Slippage or Spurious Correlation: An analysis of the Conservation Reserve Program

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Abstract: Previous research finds that some environmental benefits stemming from the Conservation Reserve Program (CRP) are offset by slippage: farmers simply plant more acreage to substitute for land that was idled. Our analysis shows that previous slippage estimates likely stem from spurious correlation. Most land retired under CRP is of lower-than-average quality. Due to the marginal economic viability of these lands they also are more likely to move both into and out of agricultural production. CRP enrollments therefore will be spatially correlated with non-cropland to cropland conversions even if no slippage is present. Using time-series rather than cross-sectional variation in CRP enrollments, we obtain new slippage estimates that control for land heterogeneity using fixed and random effects. Contrary to previous findings, we find little or no slippage in the form of new plantings of commodity crops. Moderate CRP-induced plantings take the form of new hay plantings that arise mostly from converted pastureland, but these conversions create little in the way of unintended environmental damages. Total commodity production is reduced by less than the proportion of acres idled because land retired is of lower-than-average quality and because it sometimes stood fallow or in hay before it was enrolled in CRP. Aside from its policy implications, our study demonstrates the crucial importance of accounting for spatial heterogeneity in empirical research.

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1. Introduction

There are two reasons economics has been decried a "dismal science," one born of pessimism, the other of skepticism. The pessimism stems from early classicists Malthus and Ricardo who hailed that technological change cannot forever outstrip population growth so that diminishing marginal returns and limited natural resources will one day relegate the human condition to a dismal state of welfare near subsistence. Skepticism (and sometimes-wise reflection) stems from economists' penchant for pointing out unintended and sometimes dismal consequences of governmental policies. In this paper we confront skepticism about the efficacy of a conservation policy that targets conservation. Specifically, our topic pertains to the efficacy (and possible unintended consequences) of the Conservation Reserve Program (CRP), a governmental program that pays farmers nearly $2 billion per year to idle cropland so as to reduce soil and wind erosion, improve water quality, and create wildlife habitat. In accordance with previous research, we ascribe the term "slippage" to a certain unintended consequences that stem from acreage reduction programs, such as CRP.

Slippage refers to the phenomenon that total production decreases proportionately less than the number of acres idled by land retirement programs (Wu, 2000; Hoag, et. al., 1993; Love and Foster, 1990; Gardner, 1987; Rausser, et. al., 1984). Slippage stems from four potential sources: (1) a program idles land of lower-than-average quality; (2) the program causes more intensive farming (and higher yields) on non-idled land; (3) new cropland is substituted for land idled by the program; and (4) land idled by the program formerly resided within a rotation that was sometimes fallow. We subsequently refer to these sources as slippage Types 1-4. Although the first slippage type has been well established (Hoag, et al, Love and Foster, Weisgerber, Gardner (p.60), and Tweeten (p. 315)), the other causes are less studied. We focus on Type 3 slippage because it pertains especially to the environmental benefits engendered by acreage reduction programs—a lot of it implies smaller environmental benefits than these programs purport. We also touch on the Types 1 and 4, as these relate to our measurement of Type 3 slippage.

Our work builds on research by Wu (2000), that estimated the environmental consequences stemming from CRP-induced Type 3 slippage. Using 1982-1992 NRI data he estimated that for every 100 acres retired under the program, twenty non-cropland acres were converted to cropland that would not have been converted otherwise, and thereby offset between nine and fourteen percent of the soil and wind erosion benefits said to be engendered by the program. For the Corn Belt states he reported slippage in excess of 30 acres for every 100 acres retired.

In this paper we reexamine these previous estimates and create new ones based on a different data and methods that bear notably different results. The paper proceeds as follows. In the first two sections we define slippage and develop a theoretically-based approximation of Type 3 slippage. In section 4 we present evidence that previous findings are biased due to omitted land quality variables. A spurious cross-sectional correlation between CRP enrollments and land conversions arises naturally when both are correlated with land quality or other omitted variables. In section 5 we present estimates based on time-series rather than cross-sectional variation in CRP enrollments. These estimates control for land heterogeneity using county fixed and random effects. Contrary to previous findings, we find little or no slippage in the form of new plantings of commodity crops. Moderate CRP-induced plantings take the form of new hay plantings that arise mostly from converted pastureland. These conversions, however, cause little in the way of unintended environmental damages. Total commodity production is reduced by less than the proportion of acres idled because land retired is of lower-than-average quality, and because the land retired often stood fallow or in hay before it was enrolled in CRP. That is, slippage results mostly from Types 1 and 4. Section 6 concludes.

