Slippage Effects of the Conservation Reserve Program: New Evidence from Satellite Imagery

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Abstract

The Conservation Reserve Program (CRP) is the largest land retirement program ever operated in the US. Since its inception in 1985, many researchers have studied the impacts of this program; however, only a few have analyzed how the CRP affects surrounding non–enrolled parcels. In this research I examine how the CRP may affect the conversion of non–cropped land to agriculture, a phenomenon referred to as "slippage" in the literature, and specifically addressed by Wu (2000) and Roberts and Bucholtz (2005). Building on these earlier studies, I empirically model slippage using data derived from satellite imagery that provides information on land cover changes between 1992 and 2001. The study area consists of 1,053 counties located in the Northern Plains, Corn Belt and Lake States regions. Results support the existence of slippage effects from the CRP, but they are more conservative than the ones found by Wu (2000). The evidence of slippage provided here is important information for planners, given that whether and how the CRP affects land use decisions in surrounding areas is key information for implementing conservation efforts more efficiently.

Keywords: CRP, Land use change, Satellite imagery, Slippage effect

The Conservation Reserve Program (CRP) is the largest agricultural land retirement effort ever operated in the US. Since its inception in 1985, the CRP has retired over 30 million acres of cropland with an annual rental payment of approximately $2 billion (Sullivan et al. 2004). Several evaluations have been made of the environmental and economic benefits of this program, and most researchers have agreed on overall contributions and benefits (Young and Osborn 1990; Sullivan et al. 2004). However, the spatial effects of the CRP on surrounding non–enrolled land have received much less attention in the literature. In this research I focus on the indirect effects that, within a region, the presence of the CRP may have on the conversion of forest, grass and wet lands to agriculture, a phenomenon denoted as "slippage effect" in the agricultural economics literature.

Only two previous studies have investigated (and debated) the slippage effect of the CRP in depth: Wu (2000), and Roberts and Bucholtz (RB) (2005). While the former claims that the CRP produces a 20% rate of slippage, the latter states that there is no evidence of real slippage coming from the CRP.[1] Both studies, however, leave more questions than clarifications about the slippage issue. Given these inconsistent findings and the importance of the topic for agricultural policy and environmental issues, my research questions can be summarized in two main points:

1) Does satellite imagery provide evidence of slippage effects from the CRP?

[1] This debate has taken place in the *American Journal of Agricultural Economics*. In a comment to Wu (2000), Roberts and Bucholtz presented evidence refuting the findings of slippage. Addressing the disputed issues of Roberts and Bucholtz's comment, Wu presented a reply (Wu 2005) that was later questioned by a rejoinder of Roberts and Bucholtz (2006).

2) If slippage from the CRP is occurring, why and how is this affecting different land covers?

In order to address these questions, using spatial cross–sectional models for a sample of 1,053 American counties, this article analyzes the potential slippage produced by the CRP looking at data obtained from satellite imagery provided by the U.S. Geological Survey (USGS). In 2008 the USGS released a “National Land Cover Data (NLCD) Retrofit Change Product” that provides information on land cover changes across the U.S. between two periods (Fry et al. 2009). This product allows researchers to observe changes in land covers from, for instance, forest land to agriculture and *vice versa*. With this information, new evaluations and assessments can be done for policies that affect land use decisions such as the CRP.

Other studies have modeled the sources of slippage theoretically (Rygnestad and Fraser 1996; Wu, Zilberman, and Babcock 2001) and empirically quantified this problem for conservation programs (Fraser and Waschik 2005). However, to my knowledge, no one has addressed either theoretically or empirically the open questions left by the studies of Wu (2000, 2005) and RB (2005, 2006).

Slippage Sources and Land Use Theory

Among the theoretical explanations for the sources of slippage, Wu (2000) postulates two alternatives: an output price feedback effect, and land substitution effects. The former effect refers to slippage coming from the reduction in output from the retired land that causes a supply shortage, leading to an increase in the output price. The increase in commodity prices provides an incentive to farmers to convert non–cropped land into production (Wu 2000; Wu, Zilberman, and Babcock 2001). However, as Wu states, it is not possible to examine how the CRP affects output prices, while at the same time examining how these changes in output prices affect land conversion, using cross–sectional data (Wu 2000). Therefore, given that my analysis of slippage considers a one period cross–sectional model, I focus this section on expanding the land substitution effects and other theoretical sources of slippage.

Other potential sources of slippage related to programs paying for working land retirement are related to (*i*) land substitution effects, (*ii*) the re–allocation of fixed inputs used in agriculture, and (*iii*) and changes in land option value. These are important issues related to CRP enrollment that could affect farmers' decisions about converting non–cropped land into production. Final decisions will be explained by land use theory.

Land Substitution Effects

Wu (2000) describes these effects as a farmer's land use decision based on the marginal productivity of land. Figure 1 describes the logic of this source, where A_H, A_{MC}, A_{MN}, A_L, and A_{CRP} denote acres of high land quality cropped, medium land quality cropped, medium land quality non–cropped, low non–cropped land quality and land under the CRP, respectively.

