Price Uncertainty, Moral Hazard, and Adverse Selection in Agricultural Insurance

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In recent studies, Ahsan et al.(1982) and Skees and Reed(1986) focused on adverse selection. Nelson and Loehman(1987) and subsequently Chambers(1989) considered the problem of moral hazard and demonstrated that the general theory of insurance can be applied to agriculture. These studies did not discuss the differences between agricultural and other insurance. They did not, moreover, discuss whether the existence of those unique characteristics of agricultural insurance would affect the applicability of general insurance theories to the agricultural sector.

A major difference between agricultural insurance and other insurance is the price uncertainty of agricultural products due to seasonality. As crop prices at harvest are not known with certainty at the time farmers decide to purchase crop insurance, the choice of the insured price becomes critical in the crop insurance program. The price option chosen by the insured may be different than the market price at harvest. As a result, an additional source of moral hazard is introduced when the insured price is higher than the net expected market price. In contrast,the moral hazard problem may be mitigated when the insured price is lower than the net expected market price.

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Most previous research in agricultural insurance emphasizes the yield uncertainty. Chambers(1989) mentioned price uncertainty but his analysis was based on the assumption of a degenerate price distribution, i.e., no price uncertainty is assumed. Since price uncertainty only occurs in agricultural insurance and is seldom examined in other insurance markets, this study examines the effects of price uncertainty on the agricultural insurance theories.

The other major difference between crop insurance and other insurance is that the probability of collecting indemnities in crop insurance is dependent upon the coverage level. In other insurance such as liability and health insurance, the probability of an accident or ill/health depends upon the state of nature and not upon the coverage level; however, the coverage level does depend upon the insured's riskiness. As a consequence, the actions of an insured farmer, such as input activities and care, influence not only the probability of claim for a loss but also the size of the loss. As a consequence, a deductible alone may not be able to control moral hazard in crop insurance. Thus, a program like the current U.S. Federal crop insurance policy may not be optimal since it only includes a deductible. Furthermore, this characteristic links the problems of moral hazard and adverse selection to each other through measurement errors in the yield distributions.

The objectives of this paper are: (1) to illustrate the unique characteristics of agricultural insurance like multiple peril crop insurance (MPCI) as compared to other types of insurance, and (2) to examine the causes of moral hazard and adverse selection in the agricultural insurance program with and without considering price uncertainty.

The paper proceeds as follows. First, the relationship among adverse selection, moral hazard, and price uncertainty under the assumption of perfect in-

formation about yield distributions is examined. Secondly, the relationship among adverse selection, moral hazard, and measurement errors under the assumption of imperfect information about yield distributions is explicated. Finally, conclusions are presented in the last section.

I. Yield Distributions are Known: Perfect Information

Since government usually plays an important role in reinsuring private companies in the crop insurance program, it is reasonable to assume that the insurer is risk neutral. Only the case of a risk neutral insurer will be concerned in this paper. Arrow(1971) and Raviv(1979) showed that an insurance contract with coinsurance of loss above the deductible is Pareto optimal without considering the problem of moral hazard. They also demonstrated that full coverage above deductible is Pareto optimal when the insurer is risk neutral and the insurance cost (loading factor) is linearly dependent on the coverage. Holmstrom (1979) showed that a deductible alone is Pareto optimal with the consideration of moral hazard when the insured's action only affects the probability of an accident but not the size of damage and the insurer is risk neutral. As the insured's actions affect both probability and size in the current crop insurance program, a deductible alone may not be optimal. Loss-sharing arrangements are needed in crop insurance to provide the insured appropriate incentives to minimize the moral hazard problems. This paper will focus on the coinsurance of loss as one of solutions for moral hazard.

