Crop Insurance, Government Agricultural Policies, and Soil Erosion*

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Abstract

This paper investigates the relationship between government agricultural programs and soil erosion. Using county-level data from the years 1992 and 1997, we estimate a model of water-induced (i.e., sheet and rill) soil erosion and crop insurance participation for counties where corn, soybean, and winter wheat account for at least 90% of total planted acreage. This includes most of the areas that have exhibited the highest historical levels of sheet and rill erosion. We find that crop insurance participation and conservation payments are significantly associated with county average soil erosion levels. In particular, corn insurance participation exhibits a positive impact on soil erosion, while wheat insurance participation exhibits a negative impact. After controlling for differences in soil erodibility, counties that receive higher conservation payments exhibit lower levels of soil erosion. We also find that government price and income support program payments (e.g., target price-based/loan deficiency payments and AMTA payments) exhibit no statistically significant association with our soil erosion measure.

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1 Introduction

Concerns about the potential impact of agricultural production on indicators of environmental quality have become prominent in policy discussions and the environmental/economic literature. A number of theoretical and empirical studies (for example, Chavas and Holt (1990); Horowitz and Lichtenberg (1994); Wu and Brorsen (1995); Goodwin, Vandeveer and Deal (2004); and Wu (1999)) have been conducted to analyze the impact of disaster payments, crop insurance, price supports, and acreage retirement programs on land allocation and input use. Many have argued that unintended negative environmental consequences could result from acreage and input use changes in response to government efforts to stabilize farm income and reduce the risk associated with agricultural production. In addition, concerns have been expressed that these programs may be working at cross-purposes with other programs, such as the Conservation Reserve Program (CRP), that are designed to mitigate the effects of the environmental damage resulting from agricultural production activities.

Another line of research (for example, Pionke and Urban (1985) and Amos and Timmons (1983)) focuses on the impact of input and land use on measures of soil and water quality, though much of this research has centered on the impact on water quality. A number of researchers (see Johnson, Wolcott and Aradhyula (1990); Just and Antle (1990); LaFrance (1992); Innes and Ardila (1994)) have recently explored the theoretical connection between government policy, extensive and/or intensive margin changes, and environmental outcomes. In particular, Innes and Ardila provided a theoretical framework in which to study the impact of agricultural insurance on soil depletion. While these studies have contributed to an understanding of the theoretical relationship between production choices and environmental quality indicators, research that addresses the empirical connection between government agricultural policies and environmental outcomes is relatively sparse (for example, Wu (1999); Goodwin and Smith (2003); and Plantinga (1996)). The limited research that has occurred has often been conducted over very small geographic areas. This limits the ability to draw general conclusions based on the findings in these studies. On the other hand, researchers who have attempted to study larger geographic areas have often not taken into account the importance of site-characteristics and land heterogeneity.

Soil erosion is one of those key indicators of changes in environmental quality. Soil erosion is defined as the detachment and transportation of soil particles by wind or water activity (Larson, Pierce and Dowdy 1983). The extent of soil erosion on agricultural land is dependent on the specific use of the land (e.g., cultivated vs. noncultivated cropland), the level of cover vegetation, the physical and chemical characteristics of the soil, and the agricultural practices employed on the land. In particular, agricultural practices such as plowing, discing, and planting remove cover vegetation and break down soil structure. The breaking down of the soil structure leads to increases in leaching and surface runoff. Among other things, this increase in leaching and surface runoff accelerates water quality degradation, habitat destruction, and flooding associated with increases in sedimentation. Therefore, soil erosion has a substantial impact on a number of measures of environmental quality. In addition, soil erosion has a direct impact on the future productivity of the land where the erosion occurs. Specifically, soil erosion reduces the future productivity of the soil by reducing plant-available water capacity, reducing plant-nutrient supply, degrading soil structure, and minimizing the impact of chemical applications and other management strategies (National Soil Erosion Soil Productivity Research Planning Committee and Administration 1981).

Several studies (Wu and Babcock (1998); Goodwin and Smith (2003)) have included soil erosion in a structural model of agricultural production. Wu and Babcock included a dummy variable to capture whether or not the farmer had purchased crop insurance, while Goodwin and Smith included government program payments, in addition to crop insurance, as explanatory variables in their soil erosion equations.[1] While Goodwin and Smith included a measure of aggregate government expenditures as an explanatory variable in their soil erosion model, they failed to account for differences that may exist between the myriad of government programs available to the farmer.[2] For example, payments tied to current production (e.g., loan deficiency payments) may induce production activities that affect soil erosion, while payments that are "decoupled" from current production (e.g., AMTA payments) may provide little incentive to alter production, and thus may have little impact on soil erosion.

Recent research has demonstrated that different agricultural policies may have significantly different impacts on crop mix and planted acreage. Keeton, Skees and Long (2000) and Griffin (1996) found substantial acreage increases due to the availability of federally-subsidized crop insurance, while Young, Schnepf, Skees and Lin (2001) and Goodwin et al. (2004) found relatively small production increases due to insurance availability. Deal (2004) found that the impact of crop insurance on planted acreage varies by crop and geographic location and that payments tied to current production (deficiency payments), decoupled payments (AMTA payments), and ad hoc payments (disaster and Market Loss Assistance payments) exhibit differential impacts on acreage

[1]Using an indicator variable having the value of one if the producer purchased crop insurance and zero otherwise, Wu and Babcock found that crop insurance participation had no significant impact on a composite measure of water- and wind-induced soil erosion.

[2]Goodwin and Smith found that their aggregate measure of government payments had a positive impact on soil erosion, while crop insurance participation exhibited a negative, though very small, impact on soil erosion.

response. Finally, Goodwin and Mishra (2003) and Adams, Westhoff, Willott and Young (2001) found that even decoupled payments may have a statistically significant, though quantitatively modest, impact on planted acreage.