In figure 1 the distance between the vertical lines is the total amount of medium quality land ($A_{MC} + A_{MN}$). Thus, when the CRP reduces the amount of A_{MC}, the marginal profitability of cropping increases with respect to non–cropped land, producing slippage (A_S). If not regulated, a farmer would engage in slippage (within her farm) up to the point of equalizing the marginal profitability of cropping to the marginal profitability of non–cropping (Wu 2000);

$$(1) \quad \frac{d\pi_C(A_H, A_{MC} - A_{CRP} + A_S)}{dA_{MC}} = \frac{d\pi_N(A_L, A_{MN} - A_S)}{dA_{MN}} \quad ,$$

where π_C and π_N denote the profitability of cropping and non–cropping, respectively.

Reallocation of Fixed Inputs

Given that a land retirement program reduces land under actual production, it can be expected to produce an oversupply of resources considered fixed in agriculture such as machinery, buildings or even household labor (Hoag, Babcock, and Foster 1993). In this context fixed resources would be underutilized in scenarios where agricultural land is reduced due to CRP enrollment. Given this oversupply, there is an incentive to bring land into agriculture in order to use the available resources and thus take advantage of sunk costs.

Although this point can be interpreted as an increase in the marginal profitability of cropping as described before, the concept is slightly different because it is a source of slippage at the farm *or* community levels. Fixed inputs can be allocated within the same farm or somewhere else (with no market constraints). For example, if a particular farm has all land in agriculture and the CRP is implemented there, the available fixed resources no longer fully used (like tractor hours) can be sublet to neighboring farms (that can expand agriculture now that more inputs are available).

Even if in the long term oversupplied inputs can be liquidated, there would be a kind of input price effect similar to the output price effect: an increase in the availability of agricultural inputs (not used because of CRP land) would reduce the price of these and consequently increase demand that could facilitate conversion of non–cropped land to agriculture. Observing a farm's profit function,

$$(2) \quad \pi_C = p(q) \times q - C(q) - F$$

where p is output price, q is total output, C is variable cost, and F denotes fixed costs), as F decreases, agriculture becomes more profitable and therefore more land is demanded for it. This phenomenon would have limitations similar to the output–price effect when measuring it with cross–sectional data, but to a lesser extent given that the input price effect would be more local: a fixed input, like a tractor, is difficult to transport so prices would vary more across counties or regions.[2] The liquidation of fixed inputs by a local farmer would be more available only in that certain location and under transport/distance limitations.

[2] Differently from output prices that have little (or no) variation across counties.

Changes in Land Option Value

As Wu mentions in his reply to RB comment (Wu 2005), and as more fully described by Lin and Wu (2005), the land value of a particular farm can be increased due to the presence of CRP. The CRP provides a new option value to farmers by the potential enrollment to CRP and the revenues that this non–uncertain federal payment can generate to farm households. Thus, for instance, land that in the past was not cultivated because generated not marginally gains to the farm can now be brought into production triggered by an expected CRP enrollment that would generate income to the farm household. The expected net return to cropland increases as CRP becomes an institution in a county, which in consequence may foment the incorporation of non–cropped land to agriculture.

The expected returns from parcel *j* once converted to agriculture (R^a), can be described by (Lin and Wu 2005):

$$(3) \quad R^a = \pi_C (1-m) + m\,Max(\pi_C, \mathbf{P}b^* + (1-\mathbf{P})\,\pi_C)$$

$$= Max(\pi_C, \pi_C (1-m) + m(\mathbf{P}b^* + (1-\mathbf{P})\,\pi_C)$$

where **P** is the probability of a bid being accepted into CRP and b* is the optimal bid that a farmer will submit *m* equals 1 if the land is eligible to enroll into the CRP, 0 otherwise (Lin and Wu 2005). Thus, if a farmer considers that **P** increases because the CRP is a common practice in her region, there would be an increase in the expected returns to obtain from a parcel converted to agriculture. There would be option values of obtaining not only agricultural profits, but the certainty of the CRP payments.[3]

Land Use Change Decisions

While Wu's substitution effect is based on decisions made within farms, I argue that slippage effect could be a community phenomenon given that slippage sources coming from land option values and the reallocation of fixed inputs are clearly affecting land beyond the limit of farms enrolling in the CRP. This would support why the slippage effect can be explained by cross–sectional aggregated–(county)–level evaluations. However, these points must be considered as only potential *sources to* slippage. In real life probably none, one or many of these sources will affect the final land use decisions made by a particular farmer or group of farmers. The final slippage decision would be considered by a farmer given her present value (*PV*) of land that currently is out of production:

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[3] Criticizing this slippage source, RB rejoinder to Wu's reply (Roberts and Bucholtz 2006) establishes that "S*lippage stemming from new CRP–induced option values would be similar to that stemming from a CRP–induced rise in commodity prices*."(Roberts and Bucholtz 2006, p. 513). However, differently from the output price effect, the effects of CRP in option values are likely to be more local than output prices change effects. The land price effect of a farm enrolled in the CRP can only be observable by neighbor farmers: a farmer (farmer A) can observe how much farmland her neighborhood (farmer B) has under CRP and also observe the consequent change in the price of farmers B land. This is not necessarily true when farmers A and B are far enough that to obtain information about each other becomes restrictive. This kind of relation would allow estimating CRP slippage effects using cross–sectional models.