Adverse Selection and Moral Hazard

Without considering moral hazard, Borch(1960), Arrow(1971), and Raviv(1979) obtained Pareto optimal insurance policy designs by taking a general ap-

proach under the assumption of perfect information. In this paper, their models will be modified with the consideration of moral hazard by using a linear coinsurance contract instead of a general form of coinsurance as in Arrow (1971) and Raviv (1979). We start with the case that the insured crop price is assumed to be equal to the expected market crop price. We define:

x: loss, which is a random variable.
I(x): insurance policy, or coverage function.
d: deductible level
$0 \leqq I(x) \leqq x$
$I(x) = 0$ for $x \leqq d$
$= \gamma (x-d)$ for $x > d$, where $\gamma = 1$ for full coverage,
$0 < \gamma < 1$ for coinsurance.

When $\gamma = 1$, this indemnity schedule has been shown to be Pareto Optimal if the insurer is risk neutral and insurance cost is linearly dependent on coverage. This paper shows that the current U.S. Federal crop insurance policy falls into this form of indemnity schedule.

μ :average yield or mean of the yield distribution (in bushels). Let
σ : variance of the yield distribution.
γ : coinsurance rate of loss shared by the insurer,
Y: actual yield(a random variable, which depends on the state of nature),
Y_g: guaranteed yield,
P_i: insured price per bushel.
Let $x = (\mu - Y)$,
$d = \alpha \cdot \mu \quad 0 < \alpha < 1$,
$Y_g = (1-\alpha) \cdot \mu$,
Then $I(x) = 0$ for $x \leqq d$
$= \gamma [(\mu - Y) - d] \cdot P_i$ for $x > d$

When $\gamma = 1$,

$$I(x) <= 0 \qquad \text{for } x \leq d$$
$$= (Y_g - Y) \cdot P_I \qquad \text{for } x > d$$

This is exactly a form of the current U.S. Federal crop insurance policy which is full coverage above the deductible i.e., $\gamma = 1$ with $\alpha = 0.25$, 0.35, or 0.5.

Under the assumption of normality, a yield distribution can be characterized by its mean and variance.

The solution for moral hazard suggested by principal-agent theories, or contract theories has been to provide an optimal sharing-loss ratio between the insurer and the insured. Consequently, the insured's incentive to cheat can be minimized in that the insured also shares the loss above deductible. Under this coinsurance, the insurance policy can be Pareto optimal. In other words, γ needs to be less than 1 to reduce moral hazard. This coinsurance rate may depend on the risk preferences of the insurer and the insured as well as on the insurance cost function.

Whereas most of the literature about the optimal insurance coverage level only discusses the case of one insurer and one insured under perfect information, the problem of adverse selection is seldom discussed. However, there is an adverse selection problem under imperfect information when the insured's risk is not homogeneous and the insurer can not distinguish between the high risk insured and the low risk insured. Even when perfect information about relative risk is available, if the insurer does not use that information to differentiate the high risk insured from the low risk insured, the problem of adverse selection still exists. Current U.S. Federal crop insurance belongs to the latter case; namely, it does not employ information of the insured's relative risk, though still imperfect,

to charge different premium rates or to give different coverage levels. One way to reduce adverse selection in the current crop insurance program is to differentiate high risk insured from low risk insured through premium payments or coverage levels which vary as functions of riskiness. In crop insurance, the insured's risk is characterized by the value of relative risk, CV or σ / μ .In other words, adverse selection can be reduced by letting the coinsurance rate vary as relative risk varies.

The optimal insurance policies will be first explicated without considering their interactions with price uncertainty. Four different cases are presented below.

(1) no Adverse Selection, no Moral Hazard

Since there is no moral hazard, the full coverage can be provided, i. e, $\gamma = 1$. In addition, as adverse selection does not exist, neither the deductible nor coinsurance rate needs to be a function of relative risk. Thus, both the deductible and coinsurance rate should be the same for every insured. Thus, the current U.S. Federal crop insurance policy is pareto optimal only when both adverse selection and moral hazard do not exist. Adverse selection could arise from the fact that neither the deductible nor coinsurance rate depends on the relative risk; moral hazard could arise from full coverage above deductibles.

