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Agricultural Insurance as an Environmental Policy Tool

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This paper examines the possibility that insurance for row crops, livestock, and aquaculture can be used effectively to encourage producers to adopt practices that will improve environmental behavior. Examples of agricultural environmental insurance are provided and considered in the context of alternative policy mechanisms. The current state of agricultural insurance and the nonagricultural environmental insurance market are explored. We also lay out the characteristics of an insurable risk along with the theoretical basis of insurance provision. An empirical example of an environmental insurance design is provided, and the behavioral implications of such a design are examined. Finally, we discuss important considerations that should be evaluated when considering an attempt to implement an agricultural insurance program directed at environmental behavior.

Key Words: environment, insurance, liability

JEL Classifications: D81, G22, H23, K13, Q18

Agricultural production inherently creates byproducts that can pollute or damage surrounding as well as distant environments. Suspended soil particles are a source of water pollution (turbidity) stemming from tillage practices and water runoff events. Excess nitrogen (N) and phosphorus enter water bodies because of overapplying crop fertilizers and improperly managed confined animal feeding operations (CAFOs) that generate large quantities of wastes. Pesticides and herbicides enter the environment through water runoff or drift from aerial applications. Agriculture may sometimes be a readily identifiable source of environmental degradation or pollution, but in many cases, agriculture results in nonpoint-source pollution that is, in many ways, more difficult to pinpoint and reduce.

The runoff from an individual farm may cause little damage to water systems, but in the aggregate, agricultural production can generate excessive quantities of nutrients that can negatively affect the environment. The U.S. Environmental Protection Agency (EPA) and the U.S. Department of Agriculture (USDA) are working with farmers to find ways to reduce nonpoint-source pollution from agricultural production. In many cases, the implementation of best management practices (BMPs) can reduce or eliminate agricultural pollution. If BMPs are not followed when prescribed or do not otherwise succeed in achieving the desired reduction, then compliance may be enforced through fines or other penalties. Other alternatives may be more market-oriented approaches that encourage farmer compliance with less polluting production practices. Environmental insurance is a rapidly

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Table 1. Contrast of Major Mechanisms to Address Environmental Damage Risk

Attribute or Effect	Governmental Benefits for Damaged Party	Governmental Regulation of the Damaging Party	Governmental Taxation or Incentives for Damaging Party	Tort System	Insurance System
Damage due to nature	Applicable	Not applicable	Not applicable	Not applicable	Not applicable
Damage due to a responsible party	Applicable	Applicable	Applicable	Applicable	Applicable
Applicable to noninsurable risks	Yes	Yes	Yes	Yes	No
Applicable when responsible party is not identifiable	Yes	No	Yes	No	No
Incentives to mitigate damage	No	Yes	Yes	Yes	Yes
Does monitoring occur?	No	Yes	Yes	No	Yes
Level of transaction costs	Low	High	High	Very high	Varying
Is there accurate risk segregation?	No	No	Yes	No	Yes

expanding product outside the realm of agriculture that could play a greater role in agricultural-environmental risk reduction, especially as the government attempts to reduce its role as a regulator (Barnett and Skees). Agricultural-environmental insurance policies could focus on reducing pollution items such as total minimum daily limits of suspended solids, N, or phosphorus while protecting farmers from the risks associated with pollution-reducing management (Huang; Mitchell, Hurley, and Hellmich).

Providing coverage for environmental damage due to agricultural production will alter producer behavior—changes that may not be entirely consistent with desired outcomes. Poorly designed or inappropriately used, pollution-reducing agricultural insurance could actually encourage polluting behavior by reducing a farmer's exposure to penalties for polluting the environment. The characteristics of insurable risks that determine whether an insurance program is viable must also be considered. In this paper, we examine the state of environmental insurance and consider issues relevant to the advisability of such a program.

Mechanisms to Manage Environmental Risk

In assessing the potential to use insurance as an incentive to alter agricultural production, alternative mechanisms to accomplish the same goal should also be considered. This section lays out a broad framework that allows insurance mechanisms to be placed in their proper context. There are essentially five major categories of mechanisms that may be used to address environmental damage risks, which are listed in Table 1. The first category includes governmental benefit programs for the damaged party under which the government would mitigate the environmental damage to a party without attempting to identify the source or cause of the damage. The second category is governmental regulation of the damaging party, as occurs when the government enacts laws or regulations prohibiting environmental damage. Penalties are imposed against those individuals who violate the regulations. A third category is also a governmental approach that uses an incentive scheme to alter the behavior of the damaging party. This could include taxes—a negative incentive—or subsidies intended to convince the damaging party to reduce environmental damage. The fourth major category of mechanisms for managing environmental damage risks is the tort system. We distinguish this from governmental regulation in the sense that this approach largely concerns legal liability and civil damages that may be imposed on the responsible party on behalf of those who have suffered environmental damage. Finally, the fifth category represents the topic of this paper—an insurance system. For the most part, an insurance system is defined as one in which the damaging party purchases a policy that provides indemnification in case environmental damage occurs, although variations are discussed.

