Impacts of Changes in Federal Crop Insurance Programs on Land Use and Environmental Quality

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Abstract

This paper integrates economic and physical models to assess how federal crop revenue insurance programs might affect land use, cropping systems, and environmental quality in the U.S. Corn Belt region. The empirical framework includes econometric models that predict land conversion, crop choices, and crop rotations at the parcel level based on expectation and variance of crop revenues, land quality, climate conditions, and physical characteristics at each site. The predictions are then combined with site-specific environmental production functions to determine the effect of revenue insurance on nitrate runoff and leaching, soil water and wind erosion, and carbon sequestration. Results suggest that crop insurance will have small impacts on conversions of non-cropland to cropland, but more significant impacts on crop choice. These changes in crop mix have moderate impacts on agricultural pollution.

Key Words: Crop Insurance; Revenue Insurance; Crop Choice; Environmental Quality

JEL Codes: Q18, Q28,

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1. Introduction

The focus of federal agricultural policy has shifted from direct payments towards risk management, and federal crop insurance has become the central component of agricultural support in the U.S. (Woodard 2013). More than 265 million acres were enrolled in the crop insurance program in 2011, with $114 billion in estimated total liability. The corresponding costs to the federal government in 2011 were estimated at over $11 billion (Glauber 2013). The shift of agricultural policy focus continues with the Agricultural Act of 2014, which eliminates direct government payments and significantly expands crop insurance. The Act establishes the Supplemental Coverage Option (SCO), which provides additional protection to producers of covered commodities beyond traditional crop insurance policies. It expands the Noninsured Crop Assistance Program (NAP) to allow additional "buy-up" coverage above catastrophic loss levels. There has never been a farm bill with such a robust crop insurance program combined with price-sensitive commodity programs (Olen and Wu, 2014).

Crop insurance alters producers' incentives in two broad ways. First, premium subsidies based on the "fair" premium, by definition, add to expected revenue for crop production. As such, subsidized crop insurance may create incentives for farmers to expand crop production to marginal lands. Additionally, crop insurance reduces the riskiness of covered crops relative to other crops, thus potentially affecting farmers' choice of crop mix and input use (Wu, 1999; Goodwin et al. 2004; Babcock and Hennessy 1996; Young et al. 2001; Goodwin and Smith 2013; Walters et al. 2012).

Changes in land use and crop mix under crop insurance may lead to unforeseen secondary effects on environmental quality. Additional acreage devoted to crop production may mean increased use of fertilizers, pesticides, and other chemicals in vulnerable areas, thus potentially leading to additional runoff and surface and groundwater contamination. Changes in crop mix towards more erosive and chemical-intensive crops, such as from hay to soybeans, may also lead to increased runoff and leaching and water contamination (Goodwin and Smith 2003). On the other hand, if riskier crops have less damaging environmental effects, insurance-induced crop mix changes could improve environmental outcomes.

The extent to which changes in crop insurance policy may affect land use and crop mix, as well as the magnitude of the accompanying environmental impacts, is not clear (Walters et al. 2012). In this paper we use an integrated economic and biophysical modeling and simulation approach to examine the potential effects of expanded crop insurance on land use and cropping patterns, as well as the resulting impacts on environmental quality in the Corn Belt region of the U.S.

We start by developing a theoretical model that builds on the expected utility framework to understand how production risks affect farmers' planting decisions. By assuming farmers choose crops to maximize their expected utility, we show that the probability that a farmer will choose a crop depends on the expectation and variance of net returns from all crops, as well as the correlations of variances. Next, we conduct an empirical analysis to assess the effects of changes in crop insurance programs on farmers' planting decisions and land use patterns in the Corn Belt. Specifically, we estimate a logit model of the initial decisions to use land for crops or other uses and a multinomial logit model of crop choice, conditional on the initial decisions. These models link land use and crop choices on individual parcels to expected revenues, as well as variances of revenues to alternative crops and their correlations, production costs, land characteristics of the parcel, weather conditions at the parcel, and rotational constraints. We estimate these models using data from the National Resources Inventories (NRI), the most comprehensive data on private land use ever collected in the United States. We use the estimated land use and crop choice models to simulate the effect of changes in crop insurance on crop choices and land use patterns in the region. Finally, we link the land use models with physical models to estimate the effect of crop insurance on soil erosion, nitrate runoff and leaching, and soil carbon sequestration. Our results suggest that the most significant impacts of revenue insurance in the study region would be on crop choice and therefore on crop rotation patterns, whereas the effects on conversion from non-cropland to cropland would be small. Changes in crop rotation patterns, in turn, will have modest detrimental effects on environmental quality.

In the next section of the paper we review the relevant literature. Section 3 develops a conceptual framework. Section 4 introduces our econometric approach and section 5 describes the data used for estimation. Section 6 presents and discusses the results from the land use and crop choice models. Section 7 presents the simulation framework for the land use and crop choice impacts of crop insurance and discusses the results of the simulation. Section 8 discusses the environmental impacts. Finally, section 9 concludes.

2. Literature Review

Several previous studies have examined the land use and crop mix effects of crop insurance. For example, Wu (1999) uses simultaneous insurance program participation and crop share models to examine the effects of insurance on cropping patterns in the Central Nebraska Basin. Wu and Adams (2001) examine the relationship between production risk, cropping patterns, and alternative revenue insurance programs in the Corn Belt using logistic models for crop shares. Young et al. (2001) examine the nationwide market impacts of crop insurance by simulating changes in acreage, production, price, and net returns induced by crop insurance. Goodwin et al. (2004) use a structural model of acreage, insurance and conservation program participation, and input usage decisions to examine the effects of increased participation in crop insurance programs in the Corn Belt and Upper Great Plains. In general, these papers find statistically significant but modest impacts of crop insurance participation on crop acreage allocations. For instance, Young et al. (2001) report that subsidized crop insurance leads to an increase of only about 0.4% in total crop acreage. Similarly, Goodwin et al. (2004) find that even in their most extreme scenario (a 30% drop in insurance premiums), corn acreage increases by only 0.3 - 0.5%.

Some previous studies have considered the environmental effect of federal crop insurance programs. These studies tend to focus on land use and chemical application in agricultural production (Babcock and Hennessy 1996; Wu 1999; Young et al. 2001; Chambers and Quiggin 2002; Goodwin et al. 2004; Coble et al. 1997). Very few studies have measured the environmental consequences of crop insurance directly, with two noticeable exceptions. Goodwin and Smith (2003),develop econometric models to estimate the effect of crop insurance programs on soil erosion. They find no large measurable increases in erosion as a result of increased insurance participation. Walters et al. (2012) is the closest in spirit to this paper. They first use producer-level data from Iowa, North Dakota, Washington, and Colorado to estimate crop acreage share equations for major insured crops or crop groups. Then they use the APEX (Agricultural Policy – Environmental Extender) model to simulate effects of crop share changes on several measures of environmental degradation. They find modest effects of insurance on crop choice as well as small, positive and negative, environmental effects of changing cropping patterns. By modeling both crop choice and environmental impacts explicitly, Walters et al. (2012) provide a more complete picture of the environmental impacts of crop insurance. The study, however, does not explicitly explore separate effects of insurance on the amount of land converted to crops from other uses and, given the amount of cropland, the impact on crop choice. It also does not account for crop rotation patterns and the limitations imposed by these patterns on crop choice, or the distinct environmental effects of different crop rotations.

