Indirect Land Use Effect of Conservation: Disaggregate Slippage in the U.S. Conservation Reserve Program

by

Shinsuke Uchida

WP 14-05

Department of Agricultural and Resource Economics

The University of Maryland, College Park

Indirect Land Use Effects of Conservation:
Disaggregate Slippage in the U.S. Conservation Reserve Program

Shinsuke Uchida *
Faculty of Economics
Shinshu University

Draft Paper

July 18, 2014

Abstract

A cropland retirement policy contributes to the reduction of environmental externalities from agricultural production such as soil erosion, nutrient runoff and loss of wildlife habitat. On the other hand, participant's potential adverse behavior could undermine the environmental benefits of the policy. Several sources of such an unintended effect, known as "slippage", have been conceptually identified, but their empirical evidence has been scarce. This article tests one source of slippage caused by in-farm land substitution from noncropland to cropland as a result of farmland retirement in the U.S. Conservation Reserve Program (CRP). With the farm-level longitudinal data I can utilize cross-sectional and time variation of detailed individual farm characteristics to identify the causal relationship of CRP participation and subsequent slippage through in-farm land substitution. An identified assumption of the slippage estimate is verified by farm fixed effects, time-varying county fixed effects, and selection-on-observables. These could eliminate effects of unobservables that are potentially correlated with both the program participation and subsequent farmland reallocation decisions. Overall, slippage seems evident and fairly robust among specifications. It is found that an average program participant converts 14% of noncropland to cropping activities after enrollment. Results further show that participants with a larger share of uncropped land contribute more to slippage, indicating that farms with the excess capacity of conversion are more flexible in the land allocation decision and thus likely to give rise to slippage. This suggests that additional restrictions on the rest of land use for participants and/or introduction of penalty points reflecting the share of noncropland in the current auction mechanism can hinder such a backward incentive offsetting the program benefits.

JEL Classification: Q15, Q18, Q24, Q58.
Keywords: Conservation Reserve Program, Farmland use, Land conservation, Slippage.

* Assistant Professor, Faculty of Economics, Shinshu University. Email: suchida@shinshu-u.ac.jp. The views expressed are those of the authors and should not be attributed to USDA. The results in this paper have been screened to insure that no confidential information is revealed. I am grateful to Barrett Kirwan, Erik Lichtenberg, Charles Towe and Kirk White for their insightful comments and suggestions. I also thank Jameson Burt, Robert Hunt and Brad Suma at the USDA National Agricultural Statistical Services and Eldon Ball, Daniel Hellerstein, and Sun Ling Wang at the USDA Economic Research Service for generous assistance in providing data access and institutional knowledge.

1 Introduction

Programs that pay landowners for reductions in soil erosion, preservation of wildlife habitat, avoided deforestation or afforestation, and the like are seen as an equitable and efficient way to restore ecosystem services. In developed nations like the US and in EU countries, they are also seen as an attractive way of maintaining farm income supports, because such green payments are considered "green box" subsidy under WTO rules. But the effectiveness of the programs is open to question, because participant's potential adverse behavior could undermine the targeted environmental benefits of the policy. Answering this question is of particular importance in conducting the cost and benefit analysis of future policies where absence of the legitimate measure of such adverse effects would overestimate the benefits.

This paper evaluates such an unwanted effect, known as "slippage", as a consequence of participation in a farmland retirement program. Several sources of slippage have been conceptually identified, but their empirical evidence has been scarce. Wu (2000) and Roberts and Bucholtz (2005) analyzed the impacts of the Conservation Reserve Program (CRP), U.S. voluntary farmland setaside program, on farmland conversion from noncropland to cropland using region-level aggregate data. They indicate the possibility that benefits from retired acres in the CRP were partially offset by an increase in cropped land converted from noncropland. While these studies shed light well on the incidence of slippage, their estimation results and policy implications are confronted with methodological problems and practical limitations, respectively. First, their cross-sectional estimates may suffer from a self-selection problem due to the voluntary nature of program participation, as well as from spurious correlation between participation and farmland allocation decisions due to unobserved farm characteristics. Debates between Roberts and Bucholtz (2005, 2006) and Wu (2005) identified these potential econometric problems, yet they have remained unsolved. Second, even though their slippage estimates were proved consistent, their region-level aggregate results are not able to fully reveal mechanisms through which such slippage occurs.

This article makes three distinct contributions. First, several econometric techniques are used to identify the causal relationship of CRP enrollment and slippage. An identified assumption of the slippage estimate is verified by farm fixed effects, time-varying county fixed effects, and selection-on-observables. These could eliminate effects of unobservables that are potentially correlated with both the CRP participation and subsequent farmland reallocation decisions. With the quinquennial U.S. Census of agriculture micro file data from 1982 to 1992 cross-sectional and time variations of detailed individual farm production and demographic characteristics allow me to employ those techniques. Second, the article contrasts with the previous aggregate studies by isolating one source of slippage from others.[1] Specifically, I test slippage caused by "in-farm" land conversion from noncropland to cropland as a result of CRP enrollment. The mechanism and the testable slippage hypothesis via in-farm land substitution were illustrated by Wu (2000). By using a subsample of data from farms whose size remained constant between Census years, I single out potential effects from purchases and/or rentals of land on the farm's land allocation decision between cropping and non-cropping activities. Finally, the rich farm-level panel data also offers an opportunity to discern farm's heterogeneous responses to the CRP program across region, farm production type, farm operation size, and the timing of CRP enrollment.

Knowledge about the mechanism(s) through which slippage occurs should help policymakers devise programs with features designed to avoid or mitigate slippage incentives. A potential is large in the growing market of carbon sequestration projects where carbon leakage is one of the primary concerns. Voluntary based programs to preserve biodiversity and reduce deforestation may have also experienced similar backward incentives. For instance, the Sloped Land Conversion Program, a Chinese nationwide

[1]Slippage could occur from the redistribution of resources between farms through farmland trade because CRP enrollment may influence economies of scale of participants. In addition, the large amount of cropland retirement in certain region may influence local farmland market per se. Such a region-level effect may also occur in the commodity market where a sharp decline in crop production raises output prices thereby attracting more production (price feedback effect) in the same region and/or elsewhere. Moreover, program participants may reallocate input resources to increase the intensity of crop production at margin. Identifying these sources of slippage is equivalently important and will be investigated in the future.

cropland setaside program implemented in 1999, has a similar objective to the CRP to achieve poverty alleviation and ecological service enhancement.[2] Also, a similar type of payments-for-environmental-services programs has been recently launched in a number of other developing countries in Latin America and Asia to conserve standing forests (Mayrand and Paquin 2004).

To understand the nature of the problem, the CRP mechanism is outlined in the next section. Section 3 revisits the Wu's land substitution model that explains how CRP enrollment affects farm's land allocation behavior. Section 4 presents description of data and estimation issues related to section 5, where identification strategies are demonstrated. Estimation results and discussion are provided in section 6. Section 7 concludes.

2 The Conservation Reserve Program

The CRP was established in the Food Security Act of 1985 as a long-term federal cropland retirement program that operates on a voluntary basis. In contrast to previous setaside programs with the objective of crop supply control and farm income support, its main aim is to mitigate environmental degradation caused by excessive use of environmentally sensitive agricultural lands. The primary concern was to protect farmland from soil erosion, but after amendments in 1990 and 1996 more targets were added on broader environmental benefits such as improvement of air and water quality and restoration of wildlife habitat. Since it was implemented in 1986, this has been one of the largest land conservation programs worldwide in terms of scale and cost.[3] CRP impacts on regional ecosystems seem to be evident.[4]

[2]See similarities and differences in the two programs in Lohmar, et al. (2007).

[3]With about 1.7 billion dollars being allocated to CRP annually, according to the report by the Economic Research Service (ERS), 34 million acres of cropland had been retired as of 1997. This accounts for almost 8 percent of the total U.S. cropland in 1997 (Vesterby, 2003). This is about as large as the size of world annual deforestation rate during the last decade (Food and Agriculture Organization of the United Nations, 2010).

[4]It is estimated that the current amount of retirement mitigates 626 million tons of annual soil erosion from cropland (Anderson and Magleby, 1997). Another report estimates that CRP enrolled lands also contribute considerably to wildlife restoration, generating $428 million of recreational value from wildlife per year (Feather, Hellerstein, and Hansen, 1999).

This program offers eligible farmers an opportunity to retire part or all of their croplands from production in exchange for an annual rental payment. The contract requires holding land out of production for 10 to 15 years, in contrast with previous setaside farmland programs which were annual. Participants are obligated not to use enrolled land in any agricultural production activities during this period, but instead to maintain them with certain conservation practices such as grass introduction and forestation with cost-sharing payments of up to 50 percent for practice installation and up to $10 per acre for maintenance.

