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Crop insurance contracts typically constrain the choice of price at which indemnification occurs to be less than the expected output price. This restriction is first analyzed assuming only risk averse farmers, and yield and price uncertainty. General conditions under which the optimal price selection is bounded above by the expected output price are found to be difficult to derive. The results of numerical simulations based on a range of different utility functional forms are presented, and a strong tendency is observed for the optimal price selection to be bounded from *below* by the expected output price. The effect of increasing output price variability on the optimal price selection is also considered. The simulation results suggest that the optimal price selection is often non-increasing with a mean-preserving spread of the output price distribution. Lastly, it is noted that even in the presence of hidden-action moral hazard, if the incentives for shirking are not too high, then constraint that price selections be lower than the expected output price may still be binding.

1. Introduction

Multi-peril crop insurance programs, typically subsidized, are common in many countries. Explanations of the apparent uninsurability of these schemes have been the focus of much attention over a long period (see Pomareda (1986) for a good survey). Various reasons have been suggested to explain why the market appears to be uninsurable, ranging from high costs of raising funds (Chambers, 1989), hidden action moral hazard (Chambers, 1989), costly state verification (Hyde and Vercammen, 1994), and adverse selection (Skees and Reed, 1986). However, there is still much work to be done in narrowing the gap in our understanding between the properties of contracts predicted by sophisticated theoretical models and the contracts that we observe actually being offered. We focus here on a common feature of actual contracts—that the price selection at which indemnification occurs is lower than the expected output price—and identify conditions under which this restriction is not Pareto optimal. To help motivate the discussion we focus on the general form of the contracts offered by the FCIC in the US (see Harwood and Jagger (1994) for a discussion of FCIC contracts).

Choosing an insurance contract under the FCIC program in the US involves the farmer making a *price selection* together with a choice of *yield guarantee* from a menu of alternatives. The price selection refers to the price at which the yield deficit, the difference between actual and insured yield, is indemnified. The yield guarantee specifies the yield level up to which the FCIC will indemnify losses—indemnification occurs if and only if yield falls below the yield guarantee. Indemnity payments are equal to the yield deficit multiplied by the price selection. Any price selection can be made in the range from 30–100% of the FCIC's expected output price for the crop in question. The premium varies according to the particular pair of price selection and yield guarantee chosen. We are concerned here only with identifying conditions under which contracts constrained to offer price selections not higher than the expected output price are Pareto dominated by other contracts.

We first analyze a model in which yield and output price are uncertain, and farmers are risk averse—issues such as moral hazard are abstracted from. Insurance contracts offering indemnification at a selected constant rate for yield shortfalls below a selected yield guarantee are available to farmers—these contracts are designed to maximize the expected utility of farmers subject to the insurance provider obtaining a given level of expected profit. It is shown to be difficult to derive general conditions under which the optimal price selection in such contracts is bounded above by the expected output price. However, using numerical simulations, three different examples, involving different utility functional forms, are given for which the optimal price selection is bounded *below* by the expected output price for any yield guarantee in the range of feasible yields. In these examples a consistent negative relationship between the optimal price selection and yield guarantee is also observed, while the optimal price selection is non-increasing with mean-preserving spreads of the output price distribution. The only example in which the optimal price selection was lower than the expected output price required that the yield guarantee be sufficiently high and output price variability to be sufficiently high.

The results obtained here suggest that, in the absence of other factors such as moral hazard, possibly a large class of plausible conditions exist under which actual crop insurance contracts are Pareto dominated by contracts that allow price selections to be higher than the expected output price. In light of the well documented insurability of problems of actual crop insurance programs, this observation is of potential policy relevance.

The intuition for the optimal price selection being higher that the expected output price is that the particular form of actual crop insurance contracts are restrictive in the sense of not allowing farmers to choose a lump sum indemnity payment in addition to a price selection and yield guarantee. A lump sum payment would give further flexibility in allowing transfer of profits between different yield states. In the absence of such an instrument, the only effective way for farmers to transfer profits from high to low yield states is to choose the price selection above the expected output price. This implies a profit schedule that increases as yield decreases in the range of yields below the yield guarantee. This not only explains the observed results, but points to why actual insurance contracts will in general be Pareto dominated by contracts which give farmers a third instrument choice—a selection of fixed indemnity payment.