This paper contributes to this literature by integrating economic models of land use and crop choice with physical models of environmental quality indicators to examine the environmental impacts of revenue insurance. Specifically, we examine how risk affects both the land allocation between crop and non-crop uses and, conditional on land use, the crop choice decision. In contrast to most previous studies, which use county-level data, we conduct our analysis using fine-scale parcel-level land use and crop choice data. Our model also accounts for crop choice history, thus allowing us to explicitly simulate specific crop rotation choices. This is an important aspect of the crop choice decision and its environmental consequences have not been addressed in existing models. Simulated crop rotations are then combined with environmental production functions to assess the effect of risk-reducing insurance on nitrogen percolation and leaching, soil carbon loss, and soil erosion.

3. Empirical Models

Consider land use decisions on a farm. The farmer must decide how much land to be allocated to crop production and, if any land is allocated to crop production, which crop or crops to grow on his cropland. Let i index the alternative land uses, with i=0 indicating the non-crop use and i = 1,

..., N possible crop choices. Let $\pi_i(\varepsilon)$ be the per-acre net return to land use *i*, where ε is a random variable reflecting the random state of nature and stochastic market factors that affect crop yields and prices. The corresponding density function $f(\varepsilon)$ is defined over $\varepsilon \in [0,1]$. The unit of land is normalized such that total amount of land of the farm equals one. Let s_i be he share of land allocated to use *i*. The farmer's total net return equals

$$\pi = \sum_{i=0}^{N} s_i \pi_i\left(\varepsilon\right) \tag{1}$$

The farmer chooses land allocation $\{s_0, s_1, \ldots, s_n\}$ to maximize his expected utility:

$$\underset{\{s_0, s_1, \ldots, s_N\}}{Max} \quad Eu(\pi) = \int_0^1 \mathrm{u}\left(\pi\right) f(\varepsilon)\, d\varepsilon \text{, s.t. } \sum_{i=0}^{N} s_i = 1. \tag{2}$$

Assume the utility function has all the standard properties. The first-order necessary and sufficient conditions for the maximization problem can be derived using the Lagragian function below:

$$L = \int_0^1 \mathrm{u}\left(\pi\right) f(\varepsilon)\, d\varepsilon + \lambda\left(1 - \sum_{i=0}^{N} s_i\right), \tag{3}$$

where λ is the Lagrange multiplier for the land constraint. Differentiating (3) with respect to s_i and setting it equal zero gives the first-order necessary and sufficient conditions:

$$\frac{\partial L}{\partial s_i} = u'\left(\pi\right) E\pi_i + Cov\left(u'(\pi), \pi_i\right) - \lambda = 0,\ i = 0, 1, \ldots, N. \tag{4}$$

Using a first-order Taylor expansion to approximate the marginal utility function yields $u'(\pi) \approx u'(E\pi) + u''(E\pi)(\pi - E\pi)$. Substituting this expression into (4) gives

$$E\pi_i - r_A \sum_{k=0}^{N} s_k Cov(\pi_k, \pi_i) - \lambda' = 0,\ i = 0, 1, \ldots, N \tag{5}$$

where $r_A = -u''(E\pi)/u'(E\pi)$ is the Arrow-Pratt absolute measure of risk aversion, and $\lambda' = \lambda / u'(E\pi)$. The second term in (5) measures the farmer's risk premium for growing crop *i*. Equations (5) indicates that the expected profit minus the risk premium must be equalized for all crops in the optimal land allocation. These equations, together with constraint **Error! Reference source not found.**, define the optimal land allocation for the farm:

$$s_i^* = s_i\left(E\pi_0,...,E\pi_N;V(\pi_0),...,V(\pi_N);Cov(\pi_0,\pi_1),...,Cov(\pi_0,\pi_N),...,Cov(\pi_{N-1},\pi_N)\right) \quad (6)$$

for *i* = 0, 1, …, *N*. These equations indicate that amount of land allocated to a crop depends on the mean, variance, and covariance of net returns for all alternative crops, not just for the crop considered.

The land share equations (6) cannot be directly estimated using our parcel level data, which indicate which crop is grown on each randomly selected sample sites in the study region, and contain no farm level information (see the data section for details). To specify an empirically estimable equation, consider land use on a randomly selected site in the farm. The probability that site is used for land use *i*, P_i, must equal the share of land allocated to land use *i:*

$$P_i = s_i\left(E\pi_0,...,E\pi_N;V(\pi_0),...,V(\pi_N);Cov(\pi_0,\pi_1),...,Cov(\pi_0,\pi_N),...,Cov(\pi_{N-1},\pi_N)\right). \quad (7)$$

There are two approaches to specify equation (7) (Wu and Segerson, 1995). The first is to specify a flexible functional form, such as translog or normalized quadratic, for the profit function and then derive the implied functional form for the share equations. This is the approach taken by Moore and Negri (1992) as well as by others who have studied multi-product acreage or supply decisions (e.g., Weaver, 1983; Shumway, 1983), although these studies all assume farmers are profit-maximizers. Alternatively, one can assume a flexible functional form, such as the logistic form, for the land choice equations themselves as in Considine and Mount (1984); Chavas and Segerson (1986), and Wu et al. (2004):

$$P_i = \frac{e^{X_i'\beta_i}}{\sum_{k=0}^{N} e^{X_k'\beta_k}}, \;\; i = 0,1,...,N \tag{8}$$

where $\boldsymbol{X_i}$ is a vector of variables affecting the land use and crop choice decision, including those identified in (7): mean, variance, and covariance of net returns for all competing crops.

For estimation purposes, it is convenient to rewrite (8) as follows:

$$P_0 = P(noncrop) = \frac{e^{X_0'\beta_i}}{\sum_{k=0}^{N} e^{X_k'\beta_k}}, \tag{9}$$

$$P_i = P(i \mid crop) \cdot P(crop) = \frac{e^{X_i'\beta_i}}{\sum_{k=1}^{N} e^{X_k'\beta_k}} \cdot \frac{\sum_{k=1}^{N} e^{X_k'\beta_k}}{\sum_{k=0}^{N} e^{X_k'\beta_k}}, \;\; i = 1,...,N \tag{10}$$

This decomposition allows us to separately study the major land use decision (crop vs. noncrop) and the crop choice decision (which crop to grow, conditional on the parcel being allocated to crop production). The major land use decision can be estimated using a standard logit model and the crop choice decision can be estimated as a multinomial logit model.

The multinomial logit model has been widely used in economic analysis, including the study of the choice of transportation modes, occupations, asset portfolios, and the number of automobiles demanded. In agriculture, it has been used to model farmers' land allocation decisions (Lichtenberg 1989; Wu and Segerson 1995; Hardie and Parks 1997; Plantinga et al. 1999), the choice of irrigation technologies (Caswell and Zilberman 1985), the choice of alternative crop management practices (Wu and Babcock 1998), and crop choice (Langpap and Wu 2011).[1] This study differs from previous studies in several aspects. First, most previous studies do not consider risks on farmers' land use decisions. Second, previous studies have not recognized, at least explicitly, that variance and covariance of net returns to other crops can also affect land allocation to a particular crop. Thirds, as noted in the previous section, most previous studies on land use do not analyze the environmental impact of land use change.