Although CRP participation is voluntary, potential participants must first meet several eligibility conditions and then enter an auction mechanism to compete with other applicants in each general signup period. Producers must have been the owner, operator, or tenant of potentially qualifiable croplands for at least twelve months prior to the closing date of the CRP signup period.[5] An eligible farmer can submit their cropland parcel(s) into the CRP if the offered parcels satisfy physical land criteria. For the first nine CRP signups in 1986-1989, highly erodible cropland and cropland in wetland or near water body were only CRP eligible.[6] In addition to the farm-level land quality condition, regional-level geological characteristics were added to the eligibility criteria after 1990. As a result of the Food, Agriculture, Conservation, and Trade (FACT) Act of 1990, the National Conservation Priority Areas (NCPAs) and State Conservation Priority Areas (SCPAs) were established in 1991 to conserve environmentally sensitive areas. Areas that were first designated as NCPAs are the Chesapeake Bay, Long Island Sound, and Great Lakes regions.[7] SCPAs have been established over

[5]Tenants are allowed to submit their rented land with certain agreement with their landowners. In fact, a fair amount of CRP acreage is observed from rental land.

[6]Erodibility was initially measured by the Land Capability Classes (LCC) which categorizes soil quality into eight classes (class VIII being most sensitive to erodibility) with sub-classes of (e) erosion, (w) excess wetness, (s) problems in the rooting zone, and (c) climatic limitations. A parcel of land became eligible if it belonged to VI to VIII or II to V with a predicted annual erosion rate greater than certain level. This was altered by the Erodible Index (EI) after 1987 that qualified land as highly erodible if the EI was above 8. This was subsequently relaxed in the 1990 and 1996 Farm Bill. Land eligibility conditions for CRP signups are listed in table 1.

[7]The Federal Agriculture Improvement and Reform (FAIR) Act of 1996 added the Prairie Pothole region and the Longleaf Pine region in 1997 and 1998, respectively. The boundary information on the NCPAs is provided by the Farm Service Agency (FSA) upon request. Some of the NCPAs can be also found from the EPA's "Surf Your Watershed" webpage, http://cfpub.epa.gov/surf/locate/index.cfm.

time to increase CRP enrollment in locations that are sensitive to water, air and wildlife quality within a state. Another physical criterion pertains to cropping history. Eligible lands must have been cropped in two of the five most recent crop years.[8]

Once all the eligibility criteria are met, a qualified farmer submits an offer to the bidding process with a rental payment bid for each offered parcel. Before 1990, the offered rental payment was subject to a confidential maximum acceptable bid cap set by the federal administrating agency. The bid cap was initially determined based on an average cash rent for cropland in the multicounty areas with similar farm production and land characteristics.[9] Bids were accepted if they were at or below the bid cap at multicounty level. The bidding mechanism changed after 1990. The multicounty average bid cap was replaced by a county average soil-specific agricultural rental rate of land. In addition to the bid cap, the confidential ranking system, the so-called environmental benefit index (EBI) was introduced. Each parcel of offered land is scored according to its physical and geological characteristics as well as submitted rental payment. Bids are gathered at national level and accepted in a descending order from the highest EBI score until the targeted enrollment acres in each signup are filled up (Anderson and Magleby, 1997).[10] Upon acceptance, each county has the uniform cap on total CRP acres no more than 25 percent of total county cropland acres.[11] Thus, offered parcels that could secure the bid are even rejected when the county total CRP acres have already reached the cap.

Accepted lands must be retired from production activities and utilized for conservation practices in return for rental payment for the duration of the CRP contract. A CRP contract generally becomes effective from the following cropping year once an offer is accepted.

[8]After the amendment in the Farm Security and Rural Investment Act of 2002, eligible land is required to have cropped four of the past six years.

[9]For the first three signups in 1986, bid cap calculation accounted for rents not only for dryland cropland but also for irrigated cropland, so areas with higher share of irrigated acres had a relatively high bid cap.

[10]For details of the EBI point system, see the Appendix III in Lehmann (2005).

[11]The maximum allowable county acreage is set in order to avoid potential negative effects on the agriculturally-dependent local economies (US General Accounting Office, 1989). However, this limit can be waived by the FSA admission unless such effects are expected.

3 A Model of Farmland Allocation

In this study, I investigate one of the slippage mechanisms posited by Wu (2000). Namely, CRP participants would convert some noncropland into crop production following enrollment of some cropland. This land substitution is induced by the law of diminishing marginal returns to cropping (denoted by C) and noncropping (N) activities.[12]

Suppose that the farm has three segments of land: high-quality $\bar{A}_H$, medium-quality $\bar{A}_M$ and low-quality land $\bar{A}_L$, and chooses to allocate each of them between the two activities by the amount of A_{ij} (for $i = H, M, L, j = C, N$). Suppose also that all high-quality land is allocated for crop production because the return from crop production is always larger in high-quality land, whereas low-quality land generates higher return from non-cropping activities or the conversion cost of low-quality land into crop production outweighs its return. Allocation of medium-quality land is allocated between cropland A_{MC} and noncropland A_{MN} based on market conditions and farm characteristics.

Let $\pi_C(\bar{A}_H, A_{MC}; \mathbf{p}_C, \mathbf{w}, \phi)$ and $\pi_N(A_{MN}; \bar{A}_L, \mathbf{p}_N, \mathbf{w}, \phi)$ represent the restricted profit functions for the cropping and non-cropping activities, respectively, where $\mathbf{p}$ is a vector of expected output prices of the cropping and non-cropping activities, $\mathbf{w}$ is a vector of variable input prices, and ϕ denotes farm characteristics. They are assumed to be concave and twice differentiable in choice variables. The farmer's maximization problem can be given by

$$\max_{A_{MC}, A_{MN}} \{\pi_C(\bar{A}_H, A_{MC}; \mathbf{p}_C, \mathbf{w}, \phi) + \pi_N(A_{MN}; \bar{A}_L, \mathbf{p}_N, \mathbf{w}, \phi); A_{MC} + A_{MN} = \bar{A}_M\}. \tag{1}$$

Optimal allocation of A_{MC} and A_{MN} is then determined by the following equilibrium condition of their corresponding marginal returns,

$$\tilde{r} = \frac{\partial \pi_C(\bar{A}_H, \hat{A}_{MC}; \bullet)}{\partial A_{MC}} = \frac{\partial \pi_N(\hat{A}_{MN}, \bar{A}_L; \bullet)}{\partial A_{MN}}, \tag{2}$$

[12] I define cropping activities as crop production including rotation activities, while non-cropping activities are defined as any other land use such as grazing on pasture and forest.

where $\tilde{r}$ is an implicit rental rate of land at equilibrium, and $\hat{A}_{MC}$ and $\hat{A}_{MN}$ denote optimal cropland and noncropland acreage of medium-quality land, respectively. Figure 1 depicts the relationship in equation (2).

Suppose now that a CRP signup begins and medium-quality cropland is eligible for enrollment.[13] An eligible farm then submits a sealed bid of r^{CRP} with acreage of A_{CRP} in the competitive auction if r^{CRP} is above the reservation price of farmland $\tilde{r}$. Conditional on acceptance of the bid, a contract becomes effective and enrolled CRP acres of A_{CRP} are set aside from any production activities in the following crop year. Because A_{CRP} is taken out of medium-quality cropland acreage $\hat{A}_{MC}$, the marginal condition in equation (2) changes as

$$\frac{\partial \pi_C(\bar{A}_H, \hat{A}_{MC} - A_{CRP}; \bullet)}{\partial A_{MC}} > \frac{\partial \pi_N(\hat{A}_{MN}, \bar{A}_L; \bullet)}{\partial A_{MN}}. \tag{3}$$

Bacause the farm has the diminishing marginal return from crop production, this induces reallocation of farmland by converging land from the non-cropping to cropping activities by acreage A_S. This slippage mechanism is explained by the following new equilibrium condition, as given by

$$r^* = \frac{\partial \pi_C(\bar{A}_H, \hat{A}_{MC} - A_{CRP} + A_S; \bullet)}{\partial A_{MC}} = \frac{\partial \pi_N(\hat{A}_{MN} - A_S, \bar{A}_L; \bullet)}{\partial A_{MN}}, \tag{4}$$

where r^* is an implicit rate of land at re-equilibrium. The mechanism is illustrated in figure 2. As a result, the net impact of CRP enrollment is offset by the ratio of A_S/A_{CRP}.

In this study, the testable hypothesis of slippage identifies a *rate* of slippage, (i.e., $= A_S/A_{CRP}$). It is clear from figure 2 that a slippage rate is affected by the relative curvature of the cropping and non-cropping supply functions. Slippage A_S gets larger if the acreage response for the cropping activities is relatively inelastic. For instance, relatively inelastic cropland supply can be characterized by price and income support programs. Payments of these programs were linked to commodity prices

[13] Recall that only highly erodible cropland is CRP eligible.

prior to the 1996 FAIR Act, program participants were likely less responsive to market prices. On the other hand, relatively elastic demand for non-cropping activities can stem from the large share of economically marginal land. Marginal land is frequently converted in and out of crop production as commodity prices fluctuate.

4 Data

4.1 Data Description

To test farm-level slippage, I obtain individual farm information on CRP enrollment, production activities and operator demographics from the U.S. Census of Agriculture longitudinal micro files. The Agricultural Censuses are conducted every five years which essentially cover all U.S. farmers.[14] Access to this confidential data is permitted under an agreement with the USDA National Agricultural Statistics Service (NASS). Farm samples in 1982, 1987, and 1992 are connected to create unbalanced panel data. In addition to the Censuses, commodity price data are used to account for market influences on the farm production decision. Monthly futures prices of commodities are obtained from the Chicago Board of Trade (CBOT),[15] and state-level price indexes are provided by the ERS.[16] Land quality data and CRP administration data are also obtained, respectively, from the Natural Resources Inventory (NRI) and the ERS.[17]

4.2 Sample Selection

The Census longitudinal micro data mainly have three advantages to examine the Wu's land substitution effect. Firstly, the Censuses are available before and after the first implementation of the

[14] U.S. Department of Agriculture defines a "farm" if farm operation produces at least $1,000 of agricultural products. Each of the Censuses consists of about 1.5 million farm observations out of roughly 2 million U.S. farms.

