Input Demand Under Yield and Revenue Insurance

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ABSTRACT

The question of how insurance programs affect agricultural input use is commanding increasing attention. Previous studies disagree on the likely effects of insurance on fertilizer application rates. Whether insurance is a complement or a substitute for fertilizer depends, in part, on whether the probability of low yields is positively or negatively affected by increased fertilizer rates. This study uses field-level data measuring the response of corn yields to nitrogen fertilizer to determine if the technical relationship between yield and nitrogen fertilizer supports the hypothesis that crop insurance or revenue insurance could induce increased application rates. Our results indicate no support for this hypothesis. At all nitrogen fertilizer rates and reasonable levels of risk aversion, nitrogen fertilizer and insurance are substitutes, suggesting that those who purchase insurance are likely to decrease nitrogen fertilizer applications.

INPUT DEMAND UNDER YIELD AND REVENUE INSURANCE

The effect of agricultural insurance on optimal per acre input levels is in dispute. Horowitz and Lichtenberg, in an econometric study, conclude that crop insurance increases the use of fertilizer and pesticides. They estimate that the purchase of crop insurance induces midwestern farmers to increase their nitrogen fertilizer applications by approximately 19 percent and pesticide expenditures by 21 percent. Two other studies conclude that per acre input levels decrease under insurance. Smith and Goodwin, in an econometric analysis of crop insurance and chemical input decisions on Kansas wheat farming, conclude that nitrogen fertilizer expenditures decrease by $5.00 per acre. And Quiggin, Karagiannis, and Stanton conclude that midwestern grain farmers who purchase crop insurance decrease fertilizer and chemical applications about 10 percent.

The issue of how input decisions change under crop and revenue insurance schemes is attracting increased attention because of proposals to force farmers to rely more on insurance and less on direct government subsidies. For example, a group of Iowa farmers and farm organizations has proposed the elimination of current commodity programs in favor of a plan that insures gross revenue. If optimal chemical use increases under insurance, as suggested by Horowitz and Lichtenberg, then it is likely that a move away from direct government payments and towards increased reliance on insurance will result in greater environmental pollution from agriculture. However, if optimal chemical use declines significantly under insurance, as concluded by Smith and Goodwin and Quiggins, Karagiannis, and Stanton, then the environment may benefit, but moral hazard issues will make the pricing of insurance difficult.

The Horowitz and Lichtenberg result depends on the assumption that farmers are risk averse and that increased applications of fertilizer and pesticides increase the probability of low yields. The pesticide result of Horowitz and Lichtenberg is somewhat surprising because it is widely accepted that pesticides do not generally increase yield potential. They only affect yields when damaging agents are present (Lichtenberg and Zilberman). Thus, pesticide use should generally decrease the probability of low yields, which suggests that a government program that insures against low yields should decrease pesticide use, not increase use. For nitrogen fertilizer use, Babcock and Blackmer's results indicate that optimizing risk-neutral farmers have the incentive to apply nitrogen fertilizer to reduce the probability of low yields. If true, then insurance should decrease the marginal payoff from nitrogen fertilizer, thus lowering optimal nitrogen rates.

This paper analyzes the issue of input demand under insurance differently than the previous econometric studies by estimating the farm-level technology that farmers face and then simulating what would be the optimal response to insurance under the estimated technology. The advantage of this approach is that it provides insight into how input use actually affects the distribution of crop yield. The disadvantage of the approach is that data measuring actual farmer decisions are not used. With this proviso, this paper makes two contributions that lead to a better understanding of the effect that insurance has on optimal input decisions. First, a careful specification of how nitrogen fertilizer affects the distribution of yield is estimated, thus showing the effect that increased fertilizer rates have on the probability of low yields. The second contribution is an examination of the effect of crop and revenue insurance under joint price and yield uncertainty. The analysis moves away from the common assumption that prices and yields are independent bivariate normal random variables by allowing price to be positively skewed and yields to be negatively skewed. A method that allows any degree of price and yield correlation to be imposed on generated random deviates is used to estimate the effects of nitrogen fertilizer on revenue distributions. Such a method that allows correlated prices and yields is critical in production regions that grow a large proportion of a crop. The analysis is conducted for Iowa corn production. The results are useful in contrast to those of Horowitz and Lichtenberg and Quiggin, Karagiannis, and Stanton.

Optimal Input Decisions Under Insurance

To clarify the issues, a simple model of yield insurance is presented first. Suppose that the farmer has an insured yield level, y_I, and that the government provides this level of insurance at a fixed cost that, without loss of generality, will be set to zero. Thus, we focus not on the demand for insurance, but rather on how optimal input decisions change once insurance is purchased. If actual yield, y, is less than y_I, an indemnity in the amount $P_I(y_I - y)$ is paid where P_I is the indemnity price. For now, we assumes that $P_I = P$, a nonstochastic output price. Given that y_I and the insurance premium are fixed, the farmer's problem is to select a level of input X to maximize expected utility of profits. The stochastic relationship between y and X is captured by the conditional probability density function $g(y|X)$, $a \leq y \leq b$. Let $\pi_1 = Py_I - P_X X$ and $\pi_2 = Py - P_X X$. Then the farmer's problem is to choose X to

$$Max\ EU = \int_a^{y_I} U(\pi_1) g(y|X) dy + \int_{y_I}^{b} U(\pi_2) g(y|X) dy. \qquad (1)$$

The first-order condition is

$$\int_a^{y_I} U(\pi_1)\frac{\partial g(y|X)}{\partial X}dy + \int_{y_I}^{b} U(\pi_2)\frac{\partial g(y|X)}{\partial X}dy - P_X EU'(\pi) = 0, \qquad (2)$$

where

$$EU'(\pi) = \int_a^{y_I} U'(\pi_1)g(y|X)dy + \int_{y_I}^{b} U'(\pi_2)g(y|X)dy, \qquad (3)$$

and P_X is the per unit price of *X*. The second-order condition is $\Delta = \frac{\partial \ EU(\pi)}{\partial X^2} \leq 0$, which will be assumed negative. The special case of no insurance is analyzed by setting $y_I = a$.

