Designing Crop Insurance to Manage Moral Hazard Costs

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Short Abstract

A new crop insurance model based on just random risk (natural states) is presented instead of traditional model based on random risk, guaranteed price, and guaranteed yield. The simulation approach shows how the incentive compatibility constraints resolve the moral hazard problem by the insured under the insurer-agency crop insurance contracting.

Introduction

For decades, multiple peril crop insurance has been the focus of crop performance risk management in the U.S. agriculture. These programs have complemented price and income policy that significantly reduced price related risk. Following reforms in federal policy that moved farm prices to market determination, private sector-based or public sector supported insurance strategies became attractive as means for managing income and financial risk in agriculture. However, the challenges of successfully implementing these types of strategies were well known. Performance of past crop yield insurance schemes had clarified that not only would such approaches not be of interest to the private sector, but they were generally not financially viable and politically defensible approaches for public sector intervention. In United States, indemnity payments on such insurance schemes have consistently exceeded premium income for the insurers, even in years of good weather conditions. Internationally, similar results have occurred. Premiums have not covered indemnity and administrative costs (Quiggin, 1994). As a result, private insurers have left the crop insurance market leaving the agricultural sector ripe for solutions to manage yield, price, and related income risk. The objective of this paper is to provide an illustration of how simulation methods can be used to quantify the nature of the malperformance of crop insurance and to success how those failures might be mitigated or eliminated.

The reasons for crop insurance market failure have been identified through a series of past studies, see e.g. Quiggin, 1986; Quiggin, 1994; Schmitz et al., 1994, Coble et al., 1997; Miranda et al, 1997; Mahul, 1999. These studies agree that two features of the agricultural insurance setting can be blamed for crop insurance failure: systemic risk and information asymmetry. Systemic risk can be defined in several ways, however, in this setting it is risk that can not be offset through pooling of insureds. This follows from the fact that insureds, drawn from a feasibly diversified spatial base, remain exposed to a common risk, or loss generating mechanism. In the agricultural setting, a good example is weather-related loss in yields. Further, actual losses are typically not predictable, complicating the feasibility of offsetting the risk through diversification, either spatially or otherwise. Information asymmetry characterizes the crop insurance setting due to differential information concerning production practices and growing conditions held by insureds (farmers) and the insurers. Existence of information asymmetry results in two behavioral responses that increase the costs of insurance and challenge the efficacy of private financing of insurance: adverse selection and moral hazard problem. Adverse selection occurs when due to information asymmetry, offers of insurance are found more attractive by potential insureds that have higher risk of loss than does the general population. The result is that the pool of insureds is more risky than the general population and the risk reduction benefits of a diversified pool are not fully achieved. This increases the cost of insurance. Under full information, insurance could be designed to be attractive for purchase by all members of the heterogeneous population of potential insureds. Moral hazard occurs when insureds change their production practices in response to the risk reduction offered by insurance resulting in an increase in risk exposure beyond that which would exist if they retained their pre-insurance production plan. The effect of this behavioral response is the post-insurance risk reduction is smaller than in the absence of moral hazard.

In this paper, we focus on quantification of moral hazard in crop insurance. To begin, we review and extent the specification of Coble et al. (1997) where limited comparative statics were reported with respect to changes in moral hazard with respect to the guaranteed yield and expected indemnity levels. This specification is extended to allow for a principal agent specification. Next, the specification is implemented within a simulation context to generate quantitative results that allow for consideration of the nature of, extent of, and sensitivity of moral hazard that goes well beyond results available from a strictly theoretical approach. We present results under risk neutrality and under risk aversion for agent insureds. Importantly, by applying a contracting framework, the insurance design goes beyond simple zero profit rules for pricing and implements pricing and indemnity design that ensures participation across a heterogeneous population, allowing for reduction in adverse selection.

Relating this contribution to past work, reduction of moral hazard has been considered within the context of area yield insurance schemes, (see Miranda, 1991; Smith et al., 1994; Skees et al., 1997; Mahul, 1999; Ramaswami et al., 2001) and specific event-based insurance schemes such as rainfall insurance (see Quiggin, 1994; Turvey, 1999). However, both approaches are imperfect solutions. Area yield insurance fails to offer insurance against individual risk while special event-based insurance fails to offer optimal indemnity schedules. In contrast, this paper suggests two new insurance schemes to resolve moral hazard problem that extent ideas within these two past approaches: use of incentive compatibility constraints in a contract design-based insurance scheme to manage moral hazard and optimal yield-based contracts. Though these approaches also have flaws, they appear to offer improved performance relative to traditional multiperil crop insurance.