[15] Available commodities from the CBOT during the 1982-1992 period include corn, soybeans, wheat, and cattle. For more details about data, refer to http://www.cmegroup.com/market-data/datamine-historical-data/.

[16] I owe special thanks to Eldon Ball and Sun Ling Wang for making this data available.

[17] I am grateful to Daniel Hellerstein for generously providing me with the refined NRI data and corresponding statistical codes.

CRP in 1986, so that I can utilize exogenous variation explaining differences in the change in land use between CRP participants and non-participants. Secondly, both cross-sectional and time variations allow for identifying the causal impact of CRP implementation on farm's land use. For the analysis of CRP enrollment and the associated change in farmland use, the two-year panel of 1982-1987 and 1987-1992, and the long panel of 1982-1992 are used for 48 consecutive states. To examine the change in crop production activities, the analyses focus only on farm observations that exist over the panel periods. Thirdly, detailed farmland ownership information permits one to select farm observations that record no farmland transactions over the periods. I restrict the sample to farms with the fixed operating farmland size over Census years. The restricted sample can thus single out the CRP-induced farmland substitution effect between farms and isolate the slippage effect underlying within-farm land substitution in response to CRP enrollment.

For the purpose of estimating the treatment effect of CRP enrollment, I further limit the sample by eliminating observations located in counties where the share of highly erodible land (HEL) is nearly zero. The county-level HEL distribution is estimated from the NRI parcel-level data.[18] The definition of CRP-eligible HEL cropland changes over time. For the 1982-1987 panel sample, the county-level HEL cropland is estimated based on the land eligibility criteria in the first three CRP signups conducted in 1986, because CRP lands enrolled in the 1987 cropping year are determined in the previous year. As documented in table 1, the eligibility criteria in the first three signups follow the LCC. Similar sample adjustment is made for the other panel periods based on the time-varying CRP-eligible land criteria.

The sample selection procedures delineated above may introduce selection bias. First, because

[18]The NRI is a panel survey of land use and physical land characteristics on non-Federal lands. It was conducted in the years of the Agricultural Censuses from 1982 to 1997 over 48 contiguous states, but data were collected from land parcels instead of farm operation units. Data include approximately 844,000 land parcels. County total HEL acres are then computed by taking a weighted sum of parcels that are qualified as HEL by definition in footnote 6. It is noted that the county-level estimates from the NRI data may not be accurate because of the nature of the data sampling procedure. Notwithstanding, correlation between the eligibility estimates and the FSA's administrative CRP enrollment data is high about 0.7, implying that the estimates could be a proxy to explain county-level enrollment variation.

only continuous farm observations over two or three consecutive Census years are used, the parameter of interest would be biased if the decision of exit or stay in farm production is correlated with the CRP enrollment and cropland conversion decisions. For instance, using the same Census longitudinal data, Key and Roberts (2007) find some evidence that supports a positive relationship between past (non-CRP) farm subsidy payments and subsequent farm business survival. Although it is unclear whether the farm survival decision is also correlated with the CRP enrollment decision, such a potential bias can be mitigated by conditioning on subsidy payments and farm operator characteristics in the pre-CRP year. The second source of sample selection bias could arise from the fact that the 1987 and 1992 Census of Agriculture did not collect *almost* all of farms that cease agricultural production activities by retiring whole farmland in the CRP.[19] Table 2 suggests that acres retired by these "whole-farm" CRP enrollees are non-negligible.[21] Omission of the whole-farm CRP observations would generate a biased estimate of interest if some underlying factors that determine the farm's decision to retire all or part of farmland in the CRP also affect subsequent cropland conversion. To condition out this retirement effect, I analyze determinants of whole-farm CRP enrollees by using the 1992-1997 Census panel data where the 1997 Census started to collect such farm observations.[22] Logit estimation results reported in table 3 suggest that small-scale and less profitable operators are more likely to retire entire cropland in the CRP. Also, older farmers with longer farm operation as well as operators who report off-farm work as their principal occupation and work more off-farm are likely to become whole-farm enrollees. Assume that these determinants remain constant over time, the potential sample selection bias in the 1982-1992, 1982-1987 and 1987-1992 panel analyses could be avoided by conditioning on

[19] Strictly speaking, the definition of the "whole-farm CRP" includes farms with all cropland enrolled in the CRP in which less than $1,000 of agricultural products other than crops are produced and sold. In fact, a few number of such whole-farm CRP observations that have non-crop products such as livestock more than or equal to $1,000 were collected in the 1987 and 1992 Censuses. I drop those farms from estimation in order to focus on pure slippage from partial-farm CRP participants.[20] Estimation exercise including those whole-farm CRP observations confirms that their slippage contribution is merely zero.

[21] Roughly 20% of the U.S. CRP acres are enrolled by whole-farm CRP enrollees.

[22] Logit regression was conducted by assigning one for whole-farm CRP observations in 1997 and zero for partial-farm CRP observations in 1997 and regressing on the base-year explanatory variables in 1992. Results are similar to findings in the ERS report about CRP farm characteristics (Sullivan, et al., 2004).

these variables. This procedure can allow me to estimate *the slippage effect of partial-farm CRP participants*. Because the sample is further restricted by grain farms due to availability of futures commodity prices, the final sample consists of 12,074 of grain farms. These farms used about 3 million acres of active cropland in 1982. Summary statistics of the Census data are provided in table 4.

5 Empirical Strategy

5.1 Identification

Several econometric techniques are used to identify the causal relationship of CRP enrollment and slippage pertaining to in-farm land substitution. An identified assumption of the slippage estimate is verified by farm fixed effects, time-varying county fixed effects, and selection-on-observables. These could eliminate effects of unobservables that are potentially correlated with both the CRP participation decision and subsequent farmland reallocation. Farm-level cross-sectional and time variations of farm characteristics allow me to employ those techniques.

The parameter of interest is obtained by a regression of cropped acreage on acreage enrolled in the CRP, as given by

$$A_{it}^{C} = \alpha_0 + \alpha_1 A_{it}^{CRP} + \alpha_2 \bar{A}_{it} + \epsilon_{it}, \tag{5}$$

where, given farm size $\bar{A}_{it}$, farm i allocates A_{it}^{C} acres for cropping activities while A_{it}^{CRP} acres are retired in the CRP at year t, α_0 is an intercept, ϵ_{it} is an error term, and the parameter of interest α_1 measures a proportional change in cropped acreage in response to acreage enrolled in the CRP. If there is no slippage, then $\alpha_1 = -1$, whereas $\alpha_1 > -1$ indicates the presence of slippage. A key assumption to obtain a consistent estimate of α_1 is $E[A_{it}^{CRP}\epsilon_{it}|\bar{A}_{it}] = 0$. Because CRP participation is voluntary and thus CRP acres are not randomly assigned, endogeneity of the CRP enrollment and crop production decisions is one of the issues that violate this assumption. Nevertheless, the slippage estimate may not suffer from this endogeneity due to the timing of enrollment. In general, a CRP contract becomes effective in October once an offer is accepted. This implies that enrolled CRP acres for cropping year t are predetermined in the previous year, thereby making the CRP decision recursive unless there exists intertemporal dependence thorough the error term.

However, serial correlation likely exists, because the irreversible CRP decision adheres to the farm's return to future production through farm's underlying parameters such as entrepreneur skill and farm productivity. These farm characteristics, denoted by u_i, are usually unobserved by econometricians, so that we likely fail to satisfy the identifying assumption because $E[A_{it}^{CRP}(u_i)(u_i + \epsilon_{it})] \neq 0$. For example, Roberts and Bucholtz (2005) indicate positive association between the frequency of CRP enrollment and a rate of noncropland conversion to cropland in areas with relatively low land quality. Land quality distribution is an important factor that determines farmland allocation among different activities. A farm with more high-quality of land is likely to stay in crop production whereas a farm with economically marginal land is sensitive to surrounding environment such as commodity prices and weather. At the same time, land quality may be highly correlated with land erodibility, which is one of the CRP eligibility conditions and therefore increase the likelihood of CRP enrollment. In addition to land quality, likely unobserved operator's management quality and natural risk attitude may also be determinants of both the CRP participation and crop production decisions. A high-skilled operator is more likely to continue crop production, so they may not get incentive for land retirement. On the other hand, they may intend to enroll in the CRP as a source of additional income from high erodible but unproductive unused land. Moreover, a more risk-averse farm may decide to enroll in the CRP to secure a future stream of certain rental payment. But such a farm would operate relatively low-level production activities. As a result, unobserved management skill and risk attitude would cause a bias on the slippage incidence although the direction of confounding effects from these operator characteristics is ambiguous. Influences of such time-invariant unobserved heterogeneity can be controlled by using farm fixed effects.

In addition, I include year fixed effects, time-varying county fixed effects and observable farm-level production characteristics to minimize any other potential confounding effects on the parameter of interest from time-varying unobserved heterogeneity. Year fixed effects capture the macro-economic shocks to farm production at time t, while time-varying county fixed effects can account for any time-varying regional effects influencing the farm's production decision, such as the change in region-specific policies, output and input markets, and weather.

