GUELPH WP 99-04

Working Paper Series

Working Paper WP99/04 January 1999

THE ECONOMICS AND IMPLICATIONS OF EX-ANTE REGULATIONS IN ADDRESSING PROBLEMS OF MORAL HAZARD IN AGRICULTURAL INSURANCE

by

Zahirul Islam
Michael Hoy
Calum Turvey

UNIVERSITY of GUELPH

Department of Agricultural Economics and Business

University of Guelph
Guelph, Ontario N1G 2W1
Canada

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Department of Agricultural Economics and Business
University of Guelph
Guelph, Ontario

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*Senior authorship is not assigned. Zahirul Islam is an Economist in the Policy Analysis Branch at the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), Guelph, Ontario, N1G 4Y2. Michael Hoy is a Professor at the Department of Economics. Calum Turvey is an Associate Professor at the Department of Agricultural Economics and Business, University of Guelph, Guelph, Ontario, Canada, N1G 2W1.

Abstract

In this paper we develop a theoretical model of input supply by agricultural producers who purchase crop insurance and so who may engage in moral hazard. We show, through simulations, that a combination of partial insurance coverage combined with a minimum standard for input use may reduce substantially the problems associated with moral hazard. Partial insurance coverage creates an incentive for the producer to increase his use of inputs since the cost of lower output is partially borne by the producer, an outcome which would not be present under full coverage insurance. Partial monitoring of inputs, in the form of a minimum requirement for input use, has a direct effect on the reduction of moral hazard. We show that, rather than being substitute instruments, these are in fact complementary methods of encouraging a more efficient supply of inputs. Moreover, the minimum level of input use that must be required by regulation turns out to be substantially lower than the optimal or actual input level chosen by producers. Since the supply of inputs for crop production occurs in many stages over the pre-planting, planting and growing seasons, the fact that only a minimal input requirement is needed means that the cost of implementing such a regulation can be kept much lower than would be the case for a regulation of complete monitoring of input usage.

I. Introduction

Moral hazard exists whenever insurance for some activity creates an incentive for the insured to supply less than the efficient amounts of productive inputs or level of some precautionary activity. Although perfect monitoring of input usage can eliminate this problem it is often too costly to do so. When the insurer doesn't observe all the actions taken by the insured then, once insurance is purchased, the insured acts in a manner that increases the probability of loss that in turn enhances the likelihood of a large claim being filed by the insured (Rubinstein and Yaari, 1983). Thus, in order to avoid expected losses, the insurer must adjust expectations of claims relative to those that would be relevant in the absence of insurance. Specifically, in the context of crop production the cost of insurance would be higher than would be computed using pre-insurance distributions of crop yields. This would lead to a relatively high price for insurance and possible nonviability in a private market context. At the very least, inefficient input supply would result from insurance. If the insurance is provided and subsidized by a public agency then moral hazard still leads to inefficiency in input supply. Moreover, the greater is the degree of moral hazard the greater is the subsidy cost or program cost for the public insurer.[1]

Two possible instruments for reducing the impact of moral hazard are the monitoring of input use and the offering of only partial insurance coverage. Monitoring input use of producers can directly eliminate or at least reduce the inefficiency created by moral hazard. However, the fact that perfect monitoring of inputs does not generally occur for insured activities suggests it is simply too costly in general to do so and so at best imperfect monitoring with accompanying imperfect resolution of the moral hazard problem is usually the best that can be expected with this instrument.[2] Partial insurance coverage is an alternative means of correcting at least partially the incentive for insured agents to engage in moral hazard[3]. However, this policy leads to some residual risk bearing cost for the inured as well as still creating some disincentive to provide

[1] *The problems associated with moral hazard that affect the efficiency of an agricultural insurance program have major implications for farm level decision making and public policy formulation. The relationship between efficiency and the program costs of the current agricultural insurance policies due to problems of moral hazard has not been well documented (Islam, 1996).*

[2] *See Holmstrom (1979) and Shavell (1979)*

efficient levels of inputs.

In this paper we develop a theoretical model of input supply by agricultural producers who purchase crop insurance and so who may engage in moral hazard. We show, through simulations, that a combination of partial insurance coverage combined with a minimum standard for input use may reduce substantially the problems associated with moral hazard. Thus, rather than being substitute instruments, these are in fact complementary methods of encouraging a more efficient supply of inputs. Although the minimum standard requirement for inputs in our model requires "partial" monitoring of input use, this is introduced in a manner substantially different from that, for example, of Holmstrom (1979) or Shavell (1979). Rather than monitoring perfectly the input levels of the producer with a given probability, we monitor some part of the inputs used with a probability of one. In the context of the production of crops this method is an attractive one. Since the supply of inputs for crop production occurs in many stages over the pre-planting, planting and growing seasons, the fact that only a minimal standard of input usage is required means that the cost of implementing such a regulation can be kept much lower than would be required by a regulation requiring complete monitoring of input usage (that is, since perhaps only inputs of one stage need to be monitored). Moreover, we show that the minimum level of input use that must be required by such a regulation turns out to be substantially lower than the optimal or actual input level chosen by producers. Thus; by introducing a combination of policies - partial insurance coverage and partial monitoring of inputs to enforce a minimum level of input usage - a public insurer can reduce the cost of insurance, and in turn reduce the level of subsidy, possibly to zero, that is required to maintain a viable crop insurance program.