2. The Sources of Slippage

Total domestic production (Q_0) eqauls the product of yield (y) and land area (l) summed over all land types harvested, $Q_0 = \Sigma\, y_i l_i(\mathbf{p})$, where i indexes land types and the amount cultivated of each type depends on a vector of prices and other state variables ($\mathbf{p}$) that guide optimal planting decisions. Yields differ across land types but are assumed exogenous within land units. CRP retires a proportion (1-z_i) of each land unit to give a new production level $Q_1 = \Sigma\, z_i y_i l_i(\mathbf{p'})$. The proportion of total acreage retired under CRP equals $\frac{\sum (1-z_i) l_i}{\sum l_i}$ and the associated proportional production change equals $\frac{Q_1 - Q_0}{Q_0}$. The difference between these two quantities constitutes slippage.

$$
\begin{aligned}
\text{Slippage} &= \frac{\sum (1\text{-z}_i) l_i}{\sum l_i} - \frac{Q_1 - Q_0}{Q_0} \\
&\approx \frac{\sum (1\text{-z}_i) l_i}{\sum l_i} - \frac{\sum (1\text{-z}_i) y_i l_i}{\sum y_i l_i} + \frac{\sum (1\text{-z}_i) y_i l_i D_{\mathbf{p}}(l_i)\Delta\mathbf{p}}{\sum y_i l_i}. \qquad (1)
\end{aligned}
$$

The expression $D_{\mathbf{p}}(l_i)$ denotes the directional derivative of $l_i(\mathbf{p})$. Type 1 slippage is comprised of the first two terms of equation 1. Notice that when yields are the same across land types, yields drop out of second term and the first two terms sum to zero. If yields on retired land units are smaller on average than those on remaining lands, then Type 1 slippage is positive.

Because we assume within-land-type yields are impervious to prices and other state variables, equation 1 cannot inform Type 2 slippage. Our own (simple) analysis using county level crop yields shows no substantive correlation between forecast prices and county-level yields. If Type 2 slippage exists then our data cannot detect it. We leave a more thorough analysis of Type 2 slippage for future work.

The third term comprises Type 3 slippage. If acreage retirement does not change the price-state vector then $\Delta\mathbf{p}$ and the third term both equal zero. If reduced supply caused by land retirement increases prices and thereby induces farmers to bring more land into production $\left(D_{\mathbf{p}}(l_i)\Delta\mathbf{p} > 0\right)$ then the third term is positive.

Finally, Type 4 "slippage" may be more accurately described as mis-measurement of CRP-induced reduction of plantings. If a unit of land is cropped an average of two of every five years (usually the minimum required to qualify for CRP) then enrollment of five acres reduces subsequent plantings by an average of just two acres. Given current CRP guidelines this kind of "slippage" could be substantial, but it does not imply that CRP causes unintended environmental damages.

3. Theoretical Basis of Type 3 Slippage

Our next objective is to derive a theoretically-based approximation of Type 3 slippage in order to obtain a better understanding of the fundamental forces that determine its size. With this goal in mind, we simplify the analysis by assuming that for each land type i there exists a supply curve, $l_i(P)$, that depends on a scalar price P that aggregates the marginal revenues from all profitable cropping activities. Similarly, we assume there exists a derived world demand for cropland, $Q^d(P)$. Both demand and supply should be more inelastic as compared to individual commodities because substitution effects have been subsumed into a composite commodity, cropland. Under these assumptions, a constant elasticity of derived world cropland demand (ε^d), constant supply elasticities (ε^s) for all land types (both foreign and domestic), and zero slippage of Types 1,2, and 4, then Type 3 slippage equals:

$$v \frac{v(1-z)-1}{\varepsilon^d / \varepsilon^s + v(1-z)-1}, \qquad (2)$$

where v denotes the domestic share of world production.

We derived equation 2 using the following definitions:

Q_0 domestic quantity land supplied prior to CRP

Q_W world quantity of land supplied prior to CRP

Q'_W world quantity of land supplied after CRP: $Q'_W = \{Q_0/v - (1\text{-}z)Q_0 + S\}$

S difference between CRP land retired and the world-wide difference in land planted: $S = (1\text{-}z)Q_0 - (Q_W - Q'_W)$

$\frac{vS}{(1-z)Q_0}$ domestic Type 3 slippage as a proportion of land retired under CRP.

$\%\Delta Q$ percent change in world-wide acreage planted: $\%\Delta Q = \frac{Q'_W - Q_W}{Q_W}$

$\%\Delta P$ percent change in price associated with $\%\Delta Q$

The three quantities $\%\Delta Q$, $\%\Delta P$, and S are found by solving the following three equations:

(world demand) $$\%\Delta Q = \%\Delta P \varepsilon^d \qquad (3)$$

(supply response) $$S = \{Q_0/v - (1\text{-}z)Q_0\}\varepsilon^s \%\Delta P \qquad (4)$$

(CRP less supply response) $$\%\Delta Q = -\frac{(1-z)Q_0 + S}{Q_0 / v} = \frac{vS}{Q_0} - v(1-z) \qquad (5)$$

Equation 2 is derived by substituting equation (3) into equation (5) and solving for %Δ*P*, then substituting the solution for %Δ*P* into equation (4), and solving for *S*. Simplification gives

$$S = (1-z)Q_0 \frac{v(1-z)-1}{\varepsilon^d / \varepsilon^s + v(1-z)-1}$$

Type 3 slippage $\left(\frac{vS}{(1-z)Q_0}\right)$ therefore equals the expression in equation 2. If other slippage types (Types 1,2 or 4) are also present, then these reduce the amount of Type 3 slippage, because CRP then reduces world production by an amount smaller than (1-*z*)Q_0.