The remained of the paper is organized as follows. In the next section, a review of the market failure of crop insurance is offered and basic notation is introduced. Next, the detection of the existence of and measurement of the extent of moral hazard in crop insurance markets is considered. Finally, results of simulation-based design of insurance is presented.

Crop insurance market failure

We consider first the role of systematic risk as a problem in insurance design. While many past studies have attributed insurance failures to information asymmetry and resulting moral hazard and adverse selection (see e.g. Miranda et al., 1997), systematic risk also plays a key role.

Following the financial literature where the term 'systemic risk' was first used, systemic risk is risk that is not diversifiable through portfolio allocation. In a financial setting it is general market risk. In contrast, non-systemic risk can be diversified by making a portfolio of investment assets (Eisenburg et al., 2001). In insurance, systemic risk can be considered to be factors that affect all participants in insurance that generate a significant correlation across individual insured performance. In agriculture, systematic risk follows primarily from geographically common weather and specific events such as droughts of extreme temperatures. Following financial literature, systemic yield risk can be modeled by partitioning crop yield:

1) $$\tilde{y}_i = m_i + b_i(\tilde{y} - m) + \tilde{e}_i$$

where $\tilde{y}_i$ is actual individual yield, m_i is the average of individual yield representing the "risk free" yield across the population, while $\tilde{y}$ is the area yield and m is the average of area yield, their difference reflecting the systematic risk in the area, $\tilde{e}_i$ is the non-systemic risk impacting the individual, and b_i is the measure of sensitivity of individual yield to systemic factors. Equation 1) indicates that while the nonsystematic risk across individuals may be independent, the systematic risk induces interdependence across individuals. In fact, the high magnitude of this correlation renders pooling of individuals to reduce portfolio risk ineffective, increasing the cost of private insurance that covers this remaining nondiversified risk. Following Quiggin (1986), the total variance of an insurer's portfolio can be written:

2) $$V = n^2 t s^2 n^2 + h t n^2 s^2$$

when n is large and n is the number of individuals, t is correlation among risks, s is the variance of returns from growing, n is the proportion of risk insured, and h is the ratio between the variance of the pre-existing portfolio and the variance of the insurance pool. In equation 2), system risk increases in t, implying the total variance of the insurer's portfolio is also increased.

While risk pooling across insureds fails when correlation of risk is high, portfolio strategies going beyond the pool of insureds can easily offset any pool's systematic risk. Intuitively, all that is required is diversification into other risks that are uncorrelated with the systematic risk. This is the essence of reinsurance through either private or public sector mechanisms.

The second source of market failure in crop insurance follows from information asymmetry between farmers and the insurers: adverse selection and moral hazard. Because the focus of this paper is on the moral hazard, the discussion about adverse selection is kept brief and that of moral hazard is extended.

Adverse selection arises when the insured farmer has more information than the insurer. In crop insurance, three examples of adverse selection based on particular information asymmetries are often cited in the literature, see e.g. Quiggin (1994) . First, given asymmetry in yield distribution, participation is biased toward farmers that have expected indemnity in excess of premia. Second, through annual renewal participation will be biased toward farmers that expect temporally anomalous losses, e.g. following a year of large pest infestations, or high snow falls that are likely to result in reduced germination rates. Third, potential insureds may exploit local knowledge of land potential, biasing insured fields to those with higher yield risk.

Moral hazard follows froim information asymmetry with respect to insured choices. Absence of observability at a reasonable cost allows insureds to change production plans, altering the risk reduction achieved through insurance and thereby altering the risk of the pool. As illustrated in figure 1, in the absence of moral hazard, when the outcome of $e < e^*$ is insured, the insurer pays an indemnity of $price * \{f(x^*,e^*) - f(x^*,e')\}$. In contrast, if behavioral response to insurance is allowed, the indemnity would be $price * \{f(x^*,e^*) - f(x',e')\}$. In this case, risk-reducing inputs are reduced in application. Therefore, the insurance cost of moral hazard is $price * \{f(x^*,e') - f(x',e')\}$.

