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An Ex Post Evaluation of the Conservation Reserve, Federal Crop Insurance, and Other Government Programs: Program Participation and Soil Erosion

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Recent research has questioned the extent to which government policies, including conservation and risk management programs, have influenced environmental indicators. The impacts of income-supporting and risk management programs on soil erosion are considered. An econometric model of the determinants of soil erosion, program participation, conservation effort, and input usage is estimated. While the Conservation Reserve Program has reduced erosion an average of 1.02 tons per acre from 1982 to 1992, approximately half of this reduction has been offset by increased erosion resulting from government programs other than federally subsidized crop insurance.

Key words: Conservation Reserve Program, farm policy, soil erosion

Introduction

The Conservation Reserve Program (CRP) was established under Title XII of the Food Security Act of 1985 as a voluntary, long-term cropland retirement program. Participants receive an annual rental payment plus 50% of the cost of planting an eligible cover crop in exchange for removing highly erodible cropland from production for 10 years. The 1985 law had a goal of enrolling 40–45 million acres by the end of the 1990 crop year, of which 12.5% was to be planted in trees. While these goals were not met, nearly 34 million acres were enrolled in the CRP by the end of 1990. The primary objective of the program was to reduce soil erosion, but secondary objectives included protecting agricultural productivity, reducing sedimentation, improving water quality and wildlife habitat, curbing surplus commodity production, and providing income support to farmers.

Federal crop insurance and disaster relief programs have a much longer history. A systematic federal crop insurance program was first introduced under the provisions of the 1938 Crop Insurance Act. From the outset, concerns were expressed about the potential land-use effects of the legislation, which initially provided insurance for only

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a limited number of commodities. A 1937 *Christian Science Monitor* editorial, for example, raised the following rhetorical question:

> Will the [crop insurance] program become in effect an underwriting of high risk farming areas which in fact ought to be retired from farming and put to grazing, forests, and other uses...? (quoted in Kramer, p. 184).

Under the provisions of the 1980 Federal Crop Insurance Act and subsequent legislation, beginning in 1983, the federal crop insurance program was substantially expanded to cover many more crops in most geographic regions of the United States. Thus the potential for the federal crop insurance program to have an impact on land-use decisions and environmental indicators increased over approximately the same time period in which the U.S. government also introduced and expanded the Conservation Reserve Program.

The federal crop insurance program has undergone significant changes in recent years. In 1994, the Federal Crop Insurance Reform Act brought about major changes to the legislation, including a brief period of mandatory participation in the programs (at least in order to be eligible for other program benefits). The 1994 Act mandated a pilot program to develop cost of production coverage, which, along with innovations by the private insurance sector, eventually led to the development of a number of crop revenue insurance products. These revenue insurance products have had a major impact on insurance participation, now accounting for the largest share of overall crop liability.

Another major change to crop insurance programs was incorporated into the 2000 Agricultural Risk Protection Act (ARPA). This Act substantially increased premium subsidies, and thus provided further incentives for participation. ARPA brought about a number of other important changes to insurance programs, including expanded incentives for research and development.[1]

As will be made clear below, our analysis is focused on the period of time in which the Conservation Reserve Program was introduced (1982–1992, with CRP beginning in 1985). Therefore, we do not consider the effects of these major expansions and changes in crop insurance programs, although it is important to note that crop insurance was expanded in the 1980s by the introduction of new county and crop programs under the provisions of the 1980 Crop Insurance Reform Act.

Soil loss is a key environmental indicator. Thus a major objective of this study is to obtain quantitative estimates of the effects of the CRP and the federal crop insurance program on soil loss. Although a large body of research has considered factors affecting CRP enrollment and the potential effects of the expiration of CRP contracts, the aggregate quantitative effects of the empirical relationships among soil erosion, the Conservation Reserve Program, crop insurance, disaster relief, and other government programs have not been examined.

This study estimates a model applied to two years (1982 and 1992) of cross-sectional, county-level data encompassing agricultural production and soil erosion both before and after the introduction of the CRP and the rapid expansion of crop insurance programs subsequent to 1983 (Goodwin and Smith 1995). Observed patterns of soil erosion are considered using data collected under the U.S. Department of Agriculture's (USDA's) National Resources Inventory (NRI). Attention is also given to other government

[1] See Goodwin (2001) for a detailed discussion of changes in crop insurance legislation that occurred during the 1990s.

programs that may influence production and observed patterns of soil erosion. To obtain quantitative estimates, a five-equation structural model of CRP participation, soil erosion, crop insurance participation, conservation, and fertilizer usage is estimated using two-stage least squares procedures.

Soil Erosion, the CRP, Crop Insurance, and Other Government Programs

The highest participation rates in the CRP have been realized in the Great Plains and the Mississippi River delta areas. High rates of CRP participation have also been realized in the southeastern United States. In contrast, an examination of soil erosion patterns as reported in the NRI indicates the most serious erosion occurred in southwestern states. Most soil losses in this region result from wind erosion. Relatively severe erosion also occurs along the Mississippi and Missouri rivers. Thus, the areas with the most serious erosion levels only partially correspond to the areas with the highest CRP enrollment levels. In comparison, in the 1980s and 1990s, federal crop insurance program participation rates were high in relatively arid Northern Great Plains states such as the Dakotas and Montana for crops like wheat, and in parts of Texas for crops such as cotton.

Colacicco, Osborn, and Alt highlight several reasons for concern about the productivity effects of soil erosion. They found that large productivity losses occurred on limited amounts of land in each of the farm production regions. Their results suggest soil erosion increases production variability, and the detrimental effects of soil losses are irreversible and cumulative in nature. Ribaudo, and Ribaudo et al. estimated that the CRP has provided positive benefits by preserving natural resources.

In a recent study, Wu evaluated the extent to which new land was brought into production as other land was being removed by enrolling in the CRP. His study examines the effects of increased commodity prices resulting from output decreases associated with the CRP itself and scale economies. While Wu's analysis did not account for the effects of other government programs such as crop insurance and disaster relief, his results established that for each 100 acres enrolled in the CRP, an additional 20 acres of land not previously used to raise crops were brought into production.

Although the goal of reducing soil erosion may be laudable, various aspects of the CRP have been subject to substantive criticisms. The bid selection criteria for the CRP have been criticized on the grounds they have maximized acreage enrolled and income transfers to farmers instead of reducing soil erosion. Land must satisfy erodibility criteria to be eligible for participation. A bidding scheme was initially employed to enroll eligible land within regional bid pools subject to a bid cap. However, the bids resulting from this process were perceived to be too high and the program was amended in subsequent years. Currently, one regional rental rate for several different categories of land is offered to participating farmers. While this design may reduce program costs, it does not distinguish among tracts of land according to the effects and severity of erodibility.

As noted above, concerns have also been raised about crop insurance, disaster relief, and other agricultural programs which may have discouraged CRP enrollment and encouraged production on erodible land. In particular, price and income support programs, provisions for expanding program acreages, and the expansion of yield risk-protection policies such as disaster payments and federal crop insurance programs have

all been hypothesized to encourage production on erodible land and to discourage CRP participation (see, e.g., Griffin; Keeton, Skees, and Long; and Goodwin and Vandeveer).[2] Since 1985, the CRP has been extended and, in successive farm bills, refocused to include water quality, wildlife habitat, wetlands, and other environmental concerns. However, while land continues to be enrolled (and re-enrolled), the overwhelming majority of CRP acreage was initially placed in conserving uses under the 1985 legislation.

Reichelderfer and Boggess evaluated CRP objectives and simulated a series of implementation alternatives. Their results showed the goals of cost reduction and erosion management were to some extent mutually inconsistent, and optimal erosion control would be quite costly. Their research was critical of the bid process for selecting participating acres, and concluded more cost-effective erosion management would be possible if the selection process also considered the level of erosion reduction obtained on individual tracts of land.

A 1990 U.S. General Accounting Office report suggested the offer system was inefficient and often resulted in rental rates exceeding the rental value of farmland. Smith (1995), however, argues it might be difficult to construct an alternative bid process that operates more efficiently. Among the total acres eligible for the CRP, Sinner asserts all but 25% could be farmed effectively with erosion-control cropping practices, and that subsidizing these changes would be less costly than retiring cropland from production. Finally, in an analysis of landowner incorporation of onsite soil erosion costs and the CRP, Miranda notes the regional offer system for CRP rental rates does not recognize erosion cost and benefit differences among individual producers.

A Simple Conceptual Framework

Soil erosion measured at the county level is linked to several important farm-level decisions, including choices about the allocation of land among the CRP and crop production, conservation efforts, and production practices as also reflected by input use. The quantitative linkages among participation in the CRP, the federal crop insurance program, other government programs, and soil erosion rates are the main focus of this study. However, while there is no intent here to develop a detailed model of farm-level production decisions, the specification of the empirical models presented below is usefully informed by a simple exposition of theoretical considerations.

Enrollment of land in the CRP and participation in subsidized federal crop insurance and other programs is voluntary.[3] Thus, each producer determines whether to participate in each program in the context of the farm's overall objective function. Typically, in a context in which attitudes toward risk have important effects on choices, and production and program participation decisions have intertemporal consequences, producers are assumed to maximize the expected utility of an appropriately discounted stream of profits over time. In the case of the CRP, the farm's participation decision is clearly intertemporal, as CRP contracts require multi-year and multi-harvest commitments of

[2] Goodwin and Smith (2003) estimated the effects of crop insurance programs on soil erosion in counties predominantly producing corn and soybeans, and found higher insurance participation increased erosion for corn but decreased erosion for soybeans. They suggest this "may reflect the fact that participation and the intensity of production of these crops appears to be higher in those parts of the country that experience higher soil erosion" (Goodwin and Smith 2003, p. 191).

[3] Occasionally, as in 1989 and 1995, participation in crop insurance has been mandatory for producers who participated in other programs (for details, see Goodwin and Smith 1995).

land resources to a specific use. Insurance program participation decisions are made on a year-to-year basis but, as Vercammen and van Kooten have noted, these decisions have dynamic consequences.

Both the CRP and federal crop insurance programs can also be viewed as tools for managing the risk associated with farm income volatility. In this context, the role of crop insurance is relatively transparent but, by providing farmers with a guaranteed stream of fixed payments, CRP contracts may stabilize farm income streams. Consequently, it is appropriate to think of participation in both programs as decisions being made in an intertemporal, dynamic context in which producers maximize the expected utility of profits.

Producers can be viewed as producing two types of output that generate revenues: crops and land allocated to the CRP. While the allocation of land to the CRP provides producers with a stream of revenues through the contract payments they receive, it also causes them to incur some one-time and some recurring costs, including the establishment and maintenance of appropriate cover. Likewise, crop production generates revenues and involves costs. The revenues associated with crop production include market receipts (price multiplied by output), government payments linked to crop production (such as payments under the Marketing Loan Program), and indemnities resulting from participation in crop insurance programs. Producers also incur costs in producing crops, including payments for physical inputs such as seed, fertilizer and other chemicals, hired labor, and the use of machinery and equipment—and crop insurance premiums.

Suppressing time subscripts, the single-period profit function for a representative producer producing a single composite crop within a county can be written as:

$$\Pi = pAY(\sigma^2, \lambda, z) + gA + r(T - A) - c(z) - \pi(\lambda), \tag{1}$$

where Π is profit, p is crop price, A is the area planted to the crop (measured in acres), Y is the farm's effective yield per acre, g denotes per acre government payments associated with crop production,[4] T is total land available for allocation to crop production or CRP, r is the CRP per acre payment to the producer, z is a measure of physical input use on the farm, $c(z)$ is the total cost of those inputs, π is the per acre premium rate for crop insurance, and λ is the level of insurance purchased.

Actual physical yield depends on the producer's use of physical inputs (z) and a random shock, represented by the variance of yields (σ^2), but the farmer may purchase insurance (λ) to offset physical yield shortfalls. Thus, as illustrated in (1), the producer's effective crop yield Y is a function of both σ^2 and λ, as well as z.[5] The per acre premium rate $\pi(\lambda)$ is assumed to be an increasing function of the level of insurance purchased by

[4] A reviewer noted government payments were not fixed on a per acre basis in 1982 or 1992. The structure of actual government payments depended on the crop. Many payments, for example, were functions of realized crop prices (e.g., deficiency payments and subsidies deriving from the Marketing Loan Program). At the county level, therefore, prior to 1996, total government payments received depended heavily on crop mix and market prices. From a profit-maximizing perspective in making production decisions, what matter are expectations about program benefits. Thus, to indicate the potential importance of government programs in output and resource use decisions in (1), we use a simplified representation of their potential effects through the term gA. A more detailed description of U.S. commodity programs and important changes in those programs during the period 1972 to 1996 are provided by, among others, Smith and Glauber.

[5] This specification implies crop insurance indemnities are paid in kind (for example, in bushels of wheat). In fact, farmers receive indemnity payments in dollars, but the representation in (1) is a useful abstraction that captures the intent of crop insurance to reduce the volatility of farm incomes.

the producer. The cost function associated with physical inputs, $c(z)$, can be viewed as including costs associated with crop production and related conservation compliance practices as well as inputs allocated to maintaining land in the CRP.

In an intertemporal context, the representative producer will select values for A, z, λ, and, by implication, $T-A$ to maximize the discounted present value of the expected utility of profits over the producer's relevant time horizon. Specifically, the objective function is designated by:

$$EV = \int_0^S \delta^t U(\Pi_t)\, dt, \tag{2}$$

where U is the utility function, E is the expectations operator, t denotes time, 0 is the current period in which decisions are being made, δ is the representative producer's rate of time preference, and S is the terminal point of the producer's planning horizon.

In this context, because land is a jointly allocable input, optimization by the producer implies the allocation of land to one enterprise, say the CRP, in any given period will be a function of the amount of land allocated to the other enterprise, say crops (see Shumway, Pope, and Nash; Lau; Lynne), which itself depends on the incentives for placing land in that use. Thus, the proportion of total land available for use allocated to the CRP depends inversely on expected government payments associated with crop production, participation in crop insurance programs (which is itself a function of premium rates and indemnities linked to government subsidies), and input choices which, in the case of fertilizers and other inputs, may also be related to crop insurance decisions (Smith and Goodwin; Babcock and Hennessy). Conservation practices, which likewise have implications for soil erosion, will also be affected by the mix of crops produced, input use, CRP choices, government payments,[6] and by the exogenous variables affecting those choices. Observed soil erosion rates will therefore be affected by CRP participation, conservation efforts, crop insurance participation, and input uses which are endogenous choices, as well as other, exogenous, variables.

The above theoretical considerations therefore suggest that an empirical model of the effects of participation in the CRP and federally subsidized crop insurance programs on soil erosion should account for endogeneity among those three variables and conservation efforts. In addition, chemical input choices are endogenous, and the effect of crop insurance participation on chemical use has been the subject of some debate. Thus we estimate a simultaneous system of five structural equations using county-level data in which soil erosion, CRP participation, participation in federal crop insurance programs, conservation effort, and fertilizer use are the endogenous variables. Exogenous variables include measures of the inherent characteristics of the soil and land class, the mix of crops and livestock operations, per acre government payments, yield risk, insurance premium rates, CRP rental rates and government cost-sharing, and the extensiveness of agriculture within the county. Although the theoretical model is specified in terms of individual farm decision making, county-level data are utilized to estimate the empirical models presented below because of the availability of countywide measures of soil erosion and other important variables.

[6] Eligibility for government payments involves cross-compliance requirements that encourage conservation practices, but government payments may also reduce pasture in counties through increased incentives for crop production. Thus, a priori, the effect of government payments on conservation practices is ambiguous.

Empirical Application

County-level data describing soil erosion, soil characteristics, conservation activities, and land-use patterns were collected for every U.S. county from the USDA's National Resources Inventory (NRI) database.[7] The NRI is a comprehensive survey of land characteristics, soil erosion, and land usage patterns. The survey was taken in 1982, 1987, and 1992. Data were collected corresponding to the period preceding the CRP (1982) and the period following most CRP enrollment (1992). The NRI contains expansion factors intended to allow aggregation to the county level. In particular, the sum of expansion factors corresponding to specific land uses must match the 1980 Census county-level land-use patterns. The sampling design for constructing the NRI data is discussed in detail by Nusser and Goebel. The analysis included 4,115 observations. Crop production patterns and crop yields were taken from unpublished USDA/National Agricultural Statistics Service (NASS) files.

Planted acreage yields for the 20 years preceding each observation year (1982 and 1992) were used to construct average yields and measures of yield risk (coefficients of variation) at the county level. Yields were detrended by regressing them on a quadratic time trend.[8] Costs of production and revenues from crops, livestock, and government payments were collected for each county from the U.S. Department of Commerce's Regional Economic Information System (REIS). CRP participation, program rental and cost-share payments, and disaster payments[9] were taken from unpublished USDA data. Similarly, premium payments and liability statistics for the U.S. federal crop insurance program were obtained from unpublished USDA Risk Management Agency data.

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[7] A small number of counties having no agricultural land, almost entirely federally owned, or for which relevant economic data were missing were omitted from the analysis. Wu cautions that the accuracy of NRI soil erosion measures at the county level may be questionable in some cases, and thus argues in favor of analysis at the major land resource area (MLRA) level, a multi-county geographic area. However, while there is possible measurement error in the NRI variables due to aggregation to the county level rather than the MLRA level, aggregating from the county level to the MLRA level also results in the potential for measurement error in other important variables such as crop insurance participation, yields, yield variances, and other government program expenditures. Based on these considerations, the county is utilized as the geographic unit of measurement for this study.

[8] In particular, detrended planted yields for each crop for which NASS collects data in each county were estimated using data for the period 1961 to 1992. Coefficients of variation (CVs) for each crop in each county, centered on predicted yield levels for 1992, were computed for 1982 using the residuals from the regressions for the preceding 20-year period 1961 to 1981. Similarly, CVs for 1992 were estimated using the residuals from the regressions for the preceding 20-year period 1971 to 1991. The centering was accomplished by adding residuals from each year back to the predicted value for each county in 1992. This adjustment and the use of the yield CV permits comparisons of yield risk in the two different time periods. Note that the use of the CV of yields as a measure of variability makes a scale adjustment for the mean effect. The countywide average CVs used in the regressions (for which results are reported in table 2) are weighted averages of the CVs for the individual crops, where the weights are crop shares of planted acres. Finally, in each county, crops with less than five yield observations for the preceding 20 years were dropped from the analysis. This led to some counties with limited yield data being dropped from the analysis and resulted in a total of 4,115 usable observations for the econometric analysis, of which 2,112 are for 1982, and 2,003 for 1992. Thus the same set of counties could not be utilized for each of the two observation years.

[9] Because comparable data for other years were not available, we utilize the county average of real disaster relief payments over the 1985–94 period, as compiled by the Environmental Working Group from unpublished USDA data, to represent the tendency for producers to expect ad hoc disaster assistance receipts in each county. A long-run average is required because of the random nature of disaster payments over time. Ex ante, producers do not know future realizations of disaster payments, and it is not our intention to attempt to model disaster payments as such. Rather, we hypothesize that disaster relief is largely county specific in nature, reflecting crop production patterns, regional risks, and cross-sectional differences in political support. We use the same disaster payments measure at the county level for each of the two observation years (1982 and 1992) because, as previously noted, the only data available are for the period 1985–94. Even though policy changes with respect to disaster assistance were implemented in principle (the Crop Insurance Reform Act of 1980 was supposed to remove the need for ad hoc disaster relief but was not successful in its objective), the variable used here still provides insights about regional differences in the allocation of disaster payments and can be viewed as an indicator of expectations with respect to such payments in both 1982 and 1992.

Soil erosion is measured using values from the universal soil loss equations for wind and water erosion. Soil characteristics considered in the analysis included the universal K-factor, a measure of the inherent erodibility of land, and the T-factor, a measure of the tolerance a particular plot of land has for erosion. Conservation applied to an individual plot is represented by the P-factor, a measure of the degree of conservation effort, where higher values indicate lower levels of conservation effort.[10] The NRI figures are county-level weighted averages of values collected from over one million plots nationwide (an average of more than 3,000 plots per county). The CRP enrollment and payment figures included enrollment through 1992. Eligibility for participation in the CRP was determined for individual plots using criteria values from the 1987 NRI survey. All financial variables were deflated using the producer price index for farm and processed food and feed products. Variable definitions and summary statistics are presented in table 1.

The model of CRP participation, crop insurance participation, and soil erosion includes five equations: CRP participation (as a proportion of total agricultural acres), soil loss, crop insurance participation, the conservation effort, and fertilizer usage. Modeling participation in the CRP is complicated by the fact that no program existed in 1982. CRP participation is thus zero in the first year of the sample (1982), but is endogenously determined with other variables in the second observation year (1992).[11] To account for this fact, in the estimation models, CRP participation was specified as being endogenous in 1992, but was exogenously fixed to be zero in 1982. This involved estimating the CRP participation reduced-form equation used to obtain instrumental variables only for 1992. The five-equation system was estimated using two-stage least squares.[12] Parameter estimates and summary statistics are reported in table 2.

An important econometric issue should be acknowledged before proceeding to the estimated model. CRP participation is a censored variable. In cases where no enrollments are observed, participation is censored at zero. This is, of course, only relevant in the portion of our data applying to 1992, since the CRP did not exist in 1982, and thus participation is exogenously fixed to be zero.

To address the potential for censoring in the CRP equation, a two-stage Tobit type of estimator was incorporated. Following the approach of Nelson and Olson, a first-stage Tobit model is estimated using all exogenous variables as instruments, and then the index implied by the structure of the model (i.e., the predicted values from the first-stage Tobit model) is used as a representation of the inclination to participate in the CRP. As Maddala (p. 198) has noted, derivation of the correct covariance matrix can be complex. Thus, a bootstrapping procedure is utilized whereby we resample with replacement from the estimation data and calculate measures of the variability of the estimates by considering the implied bootstrapped covariance terms. The bootstrapping approach uses 2,500 replications. Parameter estimates and standard errors are given by the mean and standard deviations of the 2,500 replicated parameters.

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[10] The P-factor represents the conservation effort on land and is defined as the ratio of soil loss with a given conservation practice (surface condition) to soil loss under standard cultivation without conservation measures (up- and downhill plowing). An absence of conservation measures implies a P-factor of one, while the presence of factors expected to completely eliminate soil loss implies a P-factor of zero. Of course, aggregation to the county level will yield values ranging between zero and one.

[11] An ex post determination of the effects of the CRP program on erosion requires observations in the period preceding the program.

[12] Three-stage least squares may offer efficiency gains. However, the covariance structure is complicated by the fact that CRP participation is exogenously fixed at zero for the first half of our sample.

Table 1. Variable Definitions and Summary Statistics

Variable	Definition	Mean / (Standard Deviation) 1982	1992	1982 and 1992
CRP Participation	Percentage of total agricultural acres enrolled in the CRP	—	3.970 (5.737)	1.932 (4.467)
Soil Loss	Estimated annual soil loss (tons/acre)	3.776 (4.270)	2.777 (2.932)	3.290 (3.713)
Insurance Participation	Ratio of insured to total crop acres	0.142 (0.156)	0.254 (0.209)	0.196 (0.192)
Conservation Effort	NRI P-factor rating of conservation effort	0.704 (0.279)	0.701 (0.279)	0.703 (0.279)
Fertilizer	Chemical and fertilizer expenditures per crop acre	0.072 (0.097)	0.063 (0.065)	0.082 (0.121)
Rental Rate	CRP rental rate ($/acre)	—	57.835 (15.802)	—
Cost Share	CRP cost share ($/acre)	—	42.447 (21.800)	—
Government Program Payments	Ratio of government payments received to total gross farm income	0.035 (0.050)	0.076 (0.073)	0.055 (0.066)
K-Factor	Universal K-factor (measure of inherent soil erodibility)	0.292 (0.069)	0.292 (0.069)	0.292 (0.069)
T-Factor	T-factor (measure of soil tolerance for erosion)	4.135 (0.690)	4.149 (0.680)	4.142 (0.685)
Disaster Payments	Ten-year (1985–1994) average disaster payment receipts in dollars per crop acre	5.843 (8.990)	7.306 (9.780)	6.555 (9.410)
Corn	Proportion of county's crop acreage planted in corn	0.316 (0.297)	0.344 (0.274)	0.330 (0.286)
Soybeans	Proportion of county's crop acreage planted in soybeans	0.256 (0.241)	0.227 (0.201)	0.242 (0.223)
Wheat	Proportion of county's crop acreage planted in wheat	0.282 (0.271)	0.251 (0.276)	0.267 (0.274)
Cotton	Proportion of county's crop acreage planted in cotton	0.034 (0.116)	0.056 (0.148)	0.045 (0.133)
Sorghum	Proportion of county's crop acreage planted in grain sorghum	0.058 (0.118)	0.045 (0.094)	0.052 (0.107)
Not Planted	Proportion of county's agricultural acreage not planted	0.634 (0.275)	0.655 (0.271)	0.644 (0.273)
Agricultural Intensity	Ratio of county's agricultural to nonagricultural acres	0.834 (0.156)	0.839 (0.147)	0.837 (0.151)
Land Classification	Proportion of agricultural land in USDA productivity classes 1 and 2	0.353 (0.239)	0.361 (0.240)	0.357 (0.239)
Premium Rate	Crop insurance premium rate ($ per hundred dollars of liability)	0.061 (0.026)	0.064 (0.029)	0.062 (0.028)
Yield Risk	Acreage-weighted average coefficient of variation for crop yields	25.592 (4.329)	22.137 (9.678)	23.910 (15.406)
Size	Total number of farm acres in county (hundred thousand acres)	0.553 (0.248)	0.421 (0.329)	0.427 (0.338)
Livestock	Ratio of livestock sales to total farm sales	0.539 (0.251)	0.535 (0.254)	0.539 (0.251)

Note: The total number of observations for the two periods is 4,115, with 1982 = 2,112 and 1992 = 2,003.

The model specification includes an interaction term between yield risk and premium rates. In the federal program, insurance premium rates are calculated using county-level loss histories over the preceding 20 years [see Goodwin (1994) for a detailed discussion of the federal rate-setting process]. Premium rates may not fully reflect an individual producer's risk, and so adverse selection may influence insurance demand. Therefore, an interaction term is included between yield risk and premium rates to allow for differentiated responses to premiums. Because the analysis is at the county level of aggregation, adverse selection arising from differences among producers within a county may not be fully captured in our specification. Fertilizer usage is measured as real expenditures on fertilizer and agricultural chemicals per crop acre. Fertilizer usage is related to insurance participation as well as to a number of variables representing crop mix and the agricultural structure of each county.

The implications of the parameter estimates (table 2) are as follows. As expected, CRP participation, measured as the percentage of total agricultural acres in each county enrolled in the program, is positively related to the CRP rental rate (*Rental Rate*), and the coefficient is significant at the 5% level. In contrast, the results show CRP participation is negatively related to the amount of cost sharing (*Cost Share*). The effect, though statistically significant, is very small. The *K-Factor*, representing a parcel of land's inherent erodibility, is significant and negatively related to participation. However, the *T-Factor*, which represents a land parcel's tolerance for erosion, is not significantly related to participation. This finding indicates participation may be lower in regions with land that is more sensitive to erosion. Though this result may appear to be an indication the program is not addressing erosion issues in those areas most sensitive to erosion, it may also be related to the fact that agriculture is naturally more concentrated in areas having more erodible land but also a higher tolerance to erosion. Such areas are cropped more intensively, and so the realized soil loss tends to be higher.[13] This result may also be consistent with claims by critics of the CRP that participation does not necessarily occur in those areas most sensitive to erosion.

Paradoxically, the results also indicate CRP participation is positively related to overall government payments (*Government Program Payments*). This result may reflect the influence of the cross-sectional nature of the data—i.e., government payments were relatively large in counties that produced program crops such as wheat, corn, and soybeans where CRP participation was also substantial.

The soil loss equation estimates indicate that the CRP has had a significant effect in reducing erosion in those counties where CRP participation has been high. In particular, they imply that a one-point increase in the percentage of total acres enrolled in the CRP would reduce erosion by an average of 0.28 tons per acre. However, the results also show some other government programs have had offsetting effects. Increases in direct government payments (measured as a proportion of farm revenues) have statistically significant and substantial positive effects on soil erosion. Specifically, the coefficient for *Government Program Payments* in the soil loss equation presented in table 2 implies that a one percentage point increase in the proportion of revenues generated by direct farm program payments would increase soil erosion by 0.135 tons per acre.[14]

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[13] The Pearson correlation coefficient between soil loss and the T-factor had a value of 0.1915, which was statistically significant.

[14] An alternative measure of government payments, the county average of the proportion of revenues provided over the preceding 10 years, was also incorporated in regressions not reported here. Parameter estimates obtained from that model were very similar to those reported in table 2.

Table 2. Bootstrapped Two-Stage Least Squares Parameter Estimates and Summary Statistics

	EQUATION				
Variable	CRP Participation (Tobit Model)	Soil Erosion	Insurance Participation	Conservation Effort	Fertilizer Usage
Intercept	2.439** (1.033)	-1.266** (0.334)	0.117** (0.039)	-0.201** (0.043)	0.202** (0.041)
CRP Participation	—	-0.279** (0.047)	—	-0.006** (0.003)	—
Insurance Participation	—	-1.925** (0.908)	—	—	-0.156** (0.022)
Conservation Effort	—	6.682** (0.255)	—	—	—
Fertilizer	—	—	-0.485** (0.210)	—	—
Rental Rate	0.020** (0.008)	—	—	—	—
Cost Share	-0.016** (0.005)	—	—	—	—
Government Program Payments	30.706** (2.714)	13.523** (2.852)	0.897** (0.087)	0.663** (0.134)	—
K-Factor	-3.678** (1.659)	—	—	1.376** (0.058)	-0.014 (0.019)
T-Factor	-0.053 (0.220)	—	—	0.113** (0.006)	—
Disaster Payments	—	-0.007 (0.005)	0.004** (0.001)	—	0.004** (0.001)
Corn	—	—	—	-0.059 (0.042)	-0.086** (0.041)
Soybeans	—	—	—	-0.372** (0.037)	-0.121** (0.038)
Wheat	—	—	—	0.054 (0.044)	-0.130** (0.045)
Cotton	—	—	—	-0.333** (0.064)	-0.117** (0.047)
Sorghum	—	—	—	0.287** (0.048)	-0.164** (0.036)
Not Planted	—	—	—	—	0.037** (0.006)
Agricultural Intensity	—	0.101 (0.407)	0.095** (0.023)	0.145** (0.031)	—
Land Classification	—	—	0.039** (0.014)	—	—
Premium Rate	—	—	-1.566** (0.147)	—	—
*Yield Risk * Premium Rate*	—	—	0.020** (0.003)	—	—
Size	—	—	0.102* (0.011)	—	0.017** (0.010)
Livestock	—	—	-0.062** (0.017)	-0.032 (0.020)	-0.082** (0.011)

Notes: Single and double asterisks (*) denote statistical significance at the 0.10 and 0.05 levels, respectively. Numbers in parentheses are bootstrapped standard errors.

In contrast, federally subsidized crop insurance programs appear to have little effect on soil erosion. While the coefficient on federal crop insurance program participation (*CRP Participation*) is statistically significant, its sign is negative. The implied effect, however, is small: a 1% increase in participation in insurance programs would lower soil erosion by only 0.02 tons per acre. This finding, which does *not* show that increased crop insurance participation increases soil erosion, runs counter to claims by critics of the crop insurance program who assert participation tends to substantially worsen soil erosion.

Estimating the joint effects of changes in the average levels of insurance participation, government payments, and CRP participation between 1982 and 1992 permits an evaluation of the relative effects of these programs on erosion.[15] Essentially, the results presented in table 2 establish that participation in crop insurance had only a very modest effect on soil erosion (as noted above, the estimated coefficient is in fact negative). Other government payments are a different story. Such payments increased from 3.5% to 7.6% between 1982 and 1992 (table 1). Using the parameter estimates reported in table 2, this implies erosion was increased by 0.55 tons per acre by other government payment programs. The model parameter estimates also indicate that the introduction of the CRP, which resulted in a participation rate of 3.64% of cropland acres by 1992, reduced average soil erosion by 1.02 tons per acre. These estimates suggest about half of the decrease in erosion brought about by participation in the CRP was offset by changes in direct government payment programs, while none was offset by increased erosion resulting from changes in federal crop insurance.

The results in table 2 also show disaster aid (*Disaster Payments*) had no statistically significant effect on soil erosion. As with crop insurance participation, this finding suggests disaster payments are not important determinants of soil erosion.[16]

One other variable, the conservation effort index (*Conservation Effort*), has a statistically significant positive effect on soil erosion. Given that a higher value for the conservation effort index denotes a lower level of conservation effort, this result indicates soil erosion is reduced by increased conservation efforts (i.e., lower values for the index imply lower levels of soil erosion). The intensity of agricultural activity in a particular county (*Agricultural Intensity*), measured as the ratio of the area of agricultural land to nonagricultural land within a county, also has a positive effect on observed levels of erosion, though this effect is not statistically significant.

The parameter estimates for the insurance participation equation (table 2) confirm several findings previously reported in the literature (Goodwin 1993; Smith and Baquet; Smith and Goodwin) that crop insurance participation is negatively affected by insurance premium rates, but responsiveness to changes in premium rates often declines as yield risk increases.[17] Likewise, in accord with results presented by Smith and

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[15] As correctly noted by a referee, one could model the changes in variables between the two years of our study (1982 and 1992). Because the Conservation Reserve Program did not exist in 1982, a model that evaluates the relevant relationships in both periods (with CRP participation exogenously fixed to be zero in 1982) was preferred, although differencing across time certainly is a reasonable alternative.

[16] As Goodwin and Smith (1995) have documented, one intention of the 1980 Federal Crop Insurance Act was to replace ad hoc disaster programs with an expanded federal crop insurance program. However, Congress was more than willing to supplement crop insurance with disaster aid when the farm sector in any given region experienced even moderately adverse production conditions. Ironically, because of several major drought years (1985, 1986, and 1988), federal disaster aid expenditures may have increased in the 1980s relative to the 1970s.

[17] Note that the marginal effect of an increase in premium rates depends on the premium coefficient, the value of the risk variable, and the coefficient attached to the risk-premium rate interaction term. This marginal effect, when estimated at the sample mean for the risk variable, is negative and statistically significant with an estimated value of -1.056 and a standard error of 0.146.

Goodwin, the estimates suggest the presence of an important moral hazard effect whereby farms with more insurance tend to use less fertilizer and vice versa (i.e., farms that apply a substantial amount of fertilizer and chemicals are less likely to insure). In the insurance participation equation, the coefficient for fertilizer use (*Fertilizer*) is negative and significant, indicating farms with lower per acre fertilizer use are more likely to participate in crop insurance programs, a finding similar to those reported by Babcock and Hennessy and by Smith and Goodwin. Furthermore, insurance participation has a strong negative and statistically significant effect on the use of fertilizer.

Based on other parameter estimates in the insurance participation equation (table 2), in counties where agricultural intensity is higher (*Agricultural Intensity*), the size of the agricultural sector is larger (*Size*, in terms of area), and a larger proportion of land is in higher productivity classes (*Land Classification*), insurance participation is also statistically significantly higher. This is perhaps partly because of networking externalities with respect to information among producers about crop insurance programs and economies of scale in the supply of crop insurance. In counties where disaster payments appear to be higher, crop insurance participation is also higher, most likely because these are also counties in which production risks are generally greater. In addition, crop producers who are more heavily diversified into livestock are less likely to buy crop insurance. Clearly, such diversification can lower the overall revenue risk of a farm and thus diminish incentives for buying crop insurance.

Adoption of conservation measures, as represented by lower values for the NRI P-factor rating of *Conservation Effort*, is negatively affected by government payments (the coefficient on direct *Government Program Payments* is positive and significant), perhaps reflecting greater incentives for more intensive cropping associated with higher levels of income supporting farm programs. Conservation efforts are also affected by a county's mix of crops. In particular, relatively lower conservation efforts appear to be practiced in counties in which greater proportions of the cropped area are planted to sorghum and lower proportions are planted to soybeans and cotton. Likewise, the omitted category of crops—consisting of a broad collection of all other minor crops—tends to exhibit less intensive application of conservation than is true for soybeans, cotton, and corn. Increased conservation efforts (*Conservation Effort*) are also negatively and significantly associated with increased agricultural intensity (*Agricultural Intensity*), but are positively and significantly affected by an increase in the share of total sales accounted for by livestock (*Livestock*). The latter result indicates pasture is a more conserving use of land than cropping.

Production practices, reflected in fertilizer and chemical use patterns (*Fertilizer*) (real expenditures per crop acre), are significantly affected by crop mix and, as discussed above, are inversely related to crop insurance participation. Relative to the default category consisting of all minor crops (which include commodities such as tobacco, peanuts, potatoes, and fruits and vegetables), corn, soybeans, cotton, wheat, and grain sorghum all tend to have lower levels of fertilizer and chemical usage. The results also reveal that corn production uses fertilizer and chemicals more intensively than soybeans, cotton, wheat, and grain sorghum. In counties with a substantial amount of acreage left unplanted (*Not Planted*), expenditures on fertilizer and chemicals for planted acres are much greater. This finding may reflect the fact that counties with more idle and fallow land are likely to be less productive and require more intensive use of inputs.

The above results have important implications for the realized impacts of the CRP and other government programs on soil erosion. The estimates confirm contentions that the CRP has significantly reduced soil erosion. In particular, the estimates suggest a reduction in annual soil loss by an average of about 1.02 tons per acre as a result of the program. At the same time, however, significant changes in government programs involving direct payments appear to have resulted in substantial increases in soil erosion. In particular, increases in the proportion of farm revenues resulting from government program payments between 1982 and 1992 were estimated to have increased erosion by about 0.55 tons per acre. Nevertheless, in contrast to the findings of some previous studies, changes in the federally subsidized crop insurance program were found to have very small effects on soil loss.

These results also have important implications for the design of future farm programs, including extensions to the existing Conservation Reserve Program. Critics of the CRP have pointed out that participation has not been entirely consistent with optimal reductions in erosion. The results of this analysis suggest an important element in the effectiveness of conservation programs such as the CRP is the interaction of other programs which may have effects on erosion that often are not considered. In particular, federal commodity programs intended to enhance the profitability of agricultural production will necessarily increase the profits foregone in participating in the CRP. To the extent these programs encourage production on erodible land, erosion will increase. Effective policy design and the attainment of soil erosion reduction goals must recognize this interdependence of farm programs.

Conclusions

This analysis has focused on an ex post evaluation of the effects of the CRP, federal crop insurance, and other government programs on soil erosion patterns through the United States. The study confirms the Conservation Reserve Program significantly reduced erosion in areas where farmers have participated. At the same time, however, the analysis reveals that while federal crop insurance and disaster relief programs appear to have had little impact on soil erosion, income supports which have encouraged production have had substantial effects. In particular, about half of the reduction in soil erosion attributable to CRP enrollment was offset by increased erosion induced by increases in income-supporting federal programs. For the most part, policy makers and previous research studies have paid only limited attention to interactions between different farm programs affecting soil erosion. Attention to the interaction among policies should be considered as future farm policies and conservation programs are contemplated and the effects of individual programs are evaluated.

The conclusions of our analysis may have important implications for current crop insurance and conservation policies. Our results suggest the Conservation Reserve Program has been effective in reducing erosion, despite income-supporting programs which tend to encourage production and thus potentially increase erosion. As noted above, risk management programs have been considerably expanded in recent years through the introduction of new products and substantially increased premium subsidies. Contrary to the concerns of many, our findings establish that one should not expect large (or perhaps even any) measurable increases in erosion as a result of increases in federally subsidized insurance participation.

Perhaps of greater concern are the direct price and income supports channeled through programs to producers. The 2002 Farm Bill has expanded this degree of support and has included counter-cyclical payments intended to formalize much of the ad hoc disaster relief realized in recent years. To the extent that farming practices are influenced by such payments, erosion may increase. However, the 2002 legislation also expanded Conservation Reserve Program provisions. Consequently, increased conservation efforts, including increased enrollment in the CRP, may temper any such effects.

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