Introducing the fixed effect for farm i, f_i, the fixed effect for year t, θ_t, the county-year fixed effect in county j in year t, C_{jt}, and a vector of covariates of individual farm characteristics, X_{it} in equation (5) yields

$$A_{it}^{C} = \alpha_0 + \alpha_1 A_{it}^{CRP} + \alpha_2 \bar{A}_{it} + \mathbf{X}_{it}\alpha_3 + f_i + C_{jt} + \theta_t + \epsilon_{it}, \tag{6}$$

where the identifying assumption is replaced by $E[A_{it}^{CRP}\epsilon_{it}|\bar{A}_{it}, \mathbf{X}_{it}, \theta_t, f_i, C_{jt}] = 0$. This proves the OLS estimate of α_1 to be consistent.

Yet, one may wonder whether the CRP decision is truly predetermined as well as whether the aforementioned sets of fixed effects and time-variant observable farm characteristics fully account for confounding effects from unobservables. The identifying assumption may be still invalid if the CRP decision is highly correlated with past crop production activities, which in turn are likely correlated with current crop production activities through ϵ_{it}. This is likely true because CRP participation is contingent on the cropping history. The summary statistics of the sample in table 4 seems to indicate their association (that is, CRP participants have larger cropped acres in the base year). This potential pre-enrollment heterogeneity bias could be more problematic particularly in presence of other government payment programs affecting the production decision with a similar eligibility condition to the CRP's. A participation level in the price and income support programs in the 1980s and early 1990s is constrained by base acres that are generally determined by the 5-year average of cropping history.

These concerns can be assessed by conditioning on base-year heterogeneity among CRP participants and non-participants. Taking first-difference of equation (6) over the Census panel years enables me to include the pre-enrollment (base-year) farm characteristics, as given by

$$\Delta A_{it}^{C} = \alpha_1 \Delta A_{it}^{CRP} + \Delta \mathbf{X}_{it}\alpha_3 + \mathbf{X}_{ib}\alpha_4 + \Delta C_{jt} + \Delta\ \theta_t + \Delta\epsilon_{it}, \tag{7}$$

where the delta represents the first-difference operator between the period t and t-5 (or t-10 for the 1982-1992 panel analysis), $\Delta\theta_t$ becomes the common intercept for all farms, and $\mathbf{X}_{ib}$ denote a vector of base-year farm characteristics. Note also that given observations with fixed farm size, first-differencing eliminates the impact of the potential farmland transactions decision induced by CRP enrollment. Accordingly, the identifying assumption can be rewritten such that $E[\Delta A_{it}^{CRP}\Delta\epsilon_{it}|\Delta\mathbf{X}_{it}, \mathbf{X}_{ib}, \Delta C_{jt}, \Delta\theta_t] = 0$.

Finally, for the 1987-1992 panel data, additional source of bias may stem from violation of the strict exogeneity assumption. This is because the cropping history becomes endogenous in the subsequent CRP signups after 1986. For instance, the CRP enrolled acreage in the first CRP signup in 1986 is contingent on cropped acreage prior to the CRP, but the CRP eligibility status in 1990 can be controlled by farmers by increasing crop production in 1986-1989. This future option effect turns out that $E[\Delta A_{it}^{CRP}\epsilon_{i,1987}] \neq 0$ for $t = 1992$. But this can be avoided by additionally conditioning on pre-CRP-period variables that can characterize the farm's inherent crop production capacity. Hence, the identifying assumption for the 1987-1992 panel data can be rewritten as $E[\Delta A_{it}^{CRP}\Delta\epsilon_{it}|\Delta\mathbf{X}_{it}, \mathbf{X}_{ib}, \mathbf{X}_{i,1982}, \Delta C_{jt}, \Delta\theta_t] = 0$.

5.2 Variable Construction

5.2.1 Dependent variable

A dependent variable is defined as the change in acres in cropping activities net CRP acres. As depicted in figure 3, the Censuses categorize farmland acres into cropland, woodland, pastureland and rangeland, and all other land (land in house lots, roads, ponds, wasteland, etc.). Cropland acres are further decomposed into six subcategories: crop harvested, crop failed, cultivated summer fallow, used for cover crops, idled, and used for pasture and grazing. Among these, acres for cropping activities can be defined as the sum of cropland harvested, crop failed, summer fallowed and used for cover crops, as indicated by orange color in figure 3.[23] From cropping acres, CRP acres are subtracted to create net cropped acres for CRP participants.

5.2.2 Measurement errors in the dependent variable

Data on CRP enrollment acres introduce two measurement errors on the dependent variable. The measurement errors on the dependent variable would not affect the parameter of interest unless the corresponding explanatory variable and the dependent variable are correlated. I explain below why the measurement errors on the dependent variable matter in this exercise. First, the Censuses specify that CRP acres belong to the category of either cropland used for cover crops or idled. However, cropland used for cover crops is also counted as part of cropped acres. Thus, constructing the dependent variable by the simple difference between cropped acres and CRP acres generate the measurement error that is also correlated with CRP-enrolled acres. Second, some observations seem to double-count cropped and CRP-enrolled acres on the same parcel of land. This attributes to the fact that the Census data are collected at the end of the calendar year (and recorded as of December 31), whereas the CRP contract starts at the beginning of crop year (generally October). For instance with the 1982-1992 panel data, CRP acres which are supposed to be binding in the 1993 land use are rather counted as the 1992 land use, because the corresponding CRP contract becomes effective on October 1, 1992. Until the contract date, the contracted land parcels are free from land use restriction, so they can be used for production activities. Therefore, those parcels can be counted twice in the 1992 Census data as both cropped acres and acres enrolled in the CRP. These issues are taken into account in

[23] That is, this definition takes crop rotation into consideration.

constructing CRP-net cropped acres as follows.

First, I subtract CRP acres from cover-crop acres. If the computed value turns out negative, it is assigned zero. This truncated value is then added to the sum of cropland acres harvested, crop failed, and cultivated summer fallow. This can be given as

$$\begin{aligned} CroppedAcres = Harvested + Failed + SummerFallow + \\ + Max((CoverCrops - CRP), 0). \end{aligned} \tag{8}$$

Derived acres represent a lower bound of the CRP-net cropped acres because the maximum amount of potential CRP acres is subtracted from the current cover-crop cropland acres. Hence, the slippage estimate with this definition of a dependent variable also indicates a lower bound. Note that, for the 1987-1992 panel, the lower bound estimate is fully justified only for the sub-sample with no base-year CRP enrollment (i.e., the lower bound estimate can be guaranteed only for new participants after 1987).

Next, the measurement error from double-counting the following crop year's CRP enrollment is eliminated by dropping such erroneous observations from estimation. The constructed dependent variable in equation (8) fails to exclude such CRP acres, resulting in the potentially upward bias of a slippage estimate. I build the following criteria to endeavor to minimize this measurement error in the currently available Census data format. First, I calculate the excess acreage of CRP by subtracting acres in the CRP-potential categories of land use from total CRP acres. Although CRP land is defined as part of cropland used for cover crops and idled, it is often observed in the Census data that CRP acres exceed acres used for cover crops and idled. In fact, it appears that the current CRP acres also belong to woodland, pastureland and rangeland, or all other land categories, as indicated by green color in figure 3. This should stem from the CRP eligibility condition of cropping history. Because land is eligible for the CRP after two years of cropping activities in the previous five years, currently CRP-enrolled acres are not confined by currently cropped acres. Therefore, the excess CRP acreage is calculated as

$$\begin{aligned} ExcessCRPAcres = CRPAcres - (&CoverCrops + Idled + \\ &+ Pasture + Woodland + OtherLand). \end{aligned} \tag{9}$$

If this excess CRP acreage is positive, then it indicates the least evidence of double-counting. Such observations are dropped from estimation. Despite that the criteria may still leave some more double-counting observations, I find that a dropping rate for e.g., the 1982-1992 panel data is about 6% of the sample size of CRP participants, which is larger than an actual enrollment rate of 1992 CRP contracts during the 1986-1992 signups (less than 5%). Hence, this procedure reasonably reduces the measurement error from double-counting.

5.2.3 Independent variable

Several time-varying farm production characteristics are added as covariate to minimize the potential impacts of unobservables on the parameter of interest.

First of all, cropland conversion is affected by exogenous market shocks of output and input prices. Time-varying county fixed effects can account for them only if farms within a county have the identical elasticity. Because the farm's production decision is determined inherently to location-specific soil and climatic properties and they could vary even within a county, farms would respond to prices of certain sets of outputs and inputs unique to their farmland capacity. To account for this heterogeneous response by farm production type, I classify farms into a similar type of commodity production by following the six-digit Standard Industrial Classification (SIC) code.[24] The interaction term of the county-year and SIC fixed effects is then included in regression assuming that a similar type of farms in the same region is likely subject to a similar choice set of commodities and input types.