The critical question is, under what conditions does an increase in y_I increase the optimal level of *X*? Differentiation of (2) and (3) with respect to *X* and y_I results in the following comparative static result:

$$\frac{\partial X}{\partial y_I} = -\Delta^{-1}[-P_X PU''(\pi_1)\int_a^{y_I} g(y|X)dy + PU'(\pi_1)\int_a^{y_I}\frac{\partial g(y|X)}{\partial X}dy], \qquad (4)$$

which can be rearranged as

$$\frac{\partial X}{\partial y_I} = -\Delta^{-1}PU'(\pi_1)\int_a^{y_I} g(y|X)dy[P_X\frac{-U''(\pi_1)}{U'(\pi_1)} + \frac{d\log\int_a^{y_I}\alpha(y|X)dy}{dX}]. \qquad (5)$$

Equation (5) is analogous to equation (3) in Horowitz and Lichtenberg. The terms outside the brackets in (5) are positive. Under risk aversion the first term inside the brackets is positive. That is, as Horowitz and Lichtenberg point out, increases in the insurance level tend to increase input use because the "scale of production risk" (Sandmo) is decreased. The second bracketed term in (5) is the percent change in the probability that an indemnity is paid due to a one-unit increase in *X*. A sufficient condition for (5) to be positive is if an increase in *X* increases the probability of low yields; that is, *X* is a risk-increasing input.

The two panels of Figure 1 illustrate how the sign of the second term in brackets is determined. In Panel A, an increase in X from X_1 to X_2 increases the probability of achieving high yields and decreases the probability of achieving low yields. As drawn, the density of y is decreased for all $y < y_I$ and (5) cannot be unambiguously signed unless the producer is risk neutral, in which case (5) is negative. That is, input use and yield insurance are substitutes. In Panel B, an increase in X increases both the probability of high and low yields. As drawn, the density of y increases for all $y < y_I$, and (5) is positive for all risk aversion levels. Thus, the two critical factors that determine how insurance affects input use is the degree of risk aversion and the marginal effect of increases of X on the conditional density of y.

When is it likely that the second bracketed term in (5) is positive? First note that for $a = y_I$, the expected marginal product of X must be positive for (2) to hold. Thus, for at least some range of $y_I > a$, the marginal product of X will also be positive and an increase in X must increase both the probability of high yields and low yields as drawn in Panel B, if the second bracketed term in (5) is to be positive. Can pesticides achieve this kind of yield impact? It is well accepted that pesticides only affect yields in the presence of damaging agents. That is, pesticides do not increase yield potential. Thus, it seems likely that increased pesticide use could increase the probability of high yields. But when will pesticide use increase the probability of low yields? That is, when will increased pesticide use increase the probability of damage? To our knowledge, there are no studies that demonstrate that pest populations increase with increased pesticide use in a single growing season. Thus the increased probability of low yields cannot be caused by increased pest damage. If pesticides themselves can damage crops, such as overspray from herbicides, then increased use may increase the probability of low yields. But the pesticide must have the seemingly rare characteristic that it can be applied at rates that damage crops and still provide more protection against the damaging agent. Unless farmers' risk aversion levels explain the results of Horowitz and Lichtenberg, the most important pesticides in corn production must have this characteristic and insured farmers must know about it. Furthermore, insured farmers must be submitting claims for yield losses that are caused, at least in part, by increased pesticide use.

Now how likely is it that nitrogen fertilizer can exhibit this sort of behavior? As Horowitz and Lichtenberg point out, fertilizer must be applied at rates that decrease yields when growing conditions are bad. But as the previous discussion points out, this damage must occur at rates of fertilizer use rates that also improve yields when growing conditions are good. The empirical analysis that follows sheds light on this issue.

This discussion about how yield insurance affects the per acre use of inputs under output price certainty guides the determination of how revenue insurance under price uncertainty affects input use. Suppose that a payment is made if revenue, R, falls below some insurance level, R_I. If price and yield are independent with marginal density functions $h(P)$, $P > 0$, and $g(y|X)$, $a \leq y \leq b$, then the producer's optimizing condition is to choose X to maximize

$$EU = \int_0^\infty \int_a^{R_I/P} U(\tilde{\pi}_1)h(P)g(y|X)dydP + \int_0^\infty \int_{R_I/P}^{b} U(\tilde{\pi}_2)h(P)g(y|X)dydP, \qquad (6)$$

where $\tilde{\pi}_1 = R_I - P_X X$ and $\tilde{\pi}_2 = Py - P_X X$. From (6), the effect of increasing R_I on optimal X can be derived from differentiating the first-order condition with respect to X and R_I:

$$\frac{\partial X}{\partial y_I} = -\Delta^{-1}U'(\tilde{\pi}_1)\int_0^{\infty}\int_a^{R_I/P} h(P)g(y|X)dydP[P_X \frac{-U''(\tilde{\pi}_1)}{U'(\tilde{\pi}_1)} + \frac{d\log(\int_0^{\infty}\int_a^{R_I/P} g(y|X)h(P)dydP)}{dX}]. \quad (7)$$

The sufficient condition for an increase in the coverage level to increase X is directly analogous to the sufficient condition under yield insurance, namely that an increase in X increases the probability that a claim will be made. For revenue insurance, the claim is made with respect to revenue rather than simply yields, but the results illustrated in Figure 1 hold true for both yield and revenue insurance when yields and prices are uncorrelated. If price and yield are correlated, then the joint distribution function must be used to determine how revenue insurance affects optimal input decisions. A method for estimating the effects of yield and revenue insurance for correlated price and yield is presented in a later section. But first we estimate the marginal yield distribution and revenue distribution.