Another comment that RB (2006) make about the option value refers to the threshold that the CRP program has for every county (25% of a county's land). The authors state "…*one might expect a negative relationship between past enrollments and future opportunities, especially for areas near mandated CRP enrollment thresholds or having little remaining land that might be made eligible for CRP.*"(Roberts and Bucholtz 2006, p. 513). I argue that this argument could be valid, but difficult to occur in reality because of two points: (a) it is very unlikely that all farmers would have the exact knowledge that their particular county is in the edge of the mandated enrollment threshold; and (b) with the implementation of the Environmental Benefits Index (EBI) system, land eligible for CRP is based on a competitive bid system that could transform non–eligible land for old CRP sign–ups to land eligible for new CRP enrollment.

(4) $$PV = E\left\{\int_t^{t+h} R^{nc}\, e^{-r(\tau-t)}\, d\tau + \int_{t+h}^{\infty} R^a\, e^{-r(\tau-t)}\, d\tau - Cc\, e^{-rh} \;\middle|\; R^a\right\},$$

where E{} is the expectation operator, R^{nc} is the current rent obtained from the non–cropped land, *Cc* is the conversion cost (the cost of transforming non–cropped land to agriculture), *t* is time, *t+h* is the time when the land is converted to agriculture, and *r* is the discount rate. Equation (4) implies that non–cropped land value equals the present value of expected returns of the non–cropped land up to date of conversion plus the present value of the expected agricultural returns minus conversion costs.

As described in equation set (3), R^a is directly affected by the probability of having the CRP in a farm. So, the presence of this program induces an increase in R^a. On the other hand, R^a would tend to be increased with CRP presence in other parcels given that the output price effect increases *p* and/or slippage sources (*i*) and (*ii*) increase π_C. There is an increase in the expected profitability of agriculture.

Given (4) and following (Capozza and Helsley 1990), the farmer chooses the conversion of non–cropped land to agriculture when the agricultural land rent is greater than or equal to a reservation rent: $R^a \geq R^*$, with $R^* \equiv R^{nc} + r\, Cc$.

The reservation rent is given by the rent that is obtained from the non–cropped use of land plus the conversion costs. Given this specification, it is clear that slippage will directly depend on the R^a, R^{nc} and *Cc* variables. It was already discussed that CRP will tend to increase R^a, therefore important is to define how R^{nc} and *Cc* weight in the decision of slippage. Of these factors it is more straightforward to observe the role of *Cc* in the final decision. Thus, for instance, let say that a farm faces three different conversion costs in three different parcels: $Cc_a > Cc_b > Cc_c$; it would be more expectable to find slippage in the parcel with the conversion costs given by Cc_c and less in the land with conversion costs of Cc_a. Slippage will present higher rates in parcels with Cc_c, given other factors constant.

With respect to R^{nc}, the values of this variable will depend directly on the market or non–market value given to the non–cropped land. For commercial use the price obtained for non–agricultural production is important to consider when estimating final decisions of slippage. Logically a farmer will not convert if $R^{nc} > R^a$, whatever the level of Cc. The analysis turns more complex when non–cropped land is not used for commercial ends (at least not entirely) and bequest or amenity values are important to the farmer.

Methodology of Research

In order to have a direct comparison, the area under study in this research is chosen to be similar to the one used by Wu (2000) and RB (2005), i.e., the Northern Plains, Corn Belt and Lake States regions of the U.S. However, one difference of this study is that instead of using the regions' 107 Agricultural Districts as subjects of analysis (as the mentioned authors do), I expand the sample to the 1,053 counties encompassed in this 12 states area (see figure 2).[4]

[4] Menominee County (WI) is excluded from the analysis because it does not report data on most of the sources used.

Following RB (2005) –who follow Wu (2000), I first employ linear regression models to predict non–cropped land conversion to agriculture (*NewAg*) based on four main covariates: beginning of the period percentage of acres under the CRP over the total non–urbanized acres of the county (variable that is going to show slippage), population change (*Pop*Δ), farm size change (*FarmSize*Δ) and total county land area[5] (*Land*). Thus, similarly to the approach of RB, the basic empirical model is denoted by:

$$(5) \quad NewAg = \beta_0 + \beta_1\, CRP + \beta_2\, Pop\Delta + \beta_3\, FarmSize\Delta + \beta_4\, Land + e\ .$$

In order to expand RB's model and include variables that may affect a farmer's final land use decision, I include four covariates to (5): the distance of the country centroid to the closest highway (*Dist*) –to control for county accessibility; the percentage of urban growth in surrounding counties (*Sprawl*) –to control for urban land demand; changes in net agricultural rent of counties between 1992 and 2002 (*Netcroprent*) –to control for changes in R^a; and a dummy variable for the nonmetropolitan status of the county (*Rural dummy*) –to control for non–agricultural income sources. Additionally, all models include binary variables to control for state fixed effects.