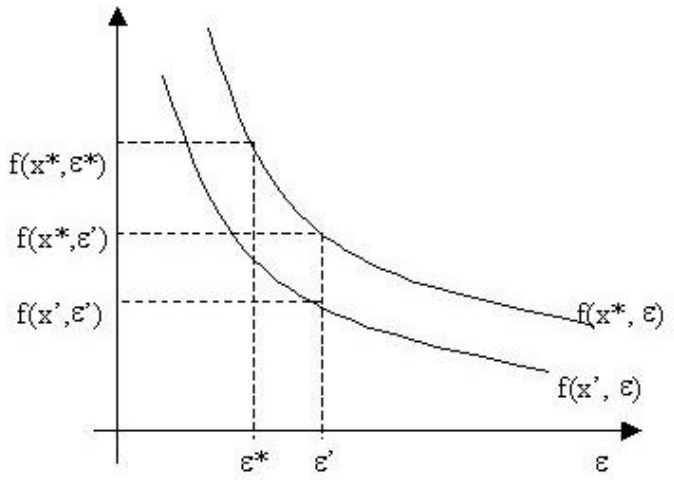


Figure 1. Moral Hazard

Modeling moral hazard

Coble et al. (1997) consider a limited number of the comparative-statics of moral hazard in crop insurance. They examine the effect of an increased in guaranteed yield on the optimal amount of controllable inputs and on the expected indemnity. Their basic model may be written as follows;

$$3) \qquad \underset{x}{MaxL} = EU(W) = \int_{\underline{e}}^{e^*} U(W_L)g(e)de + \int_{e^*}^{\bar{e}} U(W_H)\, g(e)\, de$$

where e^* is the trigger state where the loss of farms starts, the wealth of low yield case: $W_L = W_0 + A[pf(x, e) - rx + p_g\{y^* - f(x, e)\} - p_g y^* g(y^*)]$ *if* $e < e^*$, the wealth of high yield case: $W_H = W_0 + A[pf(x, e) - rx - p_g y^* g(y^*)]$ *if* $e > e^*$, W_0 is the beginning wealth, A is acres, $g(y^*)$ is premium rate that is the function of the guaranteed yield, y is the observable yield, y^* is the guaranteed yield that is the function of the production ability, p is the deterministic product price, p_g is the guaranteed price, r is the input price, $f(x, e)$ is the production function $(f_e(x, e)>0)$, $g(e)$ is the density function of random state of nature. Comparative-statics for the effect of the increase of y^* on the x is considered as an indicator of moral hazard:

$$4) \qquad \frac{\partial x}{\partial y^*} = -\frac{1}{L_{xx}}\{-U'(W^*)p_g\, f_x(x,e^*)g(e^*)\frac{\partial e^*}{\partial y^*} - [1 - g(y^*) - y^* g_{y^*}]p_g$$
$$-[g(y^*) + y^* g_{y^*}]p_g A\int_{e^*}^{\bar{e}} U''(W_H)(pf_x - r)g(e)de\}$$

where L is the Lagrangian. They conclude that the sign of $\frac{\partial x}{\partial y^*}$ is ambiguous. They further note that even if the behavioral response to insurance were observable, whether the combined changes made in the production plan would reduce insurer income would

need to be determined. Thus, the issue of interest is not addressable through single comparative-static results.

To consider the impact of insurance coverage on the expected indemnity, they define expected indemnity as:

5) $$E[I] = \Omega = \int_{\underline{e}}^{e^*} p_g[y^* - f(x,e)]g(e)de\,,$$

and evaluate the impact of a change in y^*. By definition, moral hazard exists when:

6) $$\frac{\partial \hat{\Omega}}{\partial y^*} - \frac{\partial \Omega}{\partial y^*} < 0\,.$$

Where the second term involves a Slutsky-Hicks type relationship intrinsic to the specification, i.e. $\frac{\partial \Omega}{\partial y^*} = \frac{\partial \hat{\Omega}}{\partial y^*} + \frac{\partial \Omega}{\partial x}\frac{\partial x}{\partial y^*}$. (The first term of right hand side is the impact of y^* when the insured keep the same amount of inputs as when uninsured and the second term is the impact of y^* when the amount of inputs used is changed following the change of y^*.) Thus, 6) can be rewritten as:

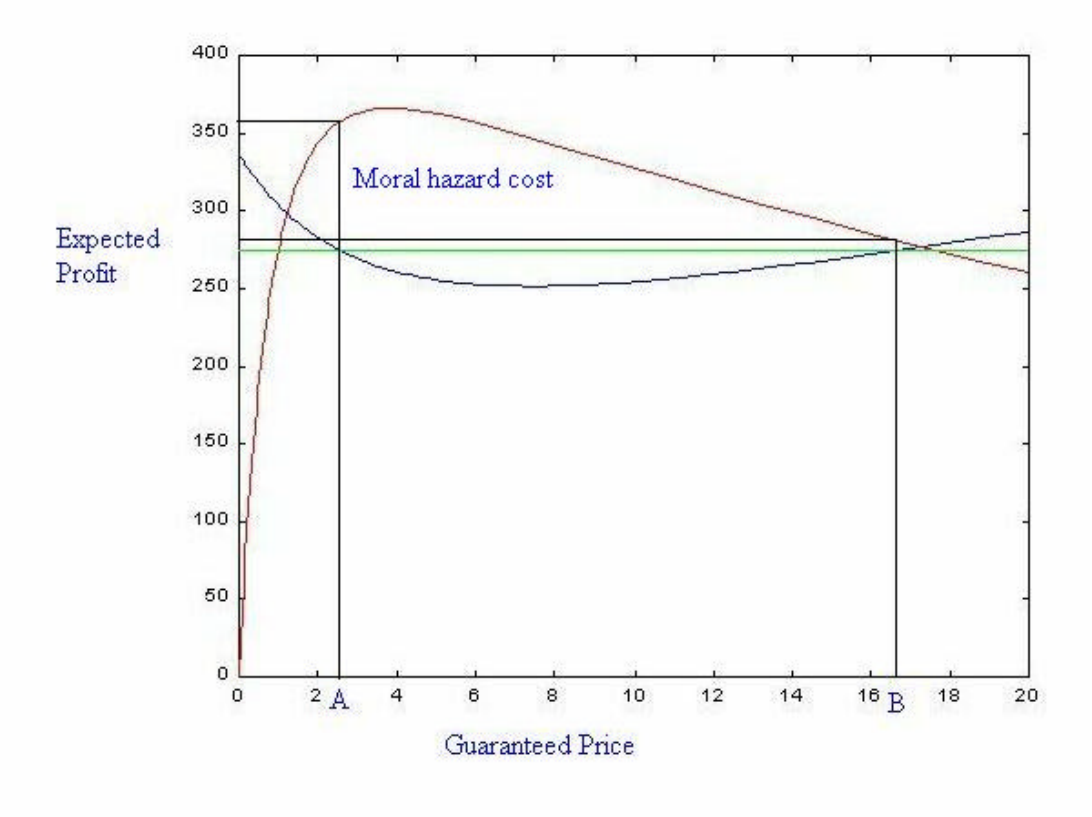
7) $$\frac{\partial \Omega}{\partial x}\frac{\partial x}{\partial y^*} > 0$$

Because indemnity is decreasing in x, $\frac{\partial \Omega}{\partial x} < 0$, moral hazard will exist whenever insurance induces reduction in inputs, i.e. $\frac{\partial x}{\partial y^*} < 0$. This might be expected if all inputs are risk-reducing. In general, the problem is far more complicated and requires consideration within a multiple input, multiple output setting.

Empirical consideration of moral hazard through simulation

To proceed, we illustrate a new approach to the consideration of moral hazard based on simulation. We consider variants of the Coble et al. (1994) model and evaluate the extent and variation of insurance impacts on insureds and insurer under risk neutrality and risk aversion. The simulation is implemented through specification of the producer cost function and the distribution of the process generating the randomness in yield. Details are available from the authors.

Risk Neutral CaseThe results are summarized in Figure 2.



: no insurance agent : insured , : the insurer
Figure 2. The behavior of expected profit functions and optimal contracting points

The results of the simulation provide a significant extension of knowledge concerning the nature of moral hazard. First, in green is plotted the reservation expected income for the insured under no insurance. Under insurance, participation requires at least that level of expected profits. Now, consider the full information case. Here, the insurer, agency earns a maximum expected profit (356.85) guaranteeing the reservation expected profit (274.54) for agents at an optimal guarantee price of 2.52. The insurer cannot set the guarantee price higher that this optimal level without losing particpation by the agent. This constitutes the optimal insurance outcome under no moral hazard.