The remainder of this paper is arranged in four sections. Section II presents the theoretical model used for deriving producers' input decisions in the presence of partial insurance and a minimum input regulation. In Section III we develop the intuition concerning how the minimum input requirement may encourage the producer to choose an actual input level which is substantially higher than the amount required by the regulation despite the fact that in the absence of such a regulation the producer would in fact not do so. Roughly speaking, the reason for this outcome is that once the producer is required to employ some minimal

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[3] *See Pauly (1974), Arrow (1971) and Spence and Zeckhauser (1971)*

input level this reduces the probability of making an insurance claim. With more possible states of the world in which the insured would actually benefit from increased input use (i.e., instances for which output exceeds that level for which claims are made), it follows that the insurered will voluntarily increase his input usage beyond the minimum required. Simulation results are presented in Section IV, while conclusions and policy implications are considered in Section V.

A note about how our model and results compare to the literature on regulation and incentives is in order here. We refer to the input requirement as an ex ante regulation since this is stipulated in the contract before production decisions are made, while the partial coverage of insurance is an ex post device for providing incentives to producers to enhance the efficiency of input usage. This is a similar problem to that of considering whether to use safety regulations (an ex ante mechanism) or exposure to liability for harm to third parties (an ex post mechanism) as means for encouraging risk reduction for individuals or firms engaged in potentially hazardous activities such as the production of nuclear energy.[4] There are, however, many differences. The most important differences are that: (i) in our model the "harm" from under employing inputs accrues to the individual who chooses the rather than externalities or exposure to risks, which harm others, through a liability rule, (ii) in our model it is implicit that the first-best level of input usage is not regulated because it would be too costly to do so, while in the other models there is no explicit assumption about the cost of regulating inputs at their first best efficient levels, and (iii) in our model agents are risk averse, otherwise there would be no role for insurance.

II Model Formulation

We use a very simple model of production in order to focus on the incentive effects of insurance with both ex ante and ex post regulatory mechanisms. We select this structure in order to explicitly recognize that there is a temporal relationship between the a priori decision to use an input mix, and the ex post realization of stochastic outcomes. The ex ante regulators regime monitors the a priori decision, while the ex post pays off in terms of partial coverage and ex ante compliance. Production is assumed to be a function of a single

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[4] *See Shavell (1984), and Kolstad, C.D., T.S.Ulen, and G.V.Johnson (1990)*

input, x, and the state of nature, ω. The state of nature ω may be interpreted as an index variable which characterizes all weather conditions and other elements outside the producer's direct control, with higher values of ω indicating more favourable conditions. Since ω is a random variable then so is the yield outcome,

$$(1) \qquad \tilde{y} = f(x,\omega)$$

denoted $\tilde{y}$, with $\partial\tilde{y}/\partial\omega>0$. Thus, we specify the production function as follows:

where $f_x>0$, $f_{xx}\leq 0$, $f_\omega \geq 0$ ($f\omega>0$ for $x>0$), and $f(0,\omega)=0$

Before knowing the true state of nature, ω, a producer chooses an input level (x) in order to maximize his expected utility of profits. Let U(.) be the producer's von Neumann - Morgenstern utility function where $U'(.)>0$ and $U''(.)<0$. Let $h(\omega)$ represent the probability density function for the random variable ω, with lower bound $\underline{\omega}$ and upper bound ω, let P be the price of output and r the unit input cost then we have, for the

$$(2) \qquad \underset{x}{\text{Max}}\ EU(x) = \int_{\underline{\omega}}^{\bar{\omega}} U\left[Pf(x,\omega) - rx\right]h(\omega)d\omega$$

case where crop insurance is not available, the following maximization problem for the producer:

The solution to equation (2) gives the input usage in the absence of insurance. We use this solution in our simulations to provide a benchmark against which to compare the input usage in the case of insurance for different regulatory scenarios.