The rows in Table 1 represent a number of attributes or scenarios that distinguish the various environmental risk management mechanisms from one other. The first scenario we consider is damage due to nature. A governmental program that provides benefits to the damaged party is applicable in a case when no one can be held responsible for the loss. The other four mechanisms are not particularly relevant in this case because there is no responsible party. In contrast to the damage caused by nature, the second scenario examines all possible mechanisms that may be applicable when the damage is due to a responsible party. The third issue that we consider in this table is whether the mechanism is applicable to noninsurable risks, which are discussed later in this paper. At this point, we note that such risks exist, as well as scenarios in which an insurance system will not be appropriate for addressing environmental damage risks.

We next consider the applicability of the environmental damage risk mechanisms when the responsible party is not identifiable. In the case of nonpoint-source pollution, in which the responsible individual is not clearly identifiable, the government may provide benefits to the damaged party if it so chooses. However, the government will find it difficult to regulate the damaging party. When the responsible party is not identifiable, the use of either the tort system or an insurance system becomes difficult unless the system is married to some type of subsidized governmental incentive.

The fifth issue considered in Table 1 is whether the presence of incentives helps mitigate risk and whether the design being considered provides an inducement to the damaging party to alter behavior and generate less environmental damage. Under a governmental benefit program, for example, very little incentive exists for the damaging party to change its behavior to mitigate the risk. The other four mechanisms in Table 1, on the other hand, all provide incentives to mitigate damages and reduce the level of environmental risk.

The sixth attribute we consider is whether monitoring occurs under the particular mechanism. Monitoring means that some responsible party is given the task of determining whether environmental damage is occurring and, if so, at what level. When the government provides benefits for the damaged party, no reason exists to monitor the cause of the damage. Nevertheless, in a governmental regulation, taxation, or incentive scheme, some type of monitoring could occur. The degree of monitoring, however, would depend on the efforts of the government.

We also consider the level of transaction costs associated with the various mechanisms, or the level of expenses incurred above the actual damages incurred. For a governmental program benefiting the damaged parties, there are very low transaction costs. We expect transaction costs to occur only *ex post* of a damage event. In the case of governmental regulation of the damaging party or a taxation incentive scheme, much larger transaction costs may occur because of the need to monitor and implement the governmental program. Both regulation and taxation measures would carry relatively high transaction costs. The transaction costs associated with the tort system tend to be very high. In an insurance system, the transaction cost tends to be relatively low, but it also tends to be variable, as the transaction costs may be relatively fixed regardless of the size of the risk involved. Therefore, the transaction costs as a percentage of the liability may vary significantly.

The eighth and final attribute that we consider in Table 1 is accurate risk segregation or whether the mechanism correctly attributes the relative riskiness of different parties and allocates the cost accordingly. In a governmental benefit program for the damaged party, there is no attempt to identify the responsible individuals, nor is there any risk segregation. In a situation in which there is governmental regulation of the damaged party, laws are imposed to prohibit certain activities, but there is no attempt to identify the degree of risk. However, the effect of the regulation will differ according to the level of environmental damage risk. In a taxation and incentive scheme for the damaging party, there may be an identification of how risky various individuals are. In a tort system, there is no attempt to accurately segregate those who are relatively riskier from those who are less risky. The tort system only comes into play when environmental damage occurs and the responsible party can be identified. An insurance system will segregate risks. As we discuss more fully later in this paper, in order for an insurance mechanism to work, the relative riskiness of different insured individuals must be identifiable.

Examples of Agricultural-Environmental Insurance Designs

Policies are being developed to diminish environmental damages from agriculture by reducing excessive input usage and externality effects. Already, insurance contributes to environmental damage risk reduction and may strengthen its role as the government attempts to encourage market-oriented approaches. What follows are examples of agricultural sources of pollution and possible insurance devices that could reduce environmental damage and producer risk exposure. The first example examines an issue of excessive corn N application, and the second example concerns CAFOs.

1) Agricultural runoff loaded with N from excessive crop fertilization is a primary cause of agricultural nonpoint-source pollution. N applied according to BMP guidelines could reduce excessive N (and phosphorus) from entering the environment. Currently, excessive amounts of fertilizers are regularly applied because the input is inexpensive, and more input is considered good management in the event N leaches into the soil or is washed away before the developing plant can use it (Mitchell, Hurley, and Hellmich). Although this practice may be rational on the part of the producer, it is not good for the environment; it represents an externality cost borne by downstream water users.