Another variation in farm's response to the output price change may stem from farmland quality

[24]Refer to http://www.osha.gov/pls/imis/sic_manual.html for a list of the SIC. The Agricultural Censuses contain farm's SIC information.

as argued by Roberts and Bucholtz (2005). Farms with more economically marginal land endowment may be more sensitive to market conditions. To account for this farmland-specific response pattern to commodity prices, I use futures contract prices of major crops and livestock products at a planting period. Monthly average futures prices in March for corn and September for winter wheat are obtained to represent expected prices at the planting period.[25] They are deflated by state-level output price index to allow for regional variation over time. Then, a variable reflecting farm-specific output price change is created by multiplying the change in the deflated futures prices by the beginning year's sales shares of respective crops and livestock products. Because the historical data of output futures prices are available only for corn, soy beans, and wheat, and cattle, I use for estimation grain farm observations whose major crop sales come from either corn, soy beans, or wheat. The differential price impact among heterogeneous farmland quality can be further explained by proxy by adding the interaction term of the farm-specific output price change and base-year yield of respective crops.

In addition to the market impacts, effects of other government subsidy programs are taken into consideration. Prior to 1996, agricultural production was supported by deficiency payments and commodity loan programs to stabilize crop prices. Program participants thus gained benefits by reducing a production risk. To refrain from excess supply as a result of risk reduction, the programs limited an amount of enrolled acreage and also required payment recipients to annually set-aside a certain proportion of farmland. Also, the program enrollment level was determined based on a five-year planting history, so that program participants were motivated to maintain their production level. As a result, the current production level of the participants are closely tied to the payment level that is also correlated with past production level. But the past production level also affects the CRP enrollment level as one of the eligibility conditions. To control for the association between farm's crop production and production support program participation, annual setaside acreage information under

[25]The construction of expected prices follows Holt, (1999). Monthly average futures prices in March for harvest-time futures contracts are taken from the December CBOT contract for corn and spring wheat and the November CBOT contract for soybeans. For winter wheat, monthly average futures prices in the previous September are taken from the July CBOT contract.

these government programs is used as an indicator of the participation level.[26]

Another time-varying farm variation that affects cropland conversion attributes to technological change through capital accumulation. The change in production technology may also affect the CRP participation decision as it likely changes marginal returns to production. Irrigation is one of the most effective technologies to improve productivity to induce production expansion. I control for the change in irrigated acres to capture the impact of technological change.[27]

Finally, several base-year farm characteristics are added as covariates to mitigate the potential of sample selection bias as discussed in Section 4.2 as well as to account for pre-enrollment farm heterogeneity. Several pre-CRP-period farm characteristics are also controlled for to avoid the violation of the strict exogeneity assumption for the 1987-1992 panel data. Farm size, per-acre sales, acres in cropland, pastureland, woodland and irrigation, and operator's age, operation experience, principal occupation and off-farm working status are included. Summary statistics for grains farms are provided in table 4.

6 Estimation Results

I estimate the model for three time periods: 1982-1987, which covers the first CRP signup; 1987-1992, which covers subsequent signups; and 1982-1992, the same period used by Wu (2000) and Roberts and Bucholz (2005). The analysis with the 1982-1992 long panel data has advantages. Because the CRP signups started in 1986, farm information in the 1982 Census is exogenous to any CRP-induced changes. Also, the long panel can enable one to observe the farm's long-term adjustment motive in production activities as a result of CRP enrollment. Moreover, the same 1982-1992 period is used

[26] One might worry about the potential for additional simultaneity bias because program participation and crop production are jointly determined. Nevertheless, inclusion of aforementioned fixed effects and exogenous output price changes can control for time-varying factors that affect the change in a program participation rate.

[27] A potential simultaneity bias between irrigation technology adoption and cropland use can be avoided by conditioning on time-varying county fixed effects, as they control for exogenous weather shocks that influence irrigation technology adoption.

by the Wu's and Roberts and Bucholtz's analyses, so results can be comparable to their aggregate estimation results. In contrast, the shorter panels allow me to see whether a slippage rate changed as the program expanded its coverage. The 1982-1987 short panel is of particular interest in analyzing instantaneous impact of first CRP implementation. Results from the three panel data analysis are integrated for robustness check.

Due to data limitation on commodity futures prices as mentioned in section 5.2, I use corn, soy, wheat, and other cash grain farms defined by six-digit SIC codes. To better capture the output price effects, I restrict the sample whose base-year sales share of corn, soy, and wheat products cover a majority of total sales. This may be a sensible approach as farm's production activities should be most influenced by the majority of their products. To see how this sample attrition affects the slippage estimate, robustness check will be provided in section 6.3 by adding non-grain farm observations.[28]

6.1 Results from the 1982-1992 Panel Data

First, I show how the parameter estimate of interest varies in absence of farm fixed effects. Table 5 provides regression results from pooled OLS and random effects estimation based on equation (5). Cropped acreage is regressed on CRP acreage with or without additional covariates. A notable difference is observed in the OLS coefficient estimates of CRP acres among specifications. With the random effects model the estimates become relatively stable. Because the parameter of interest is not robust among specifications and also because they are not able to include base-year farm characteristics which would further influence the estimate, those techniques may not yield a reliable estimate of slippage incidence.

Table 6 presents estimation results from the farm fixed effects model based on equation (7). The change in cropped acreage is regressed on the change in CRP acreage with or without additional

[28] I also exclude CRP participants that break their contracts during the periods (i.e., more CRP acres enrolled in the 1987 Census than in the 1992 Census), because these cases cannot be properly identified. Such observations account for only 10% of participants in the sample.

covariates. Also, for each of the regressions, a set of fixed effects–county-year fixed effects and the interaction of county-year and SIC fixed effects–are included in addition to farm fixed effects. Slippage seems evident in table 6. There is about 14% of land conversion from noncropland to cropland if farm fixed effects are included in column (1) (i.e., -1 - (-0.861)). The slippage estimate is fairly stable even with additional covariates in columns (2) and (3). This indicates that once unobserved farm characteristics are eliminated by farm fixed effects, additional covariates barely affect the slippage estimate.[29] The slippage estimate is also robust with county-year fixed effects and its interaction with SIC fixed effects as in columns (4)-(9). These findings suggest that conditional on farm fixed effects, the slippage estimate is likely orthogonal to unobserved heterogeneity. This also provides a firm support for the supposition that the CRP participation decision is predetermined. This finding is reasonable particularly because the currently used sample only includes grain farms with a similar crop pattern, so that farms within a county or within a county and a production type are likely homogeneous to time-varying shocks.

Besides the slippage estimate, coefficient estimates of the other covariates can validate the specification used for estimation. The three price change variables reasonably capture an economic incentive of the farm's crop production decision when the base-year controls are included. As expected, crop and livestock prices create opposing effects on cropping activities. In addition, farms with low productivity (that is, lower average grain yield) are more sensitive to the change in commodity prices.[30] These estimates become hardly significant with county-year and SIC fixed effects in column (9), suggesting that these fixed effects reasonably account for the farm's heterogeneous response to price shocks.

The other two time-varying observables (i.e., indicators of commodity support program participation and technology adoption) also have the expected signs and notable influence on land allocation. The coefficient of the change in setaside acreage moves significantly when the base-year variables are

[29] I also conducted the same estimation with acreage share variables that adjust potential heteroskedasticity due to farm operation size, and results are almost identical.

[30] Note that the price change variables are weighted by output values, so the magnitude of their estimates does not reflect the actual price elasticity.

included. This indicates that commodity support program participation is highly correlated with past production activities. Nevertheless, it rarely affects the slippage estimate. The coefficient of the change in irrigated acreage changes to some extent when county-year fixed effects and its interaction with SIC fixed effects. This indicates that some county-level time-varying factors affect irrigation technology adoption and such an effect varies across farm type. Again, irrigation does not affect the slippage estimate.[31]

In addition to the mean estimate of slippage, the rich farm-level panel data offers an opportunity to further examine farm's heterogeneous response to the CRP program in multiple dimensions: across region, type and size of farm operation, and timing of CRP enrollment. Table 7 provides some evidence that could concrete the incidence of slippage underlying in-farm land substitution . Panel A examines the relationship between slippage and participation in the production support programs. Production support program participants are likely less responsive to market prices and therefore have relatively inelastic cropland demand. It appears that an average slippage rate is larger by about 10 percentage points for CRP enrollees who also participated in the production support programs. This points out the potential ineffectiveness of the land retirement program in conjunction with other market-distorted policies enhancing crop production activities. Panel B presents a marked difference in the slippage estimate by farm groups with different shares of cropped acres in 1982. Slippage is statistically and economically significant for grain farms with a larger share of *uncropped* land, indicating that farms with the excess capacity of conversion are more flexible in the land allocation decision and thus likely to give rise to slippage. This result suggests that additional restrictions on the rest of land use for participants and/or introduction of penalty points reflecting the share of noncropland in the current auction mechanism can hinder such a backward incentive offsetting the program benefits.