Equation 2 provides a useful way to obtain benchmarks for Type 3 slippage, the primary focus of this paper. The expression is intuitive: it says that slippage is larger the greater the domestic share of world production, the smaller the world demand elasticity, and the greater the supply elasticity. Holding all else the same, slippage tends toward zero as the domestic share of world production tends to zero, as the world demand elasticity tends toward infinity, or the supply elasticity tends toward zero. A rough benchmark is derived by assuming $\varepsilon^s = -\varepsilon^d$. In this case, slippage can be no greater than *v*/2. Slippage is largest (= *v*) when demand is perfectly inelastic (ε^d = 0) or supply infinitely elastic (ε^s = infinity). For example, if $\varepsilon^s = -\varepsilon^d$, CRP retires five percent of US land, and the US provides about 20 percent of world production, then equation 2 implies Type 3 slippage of about 9.9 percent—about a one-half percent of the five percent retired would be offset by new plantings. If retired land were of lower than average quality and/or not perpetually cropped with major commodities, then Type 3 slippage would be proportionately smaller.[1]

4. Previous Slippage Estimates and Spurious Correlation

In this section we replicate Wu's Type 3 slippage estimates and show how they may be biased upward due to spurious correlation. These slippage estimates were based on data from the National Resources Inventory (NRI). We begin by explaining the content and nature of these data.

The NRI is a survey of land use conducted every five years by the Natural Resource Conservation Service (NRCS). This survey is used to track land use and the condition of the nation's soil, water, and habitat resources at over 800,000 sites selected from a nation-wide geographically stratified random sample. Broad characteristics of the each parcel are collected along with detailed information on a cluster of two to three randomly chosen points at each site. The sites and points have remained roughly constant since 1982 so that changes at particular sites can be tracked over time. The sample is large enough to draw reliable population inferences at approximately the crop-district level (about 10 counties), but have large standard errors at higher resolutions.

The strengths of the NRI data set are that it contains detailed information about land quality and that it mostly surveys the same sites over the years. Its weaknesses include its

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[1] Given crop histories of CRP lands prior retirement (reported in Wu as, 19.4 percent, 10.8 percent, and 27.9 percent planted to corn, soybeans, and wheat respectively), highly inelastic estimated supply elasticities (Lin, et. al.), and past estimates of Type 1 slippage, this "back-of-the-envelope" approximation is a somewhat conservative (high) one.

infrequency and inability to draw inferences at a high geographic resolution. Also, in 1987 only about a third of the sites were sampled—the unsampled points were interpolated, mostly from previous and subsequent survey years and alternative data sources. So population inferences about 1987 land use are valid only at the state level.

Using the 1982 and 1992 NRI data, Wu estimated the amount of land in each crop district that was converted from non-cropland to cropland (denoted NC for 'new cropland') and the annual erosion reduction per CRP acre (a land quality proxy). He merged this data with CRP enrollment data obtained from the Economic Research Service (USDA-ERS). Although the NRI also collects data about CRP enrollments, the sampling error would bias regression estimates downward in magnitude. Other variables included in Wu's analysis were the corn base acres retired per CRP acre, wheat base acres per CRP acre, the percent change in population, and each district's total land area. His slippage estimates were based on a regression of NC acres against CRP acres and the other variables (denoted by the vector **X**). Denoting crop districts by the subscript *i*, the model for this regression is

$$NC_i = \alpha + \beta CRP_i + \mathrm{X}_i \gamma + \varepsilon_i. \quad (3)$$

Both NC and CRP acres were scaled as a proportion of each district's total land area. Our replication of this regression is reported in the first column of Table 1. Our estimates and standard errors closely match Wu's, although there are slight differences because we use an updated 1997 version of the NRI and account for the small amount of land that dropped out of CRP. We also report similar estimates based on the 1992-1997 NRI and associated CRP enrollment changes.

Our main concern with these regressions pertains to missing-variables bias. The source of slippage identification is from cross-sectional variation in CRP enrollments, which are logically correlated with land quality and other geographical characteristics. It is plausible that the number of CRP acres retired is therefore correlated with land quality and other characteristics that determine land use. Our concern is corroborated with data from NRI that show a strong statistical correlation between the amount of land converted from non-cropland to cropland and its opposite, the amount moving from cropland to non-cropland. This land use pattern makes sense: in high-land-quality areas land is usually cropped and rarely moves between non-cropland and cropland. In low-land-quality areas, land is marginally viable as cropland and more likely to move both into and out of production, often for idiosyncratic reasons. Low quality land is also more likely to be enrolled in CRP. So if one regresses conversion from non-cropland to cropland against CRP enrollments, one should find a positive relationship even if Type 3 slippage equals zero—it is a statistical relationship that does not imply causation. Figure 2 illustrates how this spurious correlation arises.