An insurance policy that guarantees a corn yield to the farmer if BMP levels of N are used would achieve lower environmental damage risks. A corn-N insurance policy insures a farmer's yield at the levels produced by a check strip to which the farmer applies the "normal" amount of N. Such a policy addresses a farmer's aversion to lower yields if recommended BMP levels of fertilizer leach into the soil or wash away before the corn crop can benefit. The farmer would be paid on the yield difference between a check strip and the overall field. This insurance policy would encourage short- and long-term behavioral changes that could benefit both the farmer and the environment. In the short run, the farmer is guaranteed the production level of the check strip. In the long run, the farmer may become accustomed to BMP levels of N providing a yield comparable to the "normal" (excessive) N application levels.

In reference to Table 1, this insurance policy fits some of the criteria set forth for the insurance system as a mechanism to address environmental damage. There are incentives to mitigate environmental damage by the farmer. Monitoring would require comparing the check strip's fertilization and yield levels to those of the overall crop yield, resulting in low but fixed transaction costs. The level of risk associated with individual farmers is measured to some degree by the difference between N amounts (and associated yields) applied to the check strip and the remaining field. The greater the difference between the BMP level of N application and the amount the farmer applies to the check strip, the higher the individual's risk aversion and vice versa.

2) CAFOs, especially hog operations that

have waste lagoons, create special management issues. Considerable environmental damage and public health problems can occur when waste lagoon levees breech or overflow (Barnett and Skees). Most states now require CAFOs to include plans to manage waste nutrients. Proper management includes monitoring lagoon levels and applying wastes to fields in advance of rainy seasons. If lagoon levels are too high prior to the rainy season, some contractors may not allow a farmer to receive animals for the winter grow-out period, which can be a severe financial setback to CAFOs that are highly leveraged. In other cases, state regulators monitor lagoon levels and fine operators when these levels are too high or when insufficient capacity exists prior to the upcoming rainy season. In either case, a moral hazard may result, with the operator being tempted to overapply effluent or apply it when soil is rain saturated, leading to nutrient runoff and increased environmental risk.

A lagoon waste insurance policy could reduce these temptations by guaranteeing protection to producers who follow recommended BMP effluent spraying practices and schedules. Two types of insurance policies could reduce effluent pollution from lagoons. Insurance has the potential to counter the litigation generated by spillovers of lagoon effluent, and insurance policies could also insure against unusually high rainfall during periods when lagoon effluents are normally sprayed onto row crop or pasture fields.

The first insurance design would protect the hog producer from liability resulting from environmental damages due to accidental or natural disasters. Monitoring of lagoon waste levels could be required in order to adjust premium rates. Continuous waste lagoon level monitoring could eliminate moral hazard problems, as lagoon levels could be tracked and field sprayings quantified to determine whether sprayings occurred during periods of known soil saturation. Fines or policy cancellations could ensue for those found noncompliant. The insurer would indemnify an affected community, and the insurance provisions could reduce litigation expenses and the time required to resolve pollution damages.

A Review of Our Experience with Agricultural and Environmental Insurance

It is important to frame the current discussion of using insurance as an environmental incentive in agriculture in the context of both existing agricultural insurance programs and existing environmental insurance programs.

Current U.S. Agricultural Insurance

Current U.S. agricultural crop insurance consists of private insurance as well as the public-private federal crop insurance program. A long-standing private insurance market exists in the form of hail insurance for growing crops. In addition, multiple peril crop insurance has been available since the 1930s. Multiple peril insurance has traditionally insured against yield losses due to a variety of insurable causes such as drought, floods, disease, and pests. However, since 1996, the USDA has also offered revenue insurance. The program is administered by the USDA's Risk Management Agency (RMA) and currently has more than $37 billion in liability on 215 million acres and receives in excess of $1.7 billion in subsidies per year. As operated since 1980, the U.S. crop insurance program involves a public-private partnership. Private crop insurance companies sell polices and perform loss adjustment services. The USDA approves policies and rates and reinsures the private crop insurance companies' portfolio of policies.

The reasons suggested for a governmental role in providing crop insurance are varied (Coble and Knight; Goodwin and Smith). However, two main themes predominate. One challenge is asymmetric information, such as adverse selection and moral hazard. If substantial asymmetric information problems exist, then private insurers may be simply unwilling to enter the market or will be driven out by poor actuarial performance. Correlated losses are the second major suggestion for governmental involvement (Miranda and

Table 2. Key Legislation Affecting Environmental Insurance

Title	Year
National Environmental Policy Act	1969
Clean Water Act	1970
Clean Air Act	1972
Resource Conservation and Recovery Act	1976
Toxic Substance Control Act	1976
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)	1980
Motor Carrier Act of 1980	1980
Oil Pollution Act of 1990	1990

Glauber). To the degree that private insurers cannot diversify their portfolio because drought or other disasters may trigger widespread losses, they may not be able to build cash reserves to absorb a potentially catastrophic crop loss.

The Agriculture Risk Protection Act (ARPA) of 2000 opened the door for the development of new and varied insurance designs to be supported by the USDA. This has led to the development of livestock insurance, cost of production coverage, and nutrient BMP designs.