(2) Adverse Selection exists, but no Moral Hazard

When moral hazard does not exist, the insurer can always provide full coverage, i.e., $\gamma = 1$ When adverse selection exists, one solution is to let the deductible be a function of relative risk. Otherwise, the riskiness

is not differentiated among the insured which would cause adverse selection.

(3) no Adverse Selection, but Moral Hazard exists

When there is no adverse selection, both the deductible and coinsurance rate can be constants regardless the insured's relative risk. Nonetheless, the coinsurance rate should be less than one to provide incentives for the insured to take better care of their crops.

(4) Both Adverse selection and Moral Hazard exist

In order to differentiate the insured's riskiness to prevent adverse selection, the coinsurance rate needs to be a function of relative risk and its value needs to be less than 1 to reduce moral hazard problems. The deductible may still exist due to the insurance administration costs.

The method of calculus of variations has been applied most frequently in contract theories and insurance theories in determining the optimal sharing ratios. The determination of an optimal solution of coinsurance rate or deductible is left for future research. However, the optimal coinsurance rate or the optimal deductible is very likely to be increasing functions of the insured's relative risk. That is, an insured with higher risk is expected to share more loss or to be given a higher deductible.

Price Uncertainty, Weather State, and Moral Hazard

The effects of price uncertainty on moral hazard in crop insurance will be explicated in four different cases. First, some notations are defined.

E(Y): farmer's expected yield for the insured crop,
$E(P_m)$: farmer's expected market price of the insured crop,
P_I: the price option chosen by the farmer (or the insured),
c: average cost of producing the crop per unit (bushel).
Let $Y_2 < Y_1 < Y_g$, $\triangle Y_1 = Y_g - Y_1$, $\triangle Y_2 = Y_1 - Y_2$.
Thus, $Y_1 = Y_2 + \triangle Y_2$.

Farmer's expected profit of Y_1 : $Y_1 E(P_m - c) + \triangle Y_1 \cdot P_I$.
Farmer's expected profit of Y_2 : $Y_2 E(P_m - c) + (\triangle Y_1 + \triangle Y_2) \cdot P_I$.

Farmer would choose to produce Y_1 when its expected profit is greater than Y_2. By comparing the expected profits of two yield levels, Y_1 and Y_2, the condition under which the insured would choose the lower yield level, Y_2, can be identified; namely, the condition where the moral hazard problem is more serious can be identified.

(1). $E(Y) < Y_g$; $E(P_m) > P_I$.

When $P_I > E(P_m) - c$, the insured would produce Y_2; when $P_I < E(P_m) - c$, the insured would produce Y_1. Namely, when the net expected market price, after subtracting the average cost, is higher than the insured price, the insured have incentives to produce more and sell in the market. Under certain condition, the insured may even try to increase the yield above the guaranteed yield level if possible. Thus, there would be no moral hazard due to these price effects. On the other hand, if the price gap between the expected market price and the insured price is not large enough to cover the production cost on average, there still exist moral hazard problems. Since bad weather conditions usually result in short

supply, it is more likely that the expected yields go below the guaranteed yields.

(2). $E(Y) < Y_g$; $E(P_m) < P_I$.

The insured in this case would always choose to produce less, i.e., Y_2, because $P_I > E(P_m) > E(P_m) - c$ The insured can always gain more by producing less or by increasing the gap, $(Y_g - Y)$. Thus, there would be serious moral hazard problems.

Two other cases under good harvest situations are discussed below: one with the expected market price higher than the insured price, the other with the insured price higher than the expected market price. Namely, (3). $E(Y) > Y_g$; $E(P_m) > P_I$. (4). $E(Y) > Y_g$; $E(P_m) < P_I$. In general, when the expected yield is higher than the guaranteed yield and the expected market price is also higher than the insured price, there is no moral hazard problem in that the insured expects to gain from the market not from the insurance company. Unless the expected yield is around the guaranteed yield, moral hazard should not be a problem. Finally, when the expected yield is higher than the guaranteed yield but the expected market price is lower than the insured price, the insured may be able to gain from the price gap, $P_I - E(P_m)$, by deliberately reducing production. But the insured can gain more by obtaining certain price insurance from other sources such as options and future markets. Thus, there is no reason for the insured to reduce production through moral hazard to obtain this type of price insurance from the crop insurance during the good harvest time.