Equation (4) establishes that land conversion will depend directly on conversion costs. Thus, if we consider that different land covers would have different costs of conversion, disaggregating the *NewAg* variable could help to observe whether the CRP slippage is affected by conversion costs or not. In this way, I specify a second

[5] Total land area excludes urbanized land in this article. All calculations done over total land (like the % of CRP land in a county) consider this description –see table 1.

econometric approach where the dependent variable of model (5) is transformed to three different variables: conversion of forest land to agriculture (*For_toAg*), of grassland to agriculture (*Grass_toAg*), and of wetland to agriculture (*Wet_toAg*).

Endogeneity and Contract Expirations

One important issue brought into discussion by RB (2005) is the endogeneity that the *CRP* variable may have in the model represented by equation (5) and its expansions. These authors state that given that enrollments in the CRP is a variable that reflect choices made by farmers during the same period they made decisions to convert non–cropped land to agriculture (our dependent variable(s)), OLS estimations would not be valid because of endogeneity between these variables. I approach the endogeneity issue using two instruments (in two different models): the % of CRP land lagged by two years (from the begging of the period analyzed), and the weighted average of the % of land under CRP (also lagged by two years) in the adjacent counties (*WCRP*).[6]

On the other hand, one important issue to control for when evaluating the slippage coming from the CRP, or other land retirement programs, is the expiration of contracts. Some studies have analyzed CRP expirations and appraised the consequent likelihood of land conversions (Roberts and Lubowski 2007; Sullivan et al. 2004). In particular, Roberts and Lubowski (2007) report that only 10.5% of all the CRP land by 1992 exited the program between 1992 and 1997,[7] and that from this amount approximately 62%

[6] The neighborhoods' average level (of the potential endogenous variable) has been used as an instrument in other economic empirical studies [see for example Benjamin (1992)].
[7] This period covers the expiration of contracts from the first CRP sign–ups, produced during 1985 to 1987.

returned to crop production. From this total land converted to crop after CRP contract expirations (in total, 2.2 millions of acres by 1997), 96% came from grasses and/or legumes. In relation to this conversion to agriculture, Sullivan et. al. (2004) mentions that this is a sort of "reversed slippage" given that CRP land coming into production (after contract expirations) in one area may cause non–CRP land to drop out of production in other areas.

In order to control for contract expiration, I include a variable based on difference in the levels of CRP (*CRPdiff90_00*). The endogenenity of this variable is more questionable because, differently from the initial CRP levels, many of the CRP land exiting the program are not necessarily consequence of decisions made by farmers, but by USDA planers.

Spatial Models

Given that land use change is likely to be a decision triggered by land cover changes in neighborhood areas, before doing further econometric analyses I investigate the dependent variable for spatial dependency using Moran's I statistics. These estimations indicate that there is less than a 1% likelihood that *NewAg* is the result of random chance without spatial influence.[8] This evidence implies that spatial dependence is a likely source of bias if simple linear regressions are used. For this reason, in addition to ordinary least squares (OLS), an analysis is carried out to consider the influences that

[8] Moran's I statistics were in the range 0.35–0.60. These values were calculated with ArcGIS 9.3 and GeoDa 0.9.5–i software, using different spatial weights matrices (linear and squared distance, and queen contiguity weights).

spatial dependence may have. I considered three alternative specifications. One specification, which works through a spatial lag, is the spatial autoregressive model (SAR). This model includes an additional covariate that can be written as Wy, where W is a spatial weights matrix and y is a vector of values of the dependent variable(s). A second specification is the spatial error model (SEM), in which spatial dependence works through the model's error term (Anselin 1988). A third model, known as the general spatial model (SAC), incorporates both spatial lag and spatial error terms (Anselin 1988; Kelejian and Prucha 1998). Formally, the SAC model, that includes both the SAR and SEM specifications, can be interpreted as:

$$
\begin{aligned}
&y = X\beta + \rho W y + u \\
(6)\quad &u = \lambda W u + e \\
&e \sim \mathrm{N}(0, \sigma^2 \mathrm{I}_n),
\end{aligned}
$$

where X represents a matrix containing the right–hand–side variables of the model and e is an error term normally distributed. The spatial models use a symmetric row for W – standardized adjacency matrix (derived from Delaunay triangulation) and are estimated with LeSage's (1999) Spatial Econometrics Toolbox for MATLAB.

Data

The data for the dependent variables (and the covariates *Sprawl* and *Land*) come from satellite imagery data obtained from the "NLCD Retrofit Change Product" [9] provided by the USGS, using ArcGIS version 9.3. The NLCD Retrofit Change Product is a raster GIS file provided in grid format, meaning it is divided into uniform–sized grid cells (pixels). The size of the grid cells are 30 by 30 meters, with each classified as a single land use or land use conversion. The difference of this product from other satellite raster files is that it incorporates pixels that have been adjusted to allow the most accurate satellite imagery showing land cover changes across the U.S. between two periods, up to date (Fry et al. 2009). In particular, the land cover change information is given for the period 1992–2001.