Environmental Insurance

The use of environmental insurance grew out of one principal concern—liability. In the 1970s, Americans became more socially concerned with environmental issues. At the same time, Congress began creating laws reflecting this social awareness. These regulations actually began with the National Environmental Policy Act (NEPA) of 1969, requiring the federal government to look at the potential effects of public projects on the environment. More significant and now-familiar legislative events followed, which are listed in Table 2.

As the liabilities created under new regulations increased, insurers began to eliminate or greatly reduce the coverage relating to pollutants found in traditional policies. A gap was created in risk management, contributing to the rise of the environmental insurance market. Today, pollution liability endorsements to standard general liability policies can be found, though such coverage may be limited. Although liability remains a driving force in the environmental insurance market, policies have many broader applications in a risk management context. Environmental insurance is still a rapidly evolving tool that can be difficult to grasp, and this nature—combined with the inherent complexity in developing policies that must be specialized for individual situations—explains in part why adoption is not more widespread. Furthermore, applying for environmental insurance is typically a complicated process, as an individual cannot simply be given a "quote" after providing a few pieces of information. Rather, long application forms with detailed questions that may require input from multiple individuals within a firm are often the norm. Insurers have made efforts to streamline the application process in order to increase the marketability of their policies, but an inherent level of detail remains.

In its survey of environmental insurance availability for the purpose of Brownfield redevelopment, the U.S. EPA found three principal factors affecting the marketability of environmental insurance:

1) "Policies offered focus on the 'high' end of the market."
2) "Owners of properties" are "still concerned with CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act)."
3) "Lenders" are "reluctant to finance properties."

The first factor cited comes as no surprise: insurers prefer to do business with larger firms that are more likely to be financially sound, which becomes especially important given the inherent uncertainty of environmental insurance. The second factor reflects the continued uncertainty that firms have about CERCLA, as they do not wish to sell their properties while they remain unclear about their potential liability. Similarly, lenders also have concerns about liability and are often not willing to provide credit, particularly in the case of Brownfield redevelopment. Predictably, some observers continue to find support for the notion that only about 10% of all environmental losses in the United States are insured (Dybdahl). Yet these observers continue to find that environmental insurance could be applied to many situations, and agriculture would seem to be no exception.

Basic Designs

Although Dybdahl notes that no industry standards exist, environmental insurance may be classified into several broad categories. The Environmental Risk Resources Association lists four main categories: 1) site-specific environmental impairment liability insurance; 2) contractor's pollution legal liability; 3) environmental professional errors and omissions (E&O) liability insurance; and 4) remediation stop losses. Site-specific environmental impairment liability insurance is also known as pollution legal liability (PLL) insurance and provides coverage for damages caused by pollutants discharged from a particular location. Contractor's Pollution Liability (CPL)—as its name implies—provides indemnities for damages caused by the activities of a contractor. Environmental professional E&O liability insurance indemnifies against damages as a result of negligence on the part of a contractor. Remediation stop loss insurance pays for costs exceeding a particular anticipated amount.

The private insurance industry does not appear to have delved deep into applying these forms of environmental insurance to agriculture. Again, as in the EPA survey, this may likely be because insurers concentrate primarily on the "high" end of the market. However, there are forms of PLL insurance that have been created with agriculture in mind. Known as agricultural PLL, this insurance is designed to cover accidents involving potential farm-related pollutants (American International Group). This policy is marketed as a way to meet the void created by the pollution exclusions in standard liability policies. Such a policy is in reality only a slight variation of the standard PLL insurance offered by most companies active in the environmental insurance market.

Experience

Dybdahl describes the environmental insurance market as "very competitive," with more than 100 different policy forms available from 40 companies that receive more than $100 billion in premiums annually. These numerous forms are due in part to the custom nature of environmental insurance as well as the marketing efforts of insurers. Dybdahl further states that underwriters will accept high levels of risk for an extended period of time and that "virtually any legal activity" could potentially acquire an environmental insurance policy.

In the survey by Yount, innovation in the environmental insurance market is described as being "at an all-time high, with policies and coverages changing from month to month." She finds that because of the increasing number of insurers in the environmental insurance market, premiums have declined over the past few years. Yount also notes that some observers expect consolidation within the insurance market to drive up costs in the years to come. These increases are in addition to those expected for policies and coverages due to unfavorable movements in loss ratios.

The experience in the environmental insurance market is somewhat difficult to quantify because of several factors. An important aspect previously noted is the variation in coverage due to the tailoring of policies because of the detailed information required as well as the marketing efforts of insurers. These policy innovations can make for relatively thin markets. Furthermore, Dybdahl makes a distinction between a true environmental insurance policy and "pseudo-" environmental insurance, or policies that refer only to environmental claims within their exclusions sections.

Another factor is the relative youth of the industry (about 20 years). Environmental insurance is also closely tied to the regulatory environment, which is also evolving.

