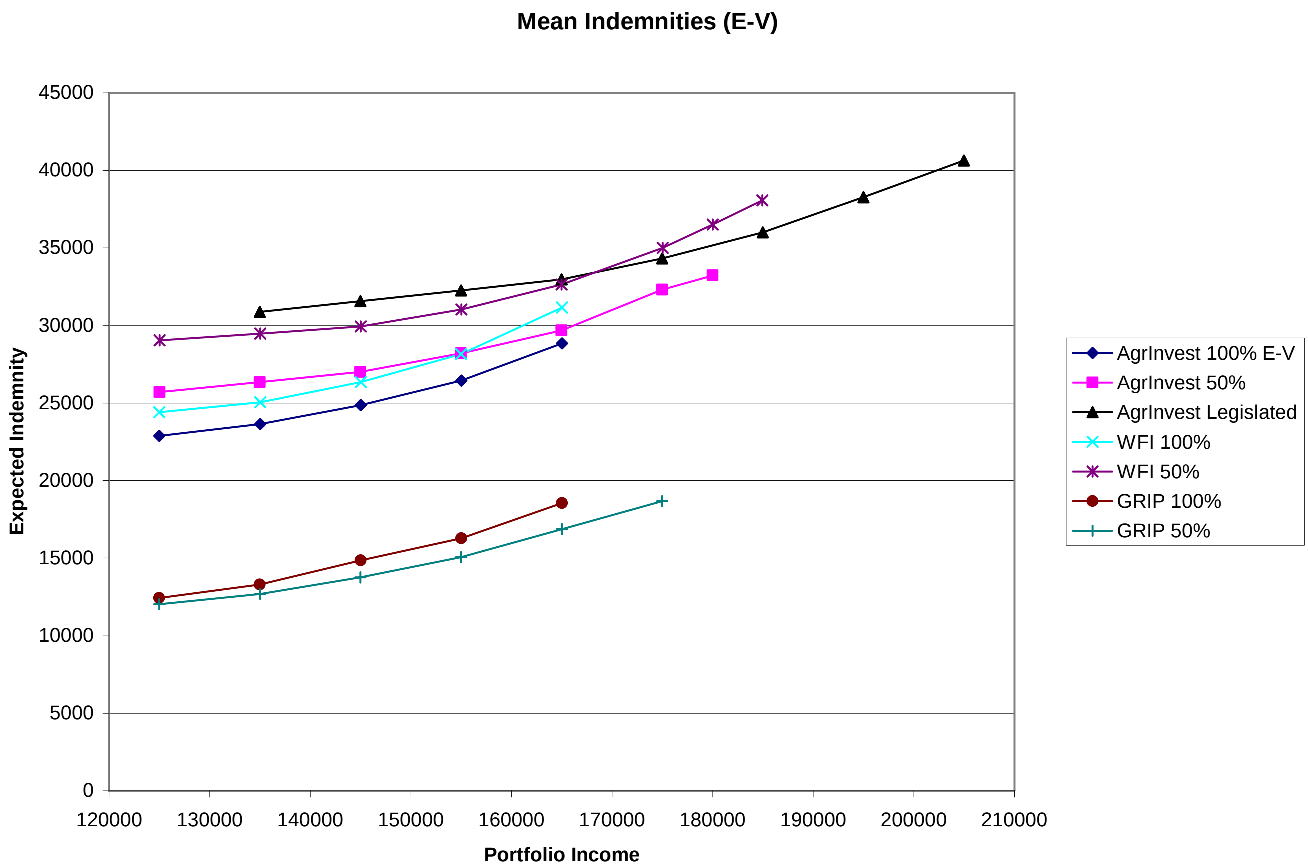

Figure 5 Expected Indemnities for E-V Solutions. The figure shows the level of indemnities for E-V solutions on AgrInvest, Whole Farm Income (WFI) and GRIP. WFI at 50% and AgrInvest at the legislated premium correspond with the higher expected indemnity. For AgrInvest and WFI expected indemnities increase with subsidy which strongly suggests that an unintended consequence of subsidy is that farmers will select lower income strategies and rely on subsidy to meat target income. This is not the case for GRIP which shows that an increased subsidy actually lowers expected payouts.

Discussion, Conclusions, and Policy Recommendations

This paper has investigated the effects of whole farm income insurance on farm portfolio choice. A representative Manitoba farm model was used for crops grown, prices received, inputs purchased, and growing conditions including crop rotational constraints. The main problem addressed in this study was to determine how safety net programs such as GRIP, Income Insurance, CAIS and AgrInvest affected crop choices. To do these two mathematical programming models were employed. The first is a mean variance model in which the objective is to minimize risk, while the second was developed to maximize skewness. There are two novel contributions here. First, the optimization models endogenized the insurance choice. That is, if farmers know the parameters of the whole farm insurance policy then it is possible that they would alter their management practices to optimize the insurance decision. Hence the model employed simultaneously solved for the insurance premium and crop choice. The second is the use of a mean-skewness model. It was shown that a utility maximizer with a strong preference for skewness would optimize differently than one who minimizes risk. By maximizing skewness the farmer would seek strategies that would cluster outcomes to the upside even if this meant more variance (albeit truncated or non symmetric) or accepting a greater downside risk, but in fewer states.

The results provide justification for some concerns raised about the neutrality of these programs in the context of decoupling. When unsubsidized, Income insurance, CAIS and AgrInvest provide identical solutions to the uninsured strategy. It is the incremental response to subsidy that creates the wealth effect that may impact or distort markets. Whether whole farm income policies are amber is debatable. On the one hand because there is no specificity in the programs, that is one crop is not specifically targeted over another, whole farm programs are seemingly decoupled. The fact that farmers with different degrees of risk aversion, as indicated by the election of low versus high target incomes, or with varying degrees of variance minimizing or skewness preference would optimize differently, bolsters this argument. On the other hand if farmers are generally homogenous in their attitudes towards risk, then many farmers optimizing according to the same rules may give the appearance of coupling and thus provide cause for a complaint under WTO.

On a more pragmatic level the methods employed in the study may too provide some benefits. The existing AgrInvest program uses the past five years of production history and tax filer information to establish margin. The data simulation in this paper applied Monte Carlo simulations to correlated prices and yields with prices modeled as a random walk and yields assumed normal. The idea of using a random walk is a departure from the historical 5-year performance stated in the legislation. Nonetheless the use of mark-to-market prices in the simulation ensures that whatever the portfolio outcomes they are based on current price paths and risk and are not distorted by historical precedent.

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