One advantage of using the NLCD Retrofit Change Product is that it is possible to observe in what direction the land cover change has occurred. Thus, we can observe how much forest, grass and wet lands have been converted to agriculture within the period 1992–2001 across the region. Thus, as mentioned previously, this feature provides data that allow constructing the dependent variables based on different initial land covers.

Additional sources used for gathering explanatory variables include the Population and Agricultural Census (provided by USA counties[10]) and the USDA CRP data. Table 1 shows the main statistics, definitions and sources of data for the variables to consider in the above described models. Figure 2 shows the enrollment levels of the CRP in the counties of the area under study to 1990.

[9] Further information about this product is available here: http://www.mrlc.gov/multizone.php
[10] http://censtats.census.gov/usa/usa.shtml

Results

All Models were estimated using state fixed effects, but these coefficients are not reported. Table 2 shows the estimation results obtained from OLS with the CRP lagged by two years (*CRP90*). Table 3 reports results from OLS for the models using the alternative instrument for the CRP variable as described before (*WCRP90*), and table 4 reports SAC estimates given that both spatial lag (rho) and spatial error (lambda) terms are statistically significant.[11] The OLS and the SAC models used in this article give (in general) similar results, so in order to expand discussion I do not discriminate one model over the other. The first column of results of tables 2 and 3 states that the CRP would have a rate of slippage close to 4%. This value is lower than the 20% rate predicted by Wu (2000), but larger than the non–statistically significant results obtained by RB (2005). After controlling for spatial dependence, table 4 shows that the CRP slippage drops one percentage point to reach a rate of 3%.

When the slippage effect is addressed by changes in particular land covers, table 2, 3 and 4 show that from each 100 acres of land enrolled in CRP by 1990, between 7 and 3 acres of grassland were converted to agriculture and only 0.2 to 0.6 acres of wetlands were converted to crop land in the period 1992–2001, respectively. However, when agriculture is being converted from forest land, all results suggest that there is a kind of *reverse slippage* –more CRP land is related to more agricultural land converted to forests. RB (2005) state that this phenomenon is possible given that farms enrolling in the CRP are in the edge of farm profitability, so land conversions is a choice variable that would

[11] SAC estimates for models using *WCRP* are not reported given that they are structurally similar to the ones presented in table 4.

happen with or without the CRP. However, one can understand also the CRP as a sort of financial support for the initial investments required for tree planting. The CRP, in this way, could be providing support in areas where farmers are interested in planting trees as business. In order to further investigate this phenomenon I ran regressions using the squared value of *CRP90* (and *WCRP90*) where I obtained structural similar coefficients for the original covariates and a positive sign for the CRP squared term. This result (not reported here) suggests that the crop land obtained from former forests presents a non–linear relationship with the CRP levels: at low levels of CRP land this program acts as a sort of investment buffer for farmers (CRP is correlated with tree planting), but at a given point (around 10.3% of CRP land in a county) slippage starts taking effect over forested lands. That is, at high levels of CRP land in a county, to transform forest to crop land is an option taken by farmers.

From the results, the model that better fits the data (explaining 34% of the changes in OLS and 70% in SAC) and that show the highest rate of slippage is the one predicting land conversion from grassland to agriculture (last column). This result is in line with our theoretic framework that state that conversion costs plays a predominant role in land use change decisions. From the three land covers analyzed, grassland is the cover type that presents the lowest conversion costs, and therefore the highest levels of slippage, other things equal. In this line, results for the *Netcroprent* variable also supports theory given that the positive coefficients reported in tables 2, 3 and 4 relates to the role that R^a has on land conversion to agriculture.

The difference on CRP levels variable (*CRPdiff90_00*) is positive and statistically significant in the first column of the three tables. However, looking at the specific land covers, the positive relation is only present in grasslands, suggesting that CRP land after contract expiration keeps its cover in the forest and wetland case; although only the conservation of wetlands after contract expiration is statistically proved. This result is in line with some studies that show that farms exiting CRP have more likelihood to return to agriculture if the land was covered with grasslands than if it was with forests (again, a phenomenon explained in part by the role of conversion costs). Alternatively, in order to observe the slippage tendency on counties only loosing CRP, I run regressions restricting *CRPdiff90_00* to be only positive (and alternative ones setting the negative values of *CRPdiff90_00* equal to zero), obtaining structurally similar results to the ones reported here.

Another interesting result is the coefficient of the *Sprawl* variable. The positive coefficient (although not consistently significant) suggests that to some extent urban growth in neighboring counties triggers the conversion of more open space land to agriculture. I also ran regressions using urban sprawl occurring in the same county but coefficients, although positive, were never significant.

Implications for Policy and Research

Results of this study have two important policy implications. First, for the efficient allocation of resources in agri–environmental programs, the evaluation of slippage effects must be considered in optimally designing conservation instruments. Whether and how much slippage occurs due to the CRP is relevant information for USDA planners and policymakers. Wu (2000) claims that the 20% slippage rate appraised in his study offset a 9% and 14% of CRP water and wind erosion reductions benefits, respectively. This means that, even if the rate of slippage is low (as found here), the environmental efficiency of the program is questionable. Planners should pursue incentives or program's restrictions to avoid the CRP slippage within farms and seek regional regulations to decrease slippage across farms.

