Risk Management and the Environment: Impacts at the Intensive and Extensive Margins

Meredith Soule*, Wesley Nimon, and Daniel Mullarkey
Economic Research Service
Resource Economics Division
1800 M St., NW
Washington, D.C. 20036

*tel: 202-694-5555
fax: 202-694-5775
email: msoule@ers.usda.gov

Paper presented at the Annual Meeting of the American Agricultural Economics Association, Chicago IL, August 5-8, 2001

Risk Management and the Environment: Impacts at the Intensive and Extensive Margins

Meredith Soule, Wesley Nimon and Daniel Mullarkey

Introduction

Farming is a risky business. Before the 1996 Farm Bill, USDA helped farmers manage risk by directly influencing farm production levels and prices for major commodities. Now, it provides a safety net composed of direct farm payments (production flexibility contract payments and emergency supplemental appropriations), commodity loans, loan deficiency payments, conservation assistance, and subsidized crop insurance. Although a considerable amount of research has been conducted to examine the impact of various government programs on aggregate supply and price (e.g., Houck and Ryan 1972, Chavas and Holt 1990), until recently, very little work has focused on the potential environmental impacts of government-sponsored risk management programs such as subsidized crop insurance. The underlying policy question is whether the benefits provided by government risk management programs are offset by the costs of such programs, including the costs of unintended environmental effects. This paper addresses the environmental cost side of the equation.

Government farm programs, such as subsidized multiple peril crop insurance, introduce potential distortions into farm-level decision-making at both the intensive (input use) and extensive (land use) margins. At the intensive margin, the theoretical literature suggests that crop insurance will increase applications of risk-increasing inputs and decrease use of risk-reducing inputs. However, the impact of crop insurance is more complicated, both theoretically and empirically, and the impact of crop insurance on input use is still an open question.

At the extensive margin, subsidized crop insurance tends to increase returns to cropping land that is currently in pasture or another non-insured use, and thus crop insurance may lead to the cultivation of riskier crops on lands that are economically marginal. Even when insurance does change land use decisions, the actual extent of the changes is not well understood.

Finally, once the changes in input and land use due to subsidized crop insurance have been established, links to associated environmental changes must be drawn to determine the impact of risk management on the environment. Impacts on the environment are largely technical relationships linking land qualities, production practices, input use, and environmental measures of interest such as erosion, chemical run-off, leaching, and loss of wildlife habitat.

The objectives of this paper are threefold. First we set up a context for thinking about government programs and risk management, farm-level decision-making, and environmental impact at the extensive and intensive margins. Next, we review the literature linking risk management policies and environmental outcomes. Finally, we assess the gaps in the literature, and present some ideas on ways to move forward to better understand the potential environmental impacts of risk management programs.

Farm-level decision making and environmental outcomes

A general model of farm-level decision-making to analyze the impact of government-sponsored risk management policies on the environment would include the following elements:

<u>Farmer decisions about resource use:</u> land use (crop, pasture, conservation reserve program (CRP)), input use, conservation practices

<u>Farm and farmer characteristics:</u> land quality, average yield, variability of yield, risk aversion, land tenure

<u>Exogenous factors:</u> output and input prices, technology

Government program participation: crop insurance, loan deficiency payments, production flexibility contract payments, emergency assistance

Risk management decisions: off-farm income, production and marketing contracts, debt, savings, futures markets, etc.

The farmer makes decisions about land use, input use, and conservation practices based on individual characteristics of the farm and farmer (including their level of risk aversion), available technologies, and prices. Choices may differ for each unit of land on the farm, depending on land attributes that make each unit of land more or less desirable for growing certain crops. Attributes of the land may also make it more or less subject to erosion or leaching. Other decisions, which may be made prior to, simultaneous with, or after the crop and input use decisions, include use of risk management strategies and participation in government programs. Generally, the farmer is assumed to maximize either profit or expected utility, which determines levels of input use and thus the level of crop and livestock production and the level of environmental outputs (erosion, chemical leaching, runoff, etc.), which are also subject to mitigation efforts such as conservation practices. The environmental attributes of the land, along with the production and conservation practices used, will jointly determine the agricultural output and environmental externalities (Antle and Just 1991). We are interested in understanding how land use and input use decisions, and thus environmental outcomes, change when farmers participate in government risk management programs.

Whether the input and land use decisions made under risk management programs are more or less damaging to the environment than decisions without such programs depends on a variety of factors, including whether input use increases or decreases, the mix of crops grown (including pasture and CRP as "crops"), the potential of those crops for harming the environment based on the attributes of the land on which the crops are grown, the vulnerability of the environment to emissions, and the environmental indicators about which society is concerned (e.g. erosion, water quality). In addition, we may wish to consider the value of the environmental benefits or damage to the public, which may be location-specific. For example, the value of improved water quality may be higher in areas with high population densities.

A review of the literature

Although a general model of farm-level decision making would include all of the elements discussed in the previous section, in practice it is difficult to model so many simultaneous interactions. This section reviews the literature that analyzes the impacts of government-sponsored risk management programs on the environment.

Impacts at the intensive margin

Over the last decade a vigorous debate has arisen over the environmental consequences of risk management tools, especially multiple peril crop insurance (MPCI). In particular, researchers have addressed the question of whether the purchase of crop insurance induces farmers to apply more or less potentially polluting chemical inputs. The literature exploring this question begins by examining the impact of risk and uncertainty on input use. Later contributions examine the impact of crop insurance on input use.

Early studies examined the impact of price uncertainty on a competitive, one-input, one-output firm (Sandmo 1971, Ishii 1977, Katz 1983, Briys and Eeckhoudt 1985, Hey 1985). Sandmo's seminal paper showed that in the presence of price uncertainty the risk-averse firm will produce less than if prices were known. He was not, however, able to determine the marginal effect of uncertainty on output. Ishii later demonstrated that optimal output declines with increasing price uncertainty. While for much of the economy price uncertainty may be the dominant source of risk, for agriculture that may not be true, and thus the agricultural literature has focused on the impact of production (yield) risk on input use.

Pope and Kramer (1979) offer one of the first models concentrating on production risk and its effects on input use. They consider a stochastic production function, a constant relative risk aversion utility function, and allow for inputs to either increase or decrease risk. In the single input case, they show that a risk-averse agent uses more (less) of an input which marginally decreases (increases) risk. In a two-input, competitive model, however, there may be interactions between inputs that make the comparative statics ambiguous.

Loehman and Nelson (1992) extend Pope and Kramer's model to include multiple inputs in which all inputs are either risk increasing or decreasing and all pairs are classified as either risk substitutes or complements. This characterization allows them to draw several general conclusions that hold for both relative risk aversion and exponential utility functions. If the inputs (or pairs of inputs) are risk substitutes and both are risk increasing (reducing) individually, then the use of at least one and maybe both inputs will decrease (increase) with increasing risk aversion. If use of only one input decreases, then use of the other will increase. On the other hand, if one input is risk reducing and the other is risk increasing, then with increasing risk aversion the use of the risk-reducing input should increase and the use of the risk-increasing input should decrease. If the inputs are risk complements and both are risk-increasing (reducing), then use of both should decrease (increase) with increasing risk aversion.