Insurance Concepts

To evaluate the potential for environmental insurance to be applied in an agricultural setting, certain insurance fundamentals must be addressed. The premise behind any type of insurance begins with risk aversion on the part of decision makers. The willingness to buy insurance is based on the premise that a decision maker facing risk will exchange it for an alternative set of less risky outcomes. Insurance offers a contingent claims contract specifying that the occurrence of certain events will trigger a financial indemnification. In exchange, the insurance company collects a premium from the purchaser. In other words, in an insurance contract, the purchaser incurs a sure small loss (the premium) in exchange for the elimination of an uncertain large loss (the catastrophic event).

The provision of insurance is possible because an insurance company is able to pool a large number of relatively independent risks of a known probability. Under the law of large numbers, the riskiness of the portfolio of insurance policies diminishes significantly relative to any one policy. Thus, the insurance company is able to estimate the magnitude and frequency of the aggregated losses more effectively than that of any one individual loss. For example, an insurance company can more accurately predict the average number of homes that will burn in a metropolitan area during a particular year than it can estimate the chances of a specific home burning in a particular year. This allows the insurance company to make accurate estimates of the reserves needed to compensate losses.

Insurers also work to segregate risks by classifying individual policyholders into groups with similar risk characteristics. This allows the insurance company to provide alternative rates for the various risk categories and to set premiums more accurately.

Insurability Issues

Not all risks are equally insurable. Furthermore, some risks are commonly deemed completely uninsurable (Rejda). As mentioned, the first characteristic of an insurable risk is the presence of a large number of homogenous independently insured units. The term homogenous means that individuals can be sorted into risk categories in which each pool of individuals will essentially be at a similar risk level. The degree of independence among insured can vary, but to the extent that losses are independent of one another, the greater the effect of the law of large numbers. If a strong statistical independence exists among insureds, then insurance companies should expect relatively constant payouts in a particular time period. This allows them then to maintain the appropriate levels of reserves and avoid bankruptcy risk if the claims exceed expectations.

A second major aspect of insurability is the need for economically feasible premiums. In other words, can the insurance policy be offered at a price acceptable to the market? The premium cost of an insurance policy is determined by the frequency and severity of claims. "Frequency" refers to how often a claim occurs, and "severity" reflects the magnitude of a loss, given its occurrence. An important component to consider in an economically feasible premium is the transaction cost associated with the policy. Some insurance policies require a significant investigation into the characteristics of the insured individual and sophisticated risk evaluations to correctly categorize policies. The more effort and time involved in characterizing the riskiness of the insured individual, the greater the transaction cost. A private insurance company seeking to maximize profits will charge a premium rate that exceeds the expected indemnity for the individual policy. When governments become involved in the provision of insurance, they frequently subsidize transaction costs or premiums.

The third characteristic of an insurable risk is that it must be measurable; i.e., independent third parties can examine a potential loss and agree on an appropriate indemnity. Although this is usually a straightforward process for most insurance policies, for a number of risks that insurance companies typically stay away from, the actual loss is difficult to define. For example, insurance companies tend to avoid attempting to insure against subjective outcomes, such as whether a professional reputation has been damaged.

Fourth, an insurable policy is not subject to significant moral hazard. A moral hazard problem may exist when the insured individual's actions are not sufficiently observable or verifiable (Coble et al.). In other words, an information asymmetry occurs when the insurer does not fully observe the behavior of the insured individual. Authors such as Holmstrom and Raviv first defined this concept. Moral hazard may also be considered an incentive problem in which the insurance contract sufficiently alters the insureds' incentives to change their behavior. The archetypal example of a policy mechanism to reduce the incentive for individuals to alter their behavior is an insurance deductible, which implies that the insured individual will not be fully protected against a loss—the first portion of a loss will be incurred before the insurance policy covers the remainder of the actual financial loss. A poorly constructed insurance policy will result in weak incentives for an individual to behave as if uninsured.

The fifth and final characteristic of insurability is the absence of adverse selection. A successful insurance policy allows individuals to be correctly classified into a risk category. Rothschild and Stiglitz are the authors of the seminal article on adverse selection, in which they model multiple individuals who are offered a common insurance policy and rates but who are not homogenous in risk characteristics. With the adverse selection problem, the insured individual holds private information about his or her riskiness not available to the insurer. If the adverse selection problem exists, then this rate will be attractive to high-risk individuals but unattractive to low-risk individuals. Adverse selection tends to result in unequal demand on the part of potential buyers, and the insurer is left with a participant pool that is riskier than the average of the entire population. Hence, the risk classification activities of an insurance company are crucial. No insurance can perfectly categorize all individuals by riskiness, but in the extreme, this problem can lead to the complete collapse of an insurance market.