However, it could be that covariates besides CRP (erosion, corn base acres, and wheat base acres) adequately control for land quality. A simple way to check the adequacy of these controls is to estimate a regression identical to equation 3 except with the dependent variable replaced with its opposite: land converted to non-cropland from cropland (excluding CRP enrollments—denoted XC for ‘exiting cropland’). The model for this auxiliary regression is given by

$$XC_i = \alpha' + \beta'\mathrm{CRP}_i + X_i\gamma' + \varepsilon_i' \tag{4}$$

If CRP enrollment predicts both entry and exit of cropland then it suggests that both relationships are spurious. These results, also reported in Table 1, suggest spurious correlation. Taken at face value, the covariates explain exiting cropland about as well as entering cropland and imply that CRP causes *negative* slippage of about 12 of every 100 acres in the Corn Belt region.

It may seem appropriate to simply sum the coefficients of the two regressions and derive net slippage. This calculation changes the slippage estimates to about 17, 11, and 22 percent for the Corn Belt, Lake States, and Northern Plains, respectively. Although the northern plains estimate is larger, the overall slippage estimate drops as compared to Wu's estimates. It seems more likely, however, that both regressions are biased due to missing land quality and geographical factors correlated with CRP enrollments, so such an interpretation is misplaced.

Heterogeneous land quality biases cross-sectional Type 3 slippage estimates but also instigates Type 1 slippage: because farmers are more likely to retire lower-than-average quality land, taken from a national perspective, average yields increase. Evidence of this kind of slippage is provided in Table 2. The table shows the estimated average yields for the major field crops on CRP land as compared to nationwide average yields. These estimates were based on county-level yields, not field-level yields, so it is likely that they underestimate Type 1 slippage. That is, they account for slippage stemming from between-county differences in CRP enrollments and land quality, but fail to account for within-county differences. Type 1 slippage is largest for corn and least for wheat acreage.

5. Alternative Slippage Estimates

In this section we present slippage from alternative data and regressions that use time-series rather than cross-sectional variation in CRP enrollments as a source of identification. This approach takes advantage of the fact that CRP enrollments vary considerably from year to year; so we may identify slippage by examining cropland changes within regions as they relate to changes in enrollment over time (see Table 3). This approach contrasts with the estimates in the last section that are based on differences in CRP enrollment across crop districts. The NRI data are not suitable for estimating slippage in this way because it only reports land use in five-year increments (or, due to the reduced sample size in 1987, just a ten-year increment between 1982 and 1992). Rather, we use year-to-year changes in acreage plantings as reported from the National Agricultural Statistical Service (NASS).

Like the NRI data, the NASS data also have strengths and weaknesses. Its strength is its relative precision at the county level and the fact that it reports plantings and harvests of major crops in every year. Its weaknesses are that it does not track individual land parcels and cannot detect double cropping, and therefore is not an exhaustive account of land use. However, double cropping is rare (about 12 million of 312 million acres harvested nationwide (USDA-ERS)), and the major field crops we examine account for the great majority of cropland use, especially in areas with the greatest CRP enrollments.

We measure land use in a given county-year by the sum of harvested acreage for barley, corn (grain), cotton, hay, oats, rice, sorghum (grain), soybeans, and wheat. We also provide estimates based on planted acreage of these crops minus hay. These crops collectively account for over 90 percent of the nation's cropland. The data span the years from 1987 to 1997 and include 2,547 counties. Although there is some measurement error associated with these estimates, due both to sampling error and the non-exhaustive account of land use, these should not bias our results or standard errors unless the year-to-year changes in these errors are systematically correlated with CRP enrollments, which seems unlikely. Slippage estimates based on harvested land will be biased upward to the extent that planted acreage is not subsequently harvested.

Our CRP data are derived from actual county-level enrollment data obtained from the Kansas City office of NASS and are like those used by Wu, with two differences. First, our data are updated with enrollments since 1992; second, our data take into account land that was enrolled in CRP but later dropped out of the program.

Each estimate is based on a special case of following model:

$$\Delta C_{\mathrm{it}} = \alpha_i + \beta \Delta CRP_{\mathrm{it}} + \gamma_{\mathrm{i}} \Delta CRP_{\mathrm{it}} + \varepsilon_{it}\,, \qquad (5)$$

where ΔC_{it} measures county i's net change in total cropland between years t and t-1 and ΔCRP_{it} measures the associated change in CRP enrollments. The parameter β measures the average change in acres harvested (or planted) for every acre enrolled in CRP; α_i measures county i's trend in land use, and γ_i measures the difference between county i's CRP-induced acreage change as compared to the average induced acreage change. In all regressions both ΔC_{it} and ΔCRP_{it} are divided by a county-level "base" acreage estimate. For each county this base value equals the largest observed value (between 1987 and 1997) of NASS harvested acreage plus CRP acreage, census-reported harvested acreage plus CRP acreage, or NASS planted acreage plus CRP acreage.[2]

This model predicts net CRP-induced retirement rather than CRP-induced slippage. The equivalency between the two approaches is portrayed by the identity $\Delta C_{\mathrm{it}} = \Delta CRP_{it} + NC_{it} - XC_{it}$.