We now model how the insurance program is implemented and how this affects the producer's input choice. We define y_c as the critical yield level which triggers insurance payments. If actual yield (y) falls below the critical yield (y_c) [i.e., $y<y_c$], the insurer makes up the difference. In this situation the insured obtains an indemnity of $P(y_c-y)$ because of the short fall in yield, where P is the price level on which insurance is determined.[5] The cost of insurance (i.e., premium cost) with ρ representing the producer's profit under agricultural insurance is as follows:

[5] *We ignore price uncertainty in order to focus on the question of how regulations for insurance affect input choice. If price were variable and negatively correlated with an individual's output, then the insurance decision may be quite different. However, the presence of a future's market allows the producer to "fix" its price as long as the insured price is at the same level.*

(3) $$\begin{aligned}\pi &= Py_c\text{-}rx - \rho \ \ if \ \ y < y_c \ \ (i.e., if \ f(x,\omega) < y_c) \\ &= Py_c - rx - \rho \ \ if \ \ y \geq y_c \ \ (i.e., if \ f(x,\omega) \geq y_c)\end{aligned}$$

Since y depends positively on x (as well as ω) it follows that for a given level of x there is a critical level of ω, denoted ω_c such that $y \leq y_c$ if and only if $\omega \leq \omega_c$. Since ω_c depends on x we explicitly note this by writing $\omega_c(x)$, with $\omega_c'(x) > 0$. Thus, we can write the probability that the producer's yield is sufficiently low so as to trigger a claim either in terms of y or x according to:

(4) $$\tau(x)=\Pr[f(x,\omega) \leq y_c]$$

This probability clearly depends on input use level, x. Formally we can define $\tau(x)$ as the probability that the producer's output level triggers a claim where

(5) $$\tau(x)=\int_{\underline{\omega}}^{\omega_c}(x)h(\omega)d\omega$$

The maximization problem for a producer with insurance can be expressed in terms of the probability density function (pdf) for ω as

(6) $$\underset{x}{MAX}\, EU(x) = \tau(x)U(Py_c - rx - \rho)\int_{\omega x_c(x)}^{\varpi} U(Pf(x,\omega) - rx - \rho)h(\omega)d\omega$$

Let the first term in equation (6) above be represented by $T_1(x)$; i.e., $T_1(x) = \tau(x)U(Py_c\text{-}rx\text{-}\rho)$. Both utility and the probability of output being so low as to trigger a claim is decreasing in x (i.e., $\tau'(x)$_0) in this state (since x only increases costs in those states where the shortfall in yield is made up through an insurance indemnity) then it follows that $T_1(x)$ is decreasing in x. The second term in equation (6), $T_2(x)= \int_{\omega sub_c(x)}^{\bar{\omega}}$ $U(Pf(x,\omega) - rx - \rho)\ h(\omega)\ d\omega$, captures the producer's payoff in those states of the world where output is sufficiently high that an insurance claim is not made. An increase in x increases the likelihood of no claim being made and also increases the level of output in these states. Of course, increasing x also increases costs, but, the optimal value of x balances all of these effects on $T_1(x)$ and $T_2(x)$.

A higher coverage level (y_c) increases the importance of the term $T_1(x)$ and so induces the firm to reduce the input level (i.e., since $T_1'(x)<0$). Moreover, increasing y_c is equivalent to an increase in the critical value of ω (i.e., ω_c), that is, according to the term $T_2(x)$ an increase in y_c reduces the likelihood that employing any positive level of input x will have any payoff whatsoever. Thus, higher values of y_c imply lower optimal values of the input level x. For sufficiently high values of y_c, input use will fall to zero.

To anticipate the effect of the ex ante mechanism, which is to require a minimal standard for input use, consider the effect of an effective regulation that $x \geq x_{min}$, where x_{min} is the minimal input level for which the producer may receive any claim. Thus, if the producer fails to use an input level at least as large as x_{min} he will not receive any claim regardless of his yield. If the producer's optimal input level from the maximization problem of equation (6) is less than this critical value x_{min} then choosing the same input value in the presence of this constraint means that in fact the producer would receive no revenue or indemnity associated with the term T_1 and would only incur the cost of production for these states of the world. Moreover, this input level would not in fact balance the incentive for a *low* value of x from term T_1 - against the positive effects of using a high value of x from term T_2 (i.e., in these states of the world using where x is productive). On balance, the positive incentive to use a greater value of x would take greater importance under this regulation and so it may be optimal for the producer to increase the use of his input. As one considers higher values of the input used the first term becomes less important and the second term becomes more important in the optimization decision. In fact, as we will show in the simulations, it is even possible that a "relatively small" value for x_{min} may be sufficient to encourage the producer to employ a substantially higher level of input than would be chosen in the unconstrained optimization problem of equation (6)

III. Economics of Ex-Ante Regulation[6]

The problems of moral hazard in agricultural insurance arises from the fact that farmers can take a variety of actions which affect the probability and/or size of loss and insurers can not observe these actions (at least not costlessly). The purpose of insurance may affect the incentives for many farm practices, including decisions concerning fertilizer usage, soil preparation, soil conservation and ploughing techniques, all of which affect the likelihood of making insurance claims.