Leathers and Quiggin (1991) develop further implications of the effect of uncertainty on input (x) use. They derive implications for input use for increasing, decreasing, and constant absolute risk aversion utility functions (IARA, DARA, and CARA, respectively). They denote input prices, output prices, and yield risk as w, p, and g . They show for a risk-averse producer and a risk-increasing input that $\frac{\partial x}{\partial w}<0$ and $\frac{\partial x}{\partial g}<0$ holds for DARA and CARA but not for IARA. The sign of $\frac{\partial x}{\partial p}$, however, is indeterminate for all three utility functions. For a risk-averse producer and a risk reducing input they show that $\frac{\partial x}{\partial w}<0$ under IARA and CARA, that $\frac{\partial x}{\partial p}>0$ under CARA only, and that $\frac{\partial x}{\partial g}>0$ under DARA and CARA. Thus, the assumption made about risk preferences is crucial.

Chavas and Holt (1990) empirically test the risk preferences of corn and soybean farmers by estimating a system of risk-responsive acreage equations for corn and soybeans. They reject the hypothesis of CARA representation and instead find a positive wealth effect in supply response, which suggests DARA. The policy implication is that since greater private wealth tends to offset the need for income and price protection, subsidized public provision of crop insurance should be targeted to the low-income farmers.

The impact of crop insurance on input use

Turning to the question of the impact of crop insurance on input use, Ahsan, Ali, and Kurian (1982) show that in the context of a one-input, one-output model, full coverage crop insurance encourages risk taking (e.g., the use of risk-increasing inputs) and causes farmers to choose inputs as if they were risk neutral. One limitation of their study is that input use is modeled with a fixed "aggregate resource endowment" that may be used in either risky or riskless production. Since this endowment reflects not just chemical inputs but acreage and land devoted to risky production, there is no way to adequately address the moral hazard problem.

Moral hazard arises when input use is altered due to asymmetric information and incompatible incentives (Nelson and Loehman). For example, farmers who buy crop insurance may change input use in order to increase the probability of an indemnity payment. Ahsan, Ali, and Kurian also argue that private crop insurance has failed because of information asymmetries creating adverse selection. Adverse selection occurs when the insurer does not have information on the inherent riskiness of each farm, so that only the farmers who are the most likely to receive indemnities sign up for the insurance.

As in the Ahsan, Ali, and Kurian work, Nelson and Loehman (1987) also show that if an actuarially fair contract dependent on all observable variables (e.g., input use, realized yield, rainfall, etc.) were defined, then input choices would be made as if the farmer were risk neutral. The above implications of crop insurance assume full coverage and no moral hazard. In the presence of moral hazard effects, they argue that input use is likely to decrease for the risk-averse farmer who buys crop insurance. *A priori*, the effect is indeterminate but depends on the relationship between the distribution of the state of nature and the marginal product of the input in each state, which affects the expected indemnity payment.

Quiggin (1992) develops a model indicating the conditions under which insurance would lead to a reduction in input use because of the moral hazard problem. For his model, he assumes that there are only two states of nature, good and bad, the marginal product of an input is greater in the good state than the bad, and that the insurance contract is not contingent on input use. He also assumes a concave production function. He concludes that under these fairly weak assumptions, the effect of insurance will be to reduce input use for risk-reducing inputs and those that have no risk effects and increase input use for those that are “strongly” risk increasing (e.g. an input for which the marginal product is negative in a bad state of nature, such as fertilizer).

The effects are more ambiguous for "weakly" risk-increasing inputs. One limitation of the model is that there is no link between expected indemnity payments and input use.

While the conventional wisdom is that pesticides are risk-reducing inputs, Horowitz and Lichtenberg (1994) make the case that in many instances they are more accurately viewed as risk-increasing ones, and thus their use may increase rather than decrease with crop insurance. To motivate their empirical work, Horowitz and Lichtenberg develop a model of moral hazard and argue that indeed fertilizer and pesticide inputs, often are "strongly" risk-increasing and that crop insurance may therefore encourage input use. An input increases risk if it adds relatively more output in good states than bad ones by increasing the discrepancy between the two. Indeed in many cases the marginal product of pesticides will be very low or negative in bad states if growing conditions are poor because (i) insect populations and weed growth are apt to be low, and (ii) crop yield and thus potential losses from pest infestation are likely to be low. Under such conditions, high pest infestations and therefore high pesticide productivity occur primarily when crop growth conditions are good. In low rainfall states of nature, fertilizers may cause burning and thereby may be strongly risk increasing by improving outcomes when the state is good and worsening outcomes when the state is bad.

Horowitz and Lichtenberg then argue that federally funded crop insurance may increase usage of risk-increasing inputs because farmers may be inclined to undertake riskier production practices knowing that the downside risk is greatly reduced. This is the traditional moral hazard problem, but inputs are presumed to be risk increasing rather than risk decreasing. Horowitz and Lichtenberg empirically test their hypothesis using farm-level data collected in 1987 in the Corn Belt. They assume that the insurance decision is made before the input use decision, and econometrically control for selection bias. The insurance purchase decision is explained by several farm specific variables such as past variability of yields. Their estimation implies that, for several indicators of chemical usage, the amount used increases with crop insurance. They find that those purchasing insurance applied 19% more nitrogen per acre, spent 21% more on pesticides, increased herbicide acre-treatments by 7% and insecticide acre treatments by 63%. These results contradict the conventional wisdom that inputs such as pesticides, which are generally considered to be risk reducing, will be used at lower levels with crop insurance. This result is, however, consistent with their proposition that pesticides may in fact be risk increasing.

Smith and Goodwin (1996) criticize Horowitz and Lichtenberg's findings that multiple peril crop insurance (MPCI) causes farmers to increase chemical input use. They argue that the moral hazard problem probably causes decreased input use. Even if an input is risk increasing and increases the variance of yields, it will also likely increase the expected yield. The increase in variance increases the likelihood of an indemnity payment but the increase in mean yield decreases it. The net effect may be that the expected indemnity payment increases with input use but Smith and Goodwin doubt it for two reasons. First, the critical yield that triggers an indemnity payment is determined by the farm's yield history. Thus, using inputs that raise expected yields decrease the expected indemnity payment. Second, the chemical inputs increase production costs and lower (increase) the expected profits (losses) when indemnity payments are made.

The Horowitz and Lichtenberg paper assumes that insurance purchase decisions must be made prior to any input use, but often that is not the case as typically farmers wait to near the deadline to sign up. At that point some fertilizer and pesticide applications are already made. Thus, it may be that the input/insurance decision is better characterized econometrically as being simultaneously determined. Thus, Smith and Goodwin argue that a simultaneous rather than recursive system is a better choice. They employ survey data of Kansas wheat farmers' production practices in 1990 and 1991. For the agricultural input variable, they use total per acre expenditures on all agricultural chemical inputs. They do not disaggregate pesticide and fertilizer inputs because they argue that there was little variation across farms in non-fertilizer input use, and non-fertilizer chemical input use among wheat farmers is low. In their econometric estimation, they find that farmers who purchase insurance apply fewer chemical inputs (fertilizer). To test the hypothesis that the input and crop insurance decisions are simultaneous, Smith and Goodwin estimate the single equation model in addition to the simultaneous one and employ the Wu-Hausman Specification Test in order to determine whether the insurance purchase decision or chemical input decisions are exogenous. In both cases exogeneity is rejected, which suggests that they are jointly determined. This sheds doubt on Horowitz and Lichtenberg's recursive structure in which insurance decisions are made prior to input decisions. They find that failure to account for simultaneity creates a positive bias in the crop insurance coefficient that potentially causes the model to indicate that the insurance moral hazard problem encourages farmers to use more chemical inputs. Furthermore, their probit estimation indicates that if a farmer applies more chemicals, then the probability that he also purchases crop insurance declines. They claim this must be because the expected return to crop insurance declines with input use. They estimate that each dollar spent on chemical inputs lowers the probability of insurance purchases by 0.9% to 1.4%. However, it must be noted that their model is really estimating the impact of crop insurance on fertilizer use and not pesticide use. The impact of crop insurance on pesticide use could be tested with a sample of wheat farmers with more variability in pesticide use, which could probably be achieved by expanding the sample beyond Kansas. In addition, results could be different for crops, such as corn or cotton, that are more pesticide intensive than wheat.