The goal of this paper is to extend the preliminary efforts of Goodwin and Smith (2003) to explore the impact of government agricultural payment and risk management policies on soil erosion. Instead of using aggregate government payment data, we employ county-level program payment data for a number of different government programs available to the farmer during the years 1992 and 1997. In addition to the government payment data, we employ National Resources Inventory (NRI) and Soils Interpretation Record (SIR) data to provide measures of soil characteristics, management practices, and conservation practices.[3] While soil erosion occurs as a result of both water-induced (i.e., sheet and rill) and wind-induced factors, we limit our study to sheet and rill erosion.[4] We use NRI data from 1992 and 1997 to estimate the impact of government payments and crop insurance participation on soil erosion within a 2SLS framework. Although the variation in our data is primarily cross-sectional, we use data from the 3 year period surrounding our 1992 and 1997 time periods in our soil erosion equations to model the expectation of government payments.[5]

This study is organized in the following manner. Section 2 provides a description of the empirical model and data used in the study. Section 3 provides a presentation and discussion of the results. A summation of the findings and concluding remarks are presented in the final section.

2 Empirical Framework and Data

To undertake this study, it is necessary to provide an empirically implementable definition of soil erosion. Soil erosion is defined as the detachment and transportation of soil particles by wind or water activity (Larson et al. 1983). While exact measures of soil erosion are difficult to obtain, the Universal Soil Loss Equation (USLE) has been employed frequently (see Amos and Timmons (1983) and Goodwin and Smith (2003)) to proxy for soil erosion. The USLE was designed to predict long-term average annual soil loss occurring from sheet and rill erosion on specific lands where specific management and cropping practices were employed. The USLE equation is $A = RKLSCP$, where

[3]It should be noted that concerns about the accuracy of aggregating NRI data to the county level have been raised by the National Resources Conservation Service (NRCS). Goodwin and Smith (2003) point out that aggregating other data collected at the county level, such as crop yields and government payment data, to higher levels of aggregation, such as the major land resource area (MLRA), may introduce even more severe aggregation problems. As a result, the county is used as the unit of observation in our study.

[4]Sheet and rill erosion occurs when layers of soil are removed due to the action of rainfall and subsequent runoff activities. We do not model wind-induced soil erosion in our study since almost all of our sample counties are located in areas where wind-induced soil erosion has not been viewed as a problem.

[5]The lack of compatible government payments data before 1990 prevents us from using a longer time-series to model producer expectations concerning the magnitude of government payments.

A is predicted annual soil loss, K is an inherent soil erodibility factor, R is a rainfall erosivity factor, L is a slope-length factor, S is a slope-steepness factor, C is a cropping management factor, and P is a factor to incorporate erosion control practices.

The K factor value for a particular soil type is determined from an equation that includes the following variables: silt percent, sand percent, organic matter content, structure (e.g., fine granular soil), and permeability . The K factor is assumed to be constant for each soil type, regardless of the production practices undertaken on the soil or the climatic differences associated with the geographic location of the soil. The rainfall erosivity factor R accounts for the soil erosivity associated with the impact of rain drops on the soil and the resulting runoff associated with the impact. It is a function of the kinetic energy associated with the rain drop impact and the maximum 30 minute intensity of the rainfall. The cropping management factor C is determined as the ratio of soil loss from a specific cropping practice to the soil loss from soil in a tilled, continuously fallow condition. Among other management activities, this incorporates the effects of crop cover, crop rotation, and tillage systems. The supporting practices factor P accounts for the impact of erosion control practices, and is constructed as the ratio of the soil loss associated with a particular erosion control practice to the soil loss using an "up-and-down" hill cropping practice. Among other things, this factor accounts for different contour plowing and terracing methods (Mitchell and Bubenzer. 1980).

Water-induced soil erosion is a dynamic and complex process driven by the interaction of physical, chemical, biological, climatic, and economic factors. Although the process is complex, the level of soil erosion is primarily determined by soil characteristics (e.g., the slope and permeability of the land), climate (e.g., the frequency and intensity of rainfall), land use (e.g., cropland vs. pastureland), cropping practices (e.g., tillage and crop rotation), and conservation practices (e.g., cover and terracing). While the soil characteristics and climate factors are exogenous to the farmer, the choice of land use, cropping practice, and conservation practice are a function of the social and economic factors.[6]

For example, the choice of how to use the land is determined by the returns to the alternative uses of the land. Assuming land meets the eligibility requirements for enrollment in the Conservation Reserve Program, whether or not the land is actually enrolled will depend on the returns to enrollment, which are primarily a function of the rental rate and cost-share arrangements, versus the returns to the best alternative use of the land, such as crop production.[7] The expected

[6]These choice variables are also a function of climate and land characteristics. For example, the land use decision is constrained by the ability of the soil to support the production of a given crop in an economically viable manner.

[7]Since CRP land is under contract for ten to fifteen year periods, the option value of the land may also be a significant consideration when deciding whether or not enroll land in the CRP. While an important concern, this is beyond the scope of the present study.

returns to crop production are a function of the expected price and yield (which are not known with certainty at the time the land allocation decision is made), the costs of production, and the agricultural price (income) support payments available to the farmer. In addition, the variability of expected returns may be affected by the risk management tools that are made available to the farmer. The choices of cropping and conservation practices are also a function of economic variables. For example, the adoption of conservation tillage, which reduces soil erosion, has been shown to be a function, among other things, of farm size and off-farm employment (Fuglie 1999).

While the inherent erodibility of the soil places some boundaries on potential soil erosion, the activities undertaken on the land drive changes in the level of soil erosion over time. The basic belief behind most of our conservation programs is that cultivated cropland is more susceptible to increases in soil erosion than lands which are noncultivated or used as forest, range, or pasture. Disregarding the impact of government support programs, the use of the land will depend on the market returns to the alternative uses. To capture the impact of the expected market returns to crop production, we included a three-year county-level average of real net returns per harvested acre for corn, soybeans, and winter wheat in our model. We constructed the revenue for each crop by multiplying the harvested yield by the state-level market price taken from the NASS online database. The price was constructed as the average of the monthly state prices for the most active harvest months for each crop.[8]

The net return variable was constructed by subtracting the average total production cost per acre from the revenue for each crop. The total crop production costs were obtained from the USDA/ERS Commodity Costs and Returns data. The production data were estimated for each crop and USDA farm resource region on an annual basis. The nominal net return variable was inflated to 2001 terms using the producer price index. We divided the net return for each crop by the total harvested acres for that crop to construct the net return per acre. Finally, the expected county-level net returns per acre for each crop were calculated as a 3 year average of net returns as previously constructed.