[6] *To conserve space, the detail theoretical (algebraic) model and comparative static results are not presented here. However, full theoretical model and computer programs for simulations model pertaining to how minimum ex ante standard (X_{min}) and the choice of input under ex ante regulations ($X_{ex\ ante}$) are determined can be obtained from authors.*

However, there are a variety of ways in which the insurer can attempt to alleviate the problem of moral hazard. One such mechanism is through ex ante regulations, such as requiring a minimal acceptable level of inputs. In order to be effective, such a policy must include monitoring of selected inputs and this may be prohibitively costly. However, we show in this section that it is possible that the level at which the inputs must be monitored may be quite modest and so only involve one or two aspects of the production decision. We model this approach by establishing a constraint on the input level x, $x \geq x_{min}$, which is intended to reflect the fact that only a subset of the inputs need to be monitored. If the producers chooses an input level less than x_{min} then in the event that output falls below the critical level y_c no payment is made by the insurer. This implies that the term $T_1(x) = \tau(x)U(Py_c\text{-}rx\text{-}\rho)$ from equation (6) takes on the value zero for all values of $x<x_{min}$. This effectively reduces the number of states of the world in which insurance is collected. Thus, in choosing his input level the producer places more emphasis on his payouts conditional on "good" states of the world occurring (i,e., as exemplified by the term $T_2(x)= \int U(Pf(x,\omega) - rx - \rho)\, h(\omega)\, d\omega$). The result is that the producer will have an incentive to increase his input usage over the unconstrained case. In fact, we show through simulations that even if the level of y_c is sufficiently high that the producer would choose to use a zero level of input in the absence of any ex-ante regulation, it is possible that for some reasonably small level of x_{min} associated with the ex-ante regulation, the producer can be encouraged to adopt a level of input usage which is quite close to the level that would be chosen in the absence of insurance.

To understand clearly the role of such an ex-ante regulation consider first an example of extreme moral hazard created by the presence of insurance coverage in the absence of any ex-ante regulation on input usage. As for all of our examples, we assume the distribution of states of the world to be uniform and we use the constant absolute risk aversion utility function[7]. In figure 1 we plot expected utility as a function of input level x for an example with coverage level y_c equal to 50% of average income[8]. As seen in Figure 1 for this

[7] For purposes of our simulations, the implications of adopting these assumptions are clearly detailed in the appendix.
[8] Other parameters values of the model: P=\$5.0, r=\$2.0, γ=0.05, and θ=2

example the global optimum for input usage is x=0. Increasing x from zero reduces expected utility because the cost of the input is not counterbalanced by the expected value of output. This occurs because the number of states of the world in which insurance coverage is obtained, and hence input usage has zero value, is so large. As the input level rises, eventually expected utility starts to increase in x because after a certain point x is high enough to induce ω_c to be high enough such that the term T_1 becomes less important (i.e., the number of states of the world in which insurance is collected shrinks). Consequently increasing x does increase expected utility through its effect on term T_2. Eventually an interior (local) optimum is reached at value x=9.38, a level which is just slightly less that the level of x in the absence of insurance [9].

Now, if the insurer could introduce a constraint $x \geq x_{min}$ as indicated in Figure 1(i.e., no insurance would be collected if x were chosen to be less than this level) then the local interior optimum of x=9.38 would become the global optimum. Intuitively, such a constraint effectively reduces the number of instances or states of the world in which insurance will be collected and so reduces the payoff to using a low level of inputs. Thus, even though the value of x_{min} is substantially less than 9.6, the ex-ante constraint is sufficient to induce a relatively high level of input usage.

Reducing the insurance coverage level (y_c) reduces the incentive to engage in moral hazard, although x=0 may still be optimal in the absence of an ex-ante regulatory constraint. However, the lower is insurance coverage the smaller must be the value of x_{min} required to induce a relatively large input usage (i.e., to make the local interior optimum the global optimum). It is in this sense that the two instruments of partial insurance coverage, rather than full coverage, and the ex ante regulatory constraint on the input usage are complementary policies for alleviating the problems of moral hazard.

IV. Simulation Results and Discussions

To evaluate the impact of ex ante regulations against the insured's optimizing behaviour, simulation

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9 Using the same parameters as used for this example we find that the optimal choice of x for the no insurance scenario

models were developed and run for a hypothetical case situation. Noting space considerations and the primary objective of this paper is to assess the effectiveness of ex ante regulations, the specific mathematical details will not be presented, but can be obtained from the authors.

Optimal Input Decisions Under Ex ante Regulations

Several properties of the two policy instruments are illustrated by the simulation results reported in Table 1. In the first column we indicate the percentage of expected output (EY) relative to the outcome under no insurance that is used for the coverage level (y_c) in each simulation run. Column 2 indicates the yield level that this percentage induces. Column 3 reports the input choice under no insurance, which is our benchmark and does not vary, while column 4 indicates the level of input that the producer would use under insurance but with no ex ante regulatory constraint. Column 5 provides the percentage reduction in input usage induced by insurance. Note that for coverage levels of 35% and less of expected output under insurance, the impact of insurance on input usage is insignificant (less than 2% reduction in each case). However, once insurance coverage reaches 40%, the producer chooses to engage in extreme moral hazard and chooses zero input level. In column 6 we show the minimum or critical level for x_{min} required as an ex ante regulatory constraint on input usage that is needed in order to induce the producer to not engage in extreme moral hazard and to instead choose the interior local optimum illustrated in Figure 1 as the global optimum. Column 7 then gives the input choice associated with this interior optimum with column 8 indicating the percentage reduction in input usage under insurance with the ex ante regulatory constraint relative to no insurance whatsoever. Input reduction is quite modest even for relatively high levels of insurance coverage[10]. Also note from columns 7 and 8 that the lower is the coverage level the lower is the ex ante mechanism required to generate an interior optimum for choice of input level.