[2] Due to sampling error and because harvested acreage includes hay whereas planted acreage does not, it is possible for any of these three variables to be largest.

The substantive difference between our model and those estimated in last section is that we effectively sum NC_{it} and $-XC_{it}$ to obtain 'net slippage', and more importantly, we include eleven years for each county rather just single difference between two years for 128 crop districts. Having multiple time differences for each county has several benefits. Aggregate changes in land use that cause different land-use changes in different regions (for instance, due to variable land quality) will tend to average out over time. This should reduce spurious correlation of the kind described in the last section. Furthermore, we can identify trends in cropland use, both in aggregate and for specific counties, which controls for entirely for spatial heterogeneity of land. The models in the last section could not include crop-district-level trends because only a single difference was available for each crop district—the source of identification was restricted to cross-sectional differences in CRP enrollment. With our panel data we can restrict the source of identification to within region differences in CRP enrollments over time.

Slippage estimates based on our county-level panel data set are reported in Table 4. The OLS estimates assume that α_i is the same for all counties and all γ_i equal zero. The fixed-effects model relaxes the assumption of homogeneous county-level trends (by estimating a different α_i for each county). We remove these fixed effects by simply removing the average values of the dependent and independent variables for each county. This model effectively controls for all county differences, obviating the need for geographically-varying covariates to serve as controls. The mixed-effects model allows for a correlation between CRP-induced cropping changes and the county level trend. In the mixed effects model, α_i and γ_i are treated as random effects with their mean values (the intercept and β) reported as fixed effects. That is, the model allows both cropland trends and the net retirement rate (or slippage rate) to be different for different counties.

Lastly, the table reports results from a robust regression, iterated re-weighted least squares, that shows that the OLS results are not fabricated by extreme observations.[3]

The first column of Table 4 reports results when total NASS harvested acreage serves as the dependent variable; the second column reports results when total NASS planted acreage serves as the dependent variable. The differences between the two dependent variables are that harvested acreage includes hay, does not include acreage planted that was later not harvested, and sampling errors. Both values therefore underestimate total cropland and should therefore underestimate land retirement, because some land retired under CRP may not be embodied in our acreage estimate. Harvested acreage underestimates cropland because it does not include all crops planted; our planted acreage does not include hay. Despite these shortcomings, the results prove to be informative.

The estimated values for β are similar across all models for both dependent variables (between 0.6 and 0.73). These estimates imply that about six to seven acres are removed from subsequent harvests and plantings for every ten acres retired. Despite the fact that planted acreage is usually less than harvested acreage (due to the omission of hay) the estimates in the second column are at least as large as those in the first column. This result suggests that acreage removed from production derives mostly or entirely from crops besides hay. The fact that some planted acreage is not subsequently harvested can explain why the second-column coefficients tend to be larger, even though it accounts for less total acreage.

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[3] This regression is based M-estimator that uses Huber's loss function (rather than least squares) with a tuning parameter c=1.345 and a scaling parameter s estimated by iterated MAD (median absolute distance of the residuals). See Venables and Ripley, p. 167-170.

How much slippage is implied by the estimated β parameters? The answer to this question depends on how frequently land was cropped prior to its enrollment in CRP—in other words, the amount of Type 4 slippage. CRP requires only that land be cropped during two of the five years prior to enrollment. Thus, $\beta = 0.7$ could imply Type 3 slippage between negative 30 percent (all CRP land formerly was cropped in just two of every five years) and positive 30 percent (all CRP land formerly was always cropped). According to Wu's calculation, 58.1 percent of CRP land resided in corn, soybeans, or wheat, prior to its enrollment. These three major crops constitute the vast majority of land measured by our planted-acreage measure (column 2), especially in counties where CRP enrollment is largest. Thus, if no slippage is experienced for these major commodity crops, the second-column β estimates should equal approximately 0.6, which they do.

One surprising result is that the coefficients in column two are equal to or greater than those in the first column. The largest difference between these two dependent variables is the omission of hay in the second column. A smaller difference is that some planted acreage is not subsequently harvested. The similarity of these coefficients suggests that hay cropland is not reduced by CRP land retirement. Our own estimates, based on the 1979-1982 disposition of land in the NRI that was subsequently enrolled in CRP, imply that up to about 30 percent of CRP-retired land was formerly planted with grassland hay.[4] Because total hay harvests appear to be

[4] This number is calculated from the 1979-1982 crop histories of NRI points classified as cropland in 1982 and subsequently classified as CRP. Across all of these points and years an average of 3.05 of 4 years were planted with cultivated crops (not fallow or grassland hay). In addition, about 7 percent of CRP land was classified as uncultivated cropland (mostly hay and fallow) or pastureland, the crop histories of which are not available in the NRI.

unrelated to the amount of land retired under CRP, it suggests slippage of up to 30 percent in the form of new hay plantings.