4. Estimating Impacts of Crop Insurance

Once the models are estimated, they can be used to evaluate the effect of crop or revenue insurance programs on land use. Because crop or revenue insurance programs affect both the expected net returns and the variances and covariances of the net returns, they are expected to affect farmers' planting decisions and hence overall cropping patterns in a region.

The federal crop insurance program provides insurance products to protect producers against losses resulting from price and yield risks. Under the program, private-sector insurance companies sell insurance products, and USDA's Risk Management Agency (RMA) approves and supports products, develops and approves premium rates, administers premium and expense subsidies, and reinsures the companies (Economic Research Service, 2014).

The federal crop insurance program provides two types of policies:

Actual Production History (APH) policies insure producers against yield losses due to natural causes such as drought, excessive moisture, hail, wind, frost, insects, and disease. The

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[1] The major land use decisions and crop choices could alternatively be modeled as a nested logit. In the first stage a farmer decides whether or not to allocate a parcel to crop production, and in the second stage he chooses which crop to grow if he decides to allocate the parcel to crop production. The main advantage of such an approach in this case is that there is a clear nesting structure. The main disadvantages are the added complexity in conducting simulations and the computational cost given the relatively large size of our data set. Furthermore, the degenerate nature of the nesting structure in our case (the noncrop branch of the choice tree has no further options and no choice-specific attributes, e.g. no expected revenue for noncrop land) implies that this model is not well-suited for nested logit estimation.

producer selects the amount of average yield to insure; from 50-75 percent (in some areas to 85 percent) before 2015, but up to 91% (???) under the new Supplemental Coverage Option (SCO) established by the 2014 farm bill and available beginning with the 2015 crop. The producer also selects the percent of the predicted price to insure; between 55 and 100 percent of the crop price established annually by RMA. If the harvested plus any appraised production is less than the yield insured, the producer is paid an indemnity based on the difference. Indemnities are calculated by multiplying this difference by the insured percentage of the price selected when crop insurance was purchased and by the insured share. We consider three coverage levels:

1. The Catastrophic Plan (CAT): Insures eligible farms for 50 percent of yield at 55 percent of USDA-announced price and charges only a nominal processing fee.
2. CAT + "Buy Up": Provide coverage up to 85 percent of yield, with the value elected between 55 to 100 percent of a USDA price. Subsidize by the government. Need to find out the actual premium and cost for farmers
3. CAT + "Buy Up"+ SCO: Provide coverage up to 90 percent of yield, with the 95 to100 percent of a USDA price.

Under APH, a farmer selects a coverage level for both the yield and price:

$$Y^I = \begin{cases} \alpha\overline{Y} & \text{if } Y < \alpha\overline{Y} \\ Y & \text{if } Y \geq \alpha\overline{Y} \end{cases}, \quad p^I = \begin{cases} \beta\overline{p} & \text{if } Y < \alpha\overline{Y} \\ p & \text{if } Y \geq \alpha\overline{Y} \end{cases} \tag{11}$$

where $\overline{Y}$ is the insurable yield, which is defined as the historic (e.g. ten-year) average yield, and α is the coverage level (i.e. the percentage of insurable revenue guaranteed), $\overline{p}$ is the USDA-announced price, and β is the percent of the USDA price the farmer selects. The censored distributions affect both the mean and variance of the variables. Since the effects of censoring are best understood in the context of a normal distribution (Chavas and Holt 1990), we examine the effect of censoring on the expected value and variance of revenue by assuming that the yield and price are normally distributed. Under the normality assumption, the expected value and variance of Y^I are:

$$E(Y^I) = E(Y) + V(Y)^{1/2}[\phi(h) + h\Phi(h)], \tag{12}$$

$$V(Y^I) = V(Y)\{1 - \Phi(h) + h\phi(h) + h^2\Phi(h) - [\phi(h) - h\Phi(h)]^2\}, \tag{13}$$

Where $h = [\alpha\bar{Y} - E(Y)]/V(Y)^{1/2}$ $h = (\alpha\bar{R} - E(R))/V(R)^{1/2}$, and $\phi(\cdot)$ and $\Phi(\cdot)$ are the density and distribution functions of the standard normal, respectively.

The expected value and variance of p^I are

$$E(p^I) = E(p)[1 - \Phi(\bar{Y})] + \beta\bar{p}\Phi(\bar{Y}), \tag{14}$$

$$V(p^I) = E(p^{I2}) - E(p^I)^2 = E(p^2)[1 - \Phi(\bar{Y})] + (\beta\bar{p})^2\Phi(\bar{Y}) - E(p^I)^2. \tag{15}$$

With the above info, we can calculate ER and V(R) under CAT

$$E(R^{CAT}) = E(p^I)E(Y^I) + \gamma V(p^I)^{1/2}V(Y^I)^{1/2} + S - C \, , \tag{16}$$

$$V(R^{CAT}) = E(p^I)^2 V(Y^I) + V(p^I)E(Y^I)^2 + 2E(p^I)E(Y^I)\gamma V(p^I)^{1/2}V(Y^I)^{1/2}, \tag{17}$$

where γ is correlation between p^I and Y^I, *C* is the insurance premium per acre before the government subsidies, and *S* is the per-acre government subsidy for insurance premium. The insurance program also increases the expected revenue by providing premium subsidies.

Actual Revenue History (ARH) policies have many parallels to the APH plan of insurance, with the primary difference being that instead of insuring historical yields, the plan insures historical revenues. We also consider three coverage levels under ARH:

1. The Catastrophic Plan (CAT): Insures 50 percent of Revenue.
2. CAT + “Buy Up”: Insures 85 percent of Revenue.
3. CAT + “Buy Up”+ SCO: Insures 90 percent of Revenue.

ARH policies guarantee minimum per-acre revenue for a crop:

$$R^I = \begin{cases} \alpha\bar{R} & \text{if } R < \alpha\bar{R} \\ R & \text{if } R \geq \alpha\bar{R} \end{cases} \tag{18}$$

where $\bar{R}$ is the insurable revenue, which is defined as the historic (e.g. ten-year) average of revenue from growing the crop, and α is the coverage level (i.e. the percentage of insurable revenue guaranteed). Under the normality assumption, the expected value and variance of R^I are:

$$E(R^I) = E(R) + V(R)^{1/2}[\phi(h) + h\Phi(h)] + S - C \tag{19}$$

$$V(R^I) = V(R)\{1 - \Phi(h) + h\phi(h) + h^2\Phi(h) - [\phi(h) - h\Phi(h)]^2\} \tag{20}$$

where *E*(*R*) and *V*(*R*) are the expected revenue and the variance of revenue without insurance. Hence, by guaranteeing a minimum for revenue, the subsidized federal insurance program may increases expected revenue and decreases its variance.