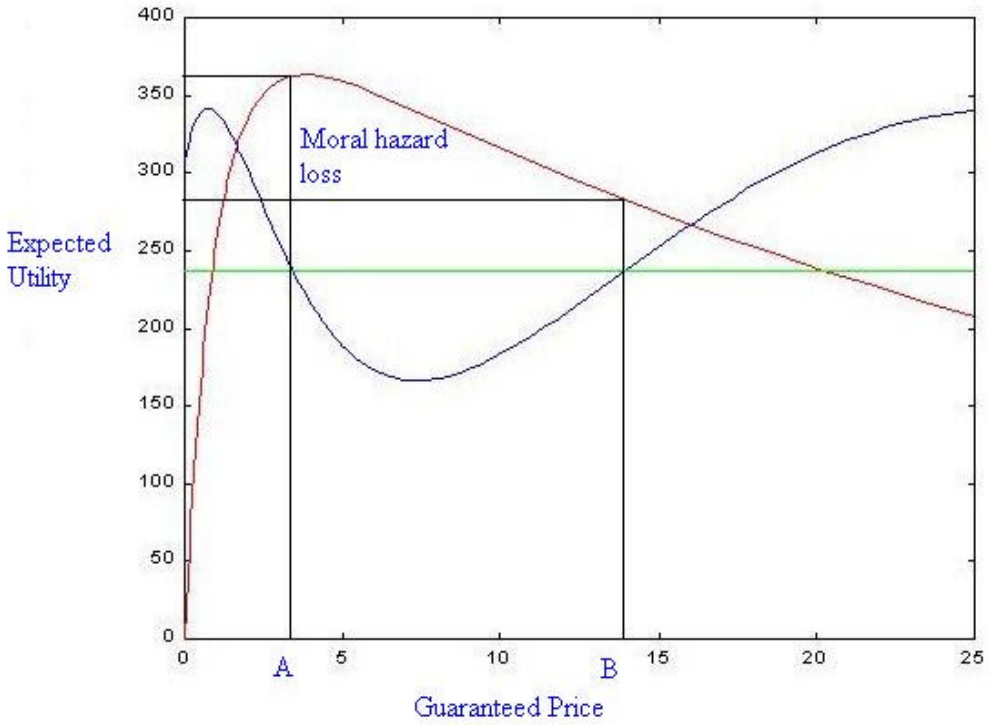
Next, consider the case of asymmetric information. Suppose that the agency can only observe the output rather than the amount of variable inputs used by agents. In this case, moral hazard will exist. From Figure 2 it is clear that as the guarantee price is varied the cost of moral hazard changes first increasing, then decreasing. To ensure participation, application of an incentive compatibility would lead the insurer to set the optimal guaranteed price at point B (with guarantee price of 16.80). In our model, the guaranteed price is decreasing in the amount of variable inputs used. It follows that agents use less variable inputs and are paid greater indemnity at point B than at point A,

though expected profit is the same. Because of this reduction in the amount of variable inputs used and the increased indemnity, the insurer agency loses expected profit (the difference 356.85-279.95=76.9) between the expected profit in point A and the expected profit in point B. This is the cost of moral hazard.

Thus, the moral hazard costs can be studied through simulation in greater detail than simply at a theoretic level. In fact, based on our specification, we show that the sensitivity of moral hazard to the guarantee price is determinant, not indeterminant as Coble et al. found. Further, we see the comparative-statics are nonlinear.

Risk averse case

Next, we examine moral hazard cost under the assumption that both agency and agents are risk averse. The results are in figure 3.



: non-contracting case, : the insured under contracting, : the insurer under contracting

Figure 3. The behavior of expected utility functions and optimal contracting points

We can use the same logic to explain these results as was applied in the case of risk neutrality. In figure 3, point A (at guarantee price 3.11) presents the optimal guaranteed price under full information. The insurer earns maximum expected utility (365.55) guaranteeing the reservation expected utility (241.30) for agents. However, if we assume asymmetric information, the optimal guaranteed price is set on point B (13.84). Again, given our specification that the guaranteed price is decreasing in the

amount of variable inputs use, agents reduce variable input use, earning increased indemnity at point B than in point A, though their expected utility is unchanged. Because of variable inputs are reduced and indemnity increased, the insurer agency loses expected utility (365.55-285.71=79.84) between the expected utility in point A and the expected utility in point B. This is the cost of moral hazard. As seen so far, the moral hazard cost can be quantified in the model based on the model of Coble et al. even under complications such as risk aversion.

Conclusion

Moral hazard costs that occur when the insurers can not observe the actions taken by insured farmers constitute an important reason for failure of crop insurance schemes. As illustrated by the simulation results, these costs can be substantial depending on how the guaranteed price is set. However, the simulations also highlighted that moral hazard costs can be managed through the design of the insurance. In fact, moral hazard costs can be eliminated or reduced substantially through choice of design.

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