Babcock and Hennessy (1996) argue that Horowitz and Lichtenberg's result -- that crop insurance leads to increased use of chemical inputs -- could be due to their assumptions that farmers are risk averse and that pesticides and fertilizers increase the probability of low yields. Babcock and Hennessy looked for evidence of fertilizer increasing the probability of low yields. Using data from four cooperating Iowa farms growing corn continuously from 1986 to 1991, they conclude that increased fertilizer use, as measured by pounds per acre, sharply decreases the probability of low yields, thus casting doubt on one of the Horowitz and Lichtenberg assumptions. They then turn to the risk aversion assumption. Using a CARA utility function they simulated the optimal fertilizer application rates given different levels of risk aversion, insurance coverage, and correlation between yields and prices. While the exact results depend on the parameterization of the model, they find that, in general, increasing insurance coverage induces decreased fertilizer application rates. They note that their results are consistent with Smith and Goodwin's (crop insurance leading to a lower level of chemical use) and that the moral hazard problem appears to have a positive environmental effect. However, they only examine the impact of crop insurance on fertilizer, not pesticide, use. Careful examination of pesticide use under crop insurance could lead to different results.

Following a methodology similar to that of Smith and Goodwin, recent work by Nimon and Mishra (2001) focuses on the relatively new, federally subsidized, revenue insurance instruments and disaggregates expenditures on fertilizers from those on pesticides. Using farm level data covering wheat growers in seventeen states, sufficient variability in both pesticide and fertilizer expenditures is available to allow estimation using each individually as well aggregate expenditures on both. Using the aggregate measure the authors reproduce the Smith and Goodwin result for revenue insurance instead of multiple peril crop insurance. The environmental impact of pesticides and fertilizers, however, may vary, so investigation of whether or not the effect of crop insurance is to reduce both individually is warranted. When disagregated expenditures are used, the results indicate that while fertilizer expenditures decrease with insurance purchases, pesticide use increases. The explanation for the differential effects of crop insurance on pesticide and fertilizer use lies in the risk properties of each.

As Horowitz and Lichtenberg noted, in many regions it is likely to be the case that when crop growth conditions are poor, insect and weed populations are likely to be low as well. As such, pesticides may not appreciably decrease the probability of low yields and hence expected indemnity payment. Furthermore, the potential losses from pest infestation are small because of the low yields in bad weather. In good growing conditions the opposite is likely to hold because pest populations are apt to be larger. Larger pest populations and greater yields imply that the marginal product of pesticides may be quite large. By increasing the upside potential more than the downside risk, pesticides are risk-increasing inputs and only marginally affect the expected indemnity payment. Thus risk-averse, insured farmers are likely to increase their use of pesticides.

Horowitz and Lichtenberg make the argument that fertilizers are risk increasing as well and so their use should increase with insurance purchases. Nimon and Mishra, however, argue that equally important is the input's effect on the probability of low yields, because that is what determines the expected indemnity payment. While pesticides may not appreciably affect the probability of low yields, Babcock and Hennessy show that fertilizers do. Although they believe pesticides are likely to reduce the probability of low yields as well, they only offer econometric results that fertilizers actually do. If so the moral hazard effect is likely to lead to less intensive use of fertilizer, as Nimon and Mishra find. They conclude that pesticides and fertilizers may affect risk in significantly different ways.

Quiggin, Karagiannis, and Stanton (1993) use a different method for analyzing the effect of crop insurance on input use. They estimate a production function with insurance as an input using data on U.S. grain farmers from the 1988 NASS Farm Costs and Returns Survey. The chemical input variable was determined by aggregating over the value of pesticides and fertilizers. The coefficient on insurance is negative and significant at the 10% level. Thus, insurance has a negative affect on output. They then estimate factor share equations for various inputs: fertilizer/pesticide index, labor, energy and other. Insurance was included as an explanatory variable in each equation and each was significant at least at the 10% level. Thus, they find that insured farmers tend to use less variable inputs. A drawback of the study is that they do not distinguish between fertilizers and pesticides.

Summary of the intensive margin literature

The effect of risk and crop insurance on input use decisions depends on the risk characteristics of the inputs used, the interactions between inputs, the utility function of the producer, and moral hazard concerns that arise if input usage affects the expected indemnity payment. Table 1 summarizes the results found in the literature. In general, for risk-averse producers, the theoretical literature suggests that crop insurance will cause a reduction in the use of risk-reducing inputs. Pesticides are generally considered to be risk-reducing inputs, but the effects of pesticides on yield risk may depend on the characteristics of the individual active ingredient, target pest, and treated crop, and in certain instances, pesticides may be seen as risk increasing. Therefore, classifying pesticides may not be a simple as is generally assumed in the theoretical models.

In the early literature, fertilizer was generally considered to be risk increasing because yield variability goes up with increased applications. However, others argue that fertilizer is actually risk reducing, and the results of Babcock and Henessy support this position.

Of course, inputs may affect the mean of yields as well as their variance. As such the effect of moral hazard for even risk increasing inputs may be to reduce their use. Smith and Goodwin argue that most inputs are likely to raise expected yields somewhat, and hence reduce the probability of an indemnity payment. Therefore, they expect to see decreased input use with crop insurance.

The functional form of the producer's utility function is another important variable that affects the results of the impact of crop insurance on input use. Leathers and Quiggin showed that the impact of risk aversion on input use depends on whether one assumes increasing, decreasing or constant absolute risk aversion. However, many analyses of the impact of crop insurance on input use depend on an assumption of constant absolute risk aversion. All of the literature reviewed also takes as a starting point that all producers are risk averse. However, considerable research on the risk preferences of farmers has not been able to establish this as a fact, and most studies find at least some proportion of farmers to be risk neutral and even risk loving (e.g. Binswanger 1980, Brink and McCarl 1978). Even risk neutral producers may purchase crop insurance if it increases expected returns, and the moral hazard effect of applying fewer inputs may also come into effect.

Ultimately, the net effect of crop insurance on input use is an empirical question. Three of the four empirical studies support the view that crop insurance reduces input use, but they were largely constrained to specific crops and regions, and only the Horowitz and Lichtenberg and Nimon and Mishra studies empirically differentiated the impacts of fertilizers from those of pesticides. Further empirical analysis is required before a firm consensus can be formed to support the view that crop insurance reduces chemical use for both fertilizer and pesticides and for all crops.