Table 8 reports region-specific slippage estimates. Definition of three regions is identical to the

[31]For instance, weather conditions in 1982 and 1992 differ significantly. Rough estimates of U.S. average temperature and precipitation from the data in Schlenker and Roberts (2009) indicate more temperature variation (hotter summer and colder winter) in 1982 than in 1992 and fewer precipitation during the 1982 crop season. Larger uncertainty in the production decision influences irrigation technology adoption.

one used in Wu (2000) and Roberts and Bucholtz (2005). Most CRP-concentrated five Midwest regions–Corn Belt, Lake States, Northern and Southern Plains and Mountain–are used to estimate the region-specific slippage incidence relative to the other regions.[32] Results in table 8 present different slippage estimates across the regions. During the 1982-1992 period, largest slippage was present in Southern Plains regions (about 35%), and Corn Belt, Lake Sates, Northern Plains and Mountain regions experienced the less amount of CRP-induced land conversion (10%, 15%, 15%, and 14%, respectively). These estimates in Corn Belt, Lake Sates, and Northern Plains are numerically comparable to the Wu's (30%, 19%, and 11%) and Roberts and Bucholtz's (17%, 11%, and 22%).[33] However, my estimates present the sole evidence of the in-farm land substitution effect, whereas theirs indicate aggregate impacts of CRP enrollment through multiple channels.[34]

Table 9 provides the relationship between the slippage rate and several other farm operation types. Panel A exhibits different slippage rates by operating farmland size. Panel B also shows differences by farm operation type and sales size. These results inform three unique findings. First, combining these two results reveal that small-scale and likely less efficient full-time farms contribute most to slippage incidence. Next, despite that small-scale farm participants give rise to the highest *slippage rate* as seen in panel A, larger farms also contribute to slippage at a steady rate over 10 percentage points, thereby causing more *slippage acres*. In fact, average acres enrolled in the CRP are much larger for larger-scale farms as provided in column (3). In addition, it is interesting to note that part-time farms in small-scale production contribute to negative slippage although statistically not significant. In other words, CRP participation possibly induces recreational farms to retire additional land from

[32] A Corn Belt region includes Illinois, Indiana, Iowa, Missouri and Ohio, Lake States include Michigan, Minnesota and Wisconsin, Northern Plains include Kansas, Nebraska, North Dakota and South Dakota, South Plains include Oklahoma and Texas, and Mountain region includes Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming. For the other region category, see `http://www.ers.usda.gov/briefing/arms/resourceregions/resourceregions.htm.`

[33] The slippage estimates of Roberts and Bucholtz presented here are OLS estimates.

[34] Despite the reliability of estimates, their aggregate estimates could account not only for the land substitution effect but for the price feedback effect and the land transactions effect. Also, both whole-farm and partial-farm CRP participants are included in their estimates, while my estimate only takes into account contribution from partial-farm CRP participants.

crop production. This may be a sign of positive spillover from an environmental conservation policy in presence of altruistic preferences.

Another advantage of the three-year panel data enables one to differentiate the CRP enrollment impact by different signup periods. CRP participants during the 1982-1992 period are categorized by: (i) 1982-1987 enrollees who enrolled in the CRP only prior to 1987; (ii) 1987-1992 enrollees who enrolled in the CRP only after 1987; and (iii) 1982-1992 enrollees who enroll in the CRP in both of the 1982-1987 and 1987-1992 periods (i.e., more than one enrollments). Estimates are reported in table 10. A slippage rate is similar for one-time enrollees in the 1982-1987 period (13.7%) and the 1987-1992 period (12.2%).[35] In contrast, slippage is clearly larger (28.2%) for participants enrolling multiple times. This could suggest that the slippage problem got worse as farmers became more familiar with the program and squeezed more rents from the policy.

6.2 Results from the 1982-1987 and 1987-1992 Panel Data

Table 11 reports estimation results from separate estimation of the 1982-1987 and 1987-1992 short panel data. A mean slippage rate for new enrollees decreases by 12% (from 24.5% to 12.5%) from the 1982-1987 to 1987-1992 periods. This implies that the initial CRP signups in 1986 induce more slippage. This could stem from the flawed program design in early signups. That is, in the first three signups in 1986, the maximum allowable rental payment was determined based on average cash rents for cropland across collections of counties with homogeneous characteristics. However, farms are likely heterogeneous even within a county, therefore uniform pricing should have given low-productive participants an incentive to overbid. Also, the region-average cash rents included rents for both non-irrigated and irrigated cropland. Since cash rents for irrigated land are clearly higher than dryland, this spurred dryland farms to enroll in the program to enjoy the miss-specified rent. The region-specific

[35] A slightly larger slippage rate in the early signup period may indicate two things: long-term adjustment effect and mechanism pitfalls. It could imply that participants could adjust their farmland allocation more flexibly (i.e., more slippage) in the longer time period after enrollment. Or it could result from the flawed program design in early signups as discussed in the nect section.

slippage rates in column (1)-(2) in table 12 partly support the evidence of this policy misspecification. Areas except the Corn Belt and Lake States regions experienced sizable fluctuation in the slippage incidence before and after the ammendment of the rental payment mechanism. In fact, these areas covered the majority of U.S. irrigated land at that time.

6.3 Slippage from All Farm Observations

Although the assessments thus far result from the restricted sample of grain farms, we saw in table 6 that inclusion of time-varying county fixed effects and SIC fixed effects could account for farm's heterogeneous response to market shocks. Provided that this is a legitimate assumption also for non-grain farms, table 13 provides regression results without price covariates for all operating farms (with fixed farmland size) during the 1982-1992 period. It is found that the slippage estimate for non-grain farms (that is, the sum of the estimate of CRP acreage change and its interaction with the non-grain indicator) changes to some degree with different sets of fixed effects and covariates. A marked change in the estimate is observed when the base-year farm characteristics are controlled for. Slippage is significantly larger for non-grain farms by about 25% than grain farms in column (6) in table 13 . In particular, a remarkable rate of slippage (about 47%) attributes to livestock farms as seen in column (7). This may pertain to the excess capacity of conversion as argued above, because farms that primarily produce livestock products likely own/rent larger share of marginal cropland. This also indicates that the non-grain farm's land allocation decision is strongly tied with initial land use constraints.

7 Conclusion

This article tests one unique source of slippage caused by in-farm land substitution from noncropland to cropland as a result of farmland retirement in the U.S Conservation Reserve Program (CRP). With the farm-level panel data I can utilize cross-sectional and time variation of detailed individual farm characteristics to identify the causal relationship of CRP enrollment and subsequent slippage through in-farm land substitution. An identified assumption of the slippage estimate is verified by farm fixed effects, time-varying county fixed effects, and selection-on-observables. These could eliminate effects of unobservables that are potentially correlated with both the CRP participation and subsequent farmland reallocation decisions.

The in-farm slippage effect is examined for the three different time periods: 1982-1987, 1987-1992, and 1982-1992. Overall, slippage seems evident and fairly robust among specifications when farm fixed effects reasonably account for unobserved heterogeneities. It is found that an average partial-farm CRP participant converts about 14% of noncropland to cropping activities after CRP enrollment. Moreover, the rich farm-level panel data also offers an opportunity to further examine farm's heterogeneous response to the CRP program across regions, farm production and operator types, and the timing of CRP enrollment. Results show that a rate of slippage incidence varies not only across region but also across time. I also find that the slippage rate increases for participants enrolling in the multiple CRP signups, suggesting that the slippage problem got worse as farmers became more familiar with the program and squeezed more rents from the policy. Moreover, participants with a larger share of uncropped land contribute more to slippage, indicating that farms with the excess capacity of conversion are more flexible in the land allocation decision and thus likely to give rise to slippage. This result suggests that additional restrictions on the rest of land use for participants and/or introduction of penalty points reflecting the share of noncropland in the current auction mechanism can hinder such a backward incentive offsetting the program benefits. Finally, the simplest solution to avoid slippage from idle land conversion seems to expand the mechanism that encourages farms to retire whole farmland, as operated by programs like the Wetland Reserve Program and Agricultural Easements. It is important in this regard to carefully reinvestigate the environmental effectiveness and the cost effectiveness of the CRP.

Results indicate that any program of this kind is likely to generate some offsetting behavior, with farmers shifting crop production to previously uncropped land in response to subsidized land setasides. Attention may be particularly given to developing countries where a number of cropland and forest conservation program have been recently launched. Poorer farmers may have relatively price inelastic demand for crop production activities because no substitutable income activities are available, hence such a program would induce larger incentive to convert noncropland (uncultivated land or non-harvested forest) into cropland. Knowledge about the mechanisms by which and whom slippage occurs should help policymakers devise programs with features designed to avoid or mitigate slippage incentives, especially by taking the heterogeneity of potential participants into account.

Besides the impact of CRP enrollment on cropland conversion during the 1982-1992 period, further research opportunities are available with the Agricultural Census data for the 1992-2002 period. It is interesting to examine whether the trends I observe for 1982-1992 in the constant farm size sample carry over from the 1992-2002 period. Another interesting question departs from the partial equilibrium setting where the land substitution mechanism within a farm causes slippage. That is to look at that possibility to identify the other source of slippage caused by cross-farm land substitution in presence of the local farmland market. This can be conducted by using variation of farm size change over the Census periods. Preliminary results show strong correlation between land transactions and CRP enrollment, and interestingly the impact of such association on cropland conversion is asymmetric by the type of land transactions (i.e., seller or buyer as well as owner or renter).

References

[1] Anderson, M., and R. Magleby. 1997. "Agricultural Resources and Environmental Indicators, 1996-97." Agricultural Handbook No. 712, U.S. Department of Agriculture, Economic Research Service.

[2] Economic Research Service. 2006. "Environmental Effects of Agricultural Land-Use Change: The Role of Economics and Policy." Economic Research Report 25, U.S. Department of Agriculture, Washington DC.