5. Data and Variable Construction

The land use and crop choice models require a substantial amount of data for estimation, which must be integrated from multiple sources. These data include the land use choice at each NRI site, farmers' expected revenues, as well as variances and covariances of revenues for different crops, input prices, and site characteristics at each NRI point (soil properties, topographic features, climate conditions). In this section we describe the data sources and construction of the variables used to estimate the models. Summary statistics for key variables are presented in table A1 in the Appendix.

Our study area is the U.S. Corn Belt region (Ohio, Illinois, Indiana, Iowa, Missouri), which accounts for over one third (35%) of total liability in the U.S. crop insurance program (USDA Risk Management Agency 2013). Parcel-level data on land use choice for the region were obtained from the 1982, 1987, 1992, and 1997 Natural Resources Inventories (NRI). NRI inventories are conducted by the USDA Natural Resources Conservation Service (NRCS) to determine the status, condition, and trend of the nation's soil, water, and related resources. Information on nearly 200 attributes was collected at more than 800,000 randomly selected sites across the continental United States. Each NRI contains crop choice information for four years (the current year plus the previous three years). Thus, we have crop choice information for 16 years at each NRI site. Our study region includes 76,817 NRI sites, of which 63,660 (83%) are in cropland. Each NRI site was assigned a weight to indicate the acreage it represents.[2] The sampling design ensures that inferences at the national, regional, state, and sub-state levels can be made in a statistically reliable manner.

We use data from 1982 – 1997 because the NRCS changed the scope and design of the NRI and has not released the parcel-level NRI data after 1997. Using data from the period 1982 – 1987 allows us to establish a baseline for our analysis that is free of the effects of crop insurance, because during this period crop insurance participation was uncommon. In our study region, the crop insurance participation rate in 1997 was only ??%. However, the vintage of the data is also a potential limitation of this analysis. Several relevant changes in commodity markets have taken place in the intervening period, including more widespread adoption of crop insurance, a severe drought in 2007, and nominal commodity prices reaching historic highs. Hence, our model may not accurately predict land use and cropping changes for recent years if underlying conditions in those years represent significant deviations from the sample used for estimation. In the next

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[2] For example, the sum of weights at all NRI sites planted to corn gives an estimate of corn acreage in the region.

section, we discuss both in-sample and out-of-sample predictions of our model, as well as the implications for our analysis.

The key explanatory variables included to capture the effects of risk on land use and crop choice decisions are the expected revenue, the variance of revenue, and the correlations of revenues for the main crops in the region. Specifically, we include the expected revenue and variance of revenue for corn and wheat, and correlations of revenues for corn – soybeans and corn – wheat. Expected revenue and variance of revenue for soybeans, as well as correlation of revenues for soybean – wheat were omitted to avoid significant multicollinearity given the high correlation between revenues for corn and soybeans. We calculate these variables using the following expressions (Bain and Engelhardt ??????):

$$E(R) = E(p)E(y) + Cov(p, y) \tag{14}$$

$$V(R) \cong E(y)^2 V(p) + E(p)^2 V(y) + 2E(p)E(y)Cov(p, y) \tag{15}$$

$$Corr(R_i, R_j) = \rho\left[V(R_i) \times V(R_j)\right]^{\frac{1}{2}} \tag{16}$$

where $E(p)$, $E(y)$, $V(p)$, and $V(y)$ are expectations and variances of price and yield, respectively, and $Cov(p, y)$ is the covariance between price and yield.

The expected prices for corn and wheat were specified as the higher of the weighted target price and the average futures price during the planting season for each crop (Shumway 1983). The weighted target price is calculated by multiplying the target price by the portion of the base permitted for planting (i.e., 1-Acreage Reduction Program (ARP) rate).[3] The average futures prices for corn and wheat during their planting seasons were estimated as the averages of the first and second Thursday closing prices in March at the Chicago Board of Trade (CBT) for

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[3] The ARP rates and target prices for corn and wheat were taken from Green (1990) and other U.S. Department of Agriculture publications.

corn and wheat. Soybean is a non-program crop, so the corresponding expected prices were specified as the average futures prices in its planting season. These were estimated as the average of the first and second Thursday closing prices in March on the CBT for November soybeans. To include an expected price for hay, which is a multi-year, non-program crop, we use market prices lagged one year. State-level, annual average market prices for hay were obtained from Agricultural Statistics (U.S Department of Agriculture).

Following Chavas and Holt (1990), the perceived variances of corn and soybean prices are estimated as

$$V(p_{it}) = \sum_{j=1}^{3} \omega_j \left[p_{i,t-j} - E_{t-j-1}(p_{i,t-j}) \right]^2 \tag{17}$$

where the weights ω_j are 0.5, 0.33, and 0.17, and E_{t-j-1} is the expectation, at planting time in period *t - j*, of the price for crop *i* at harvest in period *t - j*.[4]

Crop yield data are unavailable at individual NRI sites. We use National Agricultural Statistics Service (NASS)'s county-level, time-series crop data to estimate farmers' expected yields and yield variance in each county. Specifically, following Chavas and Holt (1990), we estimate a trend model of $y = \alpha + \beta t + \varepsilon$ in each county and use the resulting predictions as expected yields. The estimated residuals were then used to generate the variances of yields, which are assumed to be constant over time. Finally, the non-truncated correlation between price and yield was estimated to be – 0.293 for corn, – 0.149 for soybeans, and 0.029 for wheat.

We also include the ARP rates for corn and wheat. Additionally, we control for input costs by including fuel prices paid by farmers and wage rates. All prices are normalized by the

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[4] Sensitivity analysis indicates that the results of this analysis are insensitive to the choice of the weights.

current year index of prices paid by farmers for production, interest, taxes, and wage rates (U.S. Department of Agriculture 1999).

To further account for yield differences among NRI sites, we include several physical variables reflecting land quality at individual sites. Slope is a continuous variable measured as a percentage. High quality land is a dummy variable set equal to one if the parcel has a land capability class of 1 or 2, and set equal to zero otherwise. Similarly, low-quality land is a dummy variable set equal to one if a site has a land capability class above 4, and set to zero otherwise. Additionally, each NRI sample site is linked to the NRCS's SOILS5 database, providing detailed soil profile information from soil surveys. We use these data to calculate average measures of soil properties for top soil layers. These include average organic matter percentage, water content, clay percentage, soil pH, and permeability.

We also control for the effect of weather on land use and crop choices. We use historical weather data from weather stations across the study region, which were obtained from the Midwestern Climate Center. For each NRI site, we used data from the nearest weather station to estimate the average of the mean maximum daily temperature as well as means and standard deviations for precipitation during the corn and wheat growing seasons.[5]

To capture rotational constraints we include dummy variables indicating the crop grown on the site in the previous year. These rotation dummies are also interacted with state fixed effects to capture unobserved state-level heterogeneity in cropping patterns. Finally, to account for differences across the landscape that are not reflected by other covariates (e.g., cultural practices) we include dummy variables for Major Land Resource Areas (MLRA). Each MLRA is

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[5] Because the long-run average of weather conditions changes little over time, farmers' expectations of weather conditions were assumed to be constant and were represented by the averages of the means and variances of temperatures and precipitation during the corn and wheat growing seasons from 1975 to 1992.

characterized by a particular pattern of soil, climate, water resources, land use, and type of farming.