We then consider the possible effect of hidden action moral hazard—a common perspective on crop insurance problems—on the optimal price selection. The theoretical analysis quickly becomes complicated, and general conclusions about the effect of moral hazard on the optimal price selection are difficult to draw.[1] Under certain conditions, however, previous work has shown that as the cost of the unobservable action increases, the optimal contract requires farmer profits to increase more rapidly with yield (Hyde and Vercammen, 1994). Restricting attention to yield guarantee contracts, this is formally equivalent to the optimal price selection decreasing as the cost of unobservable effort increases. Thus, moral hazard emerges as a possible explanation for why it may in fact be optimal to choose price selections below expected output price. However, it is also possible even in the presence of moral hazard that the optimal price selection may be greater than the expected output price over the range of plausible yield guarantees—the requires that the cost of effort (i.e. the incentive to shirk) is not too high.

In summary, low levels of risk aversion, low yield guarantees, low output price variability, and low costs of unobservable effort, emerge as conditions under which contracts restricting price selections to be lower than the expected output price appear most likely to be Pareto dominated. The theoretical analysis here has produced little in the way of very general

[1]The inability to obtain clear results without unduly strict assumptions in this formulation of the moral hazard problem has been previously recognized by Quiggin and Chambers (1993).

insights to the problem at hand. The reliance on simulation results suggests that determination of the optimality or otherwise of actual crop insurance contracts ultimately requires empirical analysis.

2. The Model

Suppose all farmers are identical and contracts are designed to ensure an expected return of K to the insurance supplier and maximize farmer expected utility subject to this constraint. Farmers are risk averse with utility $U(\pi)$, where π denotes profit and is equal to the sum of actual crop revenues and indemnity revenues less the insurance premium and cost of crop inputs. Formally, $\pi = py + s(\gamma - y) - P - ca^2$, where y is yield, s is indemnity price selection, p is output price, P is the insurance premium, γ is the yield guarantee, a is the level of input to production, and the cost of inputs is given by ca^2. All variables are scalars. Farmers have increasing marginal disutility of effort and positive, diminishing marginal utility from profit. Yield is distributed according to the distribution function $F(y, a)$, with support $[\underline{y}, \bar{y}]$. Output price is also stochastic and determined by the distribution function $G(p)$, with support $[\underline{p}, \bar{p}]$. The costs of yield verification are ignored here. We are concerned only with determining the properties of the optimal price selection in relation to the expected output price at each level of yield guarantee.

The structure of the contracts offered is as follows: if the contract $\{s, \gamma\}$ is chosen and $y < \gamma$, then indemnity payments of $s(\gamma - y)$ are made—no indemnification occurs otherwise. A premium of $P(s, \gamma)$ is paid by the farmer regardless of realized yield. Farmers choose a contract, $\{s, \gamma\}$, prior to choosing a, which itself occurs prior to observing y and p. Although the essential elements of such a contract form can be explained by costly state verification considerations, this structure also reflects the basic structure of actual crop insurance contracts.

2.1. **Optimal Price Selection in the Absence of Moral Hazard.** Suppose that $c = 0$ (i.e. there is no moral hazard). Although solving for the optimal contract involves simultaneously choosing the optimal price selection and yield guarantee, $\{s^*, \gamma^*\}$, we consider here the simpler problem of determining the optimal price selection for a given level of yield guarantee, γ. This analysis is sufficient to give some insights into the properties of optimal contracts. Thus, the contract design problem is:

$$\max_{s\in\mathbb{R}_+} \int_{\underline{p}}^{\bar{p}} \left[\int_{\underline{y}}^{\gamma} U(s[\gamma - y] + py - P)\, f(y)\, dy + \int_{\gamma}^{\bar{y}} U(py - P)\, f(y)\, dy \right] g(p)\, dp$$
$$\text{s.t.} \quad P - \int_{\underline{y}}^{\gamma} s(\gamma - y)\, f(y)\, dy = K.$$

Equivalently, by substitution the above problem can be restated as:

$$\max_{s\in\mathbb{R}_+} \int_{\underline{p}}^{\bar{p}} \left[\int_{\underline{y}}^{\gamma} U(s[\gamma - y] + py - K - \int_{\underline{y}}^{\gamma} s[\gamma - y]\, dF(y))\, dF(y) \right.$$
$$\left. + \int_{\gamma}^{\bar{y}} U(py - K - \int_{\underline{y}}^{\gamma} s[\gamma - y]\, dF(y))\, dF(y) \right] dG(p).$$