Estimating the Effects of Nitrogen Fertilizer on Corn Yield Distributions

One critical factor in determining the effects of insurance on optimal input decisions is estimating the marginal effect of input use on the density function of yields. We estimate a yield distribution with parameters that are functions of applied nitrogen fertilizer. It is well accepted that crop yields are skewed so the beta distribution, which can exhibit both negative and positive skewness, is used as the parent distribution. The conditional beta distribution can be written

$$h(y|X) = \frac{\Gamma[p(X)+q(X)]}{\Gamma[p(X)]\Gamma[q(X)]}\frac{(y-a)^{p(x)-1}(b-y)^{q(x)-1}}{b^{p(x)+q(x)-1}}. \quad (8)$$

The functional forms relating X to p and q need to be flexible enough to exhibit both of the types of technical relationships exhibited in Figure 1. This flexibility is achieved by the following functional forms for the p and q functions:

$$\begin{aligned} p &= p_0 + p_1 X^{.5} + p_2 X \\ q &= q_0 + q_1 X^{.5} + q_2 X. \end{aligned} \tag{9}$$

Data to estimate the parameters of (8) and (9) were generated by a series of experiments on four cooperating Iowa corn farms from 1986 to 1991. The four farm locations were widely dispersed across Iowa. Ten rates of nitrogen fertilizer, varying from 0 to 300 pounds per acre were applied on each farm each year. (Typical rates for continuous corn production in Iowa are between 125 and 200 pounds per acre.) Three replications of each rate resulted in 30 observations per site-year. Thus, 600 observations were used to estimate the conditional yield distributions. Site-specific effects on the p and q functions were captured by including site-specific constant terms in (9) and by specifying site-specific a and b parameters in (8). For each site, a was set at five bushels less than the minimum observed yield and b was set at ten bushels greater than the maximum observed yield. The maximum likelihood routine of TSP was used to estimate the parameters of (8) and (9) and are presented in Table 1. Figure 2 shows how the estimated yield distribution changes as nitrogen fertilizer increases from zero to 300 pounds per acre. As can be seen, there is very little effect on the estimated yield distribution as the fertilizer rate increases from 200 pounds per acre to 300 pounds per acre. Figure 3 gives a more detailed view for these rates.

As discussed, insurance schemes increase input applications if more inputs increase the probability of low yields. As shown in Figures 2 and 3, for rates of nitrogen fertilizer less than

250 pounds per acre, increases in fertilizer applications rates decrease the probability of achieving low yields. Moving from 250 pounds per acre to 300 pounds per acre, however, results in an increase in the probability of low yields for yields less than about 100 bushels per acre. For rates up to 200 pounds per acre, increases in fertilizer rates sharply decrease the probability of low yields. For rates over 200 pounds per acre, increasing nitrogen fertilizer has very little effect on the probability distribution of yields.

While we are careful about drawing general conclusions from these empirical results, conversations with extension agronomists from the U.S. Corn Belt confirm that the estimated yield distributions illustrated in Figure 2 are typical of how corn yields respond to nitrogen fertilizer in the Corn Belt. If true, then there is little likelihood that the Horowitz and Lichtenberg results were caused by nitrogen fertilizer increasing the probability of low corn yields. It could be that risk aversion caused the increase. Or their results could be explained by their footnote 9, which proposes that perhaps farmers who take out lines of credit are more likely to buy crop insurance and use more inputs. The extent to which risk aversion could cause the reported effect for a farmer with the production technology illustrated in Figure 2 is estimated with a Monte Carlo analysis.

Estimating the Distribution of Revenue

Decision models with random yields and prices have generally assumed that both are normally distributed (see, for example, Lapan and Moschini). The reason for this assumption is that the use of any other distribution quickly makes the problem both analytically intractable for theoretical studies and numerically intractable for Monte Carlo studies. In addition, when prices and yields are correlated, the bivariate normal distribution is really the only option that allows specification of a desired degree of correlation. But it is well known that crop yields are skewed. And studies of market efficiency typically assume that price is lognormally distributed (Wilson and Fung). Monte Carlo studies use this prior knowledge about the marginal distributions of price and yield to draw nonnormal deviates. But we are left with the problem of imposing a desired degree of dependence on the deviates.

One solution to this problem is offered by Johnson and Tenenbein when the level of dependence can be captured by Spearman's rank correlation coefficient, ρ_s. Because ρ_s is invariant to nonlinear monotonic transformations, it is ideally suited for generating correlated nonnormal deviates for Monte Carlo simulations. The method is based on the simple idea that taking a linear combination of two independent deviates creates dependence. The method is presented here for convenience.

The problem is to generate a pair of random variables (*P*, *y*) with specified marginals $F_1(P)$ and $F_2(y)$. For the application in this paper $F_1(P)$ is the lognormal distribution and $F_2(y)$ is the beta distribution. Following Johnson and Tenenbein, let

$$U = U' \tag{10}$$

and

$$V = cU' + (1-c)V' \tag{11}$$

where U' and V' are iid random variables with any common density function *g(t)* and *c* is a constant in the interval (0, 1). Johnson and Tenenbein provide values of *c* that yield desired levels of ρ_s for different specifications of *g(t)*. In this application, we use the standard normal distribution for *g(t)*.