Second, results reveal which land covers are more susceptible to the program's slippage effect. Knowledge of this issue would permit planers to focus more attention and resources to restrict slippage on sensitive areas. The evidence presented in this study suggests that planners should be more careful when implementing the CRP on areas that have pristine and environmental sensitive grassland areas. In the case of forest regions the program may become a problem if too much CRP is enrolled in the county (levels over 10% of the non-urbanized land of a county).

In terms of impacts for academic research, this study contributes by testing the relevance of the NLCD retrofit change product for obtaining data to use in economic empirical studies. The economic explications and implications of land use change decisions and agricultural expansion are topics of great importance given the climate change debate, where satellite information together with GIS software are important tools to consider in social and regional sciences. Definitively more research can be performed using the NLCD Retrofit Change Product to obtain data, and presumably even more accurate and updated ones as new land cover change data become come available from future and more precise satellite imagery.

Conclusions

In recent years an interesting debate has taken place about the role of the Conservation Reserve Program on the expansion of agriculture in non–conserved lands. Wu and Roberts and Bucholtz have been the main researchers debating this issue, with the former arguing that the CRP produces a 20% rate of slippage (Wu 2000; 2005) and the latter refuting the findings of Wu arguing misspecifications in theory and an incorrect empirical approach (Roberts and Bucholtz 2005; 2006). This article provides new insights about this issue revising the theoretic explanations of slippage sources and land use change decisions, and using satellite imagery to determine real land cover changes between 1992 and 2001. Based on empirical approaches that attempt to avoid the endogeneity problems highlighted by Roberts and Bucholtz (2005), I construct an empirical model where the dependent variable is described with data captured from the NLCD Retrofit Change Product provided by the USGS.

The use of a new and detailed data set (that includes land cover change information), the instrumental variables proposed to control endogeneity of initial CRP enrollment levels, and the use of a sample with more observations, are all features that improve the methodology used by Wu (2000) and Roberts and Bucholtz (2005), and that contribute to complement their debate about the CRP slippage. Results show that the

CRP produces different rates of slippage depending on the original land cover to be converted to agriculture. The analysis finds that changes from forest to agriculture present a non–linear relation with the CRP, where slippage occurs only at high levels of CRP enrollments in a county. On the other hand, the slippage effect of the CRP presents the highest rates when land is converted from grassland to agriculture. These results are in line with theory, given that final land use change decisions would depend on conversion costs (to convert grassland to crop land is cheaper than to transform wetlands or forests to agriculture). In general, the presence of the CRP slippage is confirmed, although in a rate much lower than the 20% reported by Wu (2000).

The assessments of potential slippage effects from conservation programs like the CRP are important to consider given that the environmental benefits from these efforts could be reduced and end even become detrimental for certain ecosystems. When conserving land, it is important to evaluate how land owners take further land use change decisions. Are conservation programs promoting conservation efforts beyond targeted areas or are they influencing the ecological alteration of non–protected land cover by thirds? This research suggests that the latter effect is a problem with the CRP.

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Table 1. Summary Statistics of Variables Used in Empirical Models

Variable	Mean	Std. Dev.	Min	Max	Definition (data source)
Dependent Variables					
NewAg	0.7107	1.2163	0	13.5599	% of total forest, wet and grass land converted to crop land over total open space[a]
For_toAg	0.3152	0.5874	0	4.43	% of forest land converted to crop land over total open space[a]
Wet_toAg	0.0287	0.1248	0	2.37	% of wetland converted to crop land over total open space[a]
Grass_toAg	0.3657	1.1440	0	13.54	% of grassland converted to crop land over total open space[a]
Independent Variables					
CRP90	3.3911	3.8477	0	23.8253	% of CRP land to 1990 over total open space of county (USDA)
WCRP90	3.3675	2.9401	0	16.5725	% of CRP land to 1990 over total open space of neighborhood counties (USDA)
Sprawl	0.3931	0.6108	0.0093	7.5757	% of urban growth over open space in surrounding counties[a]
Netcroprent	2.3300	79.4383	-782.9688	2404.705	Proportion change of crop net prices (Lubowski)[b]
Rural dummy	.8271	.3782	0	1	Dummy for rural county: 1 if rural (code 3 or higher in 2003 ERS Continuum code); 0 otherwise
Dist	43.8721	43.3714	0.0794	297.4672	Distance from county centroid to closest Interstate (Km) [a]
CRPdiff90_00	0.2442	1.7299	-10.4188	8.8128	% difference between CRP enrollments, 1990 to 2000 (USDA)

*Pop*Δ	5.2542	11.3792	-25.3164	67.7498	% difference of county population, 1990 to 2000 (USA counties)
*FarmSize*Δ	18.0166	231.1453	-100	7500	% difference of county average farm size, 1987 to 1997 (USA counties)
Land	0.4248	0.2972	0.0230	3.8864	Total open space of county to 1992 –million of acres[a]

Source: Own elaboration using data from cited sources.