Since the objective function is concave in s, the first order condition determining the optimal price selection, s^*, is

$$\int_{\underline{p}}^{\bar{p}} \left[\int_{\underline{y}}^{\gamma} U'(\cdot)[\gamma - y - \int_{\underline{y}}^{\gamma} (\gamma - y)\, dF]\, dF - \int_{\gamma}^{\bar{y}} U'(\cdot)[\int_{\underline{y}}^{\gamma} (\gamma - y)\, dF]\, dF \right] dG = 0. \quad (1)$$

Totally differentiating Equation (1), the following expression implicitly defines how s^* varies with γ. S is used to denote the second derivative of the objective function with respect to s—it can be shown that $S < 0$.

$$\left\{ \int_{\underline{p}}^{\bar{p}} \left[[1 - F(\gamma)] \int_{\underline{y}}^{\gamma} \left(U'' s^* [\gamma - y - \int_{\underline{y}}^{\gamma} (\gamma - y)\, dF] + U' \right) dF + \right. \right.$$
$$\left. \left. F(\gamma) \int_{\gamma}^{\bar{y}} \left(U'' s^* [\int_{\underline{y}}^{\gamma} (\gamma - y)\, dF] - U' \right) dF \right] dG \right\} d\gamma \; + \; S\, ds^* = 0. \quad (2)$$

Without loss of generality, assume that $y \in [0,1]$ and henceforth restrict attention to yield guarantees $\gamma \in [0,1]$. Now Equation (2) implies that

$$\int_0^\gamma (U'' s^* [\gamma - y - \int_0^\gamma (\gamma - y)\, dF] + U')\, dF < 0 \tag{3}$$
$$\Rightarrow \quad \frac{ds^*}{d\gamma} < 0.$$

Dividing through the integrand above by U', Condition (3) can be restated as,

$$\int_0^\gamma \left(\frac{U''(\pi(s^*))}{U'(\pi(s^*))} [\pi(s^*) - py + K] + 1 \right) dF < 0. \tag{4}$$

Unfortunately there appears to be no simple interpretation of this condition, although it is related to both absolute and relative risk aversion. Given the difficulty of drawing general conclusions about this condition, we consider its properties under specific assumptions regarding functional form. Numerical simulations based on uniformly distributed output prices and yields are shown in Figures 1 and 2, where the function $s^*(\gamma)$ is mapped at different levels of absolute and relative risk aversion and different output price distributions.[2] A robust negative relationship is observed between the optimal price selection and yield guarantee, with s^* higher than the expected output price provided risk aversion, price variability, and the yield guarantee are not too high.[3] The observed effects of increasing risk aversion and price variability are discussed in more detail below. Although a more exhaustive search over different functional forms is necessary before general conclusions can be reached, the results above suggest that the properties of (i) a negative relationship between the optimal price selection and yield guarantee, and (ii) the optimal price selection being higher than expected output price, may commonly hold.

[2]The simulations were carried out using Mathematica.

[3]The numerical simulations also confirmed that it is difficult to draw general conclusions about the conditions under which $ds^*/d\gamma < 0$.

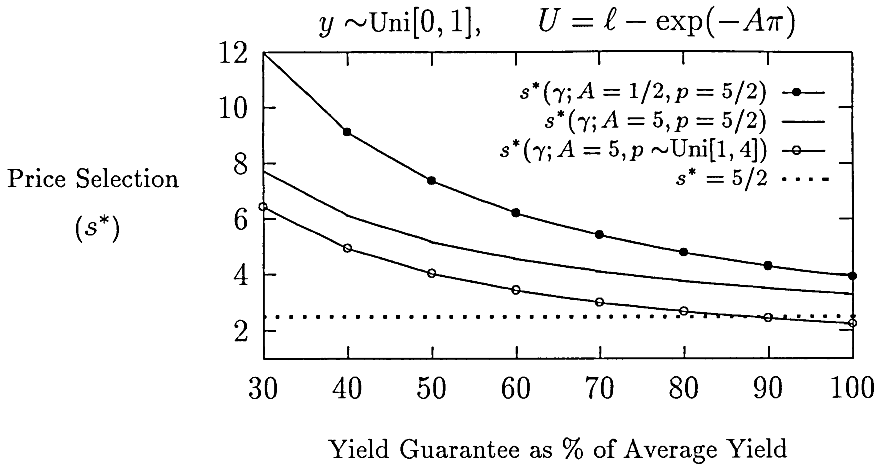

FIGURE 1. Constant Absolute Risk Aversion: Optimal Price Selection *vs* Yield Guarantee