Let $P' = H_1(U)$ and $y' = H_2(V)$ where $H_1(u)$ and $H_2(v)$ are the distribution functions of U and V. Define

$$P = F_1^{-1}(P') = F_1^{-1}(H_1(U)) \tag{12}$$

and

$$y = F_2^{-1}(y) = F_2^{-1}(H_2(V)) \tag{13}$$

or

$$y = F_2^{-1}(1-y) = F_2^{-1}(1-H_2(V)). \tag{14}$$

Johnson and Tenenbein note that because P', y', and $-y'$ are uniformly distributed over the interval (0, 1), *P* and *y* will have a joint distribution with marginals $F_1(P)$ and $F_2(y)$. For Monte Carlo studies, knowledge of these two marginal distributions is all that is required. Thus, we do not need to worry about the general properties of the joint distribution. Positively correlate deviates are obtained from (13) and negative values are obtained from (14). For price and yields, negative correlations are used. The two levels of ρ_s used in this study are 0 and $-.3$. From Johnson and Tenenbein, the required levels of *c* using the normal distribution for *g(t)* are 0 and .248. SHAZAM (White) was used to implement this procedure.

Prices are assumed to follow the lognormal distribution because it complies with the theory of efficient markets (Samuelson), and because it has found widespread use in the commodity pricing literature (Black; Wilson and Fung). The mean for the marginal distribution of price was taken from the September futures contracts quoted in April. The September contract is the closest to the corn harvest and April is the month in which most nitrogen fertilizer is applied. The Black options pricing formula was used to estimate the standard deviation of the log of prices. The average mean and standard deviation from 1991 to 1994 were used to parameterize the lognormal distribution:

$$F_1(P) = \left(P\sqrt{\pi}\sigma\right)^{-1}\exp\left[-.5\{\log(P)-\zeta\}/\sigma^2\right], \sigma = .174; \zeta = 0.921. \qquad (15)$$

To account for the average basis in Iowa, $0.35 per bushel was subtracted from the prices drawn from (15). This results in a mean price of $2.20 per bushel and a standard deviation of $.45 per bushel.

A Monte Carlo procedure for maximizing (1) and (6) was used. The marginal effect of X on the yield and revenue distributions was obtained by generating 1,000 yield and price deviates for one-pound increments of X. For each rate of $X = x$, expected utility under no insurance was calculated by:

$$EU(X = x) = \frac{1}{1000}\sum_{i=1}^{1000} U(P_i y_i - P_X x), \qquad (16)$$

where prices were drawn from (15) and yields were drawn (7) with the parameter values given in Table 1. Parameter values for site 12 were used in the simulations. The rate of X that resulted in the maximum value of EU was taken to be the optimal nitrogen rate. Denote that rate by X^*. At X^*, expected yield and expected revenue were calculated to serve as the base from which the insurance coverage levels were defined. Coverage levels of 70, 80, 90, and 100 percent of average yield and revenue at X^* were considered. Expected utility under crop insurance was calculated by:

$$EU(X=x)=\frac{N_1}{1000}\sum_{i=1}^{N_1}U(P_iy_i+P_I(y_I-y_i)-P_Xx)+\frac{1000-N_1}{1000}\sum_{i=1}^{1000-N_1}U(P_iy_i-P_Xx) \quad (17)$$

where the first summation is taken over the observations for which $y_i < y_I$ (of which there are N_1) and the second summation is taken over the observations for which $y_i > y_I$. The rate of X that results in the highest value of (17) is taken to be the expected utility maximizing rate. Expected utility under revenue insurance was calculated similarly:

$$EU(X=x)=\frac{N_2}{1000}\sum_{i=1}^{N_2}U(P_iy_i+(R_I-P_iy_i)-P_Xx)+\frac{1000-N_2}{1000}\sum_{i=1}^{1000-N_2}U(P_iy_i-P_Xx) \quad (18)$$

where the first summation is taken over the observations for which $P_iy_i < R_I$ (of which there are N_2) and the second summation is taken over the observations for which $P_iy_i > R_I$. The rate of X that results in the highest value of (18) is taken to be the expected utility maximizing rate under revenue insurance. A CARA utility function was assumed. Appropriate values of absolute risk aversion were selected by scaling the problem to a single acre of corn and by assuming that the risk premium was 0, 20, and 40 percent of the standard deviation of revenue (Babcock, Choi, and Feinerman).

Results

Table 1 presents the simulation results for crop insurance under the assumption of uncorrelated yield and price. Reported first the results under risk neutrality. The expected profit maximizing nitrogen fertilizer rate is 202 pounds per acre with no crop insurance. Expected yield is 136.5 bushels per acre and expected revenue is $300.08 per acre. Thus, returns over fertilizer costs are $269.78 per acre. The crop insurance payout is assumed to made at a rate of $1.65 per bushel, which is 75 percent of the expected price of $2.20. As yield guarantees increase from 70 percent of average yield to 100 percent of average yield, optimal fertilizer rates decrease. Thus, as suggested by Figure 2, decreases in fertilizer rates increase the probability of low yields. The probability of claims increases from approximately .11 at the 70 percent coverage to more than .5 at the 100 percent coverage, and the expected claims, conditional on a claim being made, increase from $21.14 per acre to $43.14 per acre. The unconditional expected payout, found by multiplying the probability by the conditional expected payout, increases from $2.28 per acre to $22.48 per acre.