The choice of input under insurance with and without ex ante regulations, at different coverage levels are given in Table 1. Results indicate that input choice under ex ante regulations (column 7) is close to the

(i.e., the solution to the problem of equation (2) is x=8.34).

10 For example, with 80% coverage and ex ante constraint $x \geq 4.91$ we have only a 10.62% reduction in input usage compared to a 100% reduction which occurs in the absence of any ex ante regulation.

optimal input choice under no insurance (column 3). Compared to the input choice under regular insurance (column 4), one can see a minimal effect of insurance on input use with ex ante regulations at any coverage levels. The implications of this result is that there will be minimal distortions of agricultural input use for an insurance program with ex ante regulations. At low coverage levels (up to 35% in this study), ex ante regulation are not requires, since the choice of input under insurance (x_{WI}) is close to the choice of input under an ex ante regulation ($x_{ex\ ante}$) However, at higher coverage levels, specifying a minimal level of input use as a regulatory constraint induces an insured to choose a higher level of x. For example, at a 40% coverage level, the requirement of a minimal level of input use (x_{min}) at 0.53 units is sufficient to induce the insured to use 9.43 units of input. In contrast 0 units would be used under insurance without ex ante requirements (Table 1).

Figure 2 illustrates how the ex ante mechanism works using an example based on the simulation results at a 40% coverage level. Without ex ante regulations, insureds choose only 0.01 units of input to maximize expected utility of profits, EU(Π)=-0.422. From the diagram it can be seen that there is a local interior optimum that can be achieved through specifying a regulatory constraint in the form of $x \geq x_{min}$. This constraint induces an insured to choose a higher level of input. In this example(i.e., at 40% coverage level), specifying $x_{min} \geq 0.53$ units induces the insured to choose $x = x_{ex\ ante} = 9.43$ units. Importantly, this is also the point of local maximum for optimal EU(Π)=-0.444.

Ex ante regulation works for higher coverage levels (in this model, up to 80%) in an analogous manner as explained above for the 40% coverage level. However, at full coverage level (i.e., at 100% coverage level), based on our simulation results, ex ante regulation is still applicable but may not be that effective since no local interior optimum exists. This can be seen from Figure 3. By saying "ex ante regulation may not be that effective at higher coverage levels" what we mean is that there is no "small" x_{min} value that will induce producers, in light of the constraint $x \geq x_{min}$ to choose an optimal input level under ex ante regulation ($x^{*}_{ex\ ante}$) which is "larger" than x_{min}. The reason is that there is not, for this case, (and particularly for any coverage levels at or above 85% in this model) an interior optimum which would be the global optimum for the restricted set of inputs, $x \geq x_{min}$.

Now, in this sense the ex ante restriction would not be applicable or particularly effective. But it is still true that if the constraint $x \geq x_{min}$ is imposed, the producer will choose x_{min} rather than zero (which they would choose under extreme moral hazard conditions). The ex ante regulation is effective in that the constraint is binding (by definition) and $x_{min} > 0$ induces a higher input choice than having no ex ante regulation at all. In contrast, where "an interior optimum is chosen" as a result of some x_{min} large enough, the regulation is "more effective" in that it induces an optimal choice of x which is actually larger (and perhaps substantially larger) than the minimum requirement, x_{min}.

Let us illustrate some of the intuitions discussed above with the aid of Figure 3. Suppose it was feasible - even cheap - to have a regulation $x \geq x_{min}$ where $x_{min} > 0$ for this case. Then the choice of the farmer would be $x = x_{min}$ (i.e., he would only use the level he is required to use). Here, the ex ante regulation is still applicable and effective at higher coverage levels as it induces a higher (than 0) level of input use. However, it is not as effective as it would be if there were an interior optimum involving a value of $x^*_{ex\ ante}$ being substantially greater than x_{min}.

Results presented in Table 1 further indicate that at low coverage levels (i.e., at 10-35% coverage levels), ex ante regulation is not necessary since $x_{WI} = x^*_{ex\ ante}$. However, for coverage levels of 40% to 80% associated with no input use (extreme moral hazard) under regular insurance, an ex ante regulation is very effective. At these higher coverage levels, by specifying x_{min} as a regulatory constraint, the insurer can induce insureds to choose a higher input level.