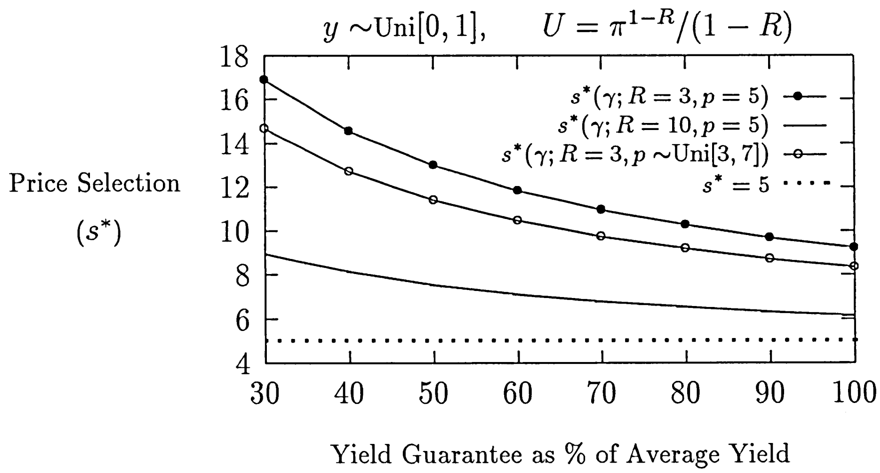

FIGURE 2. Constant Relative Risk Aversion: Optimal Price Selection *vs* Yield Guarantee

In discussing the intuition for the negative relationship between the optimal price selection and yield guarantee, it is useful to relate this to previous results in the literature. For ease of exposition the discussion below assumes output price to be deterministic. Townsend (1979) observes that in a more general contract theoretic model the optimal contracts involve a constant profit to the insured over the states in which verification and indemnification occur (i.e. $y < \gamma$). For the class of contracts considered here, farmer profit is constant over the interval $y \in [0, \gamma]$ if and only if $s = p$, which the analysis indicates is not in general the solution for the optimal price selection. The source of this apparent discrepancy with the Townsend (1979) result is that his contracts are more general in the sense of specifying a lump sum indemnity payment that is independent of the realized state. The contracts modeled here, however, lack this additional degree of freedom since s and γ are the only choice variables. Such a fixed transfer can be used to increase the expected utility of farmers by allowing full insurance to be offered over low yield states while at the same time raising profits in these same states above the level implied by the same full insurance in the class of contracts considered here.

In contrast, choosing $s = p$ in the class of contracts considered here results in a constant profit for all yields $y < \gamma$, but this profit decreases as γ decreases. Thus, lower yield guarantees imply lower profits in low yield states. This follows from

$$\begin{aligned} \left.\frac{d\pi}{d\gamma}\right|_{y<\gamma, s=p} &= \frac{d}{d\gamma}\left(p[\gamma - y] + py - \int_0^\gamma (\gamma - y)\, dF - K\right) \\ &= p[1 - F(\gamma)] > 0. \end{aligned}$$

For given γ, the only avenue for obtaining risk protection against low profits in low yield states is by choosing $s > p$, causing profits to increase as yield decreases in the range $y \in [0, \gamma]$—such a contract is illustrated and denoted C^1 in Figure 3. This allows a redistribution of profits from high to low yield states. A direct implication of this restriction on actual insurance contracts (i.e. not allowing selection of a lump sum indemnity payment that is distinct from s and γ) is that they in general are suboptimal in this framework. Furthermore, the above results suggest that there could be further losses due to restricting price selections to be bounded above by the expected output price.

Intuition for the observation that $ds^*/d\gamma < 0$ can be obtained by observing that if $s > p$, then the minimum profit of a farmer occurs at $y = \gamma$, is equal to $p\gamma - s\int_0^\gamma (\gamma - y) dF - K$, and is decreasing in s—see Figure 3. Moreover, it is straightforward to show that the rate at which it is decreasing with s is increasing with γ (i.e. $\frac{d^2\pi}{d\gamma\, ds} < 0$). That is, the lower support of the profit distribution decreases more due to an increase in s at high levels of γ than at low levels of γ. As can be seen in Figure 3, increasing s above p results in a downward shift of the support of the profit distribution faced by farmers, which adversely impacts on the expected utility of farmers. The benefit from increasing s, however, is that it allows probability mass to be shifted from low to higher profit outcomes, by allowing profits to be transferred from high to low yield states. To see this, observe that setting $s = p$ results is a high probability mass, $F(\gamma)$, being associated with the lowest profit realization—such a contract is depicted in Figure 3 and denoted C^0.[4] The first effect tends to dominate at high levels of γ, since then choosing $s = p$ implies a relatively high profit over low yield states so that the risk benefit from a redistribution of profits across states is low. The latter effect dominates at lower levels of γ, however, resulting in s^* being higher at low levels of γ.