In addition to market returns, the availability of government income support and risk management programs provide incentives for farmers to adjust land usage, at least at the margin. Payments that are directly tied to production (target price-based and loan deficiency payments) provide incentives for farmers to expand acreage and/or crop existing acreage more intensively. On the other hand, payments that are not tied to current production (AMTA payments) or those delivered on an ad hoc basis (disaster payments) may provide farmers with little incentive to alter

[8]The information concerning the most active harvest months for each crop were taken from the "Usual Planting and Harvesting Dates for U.S. Field Crops" section of the NASS Agricultural Handbook No. 628.

production.[9] Hennessy (1998) has argued that decoupled payments may affect crop acreage by encouraging producers to accept more risk as their wealth increases or by reducing financial constraints that limit their acceptance of more risk.[10] In addition, the frequency of ad hoc assistance may encourage farmers to incorporate those payments into expectations of future income and thus encourage them to accept greater risk. In addition to the risk management and income support programs, the federal government has provided payments (e.g., Conservation Reserve Program (CRP) rental income) to encourage the removal of highly erodible land from production.[11] If correctly targeted, these payments should lead to a reduction in soil erosion.

The impact of these various programs on production choices (and thus soil erosion) is primarily an empirical question. To capture the impact of these various agricultural programs on soil erosion, we included the following categories of agricultural payments in our model: (1) target price-based deficiency payments, (2) AMTA payments, (3) loan deficiency payments, (4) disaster payments, and (5) conservation payments. All of these payments are a 3 year average of county-level real payments per farm acre.

Many people have also expressed concerns about the impact of the provision of federally-subsidized crop insurance on crop mix, planted acreage, and input use. As demonstrated in Deal (2004), federally-subsidized crop insurance provides incentives for farmers to alter land allocation and input use. If those changes bring more erodible land into production, encourage the implementation of more intensive cropping practices, or discourage the adoption of conservation practices, they are likely to contribute to higher levels of soil erosion. To capture the impact of federally-subsidized crop insurance on soil erosion, we included a 3 year average of the percentage of planted acres in the county that are insured for each crop in our soil erosion equation.

Although we used a reduced-form approach with respect to modeling the impact of government payments on crop acreage, cropping practice, and conservation practices due to the lack of crop-specific payments data, we modeled insurance participation as an endogenous variable by modeling the determinants of insurance purchases within a 2 stage least squares framework. This approach was chosen since the impact of government payments on soil erosion should be directly attributable

[9] AMTA payments were authorized by Congress in the FAIR Act of 1996 to replace government support payments tied to current production and prices. Farmers were eligible to receive AMTA payments if they enrolled acreage in annual farm programs in any year from 1991 to 1995. These fixed payments, which were intended to decline and finally terminate at the end of the FAIR Act in 2002, were based on historical program benefits (which were based on historical production) and therefore not linked to current production.

[10] Hennessy's argument assumes that economic agents exhibit declining absolute or relative risk aversion (DARA or DRRA) preferences. Even with DARA or DRRA preferences, his results indicate that the effect is likely to be small, though statistically significant.

[11] The level of CRP payments received are a function of a bidding process whereby landowners submit bids on land that meet certain requirements, such as being assigned an erodibility index value of 8 or higher. These bids are accepted or rejected within the context of the program land retirement goals. In addition to CRP rental rates, our conservation payments data include, among other things, CRP cost-share payments and water conservation payments.

to their impact on crop acreage, cropping practice, or conservation practice (even though disentangling the individual effects may be difficult), while the impact of government payments (i.e., premium rate subsidies) with respect to crop insurance affect soil erosion through their impact on insurance purchases, which may then impact the other choice variables.

In our model of crop insurance demand, we included the producer-paid portion of the insurance premium rate and the loss ratio (a proxy for expected indemnity payments). We hypothesize that an increase in the premium rate will reduce crop insurance participation (as measured by the ratio of insured acres to total planted acres) and will decrease acreage in the planted crop. If that crop is associated with higher levels of erosion, the increase in the premium rate should reduce the level of soil erosion. We hypothesize the opposite effect for the loss ratio. An increase in the loss ratio should increase insurance participation and crop acreage. If that crop is associated with higher levels of erosion, the increase in the loss ratio should increase the level of soil erosion. There is also evidence that agents exhibit a differential response to premium rates when facing different expected indemnity payments (Goodwin 1993). Specifically, farmers who expect to receive larger indemnity payments are less responsive to increases in premium rates. To capture this differential response, we included an interaction term of the premium rate and loss ratio.

For given premium rates and indemnity payments, risk-averse farmers should also exhibit a higher demand for insurance if they face a higher yield risk. To capture the yield risk faced by the producer, we also included the coefficient of variation of county average yields. The productive capacity of the land may also have an impact on insurance demand. Land with high productivity may reduce the likelihood of a yield shortfall, but may also increase the magnitude of the loss in the event of crop failure. To capture land productivity, we included the county average water holding capacity, a primary constraint on agricultural productivity. Although no consensus has been reached in the empirical literature, crop insurance may act as a substitute for other inputs, such as fertilizers, in the production process. To capture the impact of fertilizer use on crop insurance demand, we included a three-year average of county-level fertilizer/chemical expenditures.[12] To capture possible borrowing constraints facing the farmer, we included a 5 year lag of county average net farm income. We hypothesize that a lower net income stream would encourage borrowing, and therefore increase the likelihood of the borrower facing insurance purchase requirements set by the lender. Finally, large farms may be more likely to purchase insurance since, among other things, they provide higher commission payments that encourage more intensive marketing by insurance agents. We include county average farm size (in acres) to capture this effect.

[12] A limitation with respect to our expenditure data should be noted. Our data are county-level expenditures and are not crop-specific. Therefore, we cannot take into account different application rates across different crops.

In addition to market returns, government program payments, and crop insurance, other factors may effect soil erosion through their impact on acreage allocation and the adoption of cropping/conservation practices. Since cropping activities, such as plowing, are major contributing factors to soil erosion, land that remains in pasture, range, or forest should exhibit lower levels of soil erosion than land under cultivation. The soil erosion measure (USLE) is reported in the NRI only on land that is designated as cropland, pastureland, or CRP land. The previously discussed variables are included to capture the impact of cropland and CRP use, but modeling pasture use is more complicated since pasture can be used for a number of activities, such as grazing and hay production. Given the data limitations, particularly with respect to the derivation of pasture costs, we chose to forego constructing a net return variable for pasture use. To capture the impact of pasture use on soil erosion, we used a 5 year lag of the ratio of pasture acres to the sum of crop, pasture, and CRP acres.