The standard deviation of net returns, which is a measure of the quantity of risk, at the 202 pounds per acre fertilizer rate is $90.66 per acre. Using Table 2 in Babcock, Choi, and Feinerman, a risk premium of 20 percent of this standard deviation implies an absolute risk aversion coefficient of approximately .0046. A risk premium of 40 percent implies a risk aversion coefficient of .01. These two coefficients represent low and moderate levels of risk aversion for the simulations presented in Tables 2 and 3. The first conclusion from the sets of results is that the introduction of risk aversion at the levels assumed here does not change the result that increases in insurance coverage decrease optimal nitrogen fertilizer rates. That is, the bracketed term in equation (5) remains negative under risk aversion. Second, the 70 percent insurance rate does not induce a large reduction in optimal fertilizer rates. Under moderate risk aversion, optimal rates only decrease by 3.54 percent. But at the 100 percent coverage level, the introduction of insurance induces a 24.2 percent reduction in optimal fertilizer rates. Thus, it appears that moral hazard is a significant problem with crop insurance only at high coverage levels.

Table 3 presents the corresponding results when price and yield are negatively correlated with $\rho_s = -.3$. A negative correlation reduces the amount of risk a producer faces because price is high, on average, when yields are low. Thus, the reduction in optimal fertilizer rates as crop insurance coverage levels increase, is less pronounced than under uncorrelated price and yield under all levels of risk aversion.

Our results contrast sharply with those of Horowitz and Lichtenberg. They conclude that introducing crop insurance induces a fairly large increase in optimal nitrogen fertilizer use. The results presented here suggest that there is only a large response when farmers have a moderate level of risk aversion and coverage levels are high. And this large response works in the opposite direction. That is, introducing crop insurance induces farmers to decrease fertilizer applications, not increase them. Our results support the econometric findings of Smith and Goodwin and Quiggin, Karagiannis, and Stanton who found that farmers who buy crop insurance decrease their nitrogen fertilizer applications by a modest amount.

Note that as risk aversion increases, the response of X to increases in y_I is more negative rather than less negative as suggested by equation (5). The reason for this discrepancy is that as risk aversion increases, the optimal level of X decreases, which as can be seen by Figure 2 increases (makes more negative) $\frac{d \log \int_a^{y_I} g(y|x)dy}{dX}$. Thus, the direct effects of increased risk aversion are overwhelmed by the indirect effect, making $\frac{dX}{dy_I}$ more negative as risk aversion increases.

Table 4 presents the results for revenue insurance under uncorrelated price and yields for revenue coverage levels varying from 70 percent to 100 percent of expected revenue under no insurance and risk neutrality. At the 70 percent coverage level, optimal fertilizer rates decrease from their optimal levels under no insurance by 2.97 percent under risk neutrality to 7.07 percent under moderate risk aversion. (The maximum 14-pound reduction in fertilizer applications represents approximately a one-bushel decrease in expected yields.) At the 70 percent coverage level, the probability of making a claim is approximately 17 percent, and the unconditional expected payout is approximately $5.90 per acre. Both the probability of making a claim and the expected indemnities increase rapidly as the coverage level increases. These increases are caused both by the direct effect of an increased coverage level and by the decrease in fertilizer rates, which shifts the yield distribution to the left. At the 100 percent coverage level, the probability of making a claim is .646, which implies that if government wanted to issue revenue insurance at 100 percent of expected revenue, then it would have to redefine the level of revenue at which insurance begins to pay because expected revenue at 122 pounds per acre of nitrogen fertilizer is significantly less than expected revenue at 200 pounds per acre.

Table 5 presents the results of revenue insurance for negatively correlated prices and yields. The qualitative results are the same as for the uncorrelated prices and yields. But under a negative correlation, a 70 percent coverage level induces a smaller reduction in optimal fertilizer rates than under no correlation. The reduction for the moderately risk averse producer is 5 percent as compared with a 7 percent reduction under no correlation. The general result that fertilizer rates decrease as the coverage level increases still holds.

Concluding Remarks

This study presents estimates of the effect of yield and revenue insurance on optimal per acre nitrogen applications on Iowa corn production. Because farm-level corn yields in Iowa are likely correlated with output price, a procedure is used to draw nonnormal correlated random deviates for the Monte Carlo analysis. The general conclusion from the analysis is that either insurance scheme is likely to lead to relatively minor reductions in farm applications of nitrogen fertilizer if the coverage levels are at or below 70 percent of mean yield or revenue.

One implication of the results is that if recent proposals to replace current commodity programs with revenue insurance were adopted, then average per acre payments to Iowa corn farmers are likely to drop dramatically. Currently, per acre deficiency payments average between \$30 and \$50. Under revenue insurance, average payments at the 70 percent coverage level are about \$6.00 per acre for uncorrelated yields and prices and about \$3.25 per acre when $\rho_s = -.3$. The corresponding increase in certainty equivalent under the two levels of positive risk aversion used in this study are between \$5.00 and \$15.00 per acre.

Figure 1.The Effect of Increasing Input Use from X_1 to X_2 on the Distribution of Yields