Finally, note that it is generally true that if $\gamma = 1$ then it is optimal to choose $s^* = p$ as this ensures that the net return of farmers is independent of realized yield and thus constant across all yield realizations. This is optimal because risk averse agents strictly prefer a constant rather than variable profit if they have the same expected value. To see this, observe that now $\int_0^\gamma s(\gamma - y)dF = s(\gamma - \hat{y})$, where $\hat{y}$ is the expected yield. It follows that Equation (1) can be rewritten as,[5]

$$\int_{\underline{y}}^{\bar{y}} U'(\hat{p}y + s^*[\hat{y} - y])[\hat{y} - \bar{y}]\, dF = 0. \tag{5}$$

[4]Note that if y is uniformly distributed and $K = 0$, then the areas A and B in Figure 3 must be equal—that is, expected indemnity payments must equal premium revenues.

[5]For some functional forms, such as the constant relative risk aversion utility function considered here, this argument breaks down since the expression for U' involves a term $(p - s)$ appearing in the denominator, so that U' is not real valued at $s = p$. In this case it is not true that $s^*(\gamma = 1) = p$—in fact, the simulation results showed $s^*(\gamma = 1) > p$.

FIGURE 3. General Form of an FCIC Contract

Since the second term of the integrand is symmetric around zero as y varies across its support, it is necessary and sufficient that s^* imply that $U'(\cdot)$ is constant for all $y \in [\underline{y}, \bar{y}]$. Thus, the unique solution is that $s^* = p$. Thus, if the yield guarantee is equal to the highest possible yield and output price is deterministic, then it is optimal to set the price selection equal to the actual output price, implying that indemnities are paid in all states. In summary, if the property $ds^*/d\gamma < 0$ holds for all $\gamma \in [0,1]$, then together with the above property it follows immediately that the optimal price selection is everywhere bounded below by the (expected) output price.

Returning to the simulation results, we now discuss several other properties displayed. Under both constant absolute and relative risk aversion it is observed that the optimal price selection is decreasing in the degree of risk aversion. This can be explained in terms of the discussion above. More risk averse farmers are more adversely affected by a lowering of the profit distribution since they are more adversely affected by the extreme profit realizations in the lower tail of the profit distribution due to the increased curvature of the utility function. Thus, it is optimal for more risk averse farmers to forego the profit redistribution opportunities associated with choosing a high level of s, in order to protect themselves from exposure to very low profit realizations. Hence, s^* will tend to be lower for more risk averse farmers at a given level of yield guarantee.

The simulations also show that a mean-preserving spread of the output price distribution can decrease the optimal price selection. Moreover, in Figure 1 the effect of a mean-preserving spread of the price distribution on s^* is seen to be larger at a higher level of risk aversion. The first of these observations is examined here. Following Sandmo (1971), redefine the output price to be $\phi = \theta p + \lambda$. The distribution $\mathfrak{G}(\phi; \theta_1, \lambda)$ is a mean-preserving spread of $\mathfrak{G}(\phi; \theta_2, \lambda)$ if $\theta_1 > \theta_2$ and $d\lambda/d\theta = -\hat{p}$, where $\hat{p}$ is the mean of the price distribution.

Note that $G(p) = \mathfrak{G}(\phi; 1, 0)$. Rewriting Equation (1) to reflect this change in notation and totally differentiating with respect to θ we obtain an expression which, if negative, implies $ds^*/d\theta < 0$. In this case a mean-preserving spread of the price distribution unambiguously results in a lower optimal price selection for any given γ. Totally differentiating the first order condition gives