If government program payments and crop insurance encourage farmers to bring economically marginal land into production, this may include land that is more steeply sloped or more inherently erodible than land already in production. This land may require more intensive cultivation than land already in production. As a result, government programs may affect our measure of soil erosion by affecting the distribution of the K (inherent erodibility), L (slope length), and S (slope steepness) factors of land under cultivation. Even if identical cropping practices are used for land already in production and this new land being brought into production, the new land would be more likely to contribute to erosion because of its physical characteristics. While bringing new land into cultivation may alter the distribution of the K, L, and S components of the USLE, it is unlikely that government programs could affect the rainfall erosivity factor (R) since this is likely not to vary within close geographic proximity (e.g., land within a county). Since it is unlikely that government policy can affect the R factor, we condition this out in our soil erosion estimation equation.

Therefore, our soil erosion estimation equation can be summarized as follows:

$$\begin{aligned} USLE = \; & \sum_{i=1}^{3} b_i \cdot MKTRET_i + b_4 \cdot DISASTER + b_5 \cdot LDP \\ & + b_6 \cdot DEFICIENCY + b_7 \cdot CONSERVE \\ & + b_8 \cdot CONSERVE * EI + b_9 \cdot LAGPAST + b_{10} \cdot RFACT \\ & + \sum_{i=11}^{13} b_i \cdot INSURE_i + \epsilon \end{aligned} \quad (1)$$

where $USLE$ is the measure of water-induced soil erosion measured in tons/acre/year, $MKTRET_i$ is the market return to crop i, $DISASTER$ is the county average real disaster payments per planted acre, $DEFICIENCY$ is the county average real deficiency payments per harvested acre, LDP is the county average real loan deficiency payments per planted acre, $CONSERVE$ is the county average real conservation payments per CRP acre, $CONSERVE * EI$ is an interaction term of conservation payments and the soil erodibility index, $LAGPAST$ is the 5 year lagged percentage of pasture acreage, $RFACT$ is the rainfall factor from the USLE, $INSURE_i$ is the percentage of crop acres insured for crop i, and ϵ is an error term. Deficiency payments were not available after 1996 and are not included in the 1997 model. AMTA payments were not available before 1996, and were not included in the 1992 model.

There is a crop insurance demand equation for each of the three crops in our model. The general form of each equation can be summarized as follows:

$$\begin{aligned} INSDMD = \ & b_0 + b_1 \cdot PREM + b_2 \cdot LR + b_3 \cdot PREM * LR + \\ & b_4 \cdot CVYLD + b_5 \cdot FMACRES + b_6 \cdot NETINCOME + \\ & b_7 \cdot AWC + b_8 \cdot CHEMEX + \epsilon \end{aligned} \tag{2}$$

where $INSDMD$ is the percentage of planted acres that are insured, $PREM$ is the producer-paid premium rate, LR is the loss ratio, $PREM * LR$ is an interaction term conditioning the impact of the premium rate on the loss ratio, $CVYLD$ is the coefficient of variation of mean yield, $FMACRES$ is the county average farm size (in acres), $NETINCOME$ is a 5 year lagged average of net farm income, AWC is the county average water holding capacity, $CHEMEX$ is the county average fertilizer/chemical expenditures, and ϵ is an error term.

Our sample consists of counties where corn, soybeans, and winter wheat account for more than 90% of harvested acres in the county.[13] In addition, we exclude any counties that meet this criteria but fail to produce all three crops. This results in a sample of 778 counties in 1992 and 773 counties in 1997. Figure 4.1 provides a map of the counties contained in our 1992 sample.[14] Our sample consists of counties from the upper Midwest states (e.g., Illinois and Ohio), the mid-Atlantic states (e.g., Virginia and Maryland), the northern sections of the Southeastern states (e.g., North Carolina and Tennessee) and the lower Plains states (e.g., Nebraska and Kansas). Excluding the Mississippi Portal region which is not well represented in our sample, we include most of the areas that have exhibited the highest levels of sheet and rill erosion and are of the greatest concern.

Table 1 contains the means and standard deviations of sheet and rill erosion by state in our sample for the 1992 and 1997 periods. In addition, the table contains the number of counties (N) from each state in our sample. Illinois, Indiana, Iowa, Missouri, Kansas, and Ohio generally contain the largest number of counties, while Arkansas, Louisiana, Delaware, and Minnesota generally contain the fewest number of counties contained in our sample. Minnesota contained five counties that met the criteria in 1992 but none that did in 1997. In 1992 the mean soil erosion rate for our entire sample was 3.3113, though the rates ranged from a high of 5.7792 in South Dakota to a low of

[13]Total crop acreage includes acreage from the production of corn, soybeans, winter wheat, durum wheat, other spring wheat, grain sorghum, upland cotton, rye, barley, oats, peanuts, and rice.

[14]A map for the 1997 sample period is not included since most of the counties appear in both samples.

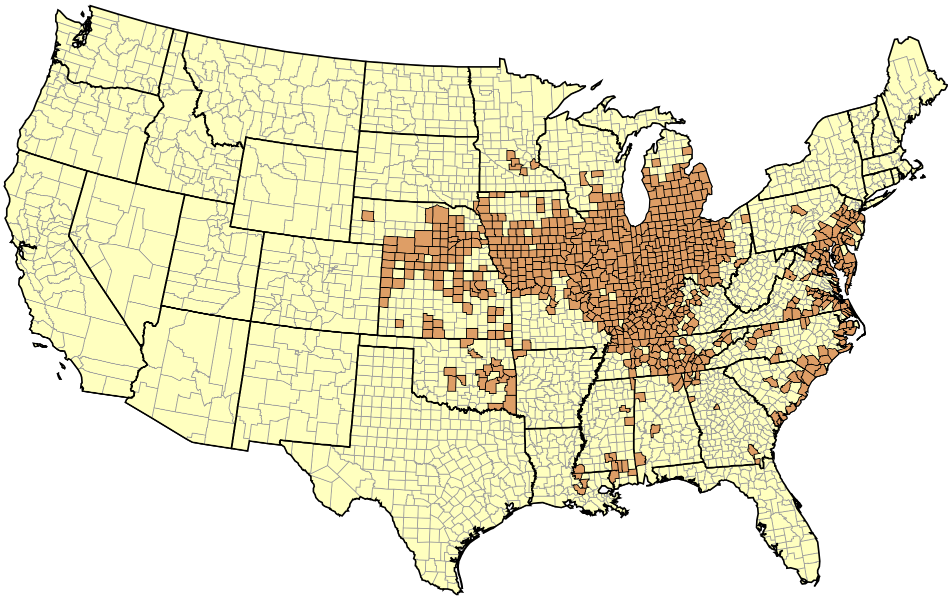

Figure 1: Sample Counties (1992)