[a] Data obtained from the NLCD Retrofit Change Product raster using ArcGIS 9.3. Open space is the county area less the raster categories "open water" and "developed land" to 1992.

[b] The author thank Ruben Lubowski for sharing these data. For reference about these data see Lubowski et al. (2008).

Table 2. OLS Regression Results

	Dep. Var. = *NewAg*	Dep. Var. = *For_toAg*	Dep. Var. = *Wet_toAg*	Dep. Var. = *Grass_toAg*
CRP90	0.0370***	-0.0207***	0.0064*	0.0513***
	(0.013)	(0.0042)	(0.0038)	(0.012)
CRPdiff90_00	0.0661**	-0.0065	-0.0110**	0.0835***
	(0.0295)	(0.0061)	(0.005)	(0.0283)
Sprawl	0.0916*	0.0528	0.0088**	0.0306
	(0.0489)	(0.0412)	(0.0044)	(0.0362)
Netcroprent	0.0002***	0.0001*	0.0000	0.0001
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Rural dummy	0.1289*	0.1278**	0.0045	-0.0024
	(0.0797)	(0.0564)	(0.0055)	(0.0515)
Dist	0.0028*	0.0008**	0.0001	0.002
	(0.0015)	(0.0004)	(0.0001)	(0.0014)
*Pop*Δ	-0.0007	0.0040**	-0.0003	-0.0045
	(0.0038)	(0.0016)	(0.0003)	(0.0035)
*FarmSize*Δ	0.0000	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Land	0.2663**	0.0665**	0.0477*	0.2856**
	(0.1327)	(0.0302)	(0.0247)	(0.1243)
Constant	0.0627	0.1576**	-0.0162	-0.082
	(0.1418)	(0.0712)	(0.0226)	(0.1205)
R-squared	0.2163	0.2436	0.1040	0.3406

Note: Robust standard errors in parentheses. State fixed effect coefficients not reported.

* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 3. OLS Regression Results Including *WCRP* as Instrument

	Dep. Var. = *NewAg*	Dep. Var. = *For_toAg*	Dep. Var. = *Wet_toAg*	Dep. Var. = *Grass_toAg*
WCRP90	0.0384**	-0.0404***	0.0026	0.0761***
	(0.0181)	(0.0075)	(0.0025)	(0.0164)
CRPdiff90_00	0.0818**	-0.0177***	-0.0088**	0.1082***
	(0.0317)	(0.006)	(0.004)	(0.0307)
Sprawl	0.0858*	0.0499	0.0065*	0.03
	(0.0483)	(0.0406)	(0.0037)	(0.0353)
Netcroprent	0.0001**	0.0001***	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Rural dummy	0.1330*	0.1293**	0.006	-0.0013
	(0.0791)	(0.0559)	(0.0054)	(0.0506)
Dist	0.0029*	0.0008**	0.0001	0.002
	(0.0015)	(0.0004)	(0.0001)	(0.0014)
*Pop*Δ	-0.0011	0.0036**	-0.0005	-0.0042
	(0.0039)	(0.0016)	(0.0003)	(0.0036)
*FarmSize*Δ	0.0000	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Land	0.2454*	-0.0755***	0.0397	0.2817**
	(0.1313)	(0.0292)	(0.0247)	(0.1228)
Constant	0.0563	0.2275***	-0.0032	-0.1712
	(0.1488)	(0.0722)	(0.0209)	(0.1274)
R-squared	0.2117	0.2547	0.0788	0.3421

Note: Robust standard errors in parentheses. State fixed effect coefficients not reported

*significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4. SAC Regression Results

	Dep. Var. = *NewAg*	Dep. Var. = *For_toAg*	Dep. Var. = *Wet_toAg*	Dep. Var. = *Grass_toAg*
CRP90	0.0285***	-0.0069**	0.0024***	0.0289***
	(3.1612)	(2.1551)	(3.5406)	(3.8945)
CRPdiff90_00	0.0392***	-0.0016	-0.0004	0.0451***
	(2.3652)	(0.2453)	(0.2641)	(3.2111)
Sprawl	0.0438	0.0259	0.001	0.019
	(0.7006)	(1.2321)	(0.2242)	(0.3723)
Netcroprent	0.0001	0.0001	0.0000	0.0000
	(0.2405)	(0.5327)	(0.0647)	(0.041)
Rural dummy	0.0705	0.077**	-0.0025	-0.0089
	(0.8602)	(2.2633)	(0.3354)	(0.1266)
Dist	0.0012	0.0001	-0.0001	0.0012*
	(1.3677)	(0.4736)	(1.65)	(1.7416)
*Pop*Δ	-0.0016	0.0011	0.0000	-0.0028
	(0.5848)	(0.9643)	(0.0617)	(1.2314)
*FarmSize*Δ	0.0000	0.0000	0.0000	0.0000
	(0.4788)	(0.8746)	(0.0849)	(0.0981)
Land	-0.0669	-0.0315	-0.0005	-0.0213
	(0.6472)	(0.744)	(0.0504)	(0.2397)
Constant	0.0335	-0.0063	-0.0081	-0.0119
	(0.2254)	(0.1199)	(0.7209)	(0.0975)
Rho	0.606***	0.825***	1.2866***	0.651***
	(15.8666)	(39.812)	(39.909)	(15.6493)
Lambda	0.496***	-0.0261***	-0.431***	0.404***
	(42.1701)	(3.1958)	(4.3586)	(19.345)
R-squared	0.64	0.67	0.5385	0.696

Note: Absolute t-values in parentheses. State fixed effect coefficients not reported.