Results pertaining to x_{min} and the choice of input under ex ante regulation, $x_{ex\ ante}$ (columns 6 and 7 respectively in Table 1) strongly support corollaries 1 and 2 ($\partial x_{min}/\partial y_c > 0$, and $\partial x_{ex\ ante}/\partial y_c < 0$). Intuitively the higher the coverage level, the higher the value of x_{min} that must be specified ex ante to induce insureds to choose a level of input that prevents extreme moral hazard. As coverage levels increase, the choice of x under ex ante regulation goes down. This implies that in states of the world in which insurance is collected the marginal physical product of x is zero, yet the marginal cost is borne in all states of the world. Consequently, coverage levels (y_c), result in more states in which reducing x makes sense. This is true whether there are ex ante regulations or not, since $\partial x/\partial y_c < 0$ in the ordinary insurance regime as well.

The first conclusion from these results is that the application of ex ante regulations can be very effective in mitigating extreme moral hazard problems which can exist with regular insurance at higher coverage levels. Second, ex ante regulations can still be applicable and effective at high coverage levels (at or above 85% in this model) but may not be as effective as lower coverage levels for which an interior optimum involving a value of x substantially larger than x_{min} exists.

Reduction in Optimal Input Use: Regular Insurance vs Ex ante Regulations

In Table 1, a percentage reduction in optimal input use under insurance alone (column 5) and insurance with ex ante regulations (column 8) were computed and compared with the no insurance scenario (column 3). Up to the 35% coverage level, percentage reductions of optimal input under insurance and insurance with ex ante regulations are almost comparable. For example, at a 35% coverage level, optimal input use decreases by only 1.35% under both insurance and insurance with ex ante regulations compared to the no insurance scenario. At higher coverage levels, optimal input use decreases more under insurance than insurance with ex ante regulations. At a 40% coverage level, the introduction of insurance induces an 99.80% reduction, while insurance with ex ante regulations induces only a 1.77% reduction in optimal input use. However, at a 80% coverage level, ex ante regulation induces a 10.62% reduction in optimal input use as opposed to 100% reduction under regular insurance. According to the simulations, the conclusion is that regular agricultural insurance will likely lead to relatively minor reductions in farm applications of agricultural inputs if coverage levels are very low, while insurance will likely lead to significant reductions in input use at higher coverage levels. This further implies that moral hazard can be a significant problem if coverage levels reach a certain threshold. Ex ante regulation raises the threshold coverage levels at which no inputs are used. The introduction of ex ante regulations, which require a minimal level of precautionary input use for a particular insurance coverage, will induce insureds to increase their level of input use, which in turn will mitigate the severity of damage and essentially could eliminate the moral hazard problem compared to regular insurance.

Program Costs From Moral Hazard: With and Without Ex-ante Regulations[11]

Program costs[12] under ex ante regulations (column 13) as opposed to regular insurance (column 12) are also presented in Table 1. There are substantial differences between program costs under insurance and ex ante regulations. For example, at a 40% coverage level, program costs under ex ante regulations is found to be $0.04 as opposed to $17.23 under insurance (Table 1). The difference increases with higher coverage levels. For instance, at a 80% coverage level, insurance alone imposes a cost of $30.67 compared to only $0.91 under ex ante regulation. The ex ante regulation induces the insured to choose a higher level of input use rather than practice the extreme moral hazard evident at higher coverage levels. Since ex ante regulations induce insureds to use more inputs under insurance, that eventually reduces the insured's chance of collecting higher expected indemnities, which in turn also reduces program costs.

V. Conclusions and Implications For Policy Formulations

The presence of moral hazard is identified in this paper and the magnitude of program costs attributed to moral hazard are found to be substantial. It is evident that existing agricultural insurance

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11 *This paper ignores the monitoring costs of regulating a minimal input use. Moreover, comparing the monitoring costs with the savings in program costs under ex ante regulations is beyond the scope of this paper. Therefore, this paper ignores this issue explicitly.*

12 *Again to conserve space, the methodology to compute program costs for a particular insurance contract under regular insurance and insurance with ex ante regulations of a myopic insurer from moral hazard are not presented here. However, the detail methodology of computing program costs that can be attributed to the problems of asymmetric information such as*

contracts are inappropriate in mitigating the severity of moral hazard problems. To alleviate the problems of moral hazard and also to reduce the magnitude of program costs attributed to it, this paper has analyzed the effectiveness of ex ante regulations. Simulation results indicate that ex ante regulations induced insured farmers to use more inputs relative to regular insurance. Moreover, such mechanisms alter insureds' optimizing behaviour, and minimize perverse program costs. Consequently, this paper provides a specific policy prescription. In addition to current provisions of co-insurance and deductibles, policy makers and/or crop insurers should introduce ex ante regulations along with closer monitoring in order to deliver more efficient agricultural insurance to farmers.