Without price uncertainty, i.e., $E(P_m) = P_I$, the following two simple cases are considered: potential good harvest with $E(Y) > Y_g$ and potential bad harvest with $E(Y) < Y_g$. By the same token, only the latter concerns crop insurance

companies partly in that it is difficult to reduce the yields below the guaranteed level in good weather. When expecting their yields to be below the guaranteed levels, the insured would try to increase the gap ($Y_g - Y$) by decreasing their inputs under the bad harvest times. This would be a serious moral hazard problem.

With the consideration of price uncertainty, moral hazard would be a serious problem only when $E(P_m) - c < P_1$. One possible way to mitigate the moral hazard problem is to set $P_1 < E(P_m) - c$.

II. Yield Distributions are Estimated: Imperfect Information

Moral hazard and adverse selection can also arise from asymmetric information. Moral hazard occurs when the insured knows his level of input activity, but the insurer does not. Adverse selection occurs when the insurer is not able to determine the risk class of the insured because of not having perfect information.

Measurement Errors, Moral Hazard, and Adverse Selection

Imperfect information results in measurement errors in both input activities and outputs. Examples of input care include the amount of seeds used, the amount of time devoted to farming, ... , etc. Shavell(1979) examined the relationship between moral hazard and the cost of observing the input care. When care is observed accurately or perfect information of inputs is available, full coverage can be offered. Otherwise, only partial coverage can be offered. Namely, when care can not be observed totally, an insurance market still exists but can not offer full coverage. Since imperfect information about input activities is the major source of moral hazard, the insurer would only be willing to offer partial coverage, either by deductible or by coinsurance.

When the imperfect information is about output levels (or yields), there is a gap between the true coverage level, $\hat{Y}_g$, and the realized (estimated) coverage level, Y_g.When the estimated mean is greater than the true mean of the yield distribution, the realized guaranteed yield is greater than the true guaranteed yield. Other things being equal, farmers would be more likely to participate in the crop insurance program partly because of higher coverage and because of a higher probability of collecting. On the other hand, when the estimated variance is higher than the true variance, other things being equal, i.e., when the estimated relative risk is higher than the true relative risk, the farmers would be less likely to participate in the crop insurance program because of less chance of collecting the indemnity. As a result, when the average yield is overestimated or the variance is underestimated, farmers would be more likely to purchase crop insurance. Similarly, the overestimation of the relative risk, measured by variance/mean, may arise from overestimation of the variance and/or underestimation of the mean.

As a consequence, measurement errors in estimating the yield distributions could be a potential source of adverse selection. Adverse selection occurs when the crop insurance program attracts more high risk farmers than low risk farmers. This may arise from underestimation of the relative risks of higher risk farmers and/or overestimation of the relative risk of lower risk farmers. Thus, higher risk farmers have more incentives to participate in the crop insurance program than lower risk farmers.

In addition, the insured is more likely to cheat when the probability of collecting increases due to overestimation of the average yield.

III. Conclusions

Three kinds of uncertainties in the crop insurance program are discussed: yield uncertainty, price uncertainty, and measurement errors in means and variances of the yield distributions. Yield uncertainty arises from the state of nature, primarily weather. Price uncertainty arises from a time lag between the harvest time and the sign-up time for crop insurance. Thus, the crop price in the insurance contract may not equal its market price at the harvest time. During this time lag, farmers form their expected prices, which may not be the same as the insured price. Measurement errors arise mainly from imperfect information. This creates another kind of randomness in estimating the yield distributions for the premium and coverage levels.