6. Results on Land use and crop choice models

We start by estimating a logit model of land use choice (cropland vs. non-cropland). The dependent variable is set equal to one if the parcel is used for crops, and to zero otherwise. NRI sites used for cropland, rangeland, and pastureland are used in the estimation. The elasticities of the probability of a parcel being allocated to crop production are shown in table 1. Estimated coefficients are presented in table A2 in the Appendix.

The main variables of interest in these models are the expectations and variances of revenues for corn and wheat. The elasticities in table 1 suggest that a 1% increase in the expected revenue for corn leads, on average, to a 0.49% increase in the probability that a parcel is allocated to cropland. A 1% increase in the expected revenue for wheat causes a 0.06% increase in the probability that a parcel is allocated to crops. On the other hand, if the variance of revenue for corn goes up by 1%, the probability that a parcel is used for cropland decreases by 0.02%. Similarly, if the variance of revenue for wheat goes up by 1%, the probability of choosing cropland goes down by 0.05%.

An increase of 1% in the expected price of hay has a small (0.007%) but negative impact on the probability that a parcel is used for crop production. The ARP rate for corn has an unexpected positive impact on the probability of choosing cropland, whereas the ARP rate for wheat has a negative impact. Additionally, parcels with high land quality are more likely to be allocated to crop production, while parcels with low land quality and steeper slope are more likely to be allocated to non-crop activities. These results are consistent with agronomic information.

Next, we estimate a multinomial logit of crop choice. Table 2 presents the elasticities of the probabilities of choosing alternative crops, estimated using the model coefficients and the sample means of the variables. Estimated coefficients are shown in table A3 in the Appendix. The results of particular interest are the elasticities with respect to expected revenues and variance of revenues. The estimates in table 2 show that own-revenue elasticities are positive and cross-revenue elasticities are negative. This indicates that an increase in the expected revenue for corn and wheat will increase the likelihood that these crops are planted, and decrease the likelihood that other crops are chosen. However, these elasticities are relatively small, which suggests that crop choice in the study region is relatively unresponsive to changes in expected revenue. This result is consistent with studies that have found small price elasticities (Wu et al. 2004), and may be explained by agronomic (rotational) constraints and the relatively few crops grown in the study region. The own–elasticities for variance of revenue are negative, suggesting that more variability in revenues for corn and wheat reduce the likelihood that these crops are planted.

The elasticities with respect to the climate variables have different impacts for corn and wheat. An increase in the average maximum daily temperature during the corn growing season reduces the likelihood that corn is planted. An increase in the average precipitation during the corn growing season increases the likelihood that corn is planted, but more precipitation during the wheat growing season reduces the probability of planting wheat. Similarly, whereas more variability in precipitation during the corn season decreases the likelihood that corn is chosen, more variability during the wheat season increases the probability that wheat is planted.

The estimates also suggest that the best quality land is used to plant corn, and that steep land is less likely to be planted to soybeans because it is an erosion-prone crop. Finally, coarse-textured soils are more likely to be planted in corn and less likely to be planted in soybeans, whereas the opposite pattern holds for fine-textured soils.

To assess how well our model predicts land use and crop choices, we apply the estimated coefficients to data from 1997 and from 2009 - 2012 and compare the predictions with actual land use data from the National Agricultural Statistics Service (NASS). Table 3 reports the predicted and actual land use and crop mixes for 1997 and for the average for 2009 – 2012.[6] Within sample (1997) the model under-predicts total cropland acreage, as well as corn and soybean acreage, and over-predicts acreage planted in other crops, but the differences are relatively small. Out-of-sample (2009-2012) the model over-predicts total cropland acreage, corn acreage, and acreage in other crops, and under-predicts acres planted in soybeans. The differences remain small for total crop acreage and corn. However, differences between actual and predicted acreage are larger than within sample for soybeans and, in particular, for other crops. Given that soybeans are the crop with the largest environmental impact, this implies that our model may be somewhat underestimating the impact of land use and crop changes induced by crop insurance.

7. The Effect of Crop Insurance on Land Use

In this section we use the estimated land use and crop choice models to evaluate the impact of crop revenue insurance on land use and crop choice. We start by establishing a baseline for the evaluation. This baseline includes three years because environmental impacts of land use depend

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[6] Our estimates are scaled to reflect differences between total crop acreage from our estimation sample (some parcels were dropped due to missing data) and total crop acreage reported by NASS in 1997.

on crop rotations rather than simply on crop choice. For example, a continuous corn rotation uses between 175% and 250% more nitrogen fertilizer than corn following soybeans. Similarly, the corn-corn-soybean rotation and the corn-soybean rotation may have different environmental impacts.

We establish land use and crop rotations at each NRI point in the baseline using the following procedure. First, we use the data and the estimated coefficients for the land use choice model to predict the probability that each NRI parcel will be used for crops. Then we use these predicted probabilities and a random number generator to determine land use (crop vs. non-crop) at each parcel. Next, for the parcels designated as cropland, we use the data and the estimated coefficients from the crop choice model to calculate the probabilities of choosing alternative crops in the first baseline year. Based on these predicted probabilities, we again use a random number generator to determine crop choice at each NRI site in the first baseline year. Once the crop choice in the first year is determined, we repeat the process for a second and then a third year.[7] Finally, based on the crop choices in the three baseline years, we determine the baseline crop rotation at each NRI site. For example, if a choice of corn is predicted in each of the three years at a site, we have continuous corn at that site.

The baseline provides a benchmark for evaluating the environmental impacts of a crop insurance plan based on historical revenues, known as an Actual Revenue History (ARH) plan. With this type of plan, the producer selects the amount of average revenue to insure, from 50 to 90 percent. If revenues are less than the insured amount, the producer is paid an indemnity based on the difference. We consider three alternative scenarios, based on the fraction of revenue covered: the Catastrophic Plan (CAT), which insures 50% of revenue, the CAT + Buy Up Plan,

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[7] To adjust for declining yields in continuous corn rotations, we decrease the expected corn yield by 8.4% when the crop planted the previous year was corn.

which insures 75% of revenue, and the CAT + Buy Up + Shallow Loss Coverage Plan, which insures 90% of revenue. These insurance plans impact expected revenues, variance of revenues, and variance correlation. Specifically, we set the coverage level α equal to 0.5, 0.75, and 0.9, respectively, for each of the three scenarios. Then we calculate the modified expected revenue $E(R^I)$ and variance $V(R^I)$ under a given insurance plan using expressions **Error! Reference source not found.** and **Error! Reference source not found.**, as well as the variance correlation by substituting $V(R^I)$ for $V(R)$ in expression **Error! Reference source not found.**.[8]

The land use choices and crop rotations under each of the scenarios are simulated in the same way as in the baseline. Specifically, we first predict land use at each site using the modified expected revenues and variance of revenues, and the original data for the remaining variables. In predicted crop parcels, we then simulate crop choices using the modified expected revenues, variance of revenues, and variance correlations, and the original data for the remaining variables. Next we determine crop rotation at each NRI site under each scenario. Finally, we compare the results under each scenario with the baseline to determine the impacts of increasing levels of crop revenue insurance coverage.