[3] Economic Report of the President. 2006. U.S. Government Printing Office. Washington DC.

[4] Feather, P., D. Hellerstein, and L.R. Hansen. 1999. "Economic Valuation of Environmental Benefits and the Targeting of Conservation Programs: The Case of the CRP." Agricultural Economic Report No. 778.

[5] Food and Agriculture Organization of the United Nations. 2010. Global Forest Resources Assessment.

[6] Holt, M.T. 1999. "A Linear Approximate Acreage Allocation Model." Journal of Agricultural and Resource Economics 24(2):383–397.

[7] Kirwan, B., R.N. Lubowski, and M.J. Roberts. 2005. "How Cost-Effective Are Land Retirement Auctions? Estimating the Difference between Payments and Willingness to Accept in the Conservation Reserve Program." American Journal of Agricultural Economics 87(5): 1239–1247.

[8] Lehmann, P. 2005. "An Economic Evaluation of the U.S. Conservation Reserve Program." UFZ-Discussion Papers. Leipzig. Germany. `http://www.ufz.de/data/Disk_Papiere_2005-012519.pdf`. Accessed November 15, 2009.

[9] Lohmar, B., C. Nickerson, E. Uchida, and X. Jintao. 2007. "Land Conservation in the United States and China: A Comparison of Practices, Policies, and Data Implications for Assessment and Evaluation." Paper prepared for presentation at the Fourth International Conference on Agricultural Statistics, Beijing, China, October 22–24, 2007.

[10] Mayrand, K. and M. Paquin. 2004. Payments for Environmental Services: A Survey and Assessment of Current Schemes. Unisfera Montreal. `http://www.cec.org/files/PDF/ECONOMY/PES-Unisfera_en.pdf`. Accessed March 1, 2011.

[11] Osborn, C. Tim, Felix Llacuna, and Michael Linsenbigler. 1995. "The Conservation Reserve Program: Enrollment Statistics for Signup Periods 1–12 and Fiscal Years 1986-93." Statistical Bulletin No. 925, Economic Research Service, U.S. Department of Agriculture, Washington, DC, November 1995, 102 pp. `http://www.ers.usda.gov/publications/sb925/`. Accessed May 15, 2009.

[12] Roberts, M., and S. Bucholtz. 2005. "Slippage in the Conservation Reserve Program or Spurious Correlation? A Comment." American Journal of Agricultural Economics 87(1): 244–50.

[13] Roberts, M., and S. Bucholtz. 2006. "Slippage in the Conservation Reserve Program or Spurious Correlation? A Rejoinder." American Journal of Agricultural Economics 88(2): 512–14.

[14] Schlenker, W. and M. Roberts. 2009. "Nonlinear Temperature Effects indicate Severe Damages to U.S. Crop Yields under Climate Change." Proceedings of the National Academy of Sciences 106(37): 15594–98.

[15] Shoemaker, R. 1989. "Agricultural land values and rents under the conservation reserve program." Land Economics 65(2): 131–7. Sullivan, P., D. Hellerstein, L. Hansen, R. Johansson, S. Koenig, R. Lubowski, W. McBride,

[16] D. McGranahan, M. Roberts, S. Vogel, and S. Bucholtz. 2004. "The Conservation Reserve Program: Economic Implications for Rural America." Agricultural Economic Report (AER–834) 112 pp, October. U.S. Department of Agriculture, Economic Research Service, Washington DC.

[17] U.S. Department of Agriculture, Farm Service Agency. 2003. "Literature Review and Research Recommendations for the Conservation Reserve Program." Appendix D in Conservation Reserve Program: Final Programmatic Environmental Impact Statement. January. `http://www.fsa.usda.gov/Internet/FSA_File/appendixd.pdf`. Accessed May 15, 2009. U.S. Department of Agriculture, Farm Service Agency. 2008. Conservation Reserve Program: Summary and Enrollment Statistics, FY2008.

[18] Vesterby, M. 2003. "Land Use." in Heimlich, R. Agricultural Resources and Environmental Indicators, Agriculture Handbook No.722, U.S. Department of Agriculture, Economic Research Service.

[19] Wu, J. J. 2000. "Slippage Effects of the Conservation Reserve Program." American Journal of Agricultural Economics 82(4): 979–92.

[20] Wu, J. J. 2005. "Slippage in the Conservation Reserve Program or Spurious Correlation? A Reply." American Journal of Agricultural Economics 87(1): 251–54.

[21] Young, C.E. and C.T. Osborn. 1990. "The Conservation Reserve Program: An Economic Assessment." Agricultural Economic Report (AER626) 40 pp, February. U.S. Department of Agriculture, Economic Research Service, Washington DC.

Table 1: Conservation Reserve Program Signup Periods and Eligibility Criteria

Signup	Type	Dates	Eligibility Criteria*	Contract Acres
1	General	March 3-14, 1986	A-B	753,668
2	General	May 5-16, 1986	A-B	2,771,660
3	General	August 4-15, 1986	A-C	4,703,379
4	General	February 9-27, 1987	A-D	9,478,599
5	General	July 20-31, 1987	A-D	4,442,719
6	General	February 1-19, 1988	A-F	3,375,364
7	General	July 18-31, 1988	A-F	2,604,901
8	General	February 6-24, 1989	A-H	2,462,382
9	General	July 17 - August 4, 1989	A-H	3,329,893
10	General	March 4-15, 1991	A-C,E,G,I-K	475,175
11	General	July 8-19, 1991	A-C,E,G,I-K	998,211
12	General	June 15-26, 1992	A-C,E,G,I-K	1,027,444

Source: USDA (2008)

* Eligibility Criteria:

A. Land capability classes 6 - 8

B. Land capability classes 2 - 5 with predicted average annual erosion rate greater than 3T

C. Land capability classes 2 - 5 with predicted average annual erosion rate greater than 2T and with gully erosion

D. Land with EI > 8 and predicted average annual erosion rate greater than T

E. Land for filter strips alongside wetlands, streams, or other water bodies

F. Land for tree planting-eligible when 1/3 of field meets criteria A or Class 2-5 soil with predicted average annual erosion rate greater than 2T

G. Land having evidence of scour erosion caused by out-of-bank water flows

H. Wetland as follows:
- Cropped wetland of at least 6 acres
- A field of which 1/3 or more is cropped wetland
- A field of 6 to 9 acres on which wetlands are present

I. Land in designated national conservation priority areas
- Chesapeake Bay Region
- Great Lakes Region
- Long Island Sound Region

Land in designated State water quality priority areas
Public wellhead protection area established by EPA
Hydrologic Unit Areas approved by the Secretary
Land located in areas designated as Clean Water Act "319" priority areas

J. Lands to be established in specified eligible practices, including filter strips, riparian buffers, windbreaks, grass waterways, and salt tolerant grasses

Wetland eligibility suspended

K. Land with an EI > 8, regardless of the predicted annual erosion rate relative to T

Table 2: The Number of Omitted Whole-Farm CRP Places and Partial-Farm CRP Observations in the 1992 Census of Agriculture, Selected States

Geographic areas	Agricultural places excluded by farm definition with acres in the CRP (Whole-Farm CRP)			Farms with acres in the CRP (Partial-Farm CRP)		
	Number	Land in places (acres)	Land in CRP (acres)	Number	Land in farms (acres)	Land in CRP (acres)
United States	66,716	11,676,115	6,705,082	166,278	159,830,072	22,792,319
Alabama	2,314	591,878	159,842	2,922	1,886,069	270,179
Colorado	620	296,313	256,408	2,890	7,841,347	1,325,574
Georgia	2,647	608,468	158,060	4,168	2,687,461	304,625
Idaho	503	179,096	136,706	1,919	2,762,605	545,880
Illinois	3,230	297,093	168,075	8,547	4,421,225	465,026
Indiana	3,260	275,385	148,066	4,843	1,869,523	214,051
Iowa	5,978	677,405	475,843	17,703	7,884,008	1,294,635
Kansas	2,359	433,833	361,183	14,786	18,159,808	2,278,157
Kentucky	2,308	264,268	124,302	4,193	1,349,657	270,166
Michigan	2,098	196,336	109,392	2,937	1,097,895	130,652
Minnesota	5,443	811,547	530,605	11,548	5,822,189	907,213
Mississippi	3,396	776,059	257,071	3,435	2,169,800	325,499
Missouri	4,185	561,327	353,119	10,380	5,271,974	1,038,935
Montana	582	376,448	313,288	3,957	14,919,550	2,159,530
Nebraska	1,319	223,148	188,878	8,083	9,133,820	989,126
North Dakota	1,277	384,726	326,623	8,615	13,335,245	2,120,670
Ohio	2,321	216,402	121,644	3,643	1,260,035	162,509
Oklahoma	929	185,398	151,689	4,678	5,371,738	827,597
South Dakota	620	154,938	135,477	6,124	10,442,626	1,300,085
Tennessee	3,140	399,213	159,049	3,393	1,363,890	207,684
Texas	3,970	1,123,267	963,392	9,914	14,761,094	2,473,797
Virginia	874	119,820	27,597	1,617	729,867	61,222
Washington	418	233,193	200,144	1,877	4,863,907	742,155
Wisconsin	5,253	536,515	238,182	8,261	2,308,351	359,072

Source: Appendix B in the U.S. Census of Agriculture 1992

Notes: The data for "whole farm" CRP places are not complete for all States. The census mail list was developed from sources which indicated the farm had agricultural production activity. It was not designed to cover all "whole farm" CRP places. Therefore, the data for these places are limited to what was reported in the census and have not been adjusted to account for nonresponse, incomplete coverage, and reporting errors.