* significant at 10%; * significant at 5%; *** significant at 1%.

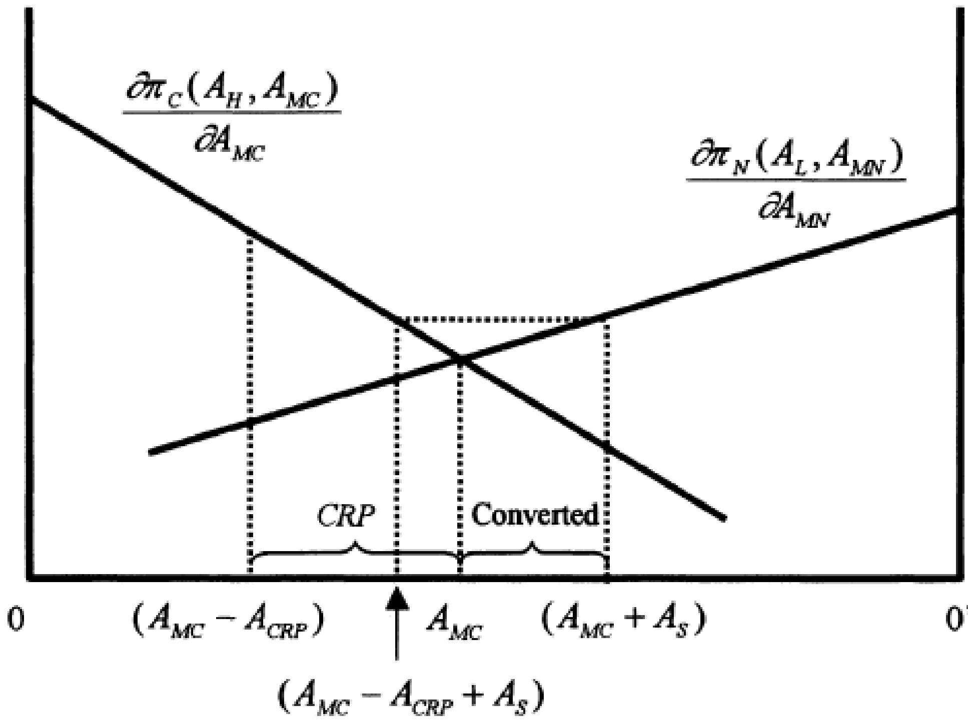

Figure 1. Slippage Effects From Land Substitution. Source: Wu (2000, p. 983)

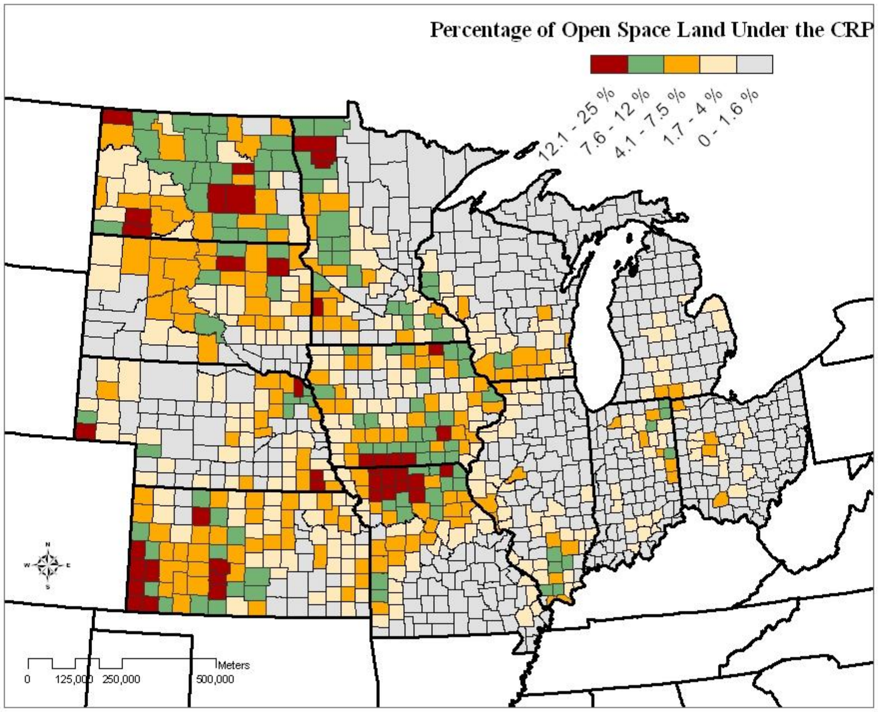

Figure 2. Counties Under Study With CRP Enrollments Rate To 1990