What are the environmental implications of hay slippage? Because we cannot discern which lands would and would not have been converted from non-cropland to hay plantings (and vice versa) in the absence of CRP, direct erosion estimates cannot be made. However, the NRI-based estimates, reported in Table 5, suggest a small difference in erosion levels stemming from hay slippage. The table reports erosion estimates of different land use categories for 1982 and 1997 based on the Universal Soil Loss Equation (ULSE). In particular, note that the erosion on land that was converted from pastureland to uncultivated cropland changed from an estimated 1.07 tons/acre to 1.04 tons/acre. Because the vast majority of land classified as "uncultivated cropland" is grassland hay, these numbers suggest that erosion was actually reduced as a result of hay slippage. Furthermore, of the lands that did not change in disposition, those residing in uncultivated cropland experienced just over half the level of erosion that occurred on pastureland. As compared to cultivated cropland erosion levels on both pastureland and uncultivated cropland are quite small—whether erosion increases or decreases due to hay slippage, the difference is clearly immaterial.

6. Conclusion

This paper presents evidence on three sources of slippage stemming from CRP: the program retires land of lower-than-average quality (Type 1 slippage); the program induces farmers to bring new land into production (Type 3 slippage); land retired under the program was sometimes fallow prior to its retirement (Type 4 slippage). Our Type 1 slippage estimates are in line with previous estimates in the literature, ranging from about 3 to 9 percent depending on the year and crop. Our Type 3 slippage estimates are approximately zero for major commodity crops but may imply substantive CRP slippage in the form pasture to hay cropland conversions. Type 4 slippage could be substantial; however, given crop histories, it should be relatively straightforward to take into account.

The theoretical basis for Type 3 slippage, outlined in section 3, implies that CRP-induced non-cropland to cropland conversions should be allocated among crops in about the same proportion as cropland idled under CRP. How can we reconcile theory with the observed difference in slippage rates between hay and commodity crops? This difference might be explained theoretically within the context of a multi-product production function wherein idled cropland, through the use of rotations, formerly served as an input to both commodity crops and non-cropping activities, such as cattle operations. The absence of commodity crop slippage can be understood as a minimal price-feedback effect per the theory in section 3. However, a byproduct of the idled cropland included hay production, which served as an input to the cattle operations. Without new hay plantings, CRP land retirement also would have induced smaller cattle operations. Rather than scale back cattle operations or purchase hay from the open market, it could be most profitable for farmers to simply convert some of their pasture into hay production.

If the policy goal of CRP is to reduce commodity supply and thereby increase prices then policy makers should take into consideration all three types of slippage that we have examined. If, however, the primary goal of CRP pertains to the environmental benefits of these programs, then Type 3 slippage is of primary interest. Does CRP have the unintended consequence of inducing farmers to simply convert pastureland to cropland to replace land that was retired? If this kind of slippage exists, it mainly takes form of conversions from pasture to new hay plantings. Because pastureland and hay cropland induce similar erosion levels, this kind of slippage entails minimal environmental consequences.

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Figure 1. Slippage determinants

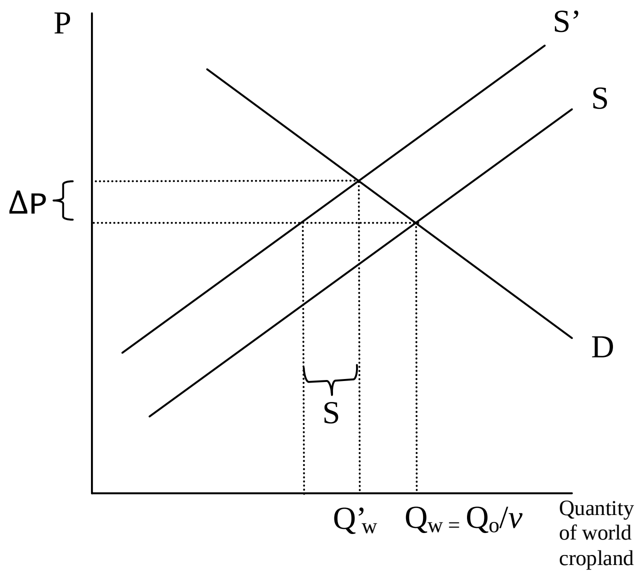

Figure 2. Anatomy of spurious correlation between CRP and cropland-non-cropland conversions