The theoretical results of this study pertaining to ex ante regulations suggest that insurers could prescribe stipulated regulations about management/agronomic practices at the time an insurance contract is signed. Because farmers would not be able to violate the stipulations of the contract without loosing insurance coverage in the next period and indemnities in the current period, this would result in reducing moral hazard problems. In addition, it is highly likely that the mere threat of auditing best management practices would be sufficient to induce x>xmin behaviour.

Finally a comment on the significance of Figures 1-3 in the paper. These figures identify multiple optimums based upon the insureds risk profile and other characteristics. Importantly all points along these curves represent optimization behaviour in one form or another. Throughout the text we have referred to the low input solutions as moral hazard or extreme moral hazard, and have done so only because our profession uses this term by convention. However, in reality figures 1-3 make no 'moral' judgement whatsoever about the levels of input used. Indeed, all responses are clearly the result of optimal input use in a risk sharing regime and it is the fault of the contract, not the insured, when seemingly 'moral hazard' behaviour is observed. As the flaw is in the contract, so must be the resolution, and the ex ante regulators regime presented in this paper will do this.

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moral hazard and adverse selection can be obtained from authors.

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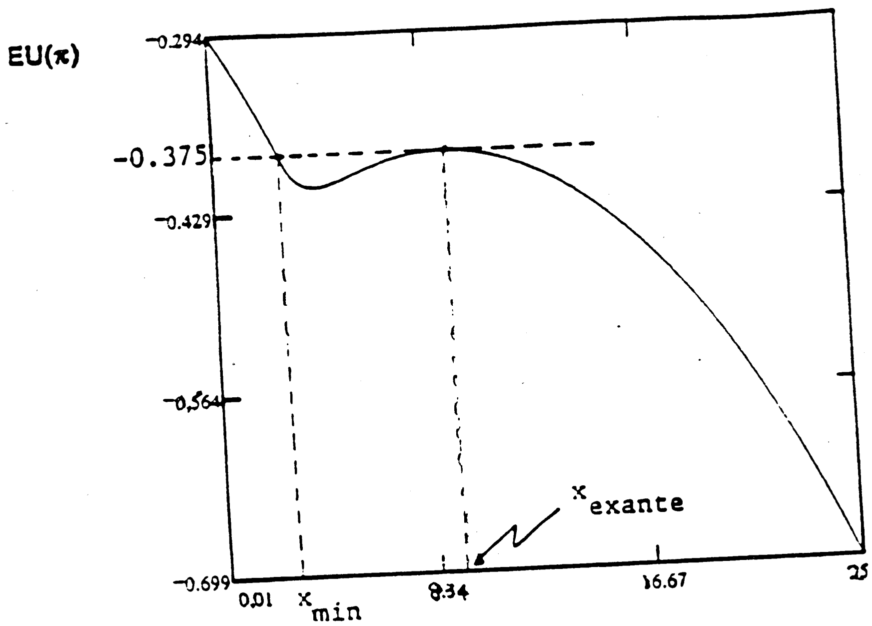
Table 1: Characterizing Moral Hazard With and Without Ex-ante Regulations Under Constant Returns to Scale Assumption
(Parameter Values: P=\$5, r=\$2, θ=2, γ=0.05, and α=1 (CRS)