Impacts at the extensive margin

The impact of risk on crop allocations and land use was modelled in an early article by Freund (1956). Theoretically, if a farmer is risk neutral, he will plant only one crop, the one with the highest expected return. Risk aversion, however, will lead to portfolio diversification, which depends on the covariance of returns, as also shown by the early finance literature. Crop insurance will change the distribution of returns to the insured crop, with the variance of returns decreasing. The change in the distribution of returns will lead to a change in crop allocations, with more land planted to the insured crop.

Studies examining the impact of government farm programs on farm-level allocation of land to various crops or uses generally fall into two categories. First, representative farm simulation models have been developed to examine the impact of crop insurance on crop or tillage choice. Second, farmers' crop choice decisions have been estimated using either cross-section farm-level or pooled cross-section, time-series county-level data. Most of the studies end the analysis at estimating the change in crop allocations under government programs. However, a few studies go on to construct measures of the change in environmental quality due to those land use changes.

Williams (1988) looked at the impact of crop insurance on crop and tillage choice in central Great Plains by developing one representative farm type for the area. He used stochastic dominance to select the most efficient cropping systems for the representative farm under risk neutrality, and several levels of risk aversion. He showed that subsidized crop insurance leads to a change from a system of mainly wheat-fallow with conservation tillage to a system of mainly conservation tillage with a wheat-sorghum-fallow rotation since crop insurance reduces the risk of having lower values of net returns more for sorghum than for wheat.

Turvey (1992) examined the potential impact of crop insurance on farm-level crop allocations using expected utility optimization applied to a representative farm in Ontario. He looked at the cropping choices of that representative farm under risk aversion both with and without crop insurance. A risk averse farmer with no insurance would allocate about 6% of acreage to corn, 60% to soybeans and the rest to wheat. Subsidized insurance leads to 60% of the farm in corn and 40% in soybeans, thus more production of riskier crops. He concluded that, in general, agricultural insurance encourages a move towards risk-neutral behavior (i.e. profit maximization), and thus encourages farmers to increase plantings of high-risk crops.

Some researchers have empirically examined the impact of crop insurance on crop allocations. Gardner and Kramer (1986) looked at the impact of the old disaster payment program, which they considered to be equivalent to crop insurance with no premiums, on acreage response. They compared counties with crop insurance and counties without crop insurance and examined changes in acreage of different crops between 1974, just as the disaster payment program was beginning, and 1981. They found that cropland expanded more in counties without crop insurance during that period, and attributed it to reduced risk due to the disaster payments program. Since the counties without crop insurance were, by program design, the ones where production was especially risky (high yield variability), it seems that the disaster assistance program encouraged crop production in marginal areas.

Young et al. (1999) estimated the impact of crop insurance subsidies on acres planted to eight crops in seven U.S. agricultural regions. Using county level data from USDA's Risk Management Agency, they created "price wedges" by converting crop insurance premium subsidies, administrative and delivery cost reimbursements and net underwriting losses or gains into per unit of production subsidies for each crop in each region. They then calculated subsidy shares for each crop in each region, using 1994-98 averages divided by average production from 1995-1998. They ran USDA's POLYSYS-ERS simulation model with and without the insurance subsidies, and estimated that the subsidies caused an aggregate acreage increase of 600,000 acres (a 0.2% increase). However, certain crops and regions saw adjustments that were masked by national averages, such as a 1.2% increase in cotton acres planted.

Young et al. point out a number of limitations of their research methods. First, crop insurance subsidies are treated as if farmers view them as actual revenue, which is probably not the case. Thus, their analysis probably overstates the impact of crop insurance subsidies on supply response. Second, the elasticities used in the model are short-run elasticities and are not reported in their paper. Finally, the subsidy price wedge is calculated as an average across all production, but some farmers do not purchase insurance, and actual subsidy levels vary across farmers and regions. Regardless of these limitations, determining the environmental impact of the regional and crop specific adjustments in crop acreage as measured by their model would require analyzing the relative environmental damage caused by each crop, the change in crops grown, and the environmental attributes of the lands on which the changes took place.

In the early 1990's Miranowski, Hrubovcak and Sutton used a regional agriculture simulation model to evaluate the potential impact of a change in farm programs on resource use. Results from the simulation model indicated that elimination of the Acreage Reduction Program (ARP) would result in small changes in nutrient and pesticide use and soil loss. However, the changes would be larger in some regions than in others. At the same time they caution that the small changes from elimination of the program are partly a result of the timing of the analysis in 1990. They argue that the 1985 Food Security Act coupled with reduced stocks has already moved farms toward more market-oriented production decisions, so that impacts from elimination of the ARP were smaller than they would have been in 1985. On the other hand, they found that elimination of the CRP as well as the ARP would result in significant increases in soil loss and fertilizer and pesticide use.

Griffin (1996) studied the impacts of crop insurance and disaster payments on wheat and pasture acreage in production in the Great Plains region. Using county-level, time series data for 1978-1992, his OLS model regressed wheat acreage as a share of wheat and pasture acreage on a variety of explanatory variables, including (but not limited to) relative returns to wheat and pasture, disaster payments, crop insurance payments, and deficiency payments. He obtained statistically significant results for disaster payments and crop insurance payments, but not for deficiency payments. This model estimated that these programs had shifted up to 2.29 million acres from pasture to wheat.

Griffin also estimated a second model using cross-sectional data for six major crops in the Great Plains. He compared two time periods: 1974-1977, a period of low subsidies, and 1989-1992, a period of high subsidies. This model regressed the change in total acres on disaster payments, deficiency payments, crop insurance participation, and the total risk subsidy. Again, he found statistically significant results with the exception of the deficiency payments. This model estimated that 16 million acres in the Great Plains had remained in production due to these government risk management programs. At the same time, 10 million acres were taken out of production by the CRP. Griffin then aggregated across counties the soil erosion effects of land induced into production by crop insurance and disaster payment programs. He estimated that the programs led to a loss of 61.4 million tons of soil. He estimated that land put into the CRP across the counties in the study reduced soil erosion by 59.1 million tons, thus most of the reduction in soil erosion gained by the CRP was lost to soil erosion occurring on acres brought into production by the crop insurance and disaster payment programs.

In a similar vein, Keeton, Skees and Long (1999) studied the effect of disaster assistance and crop insurance programs on acreage planted in the U.S. They hypothesized that total acreage in production has increased with transfers from risk management programs. To examine the issue, they compared two time periods: 1978-1982, a period of low support, and 1988-1992, a period of high support. They used data on acres planted to six major crops for 285 Crop Reporting Districts (CRD's), as well as disaster assistance and crop insurance premiums. The dependent variable was the change in total cropland use within each CRD between the two time periods, where cropland use is the 5-year average within each period. Explanatory variables included the change in expected revenue, the change in net crop insurance subsidies per dollar of revenue, the rate of disaster payments per dollar of revenue, the change in insurance premium rates paid by farmers, the change in crop insurance participation, and the change in base acres for commodity program crops (due to data limitations, they omitted deficiency payments and production costs). Using OLS, they found statistically significant effects of the expected sign for crop insurance transfers, crop insurance participation, crop insurance premium rates, and commodity base acres. Disaster payments were reported as marginally significant, and the authors suggested that since these payments are uncertain, they may be less important in land use decisions than crop insurance transfers. They concluded that these risk management programs are encouraging cropping on marginal lands and estimated that 1.5 million acres of cropland use are added for every one percentage point increase in crop insurance participation. They went on to argue that since crop insurance participation has gone up by about 30 percentage points since 1980, it is possible that crop insurance has brought 45 million additional acres into cropland use (including 30 million acres of CRP). Impacts on erosion or water quality were not calculated.