1.7901 in Oklahoma. The mean soil erosion rate declined to 2.8000 by 1997 for our sample, though a few states (Illinois, Iowa, Maryland, and Pennsylvania) still exhibited sheet and rill erosion rates in excess of 3.5 tons/acre/year.

This study makes use of data collected from a number of sources. In particular, we make extensive use of 1992 and 1997 National Resources Inventory (NRI) data. Among other things, the measure of sheet and rill erosion ($USLE$) is contained in the NRI data. The crop yield and price data are taken from the National Agricultural Statistics Service (NASS) online database. The production cost data are contained in the Economic Research Service (ERS) Commodity Cost and Returns database. County-level Commodity Credit Corporation (CCC) payment data from the 1990-1998 period are taken from unpublished USDA-FSA sources. Crop insurance program data are taken from the RMA's unpublished county level "summary of business" database. Farm acreage data were taken from the Census of Agriculture. County-level mean average water holding capacity (AWC) was constructed from data included in the SOILS-5 database. All nominal economic variables are inflated to 2001 terms using the producer price index. A list of variables and summary statistics for the 1992 model can be found in Table 2, while a list of variables and summary statistics for the 1997 model can be found in Table 3.

Table 1: Sample County Soil Erosion Rates by State

State	*1992*			*1997*		
	N	Mean	St. Dev.	N	Mean	St. Dev.
Alabama	5	2.7396	1.1348	7	1.9577	0.2935
Arkansas	1	1.0817	···	1	1.8103	···
Delaware	2	2.2437	1.8115	2	1.9166	1.4265
Georgia	8	1.2405	0.7505	2	1.6937	0.9004
Illinois	98	4.1906	1.6984	87	3.8175	1.6230
Indiana	92	2.9948	1.1574	88	2.6401	0.9910
Iowa	64	4.9747	2.4079	53	4.1609	1.9941
Kansas	37	2.5433	2.0995	53	1.9640	1.1514
Kentucky	63	3.3180	1.3258	54	2.5412	1.0476
Louisiana	3	1.8943	1.8040	3	2.8611	0.9552
Maryland	20	4.4983	3.1220	20	3.9254	2.9554
Michigan	45	1.6582	0.9832	39	1.4395	0.8289
Minnesota	5	2.8327	1.0263	0	···	···
Mississippi	11	2.3828	1.0289	7	3.1334	1.7526
Missouri	53	4.6949	2.1127	69	3.3194	1.6631
Nebraska	49	2.7397	1.7806	42	2.5035	1.4937
New Jersey	10	3.9930	2.1733	10	3.4422	1.7489
North Carolina	26	3.8058	3.1497	25	3.1025	2.7826
Ohio	59	2.8347	1.1666	67	2.2428	0.9281
Oklahoma	17	1.7901	0.9404	15	1.3702	0.7036
Pennsylvania	9	4.9151	1.6169	18	4.0701	1.3056
South Carolina	9	1.8373	0.7976	6	1.6346	0.9739
South Dakota	1	5.7792	···	13	2.1483	1.0032
Tennessee	51	1.9825	1.3135	39	1.6465	1.3105
Texas	0	···	···	1	0.5833	···
Virginia	29	3.5414	1.8867	35	3.0231	1.2340
Wisconsin	11	3.5062	0.9917	17	3.0318	1.3281
Total	778	3.3113	1.9983	773	2.8000	1.6605

3 Results

Table 4 presents the results from our 2SLS estimation of the 1992 model specification. In our soil erosion estimation equation, the 3 year average (1991-1993) of net market returns for corn are positively and significantly associated with higher levels of soil erosion, though higher net market returns for soybeans are not significantly associated with higher levels of soil erosion. Counties that experience higher net market returns for winter wheat exhibit significantly lower levels of soil erosion. A priori expectations are that row crops (for example, corn and soybeans) should be associated with higher levels of soil erosion than small grain crops (for example, winter wheat). If higher net market returns lead to higher planted acreage, our results support the a priori expectation that the returns to planting corn/soybeans will be associated with higher levels of soil erosion, while winter wheat returns will be associated with lower soil erosion.[15]

The focal point of our analysis is the impact of government program payments and crop insurance on soil erosion. The coefficient estimates on loan deficiency payments and deficiency payments are insignificant at the 10% level. While deficiency payments were not provided for soybean produc-

[15]The Pearson correlation coefficient between corn and soybean net market returns is 0.72, so a potential collinearity problem exists and identification of the separate effects may be difficult.

tion, corn and winter wheat were program crops that were eligible to receive deficiency payments.[16] The overall insignificant impact of these support payments may indicate the offsetting effects of incentives to increase production in response to the reduction in risk and conservation compliance requirements associated with the receipt of government program payments.[17] Since disaster payments are received after production decisions (e.g., crop mix and cultivation practice) are made, it is somewhat surprising that they exhibit a significant positive impact on soil erosion.[18]

An increase in conservation payments is associated with a decrease in soil erosion. This provides support to the argument that conservation payments that encourage farmers to remove erodible land from production and to adopt conservation practices are an effective tool to reduce soil erosion. The interaction term indicates that conservation payments exhibit a differential impact on soil erosion given different levels of soil erodibility. Without the inclusion of the interaction term, conservation payments exhibit a significant positive impact on soil erosion. Without controlling for differences in soil erodibility, this should not be surprising since conservation payments, if correctly targeted, are higher on more highly erodible land (i.e., land that is most likely to experience soil erosion).

Given that land used as pasture requires little (or no) cultivation, we would expect to find that the higher the lagged percentage of land used as pasture, the lower the level of soil erosion. This is consistent with our findings. As expected, the rainfall erosivity factor is associated with higher levels of soil erosion. The predicted values for corn insurance participation from our 2SLS estimation are associated with higher levels of soil erosion, while wheat insurance participation is associated with lower levels of soil erosion. Both coefficient estimates are significant at the 10% level, while soybean insurance participation exhibits no significant impact on soil erosion. Assuming that higher insurance participation is associated with higher planted acreage, our results support our findings with respect to net market returns as to the impact of row crops (at least in the case of corn) and small grains (winter wheat) on soil erosion.

The results from the 2SLS estimation of insurance participation generally confirm a priori expectations. The producer-paid portion of the crop insurance premium rate is negatively associated with insurance participation for corn and soybeans, though is not significantly associated with wheat insurance participation. The loss ratio is positively related to corn and wheat insurance participation, while the coefficient of variation of mean yield is positively associated with insurance

[16]We also estimated a model using total government payments (excluding conservation payments) and found that total payments exhibited no statistically significant impact on soil erosion.

[17]We also estimated two alternative versions of our model, conditioning out the cropping and management practices in one model and the physical characteristics, such as slope and inherent erodibility, in the other model. While the overall effect of deficiency payments is insignificant, they exhibit a statistically significant impact on cropping and conservation practices, controlling for the physical characteristics of the land, but exhibit no impact on the the distribution of the physical characteristics.

[18]Though significant, the magnitude of the change is very small. A doubling of disaster payments from its mean value of \$1.50 per farm acre would lead to a 4% increase in the level of soil erosion from its mean value of 3.3113.

participation for all three crops. The coefficient estimates on the interaction term indicate that the producers of all three crops exhibit a differential response to premium rate increases if those increases are conditioned on the expected indemnity payments (i.e., loss ratios). Producers who receive higher indemnity payments are less responsive to increases in premium rates. Land quality, as proxied by county average water holding capacity, is associated with significantly higher corn and soybean insurance participation. This may indicate that producers are more willing to insure more productive land since any systematic crop failure will be associated with higher levels of foregone production. In all three cases, larger farms (in acreage terms) are associated with higher levels of insurance participation, while chemical expenditures and lagged net farm income are negatively associated with insurance participation. In particular, this indicates that lower net income from the preceding 5 year period is associated with higher insurance purchases. This may reflect insurance purchase requirements imposed by lenders if producers find it necessary to borrow funds to supplement the lower net income.

Table 5 presents the results from our 2SLS estimation of the 1997 model specification. In our soil erosion estimation equation, the 3 year average (1996-1998) of net market returns for all three crops are not significantly associated with soil erosion. These results are inconsistent with the results from the earlier period that indicate that the production of row crops (at least corn) is associated with higher levels of soil erosion, while small grain (e.g., winter wheat) production is associated with lower levels of soil erosion. This is somewhat surprising since the elimination of planting restrictions in 1996 should elevate the importance of market returns to the producer's production decisions.

The coefficient estimates on disaster payments and AMTA payments are insignificant at the 10% level.[19] Since AMTA payments are not tied to current production decisions, it is not surprising that they do not exhibit a significant impact on soil erosion.[20] Consistent with the results from the earlier period, loan deficiency payments exhibit no significant impact on soil erosion. Unlike the results from the earlier period, disaster payments are not associated with higher levels of soil erosion.[21]

As in the 1992 specification, an increase in conservation payments is associated with a decrease in soil erosion. This provides support to the argument that conservation payments that encourage

[19]We also estimated two alternative versions of our model, conditioning out the cropping and management practices in one model and the physical characteristics, such as slope and inherent erodibility, in the other model. While the overall effect of the AMTA payments is insignificant, they exhibit a statistically significant impact on cropping and conservation practices, controlling for the physical characteristics of the land, but exhibit a negative, though statistically insignificant, impact on the the distribution of the physical characteristics that one would expect with changes in land use.

[20]If these payments affect soil erosion through their impact on crop acreage, our results lend support to the argument that the wealth effects of decoupled payments are probably small in magnitude.

[21]While county average disaster payments in the 1991-1993 period were \$1.50 per farm acre, the mean disaster payments in the 1996-1998 period were \$0.09 per farm acre.

farmers to remove erodible land from production and to adopt conservation practices are an effective tool to reduce soil erosion. The interaction term indicates that conservation payments exhibit a differential impact on soil erosion given different levels of soil erodibility. Without the inclusion of the interaction term, conservation payments exhibit a significant positive impact on soil erosion.

As in the previous period, we found that the lagged pasture variable is associated with lower the levels of soil erosion, and the rainfall erosivity factor is associated with higher levels of soil erosion. As in the 1992 specification, the predicted values for corn insurance participation from our 2SLS estimation are associated with higher levels of soil erosion, while wheat insurance participation is associated with lower levels of soil erosion. Both coefficient estimates are significant at the 10% level, while soybean insurance participation exhibits no significant impact on soil erosion. Assuming that higher insurance participation is associated with higher planted acreage, our results indicate that counties with a higher production of row crops (corn and soybeans) tend to have higher levels of soil erosion than counties that plant more acreage in small grains (winter wheat).

The insurance participation results from the 1996-1998 period are not generally consistent with those from the 1991-1993 period. This is not surprising since a number of changes in the crop insurance program occurred between these periods. In particular, revenue insurance products were available in the 1996-1998 period, but not in the 1991-1993 period.[22] In addition, efforts to increase producer participation led the government to increase premium rate subsidies by the later period. The biggest difference occurred with respect to the impact of the premium rate on insurance participation. The producer-paid portion of the crop insurance premium rate is positively associated with insurance participation for all three crops, though not significantly associated with soybean insurance participation.

The expected indemnity payment (i.e., loss ratio) is statistically insignificant for soybeans and wheat, while the coefficient of variation of mean yield is statistically significant for only soybean insurance participation. The coefficient estimates on the interaction term indicate that there is not a differential response to premium increases if those increases are conditioned on the expected indemnity payments for soybean or wheat producers. Land quality, as proxied by county average water holding capacity, is associated with significantly higher corn and soybean insurance participation, but lower, though statistically insignificant, wheat insurance participation. This may indicate that producers are more willing to insure more productive land since any systematic crop failure will be associated with higher levels of foregone production. In all three cases, larger farms (in acreage terms) are associated with higher levels of insurance participation, while chemical expenditures are negatively associated with insurance participation. Finally, there is a statistically significant

[22] Attempts were made to model revenue insurance (in addition to yield insurance), but the lack of widespread availability and adoption during this period limited the sample size to an unacceptable level.

positive relationship between lagged net income and insurance participation with respect to corn and soybeans, with no significant impact on wheat insurance participation.

4 Conclusions

The goal of this paper is to extend the preliminary work of Goodwin and Smith (2003) evaluating the impact of government program payments and crop insurance on soil erosion. Using a 2SLS framework, we estimate a system of four equations (soil erosion and three insurance participation equations) for a sample of counties where corn, soybeans, and winter wheat make up over 90% of planted acreage in the county. Therefore, our sample includes counties from many of the areas, such as the primary corn and soybean producing areas of the Midwest, that experience high levels of water-induced soil erosion.

Our results indicate that counties that receive higher conservation payments experience lower levels of soil erosion if those payments are conditioned on soil erodibility; otherwise, those payments are positively associated with soil erosion. This is expected since conservation payments are ideally targeted toward land that is more inherently erodible or land that has experienced greater levels of past soil erosion. We find that an increase in disaster payments is associated with a statistically significant increase in soil erosion for the earlier period, but exhibited no significant impact during the later period. In addition, target price-based deficiency payments (1991-1993), loan deficiency payments (1991-1993 and 1996-1998), and AMTA payments (1996-1998) had no statistically significant impact on soil erosion.

Goodwin and Smith found that crop insurance participation (as proxied by the ratio of insured to total crop acres) exhibited a significant negative impact on soil erosion, though the impact was small in magnitude. While they used total participation for all crops in their sample, we estimate separate equations for each crop (corn, soybeans, and winter wheat) in our sample. When using an alternative measure of total insured acres for the three combined crops, our results confirm those of Goodwin and Smith. The results from our estimation of separate insurance participation equations indicate substantial differences across crops. In both sample periods, higher corn insurance participation is associated with significantly higher soil erosion, while wheat insurance participation is associated with significantly lower soil erosion.

To the extent that soil erosion contributes to a reduction in environmental amenities, such a water quality, our results indicate that concerns over the impact of government income support and risk management programs on indicators of environmental quality may be exaggerated. We find that conservation payments are associated with lower levels of soil erosion, but other government program payments seem to have little impact on soil erosion, at least in the areas represented by our sample. On the other hand, crop insurance participation, particularly for corn and wheat, seems to have a significant impact on soil erosion. It should be noted that our results apply only to counties that have a large percentage of total planted acres devoted to corn, soybean, and winter wheat production. Having said that, our sample incorporates many of the areas of primary concern with respect to the impact of agricultural practices on water-induced soil erosion.

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Table 2. Variable Definitions and Summary Statistics for Soil Erosion Model (1992)

Variable	Definition	Mean	Std. Dev.
Soil Erosion	county average USLE soil erosion measure	3.3113	1.9983
Market Return (Corn)	real return per harvested acre (1991-1993)	−34.0841	45.3304
Market Return (Soybeans)	real return per harvested acre (1991-1993)	6.9648	37.2536
Market Return (Winter Wheat)	real return per harvested acre (1991-1993)	−82.5869	44.6682
Disaster Payments	real disaster payments per farm acre (1991-1993)	1.5017	1.9174
Loan Deficiency Payments	real LDPs per farm acre (1991-1993)	0.0163	0.1225
Deficiency Payments	real deficiency payments per farm acre (1991-1993)	11.9403	8.8068
Conservation Payments	real conservation payments per farm acre (1991-1993)	3.2141	3.5183
Insurance Participation (Corn)	percentage of corn acres insured (1991-1993)	0.2589	0.2276
Insurance Participation (Soybeans)	percentage of soybean acres insured (1991-1993)	0.2179	0.2290
Insurance Participation (Wheat)	percentage of wheat acres insured (1991-1993)	0.1826	0.2575
Lagged Pasture	percentage of acres in pasture (1987)	0.1283	0.1183
Premium (Corn)	producer-paid insurance premium rate (corn)(1991-1993)	0.0554	0.0265
Premium (Soybeans)	producer-paid insurance premium rate (soybeans)(1991-1993)	0.0613	0.0481
Premium (Wheat)	producer-paid insurance premium rate (winter wheat) (1991-1993)	0.0603	0.0288
Loss Ratio (Corn)	historical county average loss ratio (corn)(1986-1990)	2.0479	1.6446
Loss Ratio (Soybeans)	historical county average loss ratio (soybeans) (1986-1990)	1.8780	1.4371
Loss Ratio (Wheat)	historical county average loss ratio (winter wheat) (1986-1990)	2.5891	2.5424
CV Yield (Corn)	coefficient of variation of mean corn yield (1986-1990)	23.3512	10.9862
CV Yield (Soybeans)	coefficient of variation of mean soybean yield (1986-1990)	16.0992	6.9375
CV Yield (Wheat)	coefficient of variation of mean winter wheat yield (1986-1990)	26.7314	12.9742
Lagged Income	county average real net farm income (ten thousand dollars) (1986-1990)	0.8886	1.0605
Chemical Expenditures	county average real chemical expenditures per farm acre (1991-1993)	0.0923	0.0804
Farm Acres	total farm acres (hundred thousand)	2.1937	1.4989
Rainfall Factor	rainfall factor (R) of USLE	191.3562	63.4687
Soil Water-Holding Capacity (AWC)	average water holding capacity per inch of soil	0.1577	0.0247

Table 3. Variable Definitions and Summary Statistics for Soil Erosion Model (1997)

Variable	Definition	Mean	Std. Dev.
Soil Erosion	county average USLE soil erosion measure	2.7999	1.6605
Market Return (Corn)	real return per harvested acre (1996-1998)	−36.6597	54.1318
Market Return (Soybeans)	real return per harvested acre (1996-1998)	26.1001	42.2168
Market Return (Winter Wheat)	real return per harvested acre (1996-1998)	−11.3163	38.3583
Disaster Payments	real disaster payments per farm acre (1996-1998)	0.0948	0.2643
Loan Deficiency Payments	real LDPs per farm acre (1996-1998)	1.2119	1.0012
AMTA Payments	real AMTA payments per farm acre (1996-1998)	11.5573	7.0661
Conservation Payments	real conservation payments per farm acre (1996-1998)	2.7192	3.0724
Insurance Participation (Corn)	percentage of corn acres insured (1996-1998)	0.5372	0.2369
Insurance Participation (Soybeans)	percentage of soybean acres insured (1996-1998)	0.5213	0.2380
Insurance Participation (Wheat)	percentage of wheat acres insured (1996-1998)	0.4159	0.2492
Lagged Pasture	percentage of acres in pasture (1992)	0.1224	0.1151
Premium (Corn)	producer-paid insurance premium rate (corn)(1996-1998)	0.0337	0.0183
Premium (Soybeans)	producer-paid insurance premium rate (soybeans)(1996-1998)	0.0300	0.0193
Premium (Wheat)	producer-paid insurance premium rate (winter wheat) (1996-1998)	0.0365	0.0332
Loss Ratio (Corn)	historical county average loss ratio (corn)(1991-1995)	1.9994	2.6670
Loss Ratio (Soybeans)	historical county average loss ratio (soybeans) (1991-1995)	1.9357	5.4086
Loss Ratio (Wheat)	historical county average loss ratio (winter wheat) (1991-1995)	2.7430	2.2620
CV Yield (Corn)	coefficient of variation of mean corn yield (1991-1995)	22.2892	10.4843
CV Yield (Soybeans)	coefficient of variation of mean soybean yield (1991-1995)	15.2453	8.1567
CV Yield (Wheat)	coefficient of variation of mean winter wheat yield (1991-1995)	26.8387	13.7375
Lagged Income	county average real net farm income (ten thousand dollars) (1991-1995)	0.9936	1.3092
Farm Acres	total farm acres (hundred thousand)	2.3340	1.5639
Rainfall Factor	rainfall factor (R) of USLE	185.5089	56.5657
Soil Water-Holding Capacity (AWC)	average water holding capacity per inch of soil	0.1581	0.0243

Table 4. 2SLS Estimates of Soil Erosion Model (1992)

Variable	Soil Erosion	Corn Insurance	Soybean Insurance	Wheat Insurance
Intercept	1.6840*	−0.2223*	−0.1331*	0.0821
	(0.5331)	(0.0733)	(0.0735)	(0.0520)
Corn Returns	0.0097			
	(0.0043)			
Soybean Returns	0.0032*			
	(0.0048)			
Wheat Returns	−0.0110*			
	(0.0026)			
Disaster	0.1015*			
	(0.0535)			
Loan Deficiency	−0.9277			
	(0.5790)			
Deficiency	−0.0037			
	(0.0208)			
Conservation	−0.1804*			
	(0.0410)			
Conservation*EI	0.0221*			
	(0.0031)			
R Factor	0.0045*			
	(0.0021)			
Corn Insurance	5.1402*			
	(1.8753)			
Soybean Insurance	−1.1679			
	(2.4014)			
Wheat Insurance	−5.8505*			
	(1.8271)			
Lagged Pasture	−1.7518*			
	(0.9910)			
Premium		−1.4327*	−0.7698*	−0.3718
		(0.4029)	(0.2225)	(0.2318)
Loss Ratio (LR)		0.0206*	0.0008	0.0101*
		(0.0064)	(0.0078)	(0.0026)
Premium*LR		0.4271*	0.4974*	0.0968*
		(0.1053)	(0.1020)	(0.0386)
CV Yield		0.0051*	0.0062*	0.0011*
		(0.0009)	(0.0013)	(0.0006)
AWC		1.7950*	1.0775*	−0.4979
		(0.3970)	(0.3920)	(0.3334)
Farm Acres		0.0553*	0.0503*	0.0418*
		(0.0081)	(0.0082)	(0.0066)
Fertilizer		−0.3059*	−0.3354*	−0.2234*
		(0.1569)	(0.1506)	(0.1239)
Lagged Income		−0.0357*	−0.0317*	−0.0175*
		(0.0107)	(0.0106)	(0.0082)

The standard errors of the coefficients estimates are in parentheses.

The asterisks indicate statistical significance at the $\alpha = .10$ or smaller level.

Table 5. 2SLS Estimates of Soil Erosion Model (1997)

Variable	Soil Erosion	Corn Insurance	Soybean Insurance	Wheat Insurance
Intercept	0.9378*	0.1571*	0.1503*	0.4850*
	(0.5657)	(0.0712)	(0.0739)	(0.0814)
Corn Returns	−0.0005			
	(0.0022)			
Soybean Returns	0.0019			
	(0.0032)			
Wheat Returns	0.0031			
	(0.0030)			
Disaster	−0.1472			
	(0.3474)			
Loan Deficiency	−0.1038			
	(0.1055)			
AMTA	0.0193			
	(0.0188)			
Conservation	−0.1900*			
	(0.0429)			
Conservation*EI	0.0193*			
	(0.0034)			
R Factor	0.0103*			
	(0.0018)			
Corn Insurance	7.6226*			
	(3.3202)			
Soybean Insurance	−3.3118			
	(2.9735)			
Wheat Insurance	−5.0710*			
	(1.2260)			
Lagged Pasture	−2.2170*			
	(0.8522)			
Premium		3.2750*	0.1941	0.6272*
		(0.6548)	(0.5575)	(0.3773)
Loss Ratio (LR)		0.0163*	−0.0007	−0.0001
		(0.0058)	(0.0017)	(0.0044)
Premium*LR		−0.2720*	−0.0374	0.0578
		(0.1482)	(0.1673)	(0.1037)
CV Yield		0.0005	0.0093*	−0.0007
		(0.0009)	(0.0011)	(0.0007)
AWC		1.6714*	1.8027*	−0.5561
		(0.3802)	(0.4049)	(0.4680)
Farm Acres		0.0311*	0.0278*	0.0499*
		(0.0052)	(0.0053)	(0.0061)
Fertilizer		−1.1390*	−1.3259*	−1.2035*
		(0.2185)	(0.2202)	(0.2396)
Lagged Income		0.0178*	0.0196*	0.0035
		(0.0059)	(0.0060)	(0.0069)

The standard errors of the coefficients estimates are in parentheses.

The asterisks indicate statistical significance at the $\alpha = .10$ or smaller level.