$$\begin{aligned}\Big\{(\bar{p}-\hat{p})\left[\int_0^\gamma U'(\bar{\phi})T_1\,dF - \int_\gamma^1 U'(\bar{\phi})T_2\,dF\right] - (\underline{p}-\hat{p})\left[\int_0^\gamma U'(\underline{\phi})T_1\,dF - \int_\gamma^1 U'(\underline{\phi})T_2\,dF\right] \\ + \int_{\underline{\phi}}^{\bar{\phi}}\left[\int_0^\gamma U''[p(\phi)-\hat{p}]yT_1\,dF - \int_\gamma^1 U''[p(\phi)-\hat{p}]yT_2\,dF\right] d\mathfrak{G}(\phi) \\ + \int_{\underline{\phi}}^{\bar{\phi}}\left[\int_0^\gamma U'T_1\,dF - \int_\gamma^1 U'T_2\,dF\right][p(\phi)-\hat{p}]\,\mathfrak{g}'(\phi)\,d\phi\Big\}\,d\theta + S\,ds^* = 0,\end{aligned} \tag{6}$$

where $\mathfrak{g}(\phi)$ is the density function associated with $\mathfrak{G}(\phi)$, $\bar{\phi} \equiv \theta\bar{p} + \lambda$, $\underline{\phi} \equiv \theta\underline{p} + \lambda$, $T_1 \equiv \gamma - y - \int_0^\gamma(\gamma - y)dF$ and $T_2 \equiv \int_0^\gamma(\gamma - y)dF$.

The sign of the expression in braces is in general indeterminate, so that it is difficult to draw general results about the effect of output price variability on the optimal price selection. In the case of quadratic utility and uniform yield and price distributions, it was observed through simulations that the optimal price selection is unaffected by mean-preserving spreads of the price distribution.[6] That is, the function $s^*(\gamma)$ coincides with the locus of points satisfying $ds^*/d\theta = 0$. Moreover, in this case it is also true that $s^* > \hat{p}$ for all choices of yield guarantee in the range of feasible yields. Thus, the simulation results here suggest that it may be true for a large set of conditions, including plausible utility functional forms, that the optimal price selection is non-increasing with mean-preserving spreads of the output distribution.

[6]The quadratic utility function, $U = \ell - (\pi - k)^2$, displays decreasing absolute and relative risk aversion.

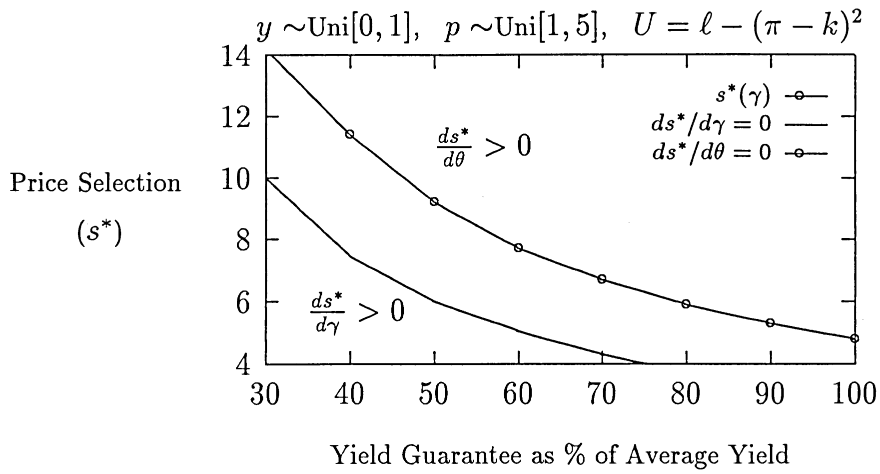

FIGURE 4. Decreasing Absolute and Relative Risk Aversion: Optimal Price Selection *vs* Yield Guarantee

In summary, while it is difficult to identify general conditions under which the optimal price selection is always higher than the expected output price, it is not difficult to identify particular functional forms which give rise to optimal contracts with such a property. Each of the different utility functions considered here (together with a uniform yield and price distribution) gave rise to optimal contracts satisfying $ds^*/d\gamma < 0$, and moreover satisfied the property that $s^* > \hat{p}$ for all yield guarantees in the range of feasible yields provided that the output price variability was not too high. Thus, in the absence of factors not considered here, rather special conditions may be required for optimal contracts to be characterized by the price selection being bounded above by the expected output price. This raises the question of whether actual crop insurance programs could increase their attractiveness to farmers and their viability by adopting relatively simple changes to the structure of the contracts offered.

The preceding analysis is only indicative, and detailed empirical evidence regarding price and yield distributions and farmer attitudes to risk are needed before more specific predictions can be made. Also, important factors, such as moral hazard, may have been omitted from the analysis. We turn to this in the next section.