Wu (1999) used farm-level data to look at the effect of crop insurance on crop allocations. He modeled the crop insurance and crop share decisions for four crops with a simultaneous equations econometric model. He used the model results to estimate the effect of crop insurance on crop mix for different farm sizes. He showed that with crop insurance, all farm sizes are less likely to grow hay and pasture. Small farms plant more corn and soybeans and less hay and pasture. To the extent that corn and soybeans are more environmentally damaging because they cause more soil erosion and use more chemicals than pasture and hay, this switch to more risky crops, which is encouraged by crop insurance, has a detrimental environmental effect. To look more closely at this effect, he used average application rates of nitrogen, phosphorus and atrazine for the study region and assumed that the study region adjusts as a medium-size farm under crop insurance. Under these assumptions, the change in crop mix with crop insurance leads to a 20% increase in nitrogen use, a 33% increase in phosphorus use and a 22% increase in atrazine. He noted that Nebraska has high nitrate concentrations in the groundwater, so crop insurance may be exacerbating the groundwater quality problem.

Goodwin, Smith, and Hammond (1999) examined the impacts of farmer participation in the conservation reserve program (CRP) and crop insurance on erosion. They used county-level data to estimate a system of five simultaneous equations. The dependent variables for the five equations were CRP participation, soil loss (estimated annual soil loss in tons/acre), crop insurance participation (ratio of liability to total crop revenue), the conservation effort (NRI P-factor rating of conservation effort), and fertilizer usage. Their results indicated that annual soil loss has been reduced an average of 1.7 tons per acre by the CRP. However, increased participation in the crop insurance program has increased average annual soil loss by 0.6 tons per acre. This suggests that, to some extent, the subsidized crop insurance program is working at cross purposes to the CRP goal of reduced soil erosion.

Goodwin and Vandeveer (2000) used a multi-equation structural model to look at the extent to which crop insurance might bring additional land into production. For the Corn Belt of the U.S., they estimated corn and soybean acreage equations, crop insurance participation equations, as well as CRP and input usage equations at the county-level for the period 1983-1993. Their results indicate that increased crop insurance participation is associated with an increase in corn and soybean acreage, but that the response is modest (elasticities of acreage response to increased insurance participation of 0.043 and 0.029, respectively). They also estimate that a 50% decrease in the insurance premium paid by farmers would result in an acreage increase of only two to three percent. The implication is that any associated environmental impacts would also be modest. For this study, it must be noted that the Corn Belt includes some of the nation's best land, and other regions of the country with higher percentages of marginal land might see a greater extensive margin response to crop insurance subsidies.

Wu and Segerson (1995) examined the impacts of the old Acreage Reduction Program (ARP) on crop allocation and thus groundwater pollution in Wisconsin. Although the ARP no longer exists, this study is a good example of integrating environmental outcomes into policy analysis since Wu and Segerson considered the impact of land quality as well as government programs on crop allocation. The empirical model, based on a theoretical model of farmer profit maximization, used county-level data for 54 counties in Wisconsin over nineteen years (1972-1990). They estimated the acreage response for six crops using a logistic model of the share of crop i in county k in period t. They included input and output prices as well as government program variables and land quality or site characteristic variables in their model. They showed that site characteristics have a larger influence on cropping patterns than economic or policy variables. Their results indicate that an increase in the target price for corn would increase the acreage of corn, soybeans, wheat and hay and reduce the acreage of oats and silage, but they also showed that corn acreage is more responsive to chemical price changes than to ARP rate changes.

The Wu and Segerson study is the only research that examined the environmental impact of policies, considering both land characteristics that make some land more polluting and regional demand for environmental benefits, such as water quality. They used the results of their empirical model to simulate the effects of potential policy changes on cropping patterns and potential groundwater contamination. The policy changes they examined were a reduction in the target price for corn, an increase in the ARP rate for corn, and an increase in agricultural chemical price. The magnitude of each policy was set to achieve a 1% reduction in high-polluting acreage (acres that are both vulnerable to groundwater pollution and that grow a chemical-intensive crop). They used the model to predict regional changes in acreage of the six crops from these policies. They then compared the regional reductions in polluting activities from the policies to the regional demand for groundwater quality to determine the differential impacts of the policies. The ARP program was determined to be the most effective in reducing high-polluting acreage in regions where demand for water quality, as measured by groundwater use, was expected to be highest.

Plantinga (1996) is another example of a study analyzing the impact of a policy other than crop insurance on the environment. He studied the potential environmental gains from reducing agricultural income supports (milk price supports) using Wisconsin data. The theoretical model was based on profit maximizing behavior by land managers. He used county-level data to estimate the probability that land is forested or used for milk production. He then used the results of the model to estimate the increase in forested area brought about by increases in the timber-to-milk price ratio, which correspond to declines in the milk price. Water quality benefits from the conversion to forest, on four land types, were then estimated by assuming rates of soil erosion and monetary damage estimates per ton of soil erosion. A 10% increase in the timber-to-milk price ratio thus resulted in \$8.1 to \$24.3 million in water quality benefits.

Summary of extensive margin literature

The results of the literature on the environmental impact of crop insurance at the extensive margin are summarized in Table 2. All of the empirical studies support the conventional wisdom that subsidized crop insurance brings economically marginal land into production. Studies that went on to examine the environmental impacts of this land use change support the notion that crop insurance has a detrimental impact on the environment. However, the extent of the impact of crop insurance on the environment is still under debate. For example, the Young et al. study suggests that only 600,000 additional acres have come into production due to crop insurance while Keeton, Skees, and Long calculate an impact of 45 million acres (or 15 million acres when 30 million CRP acres are excluded). For the measure of erosion, Griffin's study concludes that almost all of the erosion benefits generated by the CRP have been offset by the side effect of the crop insurance program, while Goodwin, Smith and Hammond report a loss of one-third of those gains.

Some of the differences between the results of the studies reviewed are due to limitations of the modeling framework used, while others are due to weaknesses or gaps in the data. In their studies, Griffin, and Keeton, Skees and Long, are essentially attempting to conduct controlled experiments by looking at the change in crop acreage with and without certain government programs. However, it is difficult to conduct such a controlled experiment as there has always been some governmental involvement in agriculture in recent history, and new programs have been introduced while others have expired. In addition, due to data gaps, they are not able to fully control for all other factors besides government programs that may affect the change in crop acreage, such as changes in technology and relative prices that do not affect all regions equally.

The Goodwin, Smith and Hammond model presents a sound econometric method for estimating the impact of crop insurance and other programs on soil erosion, but a high level of measurement error exists in the county-level data, especially for variables such as soil loss and conservation effort which are based on average values of a limited number of NRI points per county. In addition, the county-level data do not allow for inclusion of farmer characteristics as explanatory variables, which could lead to missing variable problems. The insurance and CRP participation decisions and conservation effort and fertilizer use are farm-level decisions that may be strongly impacted by farmer characteristics such as age, education, tenure status, farm size, etc. The Goodwin and Vandeveer paper concentrates on the Corn Belt, recognizing that results may vary by region. Acreage response to crop insurance might be higher in areas with a higher proportion of less productive farmland than in the Corn Belt. Wu's study is a good example of looking at the crop insurance and crop allocation decisions at the farm-level. There is still a great need for more empirical work in this area and the development of better datasets.