As the level of insurance coverage goes up, expected revenue increases for all crops but the changes are small: 1.18%, 0.35%, and 0.40% for corn, soybeans, and wheat, respectively, at the highest level of coverage ($\alpha = 90\%$). The variance of revenues, on the other hand, decreases as coverage goes up. The changes are relatively small for the minimum level of coverage considered ($\alpha = 50\%$): − 1.12%, − 0.54%, and – 0.56% for corn, soybeans, and wheat,

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[8] By allowing insurance to change expected revenues, we are implicitly assuming the insurance is not actuarially fair. We also simulated actuarially fair insurance by not allowing expected revenues to change. The resulting changes in land use and environmental impact relative to the baseline are a bit smaller but qualitatively and quantitatively very similar to those presented here. They are available upon request.

respectively. However, for the highest level of coverage (α = 90%) the variances decrease by relatively larger amounts: − 27.21%, − 12.52%, and – 7.39% for corn, soybeans, and wheat, respectively. This suggests that revenue insurance can significantly decrease the risk attached to growing these crops.

The simulation results are presented in table 4. Results show land use (acreage in crop and non-crop), the three-year average of acres of the various crops, and total acreage of land in various crop rotations. The results indicate that revenue insurance would have small impacts on land use. Cropland acreage increases by only 0.16%, 0.82%, and 1.97% at coverage levels of α = 50%, 75%, and 90% respectively. This result is consistent with existing literature on the effects of crop insurance, which has found similarly small impacts on crop acreage (e.g. Young et al. 2001; Goodwin et al. 2004). The results suggest that the meaningful impact of crop insurance might be on crop choice and thus on crop rotations. The acreage of cropland devoted to corn and soybeans increases, whereas less land is planted with wheat or hay. For all three levels of coverage considered, the biggest increase is in corn acreage (16.26% to 18.38%), whereas the largest drop is in acres planted with wheat (-23.73% to - 41.41%). Accordingly, there are relatively large increases in acres planted in continuous corn (17.51% to 22.26%) and continuous soybean (2.26% to 6.43%) rotations, and fewer acres devoted to continuous wheat (-15.92% to - 41.80%).

8. Impacts of Crop Insurance on Environmental Quality

The changes in land use will in turn affect environmental quality. In this section we use environmental production functions to predict changes in agricultural externalities resulting from land use changes induced by crop revenue insurance. The environmental production functions are estimated using a metamodeling approach (Wu and Babcock 1999).[9] For a sample of NRI points, the Erosion Productivity Impact Calculator (EPIC) (Sharpley and Williams 1990) is used to simulate environmental impacts based on crop management practices (crop rotation, tillage, and conservation practices), soil characteristics, and climatic factors at that site. Environmental production functions are then estimated by regressing simulated environmental data (e.g., measures of nitrate runoff and leaching) on the vector of crop management practices and site characteristics using appropriate econometric methods.[10] The estimated environmental production functions are then used to predict environmental impacts at the full set of NRI points. These functions use the same information as the simulation model, but they eliminate the need to conduct model simulations for all input combinations, since they predict the outcome of such simulations (Wu et al. 2004). The nitrate runoff and percolation production functions are taken from Wu and Babcock (1999). The methodologies used to develop the erosion and carbon sequestration production functions, similar to those used in this analysis, are described in Lakshminarayan et al. (1996) and Mitchell at al. (1998), respectively.

The land use, crop choice, and environmental quality models described thus far collectively form an assessment framework. We apply this framework to evaluate how crop insurance might affect agricultural nonpoint source pollution in the Corn Belt. Baseline levels of fertilizer and pesticide use are calculated using average application rates for each crop rotation and state (U.S. Department of Agriculture 1998). Then we substitute the predicted crop rotations and the corresponding level of nitrogen application at each NRI site into the environmental

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[9] Metamodeling is required because it is not feasible to simulate environmental impacts at all sites and for all sets of conditions that arise in a large regional analysis such as performed here. Furthermore, metamodels simplify the analysis of changes in crop management practices because instead of conducting new simulations, regression coefficients can reveal how changes affect predicted outcomes.

[10] For example, Wu and Babcock (1999) use a generalized Tobit model to estimate the nitrate-N runoff and percolation production functions to account for heteroskedasticity and censoring problems.

production functions. This allows us to predict baseline levels of nitrate runoff, nitrate percolation, soil water erosion, soil wind erosion, and carbon sequestration at each NRI site. The site-specific measures of environmental impacts are aggregated to the regional level using the expansion factor to facilitate presentation of the results.

The baseline provides a benchmark for evaluating the environmental impacts of a crop insurance plan. Next we substitute the predicted land use under each insurance scenario into the environmental production functions to estimate its environmental impacts. Finally, we compare the results under each scenario with the baseline to determine the impacts of increasing levels of crop revenue insurance coverage.

The simulated environmental impacts are presented in table 5. The results suggest that changes in cropping patterns under crop insurance would have some detrimental impacts on environmental quality in the region, although the effects are relatively modest. The model predicts that nitrogen runoff will increase by roughly 6.4%, whereas nitrogen leaching will go up by 3.71% to 5.11%, depending on the level of coverage. The loss in soil carbon is modest: less than 1% at $\alpha = 50\%$ coverage, and only 3.55% at the highest coverage level. The largest predicted impacts are on wind erosion, which would increase by roughly 16% - 25%. Finally, the effect on water erosion is small as well, with less than a 1.5% increase even at the highest coverage level. These results suggest that changes in land use and cropping patterns driven by increasing levels of revenue insurance coverage will lead to small or moderate increases in nitrate water pollution, water soil erosion, and soil organic carbon losses, and somewhat larger increases in wind soil erosion.

9. Conclusions

This study develops an empirical modeling framework to assess the effects of proposed changes in federal crop insurance on land use and agricultural non-point source pollution. We use econometric models to predict land use, crop choices, and crop rotations at the parcel level based on expectations and variances of agricultural revenues, as well as land quality, weather conditions, and other physical characteristics at each parcel. We then combine the data on crop rotations, nitrogen application rate, land quality and other physical characteristics with site-specific environmental production functions to determine the effect of crop revenue insurance on nitrate runoff and leaching, soil water and wind erosion, and carbon sequestration at each NRI site.

Our simulation suggests that a crop insurance plan based on historical revenues will not results in significant conversions of non-cropland to cropland in the U.S. Corn Belt region. This result is consistent with the existing literature. However, our results indicate that the more meaningful impact of revenue insurance will be on crop choice and therefore on crop rotation patterns. Total acreage of corn is predicted to increase by roughly 16% - 18%, whereas the amount of acres planted with wheat will decrease by about 24% - 40%. Accordingly, the acreage planted with most crop rotations involving corn increases considerably, by as much as 22% for continuous corn and 61% for corn-corn-soybeans. On the other hand, acres of continuous wheat decline by as much as 42%. These changes in land use and cropping systems will have small to moderate effects on agricultural runoff and environmental quality. The predicted effects on soil carbon loss and water soil erosion are small, even at the maximum coverage level. Impacts on nitrogen runoff and leaching are somewhat larger, but still relatively modest. The only relatively significant impacts are on soil wind erosion, which could increase by roughly 16% to almost 25%. In sum, we find that proposed changes in crop insurance are likely to have small effects on land use, and modest impacts on crop rotation systems and therefore on environmental quality in the U.S. Corn Belt region.