This paper shows that adverse selection in the crop insurance program could arise (1) from the coverage levels which only depend on means of the yield distributions but do not depend on the relative risk; and (2) from the measurement errors in estimating means and variances of yield distributions. Thus, one way to solve the adverse selection problems is to set the deductible or coinsurance rate as a function of the insured's relative risk. And the other way is to decrease the measurement errors by gaining more information or using more sophisticated statistical methods to estimate means and variances of the yield distributions. Under the assumption of perfect information of the yield distributions, when the deductible or coinsurance rate is a function of relative risk, adverse selection does not exist.

The problem of moral hazard arises from imperfect information about the input activities which are usually not observed or costs of observed are high.

Thus, moral hazard can not be prevented but can only be mitigated by providing appropriate incentives for the insured to minimize the loss and by decreasing the measurement errors.

Current U.S. Federal crop insurance policy only includes a deductible which is a constant regardless of the size of loss. Thus, it could not provide the insured appropriate incentives to minimize the loss and, consequently, would create a serious moral hazard problem in that the insured's actions affect the size of loss as well as the probability of collecting. Hence, to control moral hazard, coinsurance above the deductible is necessary. Namely, let the insured share a portion of the loss which depends on the size of loss. The problem should then focus on the determination of an optimal coinsurance rate, or an optimal loss-sharing arrangement.

Moreover, the problems of measurement errors can compound the problem of moral hazard when overestimating the mean or underestimating the variance of the yield distribution. For instance, overestimation of the average yield will result in overestimation of the guaranteed yield, thus, a higher probability of collecting and more moral hazard. Hence, better estimation methods are also important for reducing both adverse selection and moral hazard in the crop insurance program.

When price uncertainty is considered, the moral hazard problems can be either mitigated or compounded. For instance, when the expected prices are higher than the insured prices, the insured have an incentive to increase yields and sell at market. As long as gains from these price gaps are large enough to cover the average production cost, moral hazard problems can be mitigated. On the other hand, when the insured prices are higher than the net expected market

prices, there is an additional source of moral hazard came from these price gap. Moral hazard problems would be more serious when considering the price uncertainty than when not considering the price uncertainty.

In summary, to reduce the problems of moral hazard and adverse selection with the consideration of price uncertainty, the coinsurance rates need to be less than 1, i.e., less than full coverage. To further reduce the problem of adverse selection, this optimal coinsurance rate should also depend on the insured's relative risk. Next, the insured prices should be set below the net expected market prices to provide the insured with appropriate incentives to minimize the yield loss. Finally, more information about input activities as well as yields needs to be obtained and better estimation methods provided for measuring the means and variances of the yield distributions.

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農業保險中價格不確定性、道德危機、與逆選擇

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摘 要

本文主旨在探討農業保險本質與其他保險之差異，以及農業保險中價格不確定性與道德危機（Moral Hazard）及逆選擇（Adverse Selection）之關係。文中並以美國現行聯邦穀物保險政策（MPCI）爲例加以解說。

一般而言，農業保險與其他保險（例如：健康保險或汽車損失保險）間最大的區別在於除了量的不確定性外尚有價格的不確定性；即定保險契約時，無法得知損害發生時農作物的產量及市價。當農作物保險價格高於其淨預期價格時，可能使農業保險中道德危機之問題更嚴重，從而使得農業保險解體。然而另一方面當農作物的保險價格低於或等於淨的預期價格時，也可能減輕此一問題，而使農業保險更成功地達成保險任務。

此外，欲減輕農業保險中道德危機與逆選擇兩問題，本文指出共同保險率（coinsurance rate）必須小於 1，即政府與農民共同分擔所發生的部份損失。而此一共同保險率之訂定，必須依農民的相對風險（relative risk）而定。此外，農作物保險價格最好不要高過淨的預期價格，以減輕道德危機的影響；而與農產投入和產出的相關資訊更要詳加蒐集以提供較準確的估計。

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