Gaps in the literature and areas for further research

The review of the literature reveals several gaps and areas needing further research. The literature to date generally supports both the notions that crop insurance reduces input (at least fertilizer) use, and that it brings into production more acres of crops with high yield variability. Whether the environmental impact from increasing crop acreage is greater than the reduction in input use that may occur due to crop insurance is an open empirical question. Wu examined this question in his study of Nebraska farmers and concluded that the increased acreage induced by crop insurance had a large impact on farm-level input use (an increase of from 20-33% for nitrogen, phosphorus and atrazine). It should also be noted that the empirical studies supporting the hypothesis that crop insurance reduces input use are limited to specific regions and crops. Broader research on a wider variety of crops and regions is needed. Results may be different for high-value, more input-intensive crops such as fruits, vegetables, and cotton than for grain crops. In addition, the empirical research has neglected study of crop insurance impacts on pesticide use in favor of studies on fertilizer or aggregated chemical use, which may blur the picture for pesticides.

Most past research has concentrated on modeling and analyzing the impact of one risk management strategy at a time. In reality, farmers are operating in an environment where they have many risk management options and are probably making decisions about many of them simultaneously. As has been shown by Keeton, Skees, and Long, and Goodwin, Smith and Hammond, there may be a conflict between the crop insurance program and the CRP. The CRP is a conservation program, but it can also be seen as a risk management program as it provides a steady and certain stream of income for the farmer to include in her portfolio of land use decisions. It is important to understand how farmers weigh decisions on the use of these two programs for stabilizing income and how these and other government programs, such as loan deficiency payments, may be working as complements or substitutes. At the same time, we need to understand how the interactions of these programs affect land use, input use and environmental outcomes. For example, loan deficiency payments over the last few years have set a floor price for the major crops and may have had a greater impact on land allocation decisions than crop insurance. In addition, even if crop insurance does lead to acreage shifts among crops, an increased supply of one crop will lower the market price, which may mitigate the supply response.

There is also the possibility that government subsidized crop insurance may simply substitute for the use of other risk management options, both private and public. Thus the government may be slowing the use of private market mechanisms to deal with risk, such as futures markets or private savings. At the same time, subsidized crop insurance may not be reducing risk for farmers, but rather the farmer may just be reshuffling the deck of risk management options until he is facing the same level of risk as before. Wright and Hewitt (1994) argue that crop insurance may change the use of other risk management measures such as spatial and activity diversification, off-farm employment, contracting, savings, and debt. It is an open empirical question as to whether the U.S. crop insurance program is affecting the use of other risk management measures.

The link between changes in land or input use and changes in environmental outcomes is often weak in the literature. Generally, less land in corn and more land in pasture are considered to be positive environmental outcomes, while lower levels of pesticide or fertilizer use on an acre of land is also a good environmental outcome. While these changes may be generally consistent with environmental improvements, such gross measures do not allow us to quantify the improvement in the environmental services demanded by society. We need to develop environmental indicators that are more sophisticated such as the change in water quality, erosion, or wildlife habitat resulting from changes in land and input use. We also need to consider how land characteristics, mitigation strategies such as conservation practices, and the demand for environmental benefits affect the valuation of environmental outcomes associated with crop insurance and other policies. The Wu and Segerson study is one of the only studies to attempt to measure the environmental impact of a policy-induced crop change that includes the impact of land characteristics on agricultural pollution and the demand for water quality. To follow this example and to develop indicators of environmental outcomes that are more meaningful requires data on land characteristics that are linked to farmer decisions and production practices. Such data are not available on a national scale, although regional studies may collect this type of data. However, it is possible to link NRI land quality data with farm production data, although this is not a perfect solution since the NRI data do not come from the exact same plot as the farm data.

Much of the literature on land use has relied on data aggregated to the county or crop reporting district level. The study by Wu is the only study using farm-level data. Pooled cross-section, time-series data at the farm level would be ideal for studying land use and input use questions, but such data are generally not available. However, more studies using cross-sectional farm level data are needed for examining farmers' decisions regarding risk management, land use, and input use decisions and their impact on the environment.

Another assumption made in many studies is that economically marginal land that is brought into production by crop insurance or other programs is also environmentally marginal. For example, the environmental importance of the extensive margin effect of crop insurance depends on whether the lands that are marginal for crop production are also environmentally marginal. Heimlich (1989) addressed this question by correlating corn yields with land capability class and erodibility class.[1] In his analysis, corn yields declined as land capability class increased (correlation of –0.385), but yield levels were inconsistent among erodibility classes. Figure 1 shows the cumulative distribution of nonirrigated cropland by corn yield and erodibility class (highly erodible or nonerodible) for 1982. As Figure 1 shows, not all highly erodible land is unproductive, and some nonerodible land has low productivity. Heimlich's results do not generally support a highly positive correlation between low yields and erodibility. Heimlich's study is one example of an attempt to test this hypothesis, and he showed that it is not necessarily true. Further work is needed to better understand whether land at the extensive margin is also environmentally fragile.

Research has concentrated on the impacts of multiple peril crop insurance on input use and land use. Crop revenue insurance is a product more recently offered by the government. Revenue insurance guarantees a certain level of revenue, and thus protects the farmer from declines in both crop prices and yields. Yet to be determined is how revenue insurance may

[1] The land capability classification system divides soil into classes I-VIII. Soils in classes I-III are best suited for cultivation.

change input and land use decisions, relative to those decisions made under multiple peril crop insurance, which protects against yield declines only.

Finally, farm programs changed significantly with the 1996 Farm Bill. However, much published research examines the impact of pre-1996 Farm Programs on land and input use. This is at least partly due to the time required to collect data and publish results, but we are in need of studies examining the impact of the new programs.

Conclusions

This paper has reviewed the literature, both theoretical and empirical, analyzing the links between crop insurance, farmer decisions about land use and input use, and associated environmental outcomes. Research done to date suggests that federally-subsidized crop insurance tends to decrease fertilizer use by risk averse farmers, but that crop insurance is also encouraging farmers to plant more acres of riskier crops than they would without the insurance. Research efforts need to be broadened to include consideration of the joint effects of multiple policies, to develop better indicators of environmental outcomes, to determine the environmental vulnerability of economically marginal cropland, and to explore the potential implications of crop revenue insurance and other post-1996 farm programs.

This paper has only addressed the potential environmental costs of government risk management programs, such as subsidized crop insurance. We have not addressed the benefits of subsidized crop insurance, which may or may not outweigh the costs. If the benefits of subsidized crop insurance are great, there may be other means to mitigate any harmful environmental effects. On the other hand, there may be other programs that would be more beneficial to farmers than subsidized crop insurance with fewer environmental costs.

References

Ahsan, Syed, Ali Ali, N. John Kurian. “Toward a Theory of Agricultural Insurance.” *Amer. J. Agr. Econ.* 64(1982):502-29.