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Table 1. Major Land Use Choice Model - Elasticities of the Probability of Allocating a Parcel to Cropland

Variable	
Expected revenue for corn	0.494***
	(0.003)
Variance of revenue for corn	-0.024***
	(0.001)
Expected revenue for wheat	0.056***
	(0.002)
Variance of revenue for wheat	-0.054***
	(0.001)
ARP rate for corn	0.059***
	(0.001)
ARP rate for wheat	-0.005***
	(0.001)
Price of hay in previous year	-0.007***
	(0.002)
Good land	0.022***

	(0.001)
Bad land	-0.005^{***}
	(0.0001)
Slope	-0.073^{***}
	(0.0004)
Mean precipitation corn season	-0.189^{***}
	(0.007)
Std. Deviation precipitation corn season	0.084^{***}
	(0.008)
Mean maximum temperature corn season	-0.540^{***}
	(0.015)
Mean precipitation wheat season	0.010^{***}
	(0.001)
Std. Deviation precipitation wheat season	-0.059^{***}
	(0.003)
Observations	964,387

Note: Std. errors in parentheses.
*, **, *** denote statistical significance at α = 10%, 5%, and 1%.
All elasticities are evaluated at the sample means of variables.

Table 2. Crop Choice Model - Elasticities of Probabilities of Choosing Alternative Crops

Variable	Corn	Soybeans	Wheat	Hay	Other
Revenue, Price, and Policy Variables					
Expected revenue for corn	0.430***	-0.312***	-1.071***	-1.071***	-1.071***
	(0.015)	(0.022)	(0.036)	(0.036)	(0.036)
Variance of revenue for corn	-0.072***	0.150***	-0.149***	-0.149***	-0.149***
	(0.009)	(0.012)	(0.027)	(0.027)	(0.027)
Expected revenue for wheat	-0.009***	-0.009***	0.226***	-0.009***	-0.009***
	(0.001)	(0.001)	(0.027)	(0.001)	(0.001)
Variance of revenue for wheat	0.035***	0.035***	-0.831***	0.035***	0.035***
	(0.002)	(0.002)	(0.039)	(0.002)	(0.002)
Variance correlation corn-soybeans	0.061***	-0.076***	-0.288***	-0.142***	0.234***
	(0.011)	(0.015)	(0.043)	(0.045)	(0.041)
Variance correlation corn-wheat	0.047***	-0.109***	0.647***	0.422***	-0.484***
	(0.009)	(0.012)	(0.068)	(0.030)	(0.028)
Expected price for hay	0.0003	0.0003	0.0003	-0.014	0.0003
	(0.001)	(0.001)	(0.001)	(0.043)	(0.001)
ARP rate for corn	0.067***	-0.106***	0.026***	0.026***	0.026***
	(0.003)	(0.004)	(0.008)	(0.008)	(0.008)
ARP rate for wheat	0.009***	0.009***	-0.207***	0.009***	0.009***
	(0.0004)	(0.0004)	(0.008)	(0.0004)	(0.0004)
Fuel price	0.008	-0.424***	1.479***	0.095	1.999***
	(0.027)	(0.038)	(0.092)	(0.126)	(0.106)
Wage rate	0.065*	0.258***	-3.706***	0.571***	0.149
	(0.037)	(0.053)	(0.137)	(0.173)	(0.143)
Land Characteristics					
Good land	0.034***	-0.037***	0.016*	-0.042***	-0.094***
	(0.002)	(0.003)	(0.008)	(0.011)	(0.009)
Bad land	-0.001***	0.002***	-0.001	-0.0003	0.003***
	(0.0003)	(0.0004)	(0.001)	(0.0009)	(0.001)
Slope	0.059***	-0.142***	0.180***	0.233***	0.162***
	(0.002)	(0.003)	(0.007)	(0.007)	(0.006)
Available water capacity	-0.001	0.119***	-0.258***	-0.471***	-0.480***
	(0.016)	(0.023)	(0.055)	(0.070)	(0.057)
Organic matter	0.015***	-0.019***	-0.101***	0.013*	0.059***
	(0.001)	(0.002)	(0.011)	(0.008)	(0.005)
Soil pH	0.308***	-0.166***	-0.910***	-0.935***	-1.019***
	(0.025)	(0.035)	(0.090)	(0.122)	(0.091)
Coarse-textured soil	0.002***	-0.003***	0.0002	-0.002	0.003***
	(0.0003)	(0.0004)	(0.001)	(0.001)	(0.001)
Fine-textured soil	-0.007***	0.012***	0.006***	-0.017***	-0.010***
	(0.0004)	(0.0006)	(0.001)	(0.002)	(0.002)
Weather Conditions during Corn or Wheat Growing Season					
Mean maximum temperature corn season	-2.355***	3.001***	1.518***	1.518***	1.518***
	(0.065)	(0.094)	(0.161)	(0.161)	(0.161)
Mean precipitation corn season	0.184***	-0.127***	-0.482***	-0.482***	-0.482***
	(0.028)	(0.040)	(0.072)	(0.072)	(0.072)

Table 2 – Continued

St. deviation of precipitation corn season	-0.492***	0.499***	0.746***	0.746***	0.746***
	(0.028)	(0.039)	(0.074)	(0.074)	(0.074)
Mean of precipitation wheat season	0.006***	0.006***	-0.194***	0.091***	0.006***
	(0.001)	(0.001)	(0.023)	(0.022)	(0.001)
St. deviation of precipitation wheat season	-0.013***	-0.013***	0.432***	-0.211***	-0.013***
	(0.003)	(0.003)	(0.051)	(0.074)	(0.003)
Observations	630,417				

Note: Std. errors in parentheses.
*, **, *** denote statistical significance at $\alpha = 10\%$, 5%, and 1%.
All elasticities are evaluated at the sample means of variables.

Table 3. Predicted vs. Actual Acres of Land Uses (1000 acres)

	Actual 1997 (NASS)	Predicted	Mean Actual 2009-2012 (NASS)	Predicted
Acres of cropland	85,626	83,308	83,837	87,118
Acres of Corn	35,950	32,291	39,113	40,676
Acres of Soybeans	35,350	32,490	33,950	28,123
Acres of Other Crops	14,326	18,527	10,774	18,319

Table 4. Estimated Impacts of Crop Insurance on Land Use and Cropping Systems

	Baseline	% Change from the baseline under different coverage levels		
	(1000 acres)	α = 50%	α = 75%	α = 90%
Land Use				
Acres of cropland	66,116	0.16%	0.82%	1.97%
Acres of non-cropland	15,728	-0.67%	-3.43%	-8.27%
Acres of Corn	26,755	16.26%	17.19%	18.38%
Acres of Soybeans	24,056	8.15%	7.45%	5.83%
Acres of Other Crops	15,305	-62.18%	-60.31%	-59.75%
Cropping Systems				
Continuous corn	15,832	17.51%	19.30%	22.26%
Continuous soybeans	11,639	6.43%	5.51%	2.26%
Continuous wheat	971	-41.80%	-37.64%	-15.92%
Corn-Soybeans	20,885	12.18%	11.40%	9.53%
Corn-Corn-Soybeans	827	53.63%	58.32%	61.11%
Corn-Soybeans-Wheat	130	32.46%	29.93%	36.91%
Soybeans-Soybeans-Corn	243	3.95%	4.98%	6.30%
Wheat-Soybeans	940	-15.51%	-13.10%	5.82%
Corn-Corn-Hay	5,657	-11.30%	-8.59%	-3.59%