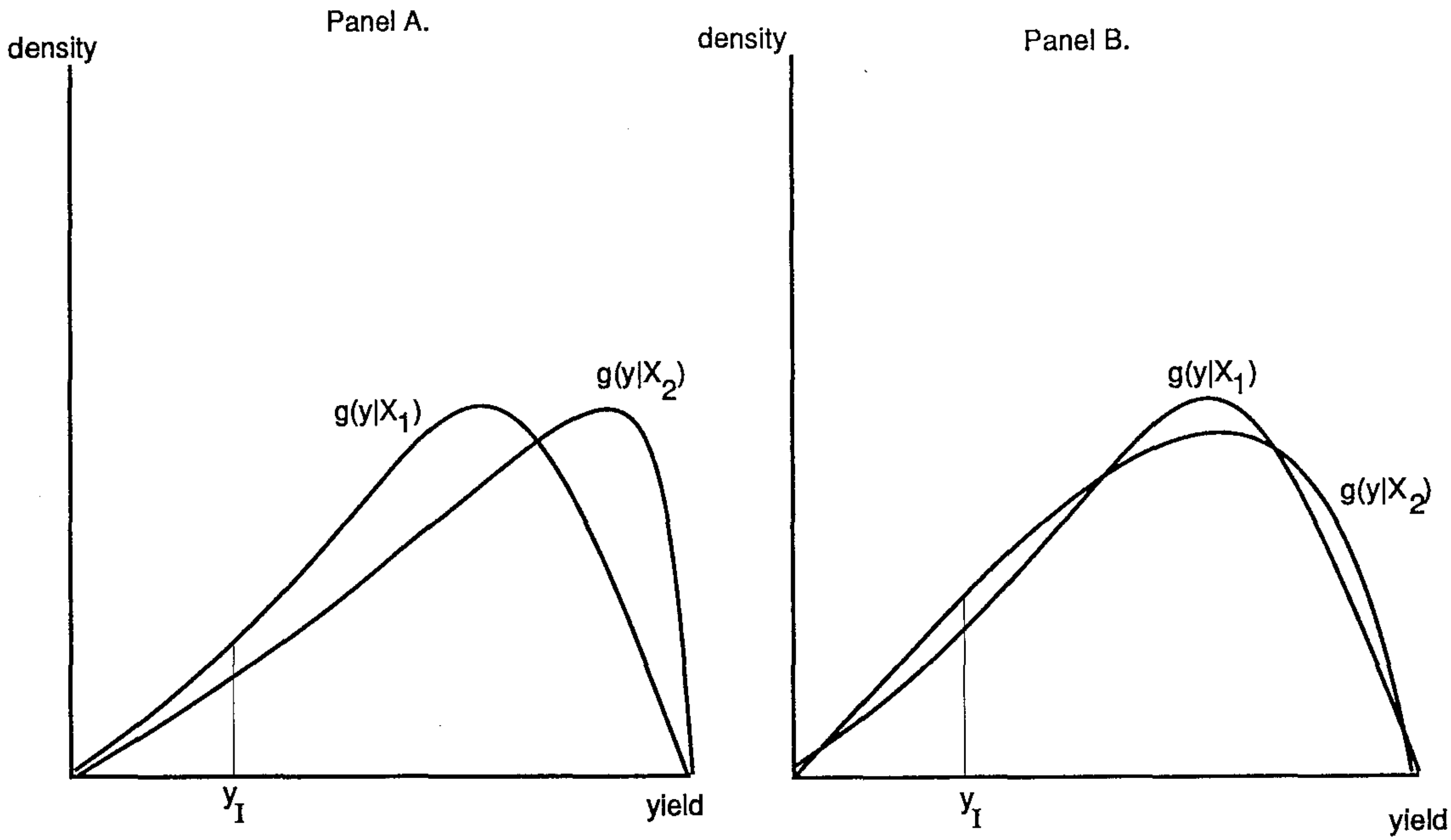

Figure 2. Effect of Nitrogen Fertilizer on the Distribution of Corn Yields

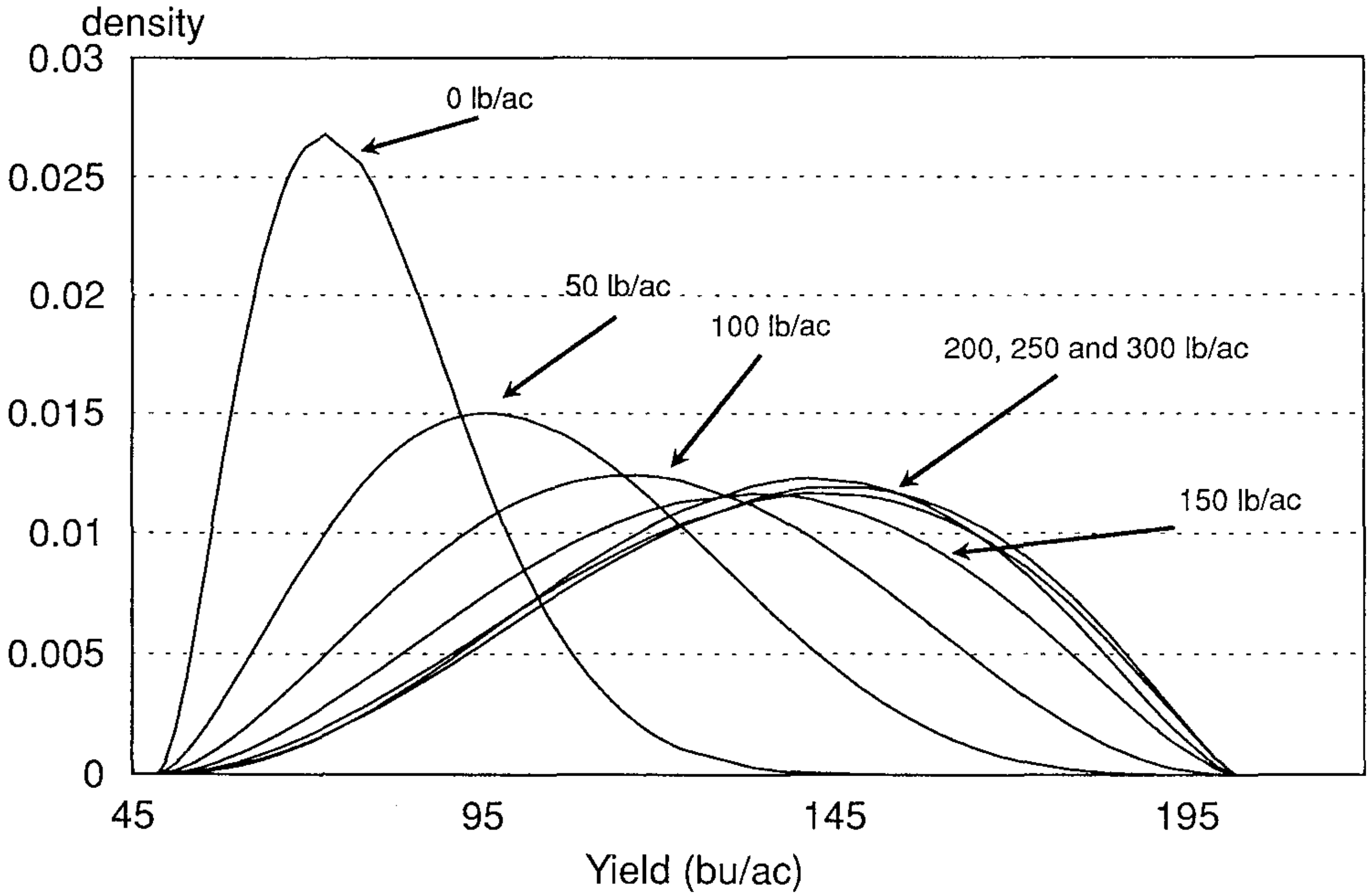

Figure 3. Effect of High Nitrogen Fertilizer Rates on the Distribution of Corn Yields

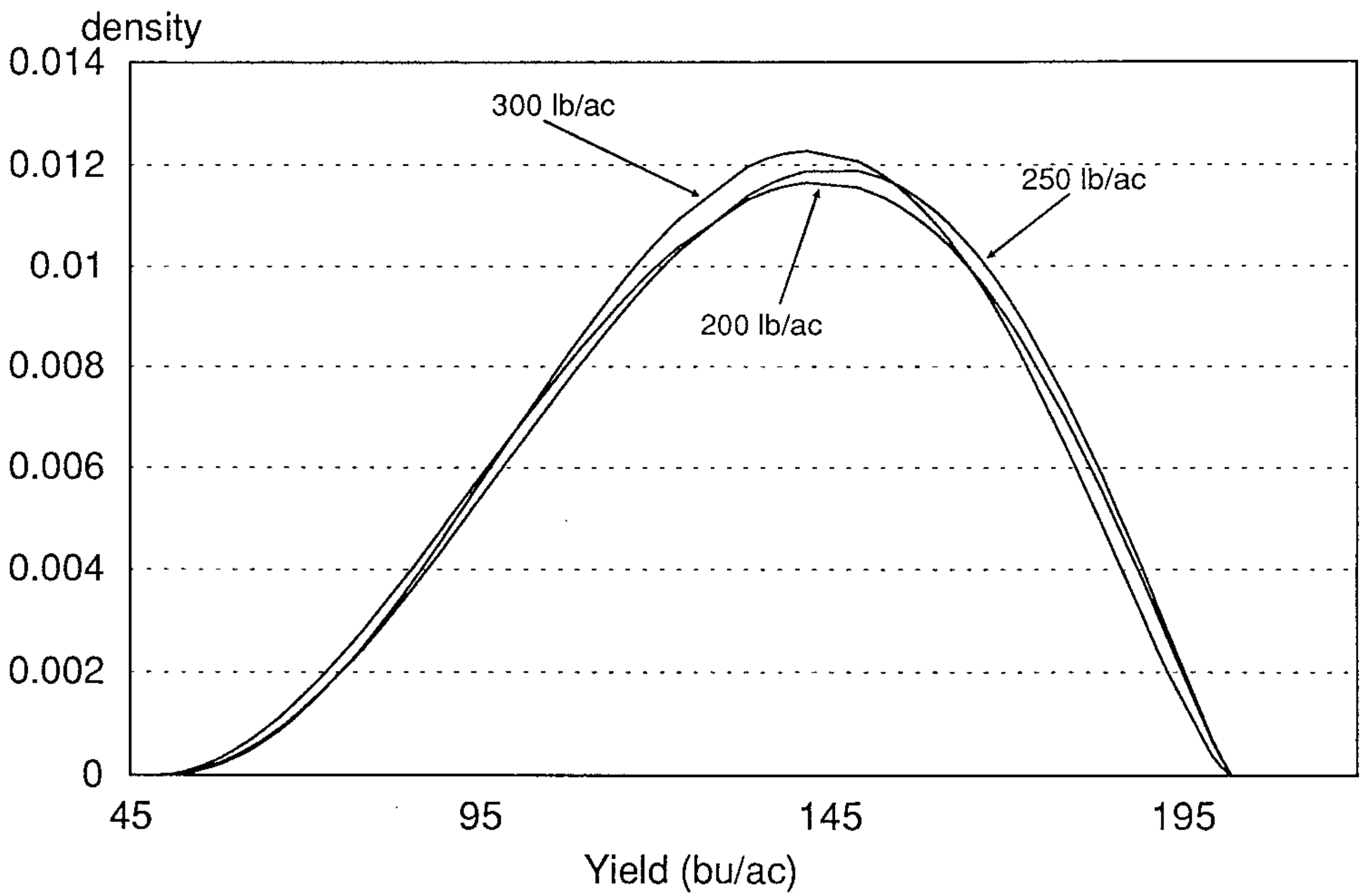

Table 1. Estimated parameters of the conditional beta distribution

Parameter	Estimated Coefficient	Standard Error
Maximum yield[a]		
Site 9	182	--
Site 10	200	--
Site 11	214	--
Site 12	202	--
Minimum yield[b]		
Site 9	30	--
Site 10	25	--
Site 11	27	--
Site 12	48	--
p function Constant:		
Site 9	4.60	.631
Site 10	3.23	.533
Site 11	3.50	.539
Site 12	3.14	.513
$X^{.5}$	-.0921	.094
X	.00603	.00511
q function Constant:		
Site 9	11.62	1.53
Site 10	11.28	1.52
Site 11	11.45	1.51
Site 12	12.30	1.51
$X^{.5}$	-1.353	.235
X	.0456	.0093

Note: See equations (8) and (9) in text for the functional forms.