Antle, J.M. and R.E. Just. “Effects of Commodity Program Structure on Resource Use and the Environment.” *Commodity and Resource Policies in Agricultural Systems.* R.E. Just and N. Bockstael, eds. Berlin: Spring-Verlag, 1991.

Babcock, B. and D. Hennessy. “Input Demand under Yield and Revenue Insurance.” *Amer. J. Agr. Econ.* 78(May 1996):416-27.

Binswanger, H.P. “Attitudes toward Risk: Experimental Measurement in Rural India.” *Amer. J. Agr. Econ*. 62(1980):395-407.

Brink, L. and B. McCarl. “The Tradeoff Between Expected Return and Risk Among Cornbelt Farmers.” *Amer. J. Agr. Econ.* 60(1978):259-63.

Briys, E., and L. Eeckhoudt. “Relative Risk Aversion in Comparative Statics.” *Amer. Econ. Rev*. 75(1985):281-83.

Chavas, J.P. and M.T. Holt. “Acreage Decisions Under Risk: The Case of Corn and Soybeans.” *Amer. J. Agr. Econ.* 72,3(August 1990):529-38.

Freund, R.J. “The Introduction of Risk into a Programming Model.” *Econometrica* 24(1956):253-64.

Gardner, B.L. and R.A. Kramer. “Experience with Crop Insurance Programs in the United States.” *Crop Insurance for Agricultural Development: Issues and Experience*. P. Hazell, C. Pomareda, and A. Valdes, eds. Baltimore: The Johns Hopkins University Press, 1986.

Goodwin, B.K., V.H. Smith and C. Hammond. “An Ex-Post Evaluation of the Conservation Reserve Program: Participation, Erosion, and Interaction with Related Programs.” Unpublished manuscript, 1999.

Goodwin, B.K. and M. Vandeveer. “An Empirical Analysis of Acreage Distortions and Participation in the Federal Crop Insurance Program.” Presented at the Workshop on Crop Insurance, Land Use, and the Environment, Economic Research Service, Washington, D.C., September 20-21, 2000.

Griffin, P. “Investigating the Conflict in Agricultural Policy Between the Federal Crop Insurance and Disaster Assistance Programs and the Conservation Reserve Program.” Unpublished Ph.D. dissertation, University of Kentucky, 1996.

Heimlich, R.E. *Productivity and Erodibility of U.S. Cropland*. USDA, Washington, D.C, ERS. Agric. Econ. Rep. 604, 1989.

Hey, J. "Relative Risk Aversion in Comparative Statics: Comment." *Amer. Econ. Rev.* 75(1985):284-85.

Horowitz, J. and E. Lichtenberg. "Risk-Reducing and Risk-Increasing Effects of Pesticides." *J. of Agr. Econ.* 45(1)(1994):82-89.

Houck, J.P. and M.E. Ryan. "Supply Analysis for Corn in the United States: The Impact of Changing Government Programs." *Amer. J. Agr. Econ.* 54,2(May 1972):184-191.

Ishii, Y. "On the Theory of the Competitive Firm Under Price Uncertainty." *Amer. Econ. Rev.* 67(1977):768-69.

Katz, E. "Relative Risk Aversion in Comparative Statics." *Amer. Econ. Rev*. 73(1983):452-53.

Keeton, K., J. Skees, and J. Long. "The Potential Influence of Risk Management Programs on Cropping Decisions." Selected paper presented at the annual meeting of the Amer. Agri. Econ. Assn, August 8-11, Nashville, TN, 1999.

Leathers, H. and J. Quiggin. "Interactions between Agricultural and Resource Policy: The Importance of Attitudes toward Risk." *Amer. J. Agr. Econ.* 3,73(1991):757-64.

Loehman, E. and C. Nelson. "Optimal Risk Management, Risk Aversion, and Production Function Properties." *J. of Agr. and Res. Econ.* 2,17(1992):219-231.

Miranowski, J.A., J. Hrubovcak, and J. Sutton. "The Effects of Commodity Programs on Resource Use." *Commodity and Resource Policies in Agricultural Systems.* R.E. Just and N. Bockstael, eds. Berlin: Spring-Verlag, 1991.

Nelson, C. and E. Loehman. "Further Toward a Theory of Agricultural Insurance." *Amer. J. Agr. Econ.* 3,69(1987):523-31.

Nimon, R. W. and A. Mishra. "Revenue Insurance and Chemical Input Use Rates." Presented at the American Agricultural Economics Association's Annual Meeting, Chicago, IL, August 5-8, 2001.

Plantinga, A.J. "The Effect of Agricultural Policies on Land Use And Environmental Quality." *Amer. J. Agr. Econ.* 78(Nov. 1996):1082-1091.

Pope, R. and R. Kramer. "Production Uncertainty and Factor Demands for the Competitive Firm." *S. Econ. J.* 46(1979):489-501.

Quiggin, J. "Some Observations on Insurance, Bankruptcy and Input Demand." *J. of Econ. Behavior and Organization.* 18(1992):101-110.

Quiggin, J., G. Karagiannis, and J. Stanton. "Crop Insurance and Crop Production: An Empirical Study of Moral Hazard and Adverse Selection." *Austr. J. Agr. Econ.* 37,2(August 1993): 95-113.

Sandmo, A. "On the Theory of the Competitive Firm Under Price Uncertainty." *Amer. Econ. Rev*. 61(1971):65-73.

Smith, Vincent, Barry Goodwin. "Crop Insurance, Moral Hazard, and Agricultural Chemical Use." *Amer. J. Agr. Econ*. 78(1996):428-438.

Turvey, C.G. "An Economic Analysis of Alternative Farm Revenue Insurance Policies." *Can. J. Agr. Econ.* 40(Nov. 1992):403-426.

Williams, J.R. "A Stochastic Dominance Analysis of Tillage and Crop Insurance Practices in a Semiarid Region." *Amer. J. Agr. Econ.* 70,1(Feb. 1988):112-120.

Wright, B.D. and J.A. Hewitt. "All-Risk Crop Insurance: Lessons From Theory and Experience." *Economics of Agricultural Crop Insurance: Theory and Evidence*. D.L Hueth and W.H. Furtan, eds. Boston: Kluwer Academic Publishers, 1994.

Wu, J. "Crop Insurance, Acreage Decisions, and Nonpoint-Source Pollution." *Amer. J. Agr. Econ.* 81(May 1999):305-320.

Wu, J. and K. Segerson. "The Impact of Policies and Land Characteristics on Potential Groundwater Pollution in Wisconsin." *Amer. J. Agr. Econ.* 77(Nov. 1995):1033-1047.

Young, C.E., R.D. Schnepf, J.R. Skees, and W.W. Lin. "Production and Price Impacts of U.S. Crop Insurance Subsidies: Some Preliminary Results." Proc. 1999 Fed. Forecasters Conf., 1999.