2.2. **Optimal Price Selection in the Presence of Moral Hazard.** Suppose that farmers incur positive but unobservable costs of ca^2 in producing output y. It is assumed that farmers take their insurance contract as given, then choosing the optimal level of effort, a. Implicitly the government solves their contract design problem for them, then offering the appropriate contract. Thus, as in the Holmstrom (1979) model, farmers choose $a = 0$ if offered a full insurance contract. Farmer utility is now $U(s[\gamma - y] + py - P - ca^2)$ for all $y < \gamma$, and $U(py - P - ca^2)$ for all $y > \gamma$. The incentive compatibility constraint is given by

$$\int_{\underline{p}}^{\bar{p}} \left[\int_{\underline{y}}^{\gamma} -U'2caf(y,a) + Uf_a(y,a)\,dy + \int_{\gamma}^{\bar{y}} -U'2caf(y,a) + Uf_a(y,a)\,dy \right] dG = 0.$$

Denote the multiplier in the Lagrangian on this incentive constraint by μ. It can be shown that $\mu < 0$. The first-order condition defining s^* is given by

$$\int_{\underline{p}}^{\bar{p}} \left[\int_{\underline{y}}^{\gamma} U'(\cdot)[\gamma - y - \int_{\underline{y}}^{\gamma} y\,dF(y)]\,dF(y) - \int_{\gamma}^{\bar{y}} U'(\cdot)[\int_{\underline{y}}^{\gamma} y\,dF(y)]\,dF(y) \right] dG(p)$$
$$- \mu \int_{\underline{p}}^{\bar{p}} \Bigg[[\gamma - y - \int_{\underline{y}}^{\gamma} y\,dF] \int_{\underline{y}}^{\gamma} -U''(\cdot)2caf(y,a) + U'(\cdot)f_a(y,a)\,dy$$
$$-[\int_{\underline{y}}^{\gamma} y\,dF] \int_{\gamma}^{\bar{y}} -U''(\cdot)2caf(y,a) + U'(\cdot)f_a(y,a)\,dy \Bigg] dG = 0.$$

Totally differentiating the above first order condition,

$$\Bigg\{ S - \mu \int_{\underline{p}}^{\bar{p}} \Bigg[\int_{\underline{y}}^{\gamma} [\gamma - y - \int_{\underline{y}}^{\gamma} y\,dF]^2(-U'''(\cdot)2ca\,f(y,a) + U''f_a)\,dy + [\int_{\underline{y}}^{\gamma} y\,dF]^2$$
$$\int_{\gamma}^{\bar{y}} -U'''(\cdot)2caf + U''f_a\,dy \Bigg] dG \Bigg\}\,ds \;+\; \Bigg\{ \int_{\underline{p}}^{\bar{p}} a^2 \Bigg[\int_{\underline{y}}^{\gamma} U''[\gamma - y - \int_{\underline{y}}^{\gamma} y\,dF]\,dF$$
$$- \int_{\gamma}^{\bar{y}} U''[\int_{\underline{y}}^{\gamma} y\,dF]\,dF \Bigg] dG - \mu \int_{\underline{p}}^{\bar{p}} \Bigg[[\gamma - y - \int_{\underline{y}}^{\gamma} y\,dF] \int_{\underline{y}}^{\gamma} U'''2a^3cf - U''(2af + a^2 f_a)\,dy$$
$$+ [\int_{\underline{y}}^{\gamma} y\,dF] \int_{\gamma}^{\bar{y}} U'''2a^3cf - U''(2af + a^2 f_a)\,dy \Bigg] dG \Bigg\}\,dc = 0.$$

The equation above implicitly defines ds^*/dc—it is a complex expression and difficult to identify meaningful general conditions under which it can be unambiguously signed. It has previously been shown using numerical simulations that if yield is normally distributed with mean a and the output price is non-stochastic, then the effect of increasing c is to decrease s^* (Hyde and Vercammen, 1994). The intuition is that under conditions of moral hazard, the optimal contract is one that provides appropriate incentives for effort provision. This calls for a contract that rewards higher yield outcomes with higher profits. As can be seen from Figure 3, a necessary (and sufficient) condition for a contract $\{s, \gamma\}$ to satisfy the property that farmer profit is increasing with yield over the interval $[0, \gamma]$ is that $s < p$ in the case where output price is deterministic. Moreover, the responsiveness of the farmer profit function to yield increases as s decreases further below p.