Table 5. Estimated Impacts of Crop Insurance on Environmental Quality

Indicator	Baseline	% Change from the baseline under different coverage levels		
		α = 50%	α = 75%	α = 90%
Nitrogen Runoff (1000s lbs.)	729,471	6.37%	6.38%	6.44%
Nitrogen Percolation (1000s lbs)	486,762	3.71%	4.11%	5.11%
Loss of Soil Organic Carbon	8,830	0.99%	1.79%	3.55%
Wind Erosion (1000s tons)	149,884	24.50%	22.38%	16.25%
Water Erosion (1000s tons)	375,296	0.41%	0.87%	6.44%

Appendix

Table A1. Summary Statistics for Main Variables

Variable	Mean	Std. Dev.
Revenue, Price, and Policy Variables		
Expected revenue for corn ($/acre)	292.57	66.95
Variance of revenue for corn	4,251.27	1,954.16
Expected revenue for wheat ($/acre)	158.68	47.25
Variance of revenue for wheat	1,194.76	645.71
Variance correlation corn-soybeans	2,445.61	773.70
Variance correlation corn-wheat	1,049.99	442.48
Expected price for hay ($/ton)	67.72	14.28
ARP rate for corn	7.41	6.53
ARP rate for wheat	9.48	9.84
Fuel price ($/gal)	4.32	0.46
Wage rate	4.92	0.88
Land Characteristics		
Good land	0.65	0.48
Bad land	0.02	0.15
Slope	3.03	3.47
Available water capacity	0.21	0.03
Organic matter	3.30	3.87
Soil pH	6.34	0.44
Coarse-textured soil	0.02	0.15
Fine-textured soil	0.04	0.20
Mean maximum temperature corn season	80.22	2.45
Mean precipitation corn season	0.13	0.02
St. deviation of precipitation corn season	0.32	0.04
Mean of precipitation wheat season	0.10	0.05
St. deviation of precipitation wheat season	0.27	0.06

Table A2. Major Land Use Choice Model – Coefficient Estimates

Variable	
Expected revenue for corn	2.177***
	(0.012)
Variance of revenue for corn	-1.164***
	(0.053)
Expected revenue for wheat	0.440***
	(0.016)
Variance of revenue for wheat	-8.982***
	(0.181)
ARP rate for corn	0.062***
	(0.001)
ARP rate for wheat	-0.004***
	(0.001)
Price of hay in previous year	-0.127***
	(0.042)
Good land	0.287***
	(0.007)
Bad land	-0.685***
	(0.012)
Slope	-0.143***
	(0.001)
Mean precipitation corn season	-11.049***
	(0.431)
Std. Deviation precipitation corn season	2.003***
	(0.181)
Mean maximum temperature corn season	-0.051***
	(0.001)
Mean precipitation wheat season	0.723***
	(0.095)
Std. Deviation precipitation wheat season	-1.649***
	(0.096)
Observations	964,387
Ln Likelihood	-355,252.88
Pseudo R^2	0.23

Note: Std. errors in parentheses.

*, **, *** denote statistical significance at α = 10%, 5%, and 1%.

Table A3. Crop Choice Model – Estimated Coefficients

Variable	Corn	Soybeans	Wheat	Hay
Revenue, Price, and Policy Variables				
Expected revenue for corn	0.849***	0.430***	-	-
	(0.025)	(0.025)	-	-
Variance of revenue for corn	0.489**	1.900***	-	-
	(0.197)	(0.204)	-	-
Expected revenue for wheat	-	-	0.244***	-
	-	-	(0.029)	-
Variance of revenue for wheat	-	-	-18.867***	-
	-	-	(0.895)	-
Variance correlation corn-soybeans	-1.883***	-3.368***	-5.666***	-4.080***
	(0.487)	(0.410)	(0.621)	(0.516)
Variance correlation corn-wheat	13.417***	9.494***	28.591***	22.899***
	(0.792)	(0.811)	(1.655)	(0.812)
Expected price for hay	-	-	-	-0.034
	-	-	-	(0.108)
ARP rate for corn	0.006***	-0.018***	-	-
	(0.001)	(0.001)	-	-
ARP rate for wheat	-	-	-0.023***	-
	-	-	(0.001)	-
Fuel price	-0.461***	-0.561***	-0.121***	-0.441***
	(0.027)	(0.027)	(0.031)	(0.034)
Wage rate	-2.824	3.719	-130.650***	14.320**
	(5.296)	(5.380)	(6.625)	(6.876)
Land Characteristics				
Good land	0.197***	0.089***	0.170***	0.080***
	(0.016)	(0.016)	(0.019)	(0.022)
Bad land	-0.187***	-0.055	-0.166***	-0.141***
	(0.037)	(0.039)	(0.049)	(0.045)
Slope	-0.034***	-0.100***	0.006**	0.024***
	(0.002)	(0.002)	(0.003)	(0.003)
Available water capacity	2.292***	2.868***	1.063***	0.046
	(0.300)	(0.301)	(0.363)	(0.409)
Organic matter	-0.013***	-0.024***	-0.049***	-0.014***
	(0.002)	(0.002)	(0.004)	(0.003)
Soil pH	0.209***	0.135***	0.017	0.013
	(0.016)	(0.016)	(0.020)	(0.023)
Coarse-textured soil	-0.085*	-0.280***	-0.151**	-0.260***
	(0.050)	(0.050)	(0.062)	(0.076)
Fine-textured soil	0.067	0.550***	0.394***	-0.171**
	(0.044)	(0.043)	(0.050)	(0.070)
Mean maximum temperature corn season	-0.048***	0.019***	-	-
	(0.002)	(0.002)	-	-
Mean precipitation corn season	5.168***	2.755***	-	-
	(0.659)	(0.699)	-	-

Table A3 – Continued

St. deviation of precipitation corn season	-3.908***	-0.782***	-	-
	(0.275)	(0.290)	-	-
Mean of precipitation wheat season	-	-	-1.992***	0.848***
	-	-	(0.239)	(0.231)
St. deviation of precipitation wheat season	-	-	1.653***	-0.735***
	-	-	(0.198)	(0.281)
Previous year crop dummies	Yes	Yes	Yes	Yes
Previous year crop × State Fixed Effects	Yes	Yes	Yes	Yes
MLRA region dummies	Yes	Yes	Yes	Yes
Observations	630,417			
Log Likelihood	-567,745			
Wald χ^2 – statistic	319,212.7			
Prob > χ^2	0.000			

Note: Std. errors in parentheses.
*, **, *** denote statistical significance at α = 10%, 5%, and 1%.