[a]Not estimated.

Table 2. Results for crop insurance paid at $1.65 per bushel for uncorrelated yields and prices ($\rho_s = 0$)

Coverage Level		Risk Neutrality				
Mean Yield	Yield	Fertilizer Rate	Reduction	Certainty Equivalence	Expected Claims	Probability of Claims
percent	(bu/ac)	(lb/ac)	percent	($/ac)	($/ac)	probability
0	0.0	202	0	269.78	0	0
70	95.55	199	1.49	272.05	21.14	.108
80	109.20	196	2.97	275.59	28.25	.208
90	122.85	190	5.94	281.62	35.87	.337
100	136.50	179	11.4	291.12	43.14	.521
			Risk Aversion Coefficient = .0046			
0	0.0	201	0	252.13	0	0
70	95.55	196	2.49	255.80	20.89	.111
80	109.20	191	4.98	260.85	28.76	.209
90	122.85	183	8.96	268.66	36.47	.343
100	136.50	168	16.4	280.07	43.76	.540
			Risk Aversion Coefficient = .0100			
0	0.0	198	0	233.97	0	0
70	95.55	191	3.54	239.68	21.10	.113
80	109.20	184	7.07	246.53	29.22	.214
90	122.85	174	12.1	256.24	37.22	.351
100	136.50	150	24.2	269.70	45.03	.580

Table 3. Results for crop insurance paid at $1.65 per bushel for correlated yields and prices (ρ_s = -.3)

Coverage Level		Risk Neutrality				
Mean Yield	Yield	Fertilizer Rate	Reduction	Certainty Equivalence	Expected Claims	Probability of Claims
percent	(bu/ac)	(lb/ac)	percent	($/ac)	($/ac)	probability
0	0.0	202	0	265.64	0	0
70	95.55	199	1.49	267.90	21.14	.108
80	109.20	196	2.97	271.44	28.25	.208
90	122.85	191	5.44	277.47	35.87	.337
100	136.50	180	10.9	286.97	43.14	.518
			Risk Aversion Coefficient = .0046			
0	0.0	201	0	253.14	0	0
70	95.55	197	1.99	256.47	20.97	.110
80	109.20	192	4.48	261.10	28.63	.208
90	122.85	186	7.46	268.34	36.21	.341
100	136.50	172	14.4	279.01	43.52	.535
			Risk Aversion Coefficient = .0100			
0	0.0	200	0	239.79	0	0
70	95.55	193	3.62	244.59	20.86	.113
80	109.20	188	6.00	250.52	29.04	.210
90	122.85	180	10.00	259.03	36.77	.345
100	136.50	161	19.50	270.93	44.09	.556

Table 4. Results for revenue insurance for uncorrelated yields and prices ($\rho_s = 0$)

Coverage Level		Risk Neutrality				
Mean Revenue	Revenue	Fertilizer Rate	Reduction	Certainty Equivalence	Expected Claims	Probability of Claims
percent	($/ac)	(lb/ac)	percent	($/ac)	($/ac)	probability
0	0.0	202	0	269.78	0	0
70	210.06	196	2.97	275.54	34.64	.169
80	240.06	191	5.45	282.21	45.28	.280
90	270.00	182	9.90	292.62	56.91	.416
100	300.08	167	17.3	307.41	70.59	.570
			Risk Aversion Coefficient = .0046			
0	0.0	201	0	252.13	0	0
70	210.06	191	4.98	261.55	34.61	.172
80	240.06	184	8.46	270.84	45.52	.286
90	270.07	172	14.4	284.16	57.22	.430
100	300.08	150	25.4	301.90	72.85	.596
			Risk Aversion Coefficient = .0100			
0	0.0	198	0	233.98	0	0
70	210.06	184	7.07	248.65	34.73	.177
80	240.06	173	14.1	260.89	45.56	.300
90	270.07	156	21.2	277.21	58.58	.452
100	300.08	122	38.4	297.92	77.77	.646

Table 5. Results for revenue in insurance for correlated yields and prices ($\rho_s = -.3$)

Coverage Level		Risk Neutrality				
Mean Revenue	Revenue	Fertilizer Rate	Reduction	Certainty Equivalence	Expected Claims	Probability of Claims
percent	($/ac)	(lb/ac)	percent	($/ac)	($/ac)	probability
0	0.0	202	0	265.64	0	0
70	207.16	198	1.98	268.79	27.67	.116
80	236.75	193	4.46	273.82	36.97	.226
90	266.35	183	9.41	282.91	45.75	.394
100	295.94	165	18.3	297.25	60.17	.574
			Risk Aversion Coefficient = .0046			
0	0.0	201	0	253.15	0	0
70	207.16	195	2.99	258.20	27.84	.116
80	236.75	188	6.47	265.16	36.54	.234
90	266.35	174	11.9	276.63	46.11	.408
100	295.94	150	25.4	293.52	61.97	.598
			Risk Aversion Coefficient = 0.0100			
0	0.0	200	0	239.79	0	0
70	207.16	190	5.00	247.73	27.69	.120
80	236.75	181	9.50	257.04	37.07	.239
90	266.35	161	19.5	271.15	47.01	.430
100	295.94	122	39.0	290.74	67.15	.658

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