Table 3: Logit Regression Results for Determinants of Whole-Farm CRP Enrollees in 1997

Independent variables	(1)	(2)	(3)	(4)	(5)	(6)
Operator's age	0.055***	0.048***	0.049***	0.048***	0.035***	0.034***
Years of operation	-0.013***	-0.008***	-0.008***	-0.007***	-0.006***	-0.005***
Principal job is farming	-1.170***	-1.107***	-1.109***	-1.087***	-0.936***	-0.922***
Number of off-farm working days		-0.001***	-0.001***	-0.001***	-0.001***	-0.001***
Log of total farmland		-0.249***	-0.260***	-0.310***	-0.108***	-0.159***
Share of land owned		-0.001	-0.001	-0.001	-0.001	-0.001
Per acre return		-0.001***	-0.001***	-0.001***	-0.001***	-0.001***
Total subsidy			0.001***	0.001***	0.001***	0.001***
Log of land rented-in					-0.181***	-0.180***
Log of land rented-out					0.093***	0.085***
Constant	-4.319***	-2.606***	-2.576***	-3.868***	-2.506***	-3.512***
County fixed effects	NO	NO	NO	YES	NO	YES
Observations	99386	96188	96188	96111	96188	96111
Pseudo R2	0.09	0.10	0.10	0.11	0.13	0.14

Note: Logit estimation is conducted with the 1992-1997 Census panel data to examine the determinants of CRP enrollment by retiring either whole farmland or part of farmland. A dependent variable indicates whether CRP participants in 1997 retire whole farmland (= 1) or not. The "whole-farm CRP" farms are defined as farms that enroll all cropland in the CRP and produce less than $1,000 of agricultural products other than crops. Initial year farm characteristics in 1992 are used as explanatory variables. ***, ** and * indicate significant difference from zero at the 99th, 95th and 90th percentiles, respectively.

Table 4: Summary Statistics: All Sample Farms and Grain Farms in the 1982-1992 Panel

Sample farm group	All Operating Farms		Grain Farms	
Number of Observations	N = 80699	N = 3456	N =10823	N = 1251
	Non-CRP	CRP	Non-CRP	CRP
	(1)	(2)	(3)	(4)
Change in net-CRP cropped acres	-0.6	-71.4	-1.6	-94.9
	(47.0)	(161.0)	(49.6)	(186.4)
Change in CRP acres	0.0	87.4	0.0	107.3
	(0.0)	(147.2)	(0.0)	(180.9)
Change in setaside acres in commodity support programs	-0.1	-3.9	-0.4	-5.5
	(7.1)	(20.8)	(14.0)	(26.7)
Change in irrigated acres	-0.4	-2.0	-0.2	-1.9
	(32.4)	(39.9)	(21.3)	(35.0)
Cropped acres	61.3	222.5	161.3	304.1
	(138.7)	(321.2)	(242.1)	(425.3)
Pastureland and rangeland acres	128.8	156.5	32.8	99.8
	(5030.6)	(639.4)	(129.9)	(271.7)
Woodland acres	12.3	19.9	9.1	20.1
	(163.8)	(170.2)	(72.3)	(248.5)
Setaside acres in commodity support programs	0.9	7.2	3.6	10.7
	(7.9)	(23.7)	(15.1)	(31.2)
Irrigated acres	7.5	10.3	8.4	10.5
	(61.4)	(68.0)	(60.5)	(70.6)
Total farmland acres	213.9	424.8	218.7	455.8
	(5096.3)	(843.9)	(349.3)	(706.7)
Years of operation	17.7	22.2	20.2	21.7
	(12.1)	(12.2)	(12.6)	(12.5)
Principal job is farming (= 1) or not	0.4	0.7	0.5	0.6
	(0.5)	(0.5)	(0.5)	(0.5)
Number of off-farm working days	123.5	85.7	116.6	97.2
	(104.6)	(101.5)	(104.9)	(103.1)
Operator's age	51.6	52.4	51.4	51.8
	(11.9)	(11.1)	(12.1)	(11.4)
Per-acre sales of agricultural products	1015.5	169.8	136.5	105.8
	(20832.8)	(380.2)	(90.0)	(77.3)

Note: Data are from confidential U.S. Census of Agriculture microfiles. Mean estimates are reported with the standard deviations in parenthesis, where estimates are weighted by the Census response weight. Variables in bold indicate base-year variables in 1982. The sample consists of farms which: continued to exist during the 1982-1992 Census period; had no land transactions during the panel period; and were located in counties with CRP-eligible acres. Columns 1 and 2 contain summary statistics for all operating farms. Columns 3 and 4 contain summary statistics for sample grain farms used in the analysis.

Table 5: Regression Results for Grain Farms from the 1982-1992 Long Panel Data with Pooled OLS and Random Effects Models

	Pooled OLS model				Random effects model			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CRP acres	-0.870	-0.757 ††	-0.953	-0.890	-0.862 † † †	-0.833 † † †	-0.821 † † †	-0.805 † † †
	(0.120)	(0.111)	(0.090)	(0.083)	(0.049)	(0.055)	(0.055)	(0.056)
Total farmland acres	0.595 ***	0.537 ***	0.615 ***	0.569 ***	0.594 ***	0.583 ***	0.573 ***	0.556 ***
	(0.031)	(0.036)	(0.027)	(0.030)	(0.036)	(0.037)	(0.030)	(0.030)
Setaside acres in commodity support programs		3.502 ***		2.295 ***		0.629 ***		0.735 ***
		(0.530)		(0.393)		(0.187)		(0.155)
Irrigated acres		0.123 ***		0.160 ***		0.224 ***		0.271 ***
		(0.036)		(0.040)		(0.047)		(0.059)
Futures price of grains		-0.013 **		0.012		-0.009		0.019 *
		(0.006)		(0.010)		(0.009)		(0.011)
Futures price of cattle		-2.041 ***		-1.671 ***		-1.806 ***		-1.402 ***
		(0.117)		(0.122)		(0.144)		(0.129)
Futures price of grains X grain yields		0.001 ***		0.001 ***		0.001 ***		0.001 ***
		(0.0001)		(0.0001)		(0.0002)		(0.0001)
County-year fixed effects	NO	NO	YES	YES	NO	NO	YES	YES
SIC fixed effects	NO	NO	YES	YES	NO	NO	YES	YES
Observations	24148	24148	24148	24148	24148	24148	24148	24148
Adjusted R2	0.78	0.82	0.87	0.88	0.78	0.80	0.73	0.75

Note: A dependent variable is cropped acreage. Cropped acreage is computed as the sum of cropland harvested, failed, summer fallowed and used for cover crops, net CRP acres. Heteroskedasticity-robust standard errors are reported in parenthesis. For the coefficient of CRP acreage, † † †, ††, and † indicate significant difference from -1 at the 99th, 95th and 90th percentiles, respectively. For the coefficient of the other covariates, ***, ** and * indicate significant difference from zero at the respective percentiles.

Table 6: Regression Results for Grain Farms from the 1982-1992 Long Panel Data with the Farm Fixed Effects Model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Change in CRP acres	-0.861 † † †	-0.857 † † †	-0.854 † † †	-0.853 † † †	-0.850 † † †	-0.856 † † †	-0.855 † † †	-0.854 † † †	-0.864 † † †
	(0.046)	(0.047)	(0.055)	(0.047)	(0.047)	(0.042)	(0.052)	(0.053)	(0.048)
Change in setaside acres in commodity support programs		0.083	1.106 ***		0.145	1.209 **		0.083	1.102 ***
		(0.161)	(0.429)		(0.152)	(0.304)		(0.166)	(0.347)
Change in irrigated acres		0.314 ***	0.341 ***		0.389 ***	0.419 ***		0.491 ***	0.532 ***
		(0.103)	(0.102)		(0.111)	(0.108)		(0.128)	(0.130)
Change in the futures price of grains		0.064	0.107 *		0.006	0.091		-0.057	0.007
		(0.052)	(0.064)		(0.051)	(0.048)		(0.099)	(0.091)
Change in the futures price of cattle		0.170	-0.678 *		0.479* *	-0.530 *		0.440	-0.626
		(0.277)	(0.361)		(0.246)	(0.317)		(0.312)	(0.390)
Change in the futures price of grains X grain yields		-0.001	-0.003 ***		-0.0004	-0.003 ***		-0.0003	-0.002 *
		(0.001)	(0.001)		(0.001)	(0.000)		(0.001)	(0.001)
Base-year farm characteristics	NO	NO	YES	NO	NO	YES	NO	NO	YES
Farm fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
County-year fixed effects	NO	NO	NO	YES	YES	YES	YES	YES	YES
SIC fixed effects	NO	NO	NO	NO	NO	NO	YES	YES	YES
Observations	12074	12074	12074	12074	12074	12074	12074	12074	12074
Adjusted R2	0.50	0.51	0.55	0.60	0.61	0.65	0.58	0.59	0.63

Note: A dependent variable is the change in cropped acreage over 1982-1992. See notes to table 5 for the definition of cropped acres. Heteroskedasticity-robust standard errