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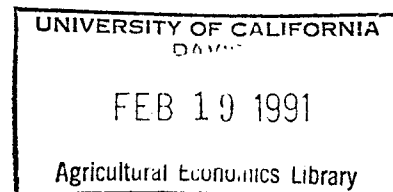
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Commodity Programs and the Internalization of Erosion Costs:

Do They Affect Crop Rotation Decisions?

by

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Soil erosion

### Abstract

Using stochastic dominance, this paper investigates the impact of commodity programs and internalization of erosion costs on crop rotation decisions. Commodity programs are found to shift decisions towards more erosive rotations. Internalization of erosion costs affect rotation decisions under historical market conditions but not under conditions of commodity program participation.

## Commodity Programs, Costs of Erosion, and Crop Rotation Decisions

A basic tenet of erosion economics is that commodity programs have a direct and indirect effect on erosion control decisions at the farm level [Batie; Osteen; Hyberg]. A direct incentive to erode is created by the fact that commodity programs are targeted towards erosive row crops [Osteen; Reichelderfer]. Batie further argues that commodity programs may also indirectly increase the level of erosion by encouraging specialization and large farms. While this thesis is broadly assumed and accepted, and has in fact been institutionalized with the cross-compliance requirements of the 1985 Food Security Act, there is little empirical evidence to support the conclusion that incentives created by farm commodity programs are strong enough to alter individual farmers' rotation and erosion decisions.

A second basic tenet of erosion economics is that erosion is characterized by intertemporal and spatial market failure [McConnell]. That is, farmers tend not to recognize the long-term effects of erosion on the productivity of the soil, and erosion is a considerable source of non-point pollution. While these unaccounted for costs are potentially quite considerable, it is not certain whether their internalization would lead farmers to adopt less erosive practices.

This paper has the following objectives: 1) To use stochastic dominance to provide evidence that commodity programs can affect ranking of crop rotations when the decision variables are short-term profit and risk; and, 2) To address the question of whether or not farmers would choose to adopt highly erosive rotations if future productivity losses

and off-site damages could be internalized into the farm's production costs.

The agricultural data for this analysis are taken from an eleven year crop rotation experiment (1977-1987) at the University of Wisconsin Research Station near Lancaster, Wisconsin. The study was conducted on a Rosetta (Fayette) silt-loam, representative of the forested unglaciated soils in Major Land Resource Area 105. This region is characterized by sloping to hilly uplands dissected by large and small tributaries of the Mississippi River, and has a high potential for reduced production resulting from erosion [Pierce, et al.]. Five different rotations were included in the experiment: continuous corn (CCCCC), corn-soybeans-corn-oats-alfalfa (CSbCOM), corn-corn-corn-alfalfa-alfalfa (CCCMM), corn-corn-oats-alfalfa-alfalfa (CCOMM), and continuous alfalfa (MMMMM). Each rotation was evaluated at four different nitrogen application rates per corn acre (0, 50, 100, and 200 pounds), resulting in a total of 17 different cropping systems.

#### Crop Rotations and Erosion

Past empirical studies of optimal choices of crop rotations have assumed that farmers base their decisions on an evaluation and comparison of each rotation's expected profit and risk (e.g. Brown; Zentner et al.). However, because rotations vary widely in rates of erosion, social efficiency criteria, if applied, suggests that farmers should also account for erosion related costs in selecting the optimal rotation.

Soil erosion has both on-site and off-site costs; in general, neither is recognized in the market. On-site costs of erosion are primarily associated with the long-term impact of soil loss on productivity potential. Excessive erosion diminishes this potential by reducing nutrient supply, water infiltration, and soil water holding capacity. This reduction in productivity potential is generally thought to be a non-linear function of soil depth, but is often modeled as a linear relationship over a specified range of soil depth or period of time. Aggregating the results from a number of soil loss studies, Lyles arrived at an average linear yield reduction per inch of top soil lost equal to 6.3 percent, with a standard deviation of 1.3 percent.

The off-site costs of soil erosion and erosion related pollutants are largely incurred by the public and can be separated into in-stream damages (biological impacts, recreational impacts, water storage damage, navigation and other "preservation values") and off-stream effects (flood damage, sediments in water conveyance, water treatment) [Clark et al.]. These costs are especially high in the lake states, a region characterized by high demand for in-stream and withdrawal uses of water. Disaggregating Conservation Foundation estimates of the national off-site costs of soil erosion, Ribaud estimated the value of off-site damages at \$2.87, in 1983 dollars, per ton of soil eroded in this region.

The Universal Soil Loss Equation (USLE) provides a method of estimating the expected level of soil erosion on a parcel of land [Wischmeier and Smith]. This equation calculates soil loss as a function of regional rainfall characteristics, erodibility of a

particular soil, field length and slope, erosion control practices, and cropping patterns. The estimated USLE values are shown in Table 1 for the five cropping rotations on a Rosetta silt-loam assuming an eight percent slope. In calculating the USLE values it is assumed crops are planted on the contour when appropriate, the tillage practice is fall chisel plow with 20 percent residue, and slope lengths are 200 feet.<sup>1</sup> Rates of erosion increase with the proportion of row crops in the rotation, and two of the rotations (CCCCC and CSbCOM) exceed the soil loss tolerance (T) value of 5 tons per acre even under the fairly stringent assumptions of contour strip cropping and chisel tillage.

#### Risk Analysis, Model and Data

Past rotation studies have used expected values (e.g. Stonehouse et al., 1988), EV analysis (e.g. McComb), safety fixed or maximin (e.g. Setia and Johnson), and stochastic dominance with respect to degree (e.g. Brown) to define and evaluate optimal crop rotations. This study uses stochastic dominance with respect to degree to compare the distributions of net returns for alternative rotations. Stochastic dominance was selected over methods that evaluated only mean and variance parameters because there is little a priori reason to believe that the distribution of net returns for each rotation differs only in location and scale parameters [Meyers; Brown; Zentner et al.]. Comparison of the estimates of the skewness of each rotation evaluated in this study lends support to this approach (Table 1). The choice of stochastic dominance with respect to degree, rather than with respect to function, was based on the hypothesis that risk aversion and

decreasing absolute risk aversion are appropriate characterizations of farmers' risk attitudes [Binswanger; Anderson et al.]. These characterizations are captured by second degree stochastic (SSD) and third degree stochastic (TSD), respectively. The only restriction for first degree stochastic dominance (FSD) is that agents have a positive marginal utility of income.

The production data were taken from an eleven year crop rotation experiment (1977-1987) at the University of Wisconsin Research Station near Lancaster, Wisconsin. The net returns per acre, summed over the  $k$  crops in the rotation ( $r$ ), for a non-participant in commodity programs can be expressed as, <sup>2</sup>

$$NR_{NP} = \sum_{i=1}^k Y_i * (MP_i - HC_i) - PHC_i - FC_r - EC_r \quad (1)$$

where  $Y_i$  is the actual yield,  $MP_i$  is the market price,  $HC_i$  are the harvest costs,  $PHC_i$  are the preharvest costs,  $FC_r$  are the fixed costs of the rotation, and  $EC_r$  are the erosion costs associated with the rotation. Harvest costs and preharvest costs are treated separately because harvest costs (e.g. drying) are stochastic, varying with yields. Fixed costs are included in the analysis based on the theory that wealth may affect the ranking of risky prospects [Sandmo].

The net returns per acre, summed over the  $k$  crops in the rotation, for a participant in commodity programs can be expressed as,

$$NR_p = \sum_{i=1}^k \{Y_i * [\text{Max}(MP_i, LR_i) - HC_i] - PHC_i + DFP_i\} \quad (2)$$

$$* (1 - SA_i) - FC_r - EC_r$$

$$DFP_i = Y_{Bi} * \text{Max}[TP_i - \text{Max}(MP_i, LR_i), 0] \quad (3)$$

where  $Y_i$ ,  $MP_i$ ,  $HC_i$ ,  $PHC_i$ ,  $FC_r$  and  $EC_r$  are defined in equation (1) and,



$LR_i$  is the loan rate,  $DFP_i$  are deficiency payments,  $SA_i$  is the set aside requirement,  $TP_i$  is the target price, and  $Y_{Bi}$  is the base yield. Calculations under the government support scenario were based on actual target prices, loan rates and set aside levels that existed each year for corn and oats<sup>3,4</sup>.

Actual input quantities for seeds, chemicals, and nitrogen fertilizer from the Lancaster experiment were used in the study. Potassium and phosphorous were assumed to be applied at maintenance levels corresponding to actual yields. Nominal market prices or indices, where appropriate, for the variable inputs and crop outputs were taken from USDA agricultural price summaries. Machinery costs were completed under the assumption of five year old equipment for a four hundred acre farm. Land and management were assumed to be residual claimants. Net returns were indexed with the consumer price index to 1983 values.

Costs of erosion are non-stochastic and calculated in the following manner. Future productivity losses are expressed in 'corn equivalents'. That is, the value of a ton of soil lost is the product of the change in the soil's capacity to produce corn and corn price. These losses are evaluated under the following assumptions: corn productivity loss is linear and cumulative at a rate of 6.3 percent per inch of topsoil lost, one acre inch of soil weighs 166 tons, base corn yields were 125 bushels per acre, corn price is \$2.50/bu., productivity losses are discounted and expressed as an annualized value, and all losses are compared to a zero erosion situation. Off-site costs are included in the analysis using Ribaud's estimate of \$2.87 (\$1983) per ton of soil eroded.

## Results

The mean, variance and relative skewness of each cropping system are presented in Table 1. Expected returns are increased and variance of returns are decreased by participation in commodity programs. Changes in the relative skewness indicate that the truncation of the price distribution attributed to commodity programs does not necessarily translate to a similar truncation in net returns. In fact, it appears that participation in commodity programs may shift the mass function to the left.

The stochastic efficiency sets under the alternative assumptions of historical market and commodity program participation are presented in Table 2. Each column is subdivided into three blocks corresponding to (1) 'private and short-term' rankings of rotations without consideration for off-site and on-site costs of erosion, (2) a twenty year time horizon when erosion costs are included as a factor of production, and (3) a forty year time horizon where erosion costs are included as a factor of production. The two latter blocks also include separate analyses for two and four percent real discount rates.

In the historic market scenario, the second and third degree efficiency sets include CCCCC, CCOMM, and MMMMM. This suggests that, under the given assumptions, less erosive crops are competitive with continuous corn. However, if erosion costs are included as factors of production, then the second and third degree efficiency sets are reduced to only continuous alfalfa for all discount rates and time frames. Thus, under market conditions, internalizing erosion costs as factors of

production do appear to have an impact on the efficiency set in favor of less erosive crop rotations.

The results are quite different in the commodity program scenario. Under the private and short-term assumptions continuous corn is FSD, SSD and TSD over all other rotations. For a twenty year time horizon with erosion costs included, continuous corn remains SSD and TSD. Only when a two percent (low) discount rate is assumed over a forty year (long) time horizon does a crop rotation with erosion less than the T value enter into the second and third degree stochastic efficiency set.

A comparison of the two columns demonstrates that commodity programs strongly affect the optimum selection of rotations even when erosion costs are included as factors of production. Under market conditions the evidence suggests that internalizing the costs of erosion will induce some farmers to adopt least erosive rotations. In contrast, commodity programs appear to create financial incentives to adopt more erosive rotations that are only offset by erosion costs when lengthy planning horizons and low discount rates are assumed. This result is stronger than the widely stated assertion that commodity programs create an incentive to erode.

#### Summary and Conclusions

Using stochastic dominance with respect to degree and eleven years of experimental farm data on 17 cropping systems ranging from continuous corn to continuous alfalfa, this paper investigated the impacts of commodity programs on optimal rotation and erosion decisions. Not surprisingly, it was determined that commodity programs do appear to

alter the choice of the optimal rotation for farmers that are risk averse and decreasingly absolute risk averse. Under the assumption of historic market conditions (without commodity programs) it was found that less erosive rotations such as continuous alfalfa and corn-corn-oats-alfalfa-alfalfa appear to be competitive with highly erosive continuous corn even when erosion costs are not internalized. In contrast, highly erosive continuous corn was clearly the optimal rotation for farmers participating in commodity programs. Such a result has been widely hypothesized and has gained apparent acceptance through recent cross-compliance legislation. The implication of this analysis is that changes need to be made in the structure of commodity programs if society is to achieve the objective of reducing erosion to an acceptable level. Towards this goal, cross-compliance may be a viable option.

A more interesting result is that continuous corn remains the optimal rotation for program participants even when erosion costs are taken into consideration. If this is true, programs that educate farmers about the costs of erosion will not affect the optimal rotation decisions of farmers that participate in commodity programs. The same is true for programs that place a tax on erosion equal to the off-site costs per ton of soil eroded. In either case, it is unlikely that the internalization of erosion costs will cause a farmer to choose a less erosive rotation. This adds further support to the conclusion that if commodity programs are to be maintained, cross-compliance or some other limit on erosion levels may be the only option for achieving acceptable levels of erosion.

Table 1: USLE, Mean, Variance and Skewness for Rotations under  
Historical Market and Government Commodity Programs

Rotation	USLE (T/A)	N	Historic Market				Gov. Comm. Programs		
			Rot. No.	mean	var	skew	mean	var	skew
CGCCC	7.9	0	1	-44.21	2292	0.71	-10.88	1205	0.03
		50	2	57.43	6278	0.44	91.41	1904	-0.12
		100	3	80.75	9758	0.52	115.16	3306	0.44
		200	4	83.77	10341	0.36	113.21	3973	0.19
CSbCOM	6.8	0	5	2.03	4148	0.15	16.81	2384	-0.33
		50	6	11.69	3791	0.08	26.60	1938	-0.22
		100	7	16.69	4370	0.12	31.01	1811	-0.64
		200	8	14.37	4324	0.00	30.42	2214	-0.40
CCMM	2.4	0	9	-1.19	3974	0.19	19.13	1684	-0.37
		50	10	15.86	3922	0.04	46.57	1862	-0.55
		100	11	23.97	5010	0.16	42.85	1442	-1.24
		200	12	5.27	4730	0.19	29.49	1764	-0.34
CCOMM	2.0	0	13	35.27	2542	-0.25	50.13	1053	-0.69
		50	14	49.15	2565	-0.36	64.19	932	-0.93
		100	15	46.67	2996	-0.25	62.20	1219	-0.95
		200	16	36.66	2419	-0.24	53.29	904	-0.47
MMMMM	0.5	0	17	61.29	2952	-0.15	n.a.	n.a.	n.a.

Notes: USLE assumptions-8 percent 200 ft. slope, contour strip cropping,  
20 percent residue cover, fall chisel plow. T value is 5 tons/acre.

Skewness calculated by skew =  $\frac{E[x-E(x)]^3}{\text{Var}^{1.5}}$

Var<sup>1.5</sup>

Table 2: Stochastic Dominance Results, Efficiency Sets

		Market	Government
Private, Short-term			
	FSD	2,3,4,14,15,17	3,4
	SSD	3,14,17	3,4
	TSD	3,14,17	3,4
20 years			
2 % Interest	FSD	2,3,4,14,17	3,4,17
	SSD	17	3,4
	TSD	17	3,4
4 % Interest	FSD	2,3,4,11,14,17	3,4,17
	SSD	17	3,4
	TSD	17	3,4
40 years			
2 % Interest	FSD	2,3,4,14,17	3,4,14,17
	SSD	17	3,4,14
	TSD	17	3,4,14
4 % Interest	FSD	2,3,4,11,14,17	3,4,14,17
	SSD	17	3,4,14
	TSD	17	3,4

Notes: FSD, SSD, TSD correspond to first, second and third degree stochastic dominance, respectively. Rotation numbers correspond to definitions in Table 2. Efficiency sets consist of those rotations that are not dominated by other rotations.

Notes:

1. The selection of the parameters as representative of the region was based on discussions with extension agents at the Soil Conservation Service Office in Madison, Wisconsin. USLE estimates of erosion rates are very sensitive to changes in parameters, and selection of alternate parameters may affect the results of this study. For example, the assumption of up and down hill planting rather than contour farming would double the estimates presented in Table 1.
2. The notation used here closely follows Kramer and Pope.
3. For a further discussion of government policy during this period and its relation to the crops in this study, refer to McComb.
4. Although loan rates did exist for soybeans during the 1977-87 interval it is assumed that these loan rates had very little effect on returns and variation in returns over the eleven year study. Loan rates exceeded prices for only three of the eleven years, and the differentials were not dramatically different in those years. Again, refer to McComb for a further discussion.

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