Ceteris paribus, the incentives to shirk increase as the cost of effort increases. It follows that as c increases, the optimal contract requires an increasingly responsive (positively sloped) profit function, $\pi(y)$. Since, in the class of contracts we consider here, the pair $\{s, \gamma\}$ completely specify a contract, the only means by which $\pi'(y)$ can be increased over the interval $[0, \gamma]$ is to decrease s and/or γ.

Assuming the property $ds^*/dc < 0$ to hold, moral hazard emerges as a possible explanation for why price selections may optimally be bounded above by the expected output price. In the previous section we saw that if the level of risk aversion is not too high and output price variability is not too high, then the optimal price selection may be everywhere higher than the expected output price. Under the conditions of moral hazard outlined above, however, if the incentive to shirk is sufficiently high (i.e. c is sufficiently high), then it is conceivable that this countervailing effect will be sufficient to lower the optimal price selection below the expected output price. The converse of this statement is perhaps just as interesting: it is possible for the optimal price selection to be bounded below by the expected output price, *even in the presence of moral hazard*, provided that the incentives for shirking are not too strong. Given that the relative importance of the hidden-action moral hazard problem in crop insurance is still not well understood, this conclusion may be of some policy relevance.

The importance of moral hazard considerations will be determined both by how costly the unobservable effort is, and also how much of the effort incurred in crop production is effectively non-contractable.[7]

The results observed here suggest that offering menus of contracts including price selections that are higher than the expected price is most likely to be welfare improving if (i) yield guarantees are low, (ii) output price variability is low, (iii) risk aversion (absolute or relative) is not too high, and (iv) incentives to shirk are not too high.

3. Concluding Remarks

Detailed empirical measurement of production costs, yield distributions and utility functional forms are required to be able to draw stronger conclusions than those here. This paper serves only to show that conditions could plausibly exist under which common restrictions on indemnity price selections would be suboptimal. Although risk and moral hazard can be expected to be important factors determining the optimal structure of contracts, other factors possibly need also to be taken into consideration, such as adverse selection.

References

Chambers, R. G. (1989). Insurability and moral hazard in agricultural insurance markets, *American Journal of Agricultural Economics* **71**: 604–16.

Harwood, J. and Jagger, C. (1994). Crop insurance and disaster assistance. Unpublished Manuscript, U.S. Department of Agriculture.

Holmstrom, B. (1979). Moral hazard and observability, *Bell Journal of Economics* **10**: 74–91.

Hyde, C. E. and Vercammen, J. A. (1994). Crop insurance: Moral hazard and contract form. Research Paper No. 437, University of Melbourne.

[7]Some crop insurance schemes do involve random monitoring of farmer activity during the season, implying that some effort is at least partially contractable.

Pomareda, C. (1986). The financial viability of crop insurance, *in* P. Hazell, C. Pomareda and A. Valdes (eds), *Crop Insurance for Agricultural Development*, Johns Hopkins University Press, Baltimore, pp. 281–291.

Quiggin, J. and Chambers, R. (1993). The moral hazard problem. Unpublished Manuscript, Australian National University.

Sandmo, A. (1971). On the theory of the competitive firm under price uncertainty, *American Economic Review* **61(1)**: 65–73.

Skees, J. and Reed, M. (1986). Rate making for farm-level crop insurance: Implications for adverse selection, *American Journal of Agricultural Economics* **68**: 653–59.

Townsend, R. (1979). Optimal contracts and competitive markets with costly state verification, *Journal of Economic Theory* **21**: 265–93.

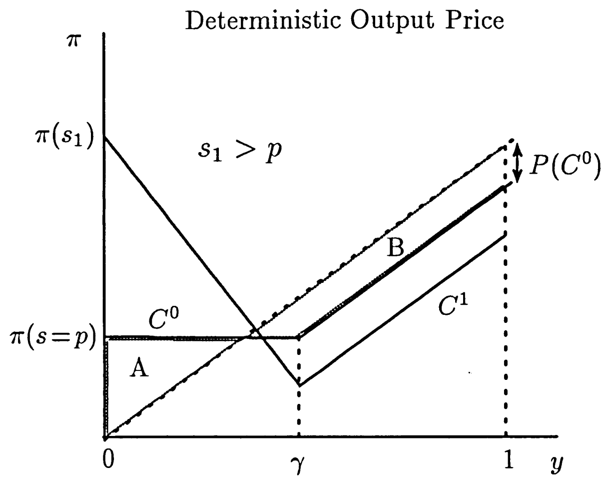

FIGURE 1. General Form of an FCIC Contract

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