Some Important Theoretical Implications of Insurance

Before contemplating the implications of offering insurance in agricultural settings, it is important to consider some fundamental aspects of insurance that are often overlooked. First, when the efficiency of markets is considered, it should be noted that the efficiency result of Arrow and Debreu also applies to the allocation of risk (Debreu). These efficiency arguments are important in policy debates in which risk protection may be involved. We usually see incomplete risk markets within both the government and the private sector. Market imperfections such as asymmetric information and transaction costs represent two major causes of these incomplete markets.

Another consideration is the effect of risk and insurance on the decisions of an agricultural producer, given our concern with the potential of insurance designs to affect environmental behavior. Sandmo demonstrated that optimal output levels for a risk-averse individual will be less than those for a risk-neutral decision maker. Therefore, risk reduction provided by insurance has the potential to create an expansionary output effect. Nelson and Loehman—in a more general model with multiple outputs—demonstrate that risk aversion has the effect of changing the crop mix but not necessarily increasing the output for all outputs. The effect of insurance on a risk-averse individual's optimal input decision is not clear. Following Just and Pope, who defined both risk-increasing and risk-decreasing inputs, a mixed effect could occur when a decision maker is confronted by an actuarially fair insurance policy. In effect, insurance may act as a substitute for other risk-decreasing inputs and may lead the individual to use more of a risk-increasing input (Horowitz and Lichtenberg).

Input use is also intimately related to the question of moral hazard. Individuals may have an incentive to shirk on certain inputs because the marginal value product of those inputs is modified by the insurance policy (Babcock and Hennessy). Therefore, because of the risk-reducing effect of insurance, the individual may choose to act more risk neutral and expand production. But such individuals may also—when moral hazard exists—have the incentive to reduce inputs as well. In an agricultural context, an individual might envision a resulting incentive to expand acreage but then apply a reduced level of inputs on the additional acres.

An Empirical Example

This section examines the complex effect of environmental insurance on producer behavior. As previously suggested, environmental insurance may affect both the level of output chosen by the producer and the level of inputs used in production. Our model incorporates two crops (corn and soybeans) and allows the producer to jointly choose the acreage of the two crops, and the optimal level of N fertilizer given a nutrient management insurance policy is offered for one crop. We consider a risk-averse farmer facing production (yield) and price uncertainty who makes the decision before the resolution of said uncertainty. The farmer is assumed to have a von Neuman-Morgenstern utility function, U_W, defined on wealth W, with $U_W > 0$ and and $U_{WW} < 0$.

$$(1)\quad \max_{A_i, x_i} = \int_{p_1}\int_{p_2}\int_{y_1}\int_{y_2} U\left[\sum_{i=1}^{2} A_i\{P_i Y_i(x_i) - w_i x_i - c_i - P_1^G[(1-d)Y_1^{ck} - Y_1] - R_1\}\right] \times f(p_1, p_2, y_1, y_2)\, dp_1\, dp_2\, dy_1\, dy_2$$

In this model, P represents uncertain output price, and Y is random yield conditioned upon N fertilizer, x, which has a per unit cost w. Other costs are assumed certain and are represented by c. The nutrient insurance policy includes a price guarantee P_1^G and deductible d. This policy is assumed to pay out when the check yield Y_1^{ck} multiplied by $(1 - d)$ exceeds the corn yield. The check yield is the actual yield occurring on a check strip fertilized at a level determined by an independent fertilizer consultant but is also subject to random effects such as weather. For this protection, the producer pays a premium R. We also assume asset fixity constrains acreage A, such that changes between corn and soybeans can be no more than 20% from one year to the next. Thus, our results are reported as a deviation from a historical 50–50 mix of corn and soybean acres. To model the stochastic yield conditioned upon N levels, we use a conditional beta distribution (Nelson and Preckel). This is achieved by assuming that the beta shape parameters are conditional upon N fertilizer levels as shown in Equation (2).

$$(2)\quad \alpha = \alpha_0 + \alpha_1 x^{0.5} + \alpha_2 x, \quad \text{and}$$
$$\beta = \beta_0 + \beta_1 x^{0.5} + \beta_2 x$$

Empirically, the conditional yield is specified according to the parameters suggested by Babcock and Hennessy. Table 3 lists additional parameters.

Table 3. Empirical Data for Nitrogen Insurance Simulation[a]

Parameter	Corn	Soybeans
Nitrogen cost per unit	\$0.15	0
Other cost	\$265	\$90
Expected price	\$2.70	\$5.00
Price variability	\$0.212	\$0.75
Expected yield	141 bu.	30 bu.
Yield check nitrogen level	202 lbs.	
BMP subsidy	50%	
BMP insurance premium	\$11.50	
Absolute risk aversion	0.015	

[a] BMP is best management practice.

Table 4. Acreage and Nitrogen Use Levels from Simulation

	Optimal Nitrogen Level	Corn Acres	Combined Effect
Uninsured	198	80%	158.4 lbs.
With 10% deductible BMP Insurance	190	102.5%	194.75 lbs.
With 5% deductible BMP Insurance	182	105.0%	191.1 lbs.

rameters of the model. Prices are assumed to be log-normally distributed. Cost data are taken from various budget sources. The simulation is conducted by GAUSS software and 40,000 iterations.

Table 4 contains the results of this analysis. Our results for the uninsured scenario indicate an optimal N application level of 198 lbs. per acre. Given the parameters used, the expected utility-maximizing strategy when uninsured is to plant 80% of historical acres to corn and an additional 20% of acres to soybeans. This suggests that the risk-averse producer prefers to shift production to soybeans given the prices and costs provided in Table 3.

Relative to the base scenario, a 10% deductible BMP policy results in the optimal N levels declining by 8 lb. per acre and optimal corn acres increasing to 102.5% of the base level. When the insurance deductible decreases to 5%, input levels again fall to 182 lb. Thus, the insurance design induces an 8.33% reduction in the per acre application of N on corn acres. The decrease in N levels results from the lower marginal value product of N in the states of nature where an indemnity occurs.

The acreage shifts that take place should also be noted. The assumption of a 50% insurance subsidy results in a mean increasing effect from the BMP insurance. However, the risk protection afforded by insurance also increases the producer's certainty equivalent. Given the parameters used in this analysis, acreage shifts back to corn with the 10% deductible policy and shifts further with the 5% deductible policy. In sum, this analysis demonstrates that environmental insurance may have complex results as well as significant potentials for counterbalancing effects.

Bringing Environmental Policy and Agricultural Insurance Together

Our analysis to this point would seem to dictate bringing these diverse issues together and thinking about the most salient questions to ask when consideration is given to offering an environmental insurance design in an agricultural context.

Will demand exist? In bringing environmental policy and insurance together, it seems fitting to begin by assessing to what degree the demand for insurance of this nature exists, if any. Environmental issues in agriculture are inherently a situation of missing markets and externalities. Environmental insurance for the most part has arisen specifically when liability exposure has created a demand for the product. The unique attributes of agricultural environmental risk are also relevant. Regulation also has the potential to create demand. For example, if the EPA has the ability to fine an individual or shut down an operation because of code violations, the demand for insurance protection may increase. Of course, the government can also create demand through subsidies. However, the governmental cost and difficulties will be large when an attempt is made to create demand where little natural demand exists. The government could very well institute a program that ties regulations to an insurance subsidy. Subsidies may take a number of forms, and the exact nature of the subsidy with respect to insurance could be quite different.

Another argument that is made in a nonagricultural context but that appears relevant to the agricultural environmental insurability question is the degree to which firms exhibit risk-averse behavior relative to legal liability.

Kunreuther, McNulty, and Kang argue that relatively small firms with a short time horizon or limited assets may view large legal liabilities from something other than a risk-averse perspective. For example, if the firm is held by a number of shareholders or confronted with bankruptcy, then a fatalistic approach to the problem may be taken.

The probability of a disastrous event may be relatively small for a number of instances involving environmental risks. Individuals clearly have difficulty assessing low probability events. When the risk is both low in probability and catastrophic, individuals either tend to overemphasize events to which they are sensitized or underemphasize other equally risky events. Individuals also have difficulty assessing information needed to evaluate such an event. For example, Huber, Wider, and Huber found that when individuals are required to seek out information about a catastrophic risk, they often ask incorrect questions. In such instances, individuals facing a risk associated with an environmental liability may inaccurately assess the need for their firm to purchase such protection because they are unable to assess its probability.

Will there be supply? For an agricultural-environmental insurance market to exist, there obviously will also need to be a supply of insurance products. The most obvious question that arises with respect to the supply side of any insurance is whether the insurability issues that were discussed earlier in this paper preclude the development of an insurance market. The issues of homogenous independent units, whether one can design a policy with clearly measurable losses, and whether the moral hazard and adverse selection effects can be precluded all affect the willingness to supply the product. There are a few additional issues that should be noted with respect to providing agricultural-environmental insurance.

Markets often have difficulties when developing an insurance design because of a lack of credible rating data. Clearly, the potential for adverse selection is greatest when developing a new product. In general, insurance firms use their historical loss experience as the primary—if not the sole—source of actuarial data for premium rates. When attempting to introduce a new line of insurance products, a great deal of uncertainty may exist on the part of the insurer creating or obtaining the appropriate data when developing an agricultural environmental insurance design. Commonly, existing data either are too aggregated or lack the needed probabilistic information, because historical time series data are often required but unavailable.

The next aspect of insurance supply involves the significant differences between governmental and private sector insurance designs. Given the crop insurance experience, the differences in policy objectives of the private sector relative to the government must be recognized. In the private sector, firms generally are motivated to seek the lowest risk and the highest liability policies. Low-risk individuals are likely to be more profitable in terms of loss experience, and larger-volume clients represent a greater return relative to the transaction cost of delivering the policy. In the private sector, the provision of insurance is skewed to a selected subset of the industry and is not readily available to extremely small or risky individuals. In general, governmental provision of insurance protection is driven by a policy agenda that differs from that of the private sector. In many instances, the government is willing to absorb some transaction costs on the basis of equity arguments. The government often insures individuals that the private sector would be less inclined to accept.

Another factor that may affect the supply of agricultural environmental insurance is the government's position as an insurer or reinsurer. As previously discussed, under the current agricultural crop insurance program, the federal government serves as a reinsurer for private crop insurance companies. Although alternatives to the U.S. crop insurance system exist, the presence of governmental reinsurance facilitates a market. The arguments for governmental reinsurance are largely based on the lack of homogenous and independent insured losses. Although private firms may have difficulty dealing with the magnitude of correlated losses, the federal government—with its large budget and borrowing capacity—

could absorb even a major drought in the U.S. agricultural sector. Another aspect of the reinsurance agreement that the federal government provides to private crop insurance companies is a reduction in the uncertainty with respect to new and unproven products. For example, when crop revenue insurance was introduced in the mid-1990s, the standard reinsurance agreement offered by the USDA protected private crop insurance companies from the uncertainty associated with offering these new policies.

Conclusions

In this paper, we have set forth what we believe to be the logical context regarding agricultural environmental insurance. Given this background, there are clearly issues that should be considered any time such an endeavor is suggested. We conclude by discussing several of these possibilities.

Is risk the reason for the environmental degradation? When consideration is given to offering insurance to improve environmental quality, the source of environmental degradation becomes an obvious question. For example, in the case of N application insurance that assumes producers overapply N as a risk management strategy, insurance that protects against such a risk is fundamentally different from CAFO lagoon insurance, in which risk-averse behavior is not the driving factor behind the environmental degradation. CAFO environmental degradation may be a by-product of a firm's production activities but not a by-product of trying to mitigate risk. We believe this to be a fundamental question, because the logic and design of insurance will differ. In general, we find it more likely that insurance will prove useful when the producer is damaging the environment because of risk aversion. An insurance policy can reduce such risk-averse behavior and lead to less environmental damage.

Will the behavioral effects of insurance mitigate the desired result? Recall the fundamental conclusion that risk generally has a diminishing effect on the output of a risk-averse producer. Consequently, risk protection has an expansionary effect on individual behavior, as illustrated in our empirical example. If insurance is provided to individuals who are risk averse, these individuals will undertake more of the activity being insured. Furthermore, if governments become involved and subsidize or support some type of risk protection, then additional incentives may exist for the insured activity. At the same time, we must recognize the moral hazard effect that leads to the possibility of shirking on the part of the insured individual. An individual could then quite plausibly have an incentive not only to expand production, but also, to operate with moral hazard behavior.

A closely related aspect of the behavioral effects of insurance involves the inducements created by agricultural environmental insurance policies to adopt management practices that producers would not otherwise adopt. For example, offering a CAFO an insurance liability protection policy in return for adopting a set of risk-reducing BMPs would likely result in mixed effects on a producer's behavior. However, offering liability protection would increase the willingness of that firm to operate and perhaps expand to a larger scale. But we adamantly believe that both aspects of offering agricultural environmental insurance should receive consideration.

Does insurance provide sufficient incentive to achieve the desired objective? When considering insurance as an incentive to modify behavior, the recognition of several factors that influence the perceived value of insurance is crucial. Aside from the characteristics of the insurance offer, the decision maker's perceptions of the risk, his or her risk aversion, and alternative risk management strategies may strongly influence a producer's willingness to accept the design. Ignoring any of these factors may lead to a gross error when predicting participation.

Is the insurance workable? We have already addressed the possibility that not all insurance will work, that potentially uninsurable risks exist, and that—even if it is involved—the government may not be able to mitigate the inequities resulting from moral hazard and adverse selection. An insurance program in-consistent with insurance principles will be largely complex and frustrating for all parties involved and, in many instances, will simply wither from the lack of acceptance by either the providers or the potential market for the product.

Does insurance have the greatest cost-benefit ratio? When policy makers consider using insurance as an incentive to induce environmentally sound behavior, the cost of insurance should be weighed relative to alternative incentives. If a complex insurance program has significant transaction costs and administrative challenges, then policy goals may be achieved through other, much simpler and more cost-effective mechanisms.

Ultimately, significant advances in our ability to design and facilitate insurance markets have clearly transpired. Outside the realm of agriculture, a well-developed private environmental insurance market appears to have evolved during a relatively short period. All of this leads to the consideration as to whether such insurance designs could be adapted to an agricultural setting. Our suggestion, which is based on the reasons discussed in this paper, is that making such an insurance design work will likely not be simple. Nor do we expect that insurance will work in all cases. However, under the right conditions, the possibility of success exists. Furthermore, we believe that the chances of developing a workable system will be greatest when attention is given to the actuarial and underwriting issues we have addressed.

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