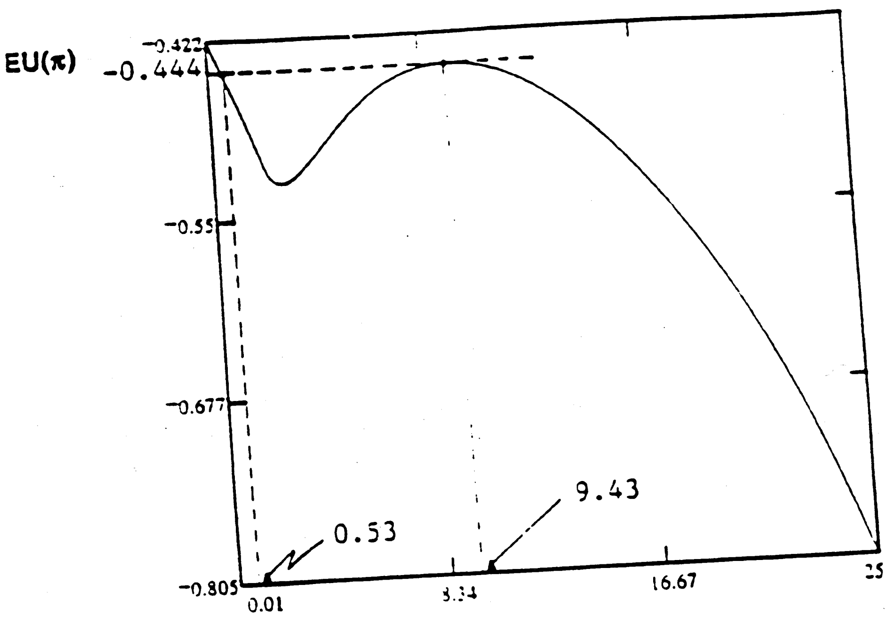
Cov. Lev. (% of EY)	y_c	Optimal Input Use		% Reduction[a]	X_{Min}	Choice of Input Under Ex-ante Regulations (X_{exante})	% Reduction[b]	Prem. (ρ) (based on uninsured behaviour)	Expected Indemnities		Program Costs for insurance	
		X(NI) No Insu.	X(WI) With Insu.						EI(WI)	EI(Ex-ante)	No Ex Ante Regulation	Under Ex ante Regulations
10	0.96	9.60	9.58	0.20	0	9.58	0.20	0.12	0.122	0.122	0.001	0.001
20	1.92	9.60	9.55	0.52	0	9.55	0.52	0.48	0.482	0.482	0.002	0.002
25	2.40	9.60	9.53	0.72	0	9.53	0.72	0.75	0.756	0.756	0.006	0.006
30	2.88	9.60	9.50	1.04	0	9.50	1.04	1.08	1.09	1.09	0.01	0.01
35	3.36	9.60	9.47	1.35	0	9.47	1.35	1.47	1.49	1.49	0.020	0.02
40	3.84	9.60	0	100	0.53	9.43	1.77	1.92	19.15	1.96	17.23	0.04
45	4.32	9.60	0	100	1.12	9.38	2.29	2.43	21.55	2.49	19.12	0.06
50	4.80	9.60	0	100	1.67	9.32	2.91	3.00	23.95	3.09	20.95	0.09
60	5.76	9.60	0	100	2.68	9.21	4.38	4.32	28.75	4.52	24.43	0.20
65	6.24	9.60	0	100	3.15	9.08	5.42	5.07	31.15	5.36	26.08	0.29
70	6.72	9.60	0	100	3.65	8.96	6.67	5.88	33.55	6.30	27.67	0.42
75	7.20	9.60	0	100	4.22	8.80	8.33	6.75	35.95	7.36	29.20	0.61
80	7.68	9.60	0	100	4.91	8.58	10.62	7.68	38.35	8.59	30.67	0.91
100	9.60	9.60	0	100	N.E	N.E	N.E	12.0	47.95	N.E	35.95	N.E

N.E: Not Effective but still applicable (no local interior optimum exists); X_{min} stands for minimum ex ante restrictions.
[a,b] Percentage reduction is computed based on no insurance solution: X(NI)= 9.6;



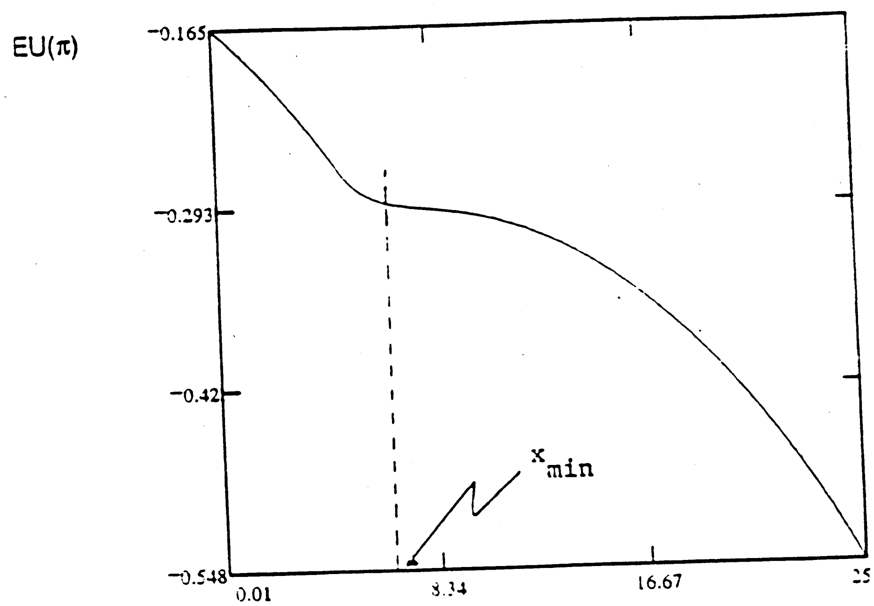
Choice of x Under Ex-Ante Regulations

Fig. 1: Choice of Optimal Level of Input With Insurance Under Ex-Ante Regulations



Choice of x Under Ex-Ante Regulations

Fig. 2: Choice of Optimal Level of Input in Insurance Scenario at 40% Coverage Level Under Ex-Ante Regulations (parameter values: P=$5.0, r=$2.0, γ=0.05 and θ=2)



Choice of x Under Ex-Ante Regulation

Fig. 3: Optimal Input Choice With Insurance Under Ex-Ante Regulation at 100% Coverage Level
(parameter values: P=\$5.0, r=\$2.0, γ=0.05 and θ=2)

(Note: Even at full coverage level, ex ante regulation is still applicable but may not be that effective since no local interior optimum exists)