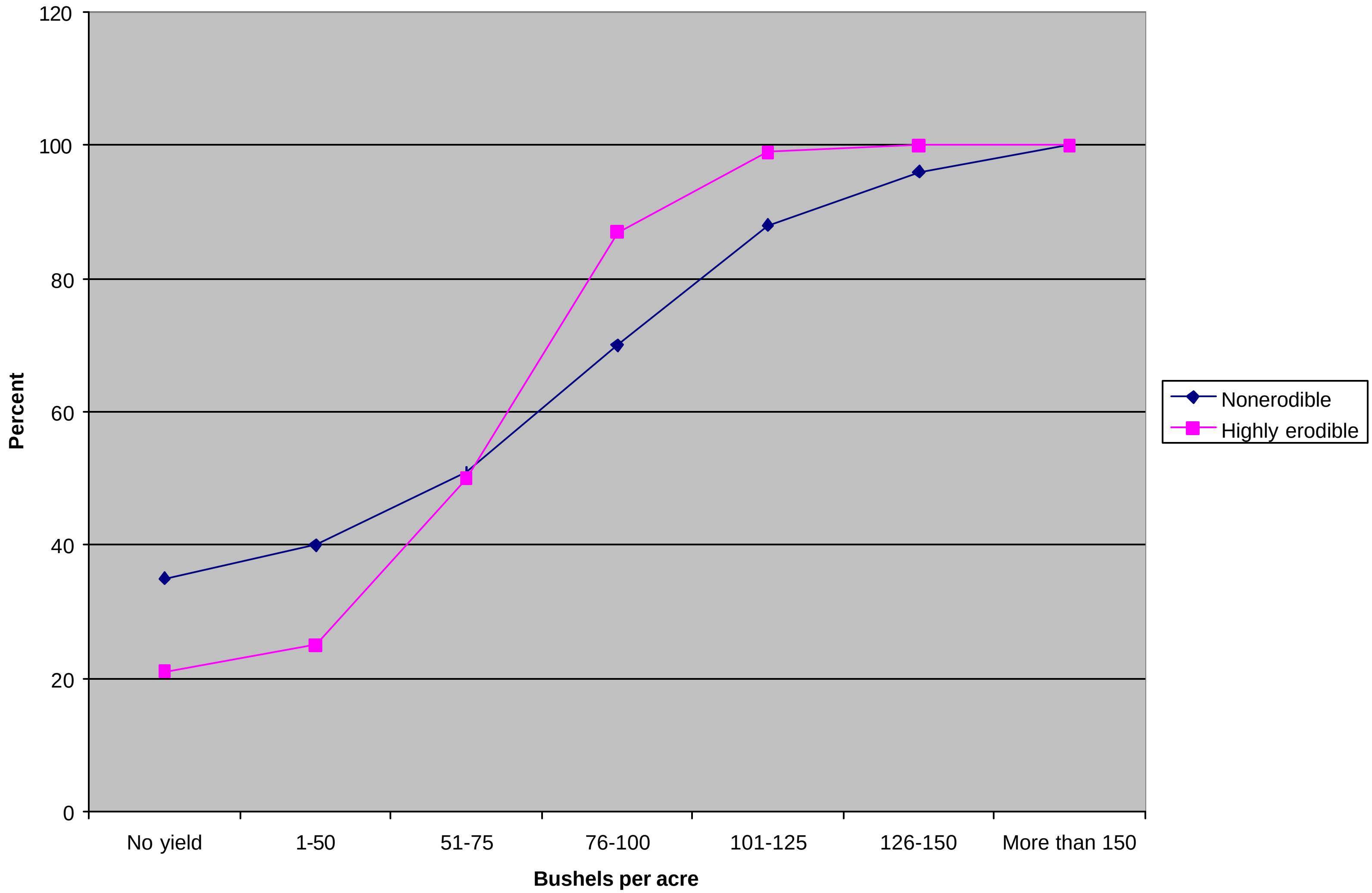
Table 1. Results of Studies Examining the Effect of Risk Aversion and/or Crop Insurance with Production Risk on Input Use

Study	Type of Study	Assumptions	Effect on input use
Pope and Kramer (1979)	theoretical	CRRA one input and two inputs	• for the one input case, risk aversion leads a producer to use more (less) of risk-decreasing (increasing) input • two inputs makes the results ambiguous
Leathers and Quiggin (1991)	theoretical	IARA, DARA, CARA	• for a risk averse producer, the impact of yield and price uncertainty on input use depends on the assumption on the utility function used
Loehman and Nelson (1992)	theoretical	CARA and CRRA two inputs	• the impact of risk aversion on input use depends on whether the two inputs are substitutes or complements and on whether each is risk-decreasing or risk increasing
Ahsan, Ali and Kurian (1982)	theoretical	EU max. with 2 states of nature one input, one output full coverage crop insurance	• crop insurance will cause risk averse producers to increase (decrease) the use of risk-increasing (reducing) inputs
Nelson and Loehman (1987)	theoretical	multiple inputs, one output crop insurance moral hazard	• although complete insurance is likely to increase (decrease) input use by risk-averse producers for risk increasing (decreasing) inputs, the moral hazard effect is likely to decrease input use
Quiggin (1993)	theoretical	two state of nature, good and bad marginal product of input greater in good state crop insurance and moral hazard	• crop insurance will tend to reduce use of risk-reducing and risk neutral inputs by risk-averse producers, and increase input use for strongly risk-increasing inputs
Horowitz and Lichtenberg (1994)	empirical econometric analysis	moral hazard pesticides can be strongly risk-increasing crop insurance decision made before input use decisions	• crop insurance increases input use • producers who purchased insurance applied 20% more N per acre and spent 22% more on pesticides
Smith and Goodwin (1996)	empirical econometric analysis	moral hazard crop insurance decision made simultaneously with input use decisions	• crop insurance reduces input use • each dollar spent on chemical inputs lowers the probability of insurance purchases by about 1%
Nimon and Mishra (2001)	empirical econometric analysis	moral hazard crop insurance decision made simultaneously with input use decisions	• crop insurance increases pesticide use • crop insurance reduces fertilizer use
Babcock and Hennessy (1996)	farm simulation	CARA farm simulation	• based on farm production data, increased fertilizer use decreased the probability of low yields • increasing insurance coverage induces decreased fertilizer applications
Quiggin, Karagiannis, and Stanton (1993)	production function estimation	insurance an input to production function	• insured farmers tend to use less variable inputs

Table 2. Results of Studies Examining the Environmental Impact of Crop Insurance at the Extensive Margin

Study	**Type of Study**	**Study region**	**Result of crop insurance subsidies and/or disaster payments**
Young et al. (1999)	simulation	U.S., seven regions, county-level data	• aggregate increase of 600,000 cropped acres • no environmental measures
Griffin (1996)	empirical econometric analysis	Great Plains, county-level data	• 16 million acres remained in production • crop insurance and disaster assistance programs wipe out most soil erosion gains of CRP
Keeton, Skees, and Long (1999)	empirical econometric analysis	U.S., crop reporting district data	• 45 million acres brought into production (including 30 million CRP acres) • no environmental measures
Goodwin, Smith and Hammond (1999)	empirical econometric analysis	U.S., county-level data	• increased average annual soil loss of 0.6 tons per acre (compared to annual reduction of soil loss from CRP of 1.7 tons per acre)
Goodwin and Vandeveer (2000)	empirical econometric analysis	Corn Belt, county-level data	• less than 0.1% increase in corn and soybean acreage • no environmental measures
Wu (1999)	empirical econometric analysis	Nebraska, farm-level data	• farms grow more corn and soybeans and less hay and pasture • crop mix changes lead to 20% increase in N use, 33% increase in P use, and 22 % increase in atrazine use

Figure 1. Cumulative distribution of nonirrigated cropland by corn yield and erodibility class, 1982



Source: Heimlich (1989)