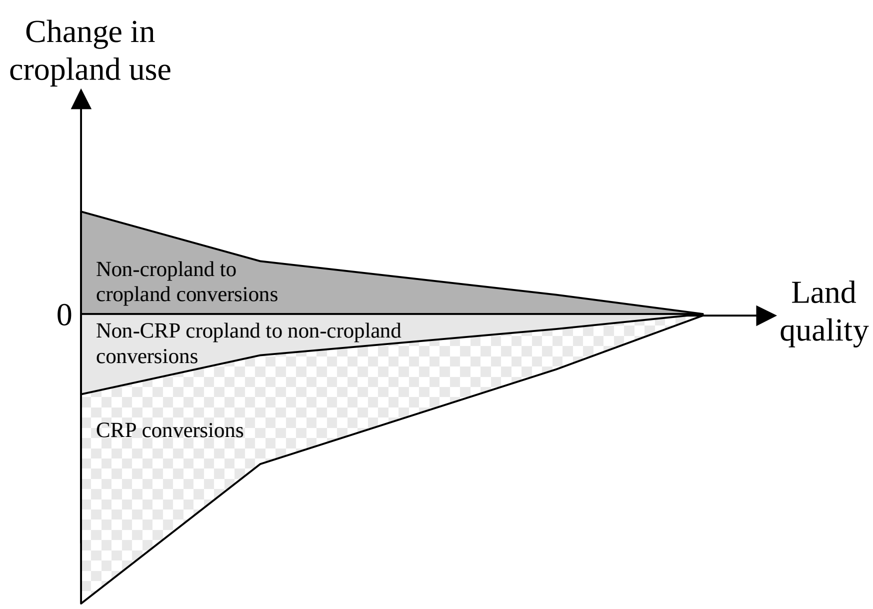

Table 1. A comparison NRI-based results suggests spurious correlation (equations 3 and 4)

Explanatory variables	1982-1992 NRI				1992-1997 NRI			
	Wu's model replicated		Wu's model reversed		Updated model		Updated-reversed	
	Non-cropland to cropland (*NC*)		Cropland to non-cropland (*XC*)		Non-cropland to cropland (*NC*)		Cropland to non-cropland (*XC*)	
	Coefficient	*T*-Stat	Coefficient	*T*-Stat	Coefficient	*T*-Stat	Coefficient	*T*-Stat
Intercept	0.0344	5.79	0.0318	5.17	0.0102	1.83	0.0125	2.33
Acres of CRP land enrolled by 1992 as a percent of the total land area (CRP)	0.2963	6.80	0.1250	2.77	0.3287	6.88	0.1187	2.57
CRP * a dummy variable for lake states	-0.1086	-1.68	-0.0455	-0.68	-0.1457	-2.61	-0.0312	-0.58
CRP * a dummy variable for northern plains	-0.1850	-3.27	-0.2362	-4.03	-0.3714	-6.27	-0.1802	-3.14
CRP rental rate ($/acre)	-0.0003	-2.85	-0.0001	-0.91	-0.00001	-0.70	0.00003	-0.50
Average annual erosion reduction per CRP acre (tons/acre/year)	-0.0003	-1.42	-0.0001	-0.71	-0.0002	-1.13	-0.0004	-2.54
Corn base acres retired per CRP acre	0.0291	2.34	0.0030	0.24	-0.0027	-0.27	0.0222	2.36
Wheat base acres retired per CRP acre	0.0284	2.08	0.0161	1.14	0.0132	1.26	0.0268	2.64
Percent change in population 1982-92	0.0001	0.92	0.0005	3.93	0.0005	1.94	0.0007	2.57
Change in average size of farm 1982-92	-0.0002	-1.57	-0.0001	-0.79	-0.0002	-0.81	-0.0008	-3.24
Total land area (millions acres)	-0.0017	-3.20	-0.0019	-3.33	-0.0008	-1.70	-0.0014	-2.93
R-square	0.43		0.42		0.49		0.50	

Table 2. County-level comparison of CRP and nationwide yields (standard errors in parentheses)

	Average Yields											
	Corn				Soybeans				Wheat			
Year	CRP	ALL	T-Stat	Ratio	CRP	ALL	T-Stat	Ratio	CRP	ALL	T-Stat	Ratio
1987	108.1	111.5	4.12	95%	31.1	33.1	8.80	94%	34.5	35.0	1.72	98%
	(0.69)	(0.46)			(0.17)	(0.17)			(0.22)	(0.24)		
1988	107.1	113.8	7.76	94%	31.2	33.5	9.62	93%	34.3	35.5	3.69	97%
	(0.73)	(0.46)			(0.17)	(0.17)			(0.22)	(0.24)		
1989	106.2	115.9	11.01	92%	31.6	34.0	9.60	93%	34.5	36.1	4.91	95%
	(0.75)	(0.46)			(0.18)	(0.17)			(0.22)	(0.25)		
1990	106.7	117.6	12.24	91%	32.1	34.5	9.59	93%	34.6	36.4	5.20	95%
	(0.76)	(0.47)			(0.18)	(0.18)			(0.22)	(0.25)		
1991	107.4	118.9	12.89	90%	32.6	35.3	10.78	92%	35.2	36.8	4.64	96%
	(0.76)	(0.46)			(0.18)	(0.17)			(0.23)	(0.26)		
1992	108.6	120.3	13.32	90%	33.2	35.8	10.29	93%	35.7	36.8	3.00	97%
	(0.75)	(0.46)			(0.18)	(0.18)			(0.24)	(0.27)		
1993	112.9	122.5	11.14	92%	33.9	36.2	9.13	94%	36.2	37.1	2.31	98%
	(0.72)	(0.48)			(0.18)	(0.18)			(0.25)	(0.27)		
1994	112.2	124.1	13.58	90%	34.4	36.7	8.90	94%	36.9	37.5	1.69	98%
	(0.74)	(0.47)			(0.19)	(0.18)			(0.26)	(0.28)		
1995	115.0	126.6	13.02	91%	34.8	37.3	9.46	93%	37.4	38.3	2.19	98%
	(0.75)	(0.48)			(0.19)	(0.18)			(0.27)	(0.29)		
1996	116.6	127.1	11.70	92%	35.2	37.6	9.05	94%	37.6	38.6	2.37	98%
	(0.76)	(0.48)			(0.19)	(0.19)			(0.27)	(0.30)		
1997	117.4	129.0	12.57	91%	35.2	37.9	9.56	93%	38.0	38.8	1.75	98%
	(0.78)	(0.49)			(0.20)	(0.19)			(0.28)	(0.3)		
1998	118.6	130.3	12.51	91%	35.6	38.2	9.50	93%	38.1	39.6	3.65	96%
	(0.8)	(0.50)			(0.20)	(0.20)			(0.28)	(0.32)		
1999	120.9	132.3	12.23	91%	36.1	38.8	9.29	93%	38.6	40.1	3.27	96%
	(0.79)	(0.50)			(0.21)	(0.20)			(0.30)	(0.33)		

Table 3. CRP Enrollments by Year

Year	Nationwide change in cumulative acres enrolled in CRP
1986	1,957,610
1987	13,478,620
1988	8,568,005
1989	5,070,582
1990	3,719,432
1991	405,885
1992	929,601
1993	954,012
1994	-68,772
1995	-37,362
1996	-476,477
1997	-1,687,202
1998	-2,688,206
1999	-303,024
2000	1,602,018
2001	2,182,812

Table 4. Alternative estimates based on NASS-reported plantings and harvests.

Model and explanatory parameters	Dependent Variable: Difference in sum of NASS-reported harvests/base		Dependent Variable: Difference in sum of NASS-reported plantings/base (excludes hay)	
OLS				
	Coefficient	Standard Error	Coefficient	Standard Error
Intercept	7.5e-5	7.84e-4	-0.0059	0.00056
Difference in CRP /base	-0.609	0.028	-0.618	0.020
R-square	0.0170		0.0338	
County fixed-effects model (county fixed-effects not reported)	Coefficient	Standard Error	Coefficient	Standard Error
Difference in CRP /base	-0.634	0.0296	0.632	0.0212
Mixed-effects model				
County random effect				
Covariance between county trend (intercept) and CRP enrollment change	-0.0253		-0.0082	
Fixed effects	Coefficient	Standard Error	Coefficient	Standard Error
Intercept	0.0002	0.0008	-0.0054	0.0006
Difference in CRP /base	-0.6138	0.0325	-0.7224	0.0309
Robust (iterated re-weighted least squares)				
	Coefficient	Standard Error	Coefficient	Standard Error
Intercept	0.0008	0.0005	-0.0023	0.0004
Difference in CRP /base	-0.613	0.0181	-0.603	0.0137

Notes:

(1) All modes estimated with 26,959 observations taken from 2,547 counties from the years 1987 to 1997. Observations with missing values for crop plantings or crop harvests were omitted.

(2) A mixed-effects model with within-county autocorrelation (not reported) also was estimated to control for a small amount of negative residual autocorrelation. The estimated coefficients change by less than half of one standard error.

Table 5. USLE Soil Erosion Change

1982 Land Use	1982 Soil Loss	1997 Soil Loss	1997 Land Use
	tons\acre\year		
	total tons per year (in hundreds)		
	Land enrolled in the CRP		
Cultivated cropland	7.20	0.41	CRP
	2,115,033	*119,518*	
Uncultivated cropland	1.64	0.56	CRP
	17,114	*5,834*	
Pastureland	1.18	0.55	CRP
	15,709	*7,366*	
	Land that changed intensity		
Cultivated cropland	5.67	0.94	Uncultivated cropland
	1,040,857	*172,802*	
Cultivated cropland	7.60	0.62	Pastureland
	1,116,940	*90,598*	
Uncultivated cropland	0.82	3.26	Cultivated cropland
	95,389	*381,147*	
Uncultivated cropland	0.86	0.66	Pastureland
	39,443	*30,068*	
Pastureland	0.69	6.16	Cultivated cropland
	64,720	*579,080*	
Pastureland	1.07	1.04	Uncultivated cropland
	63,569	*62,006*	
	Land that did not change intensity		
Cultivated cropland	4.48	3.31	Cultivated cropland
	13,307,259	*9,843,235*	
Uncultivated cropland	0.67	0.60	Uncultivated cropland
	155,210	*137,504*	
Pastureland	1.15	1.04	Pastureland
	1,058,162	*961,023*	
Total soil loss	1,908,940,258	1,239,018,093	

Source: NRI estimates based on the Universal Soil Loss Equation (USLE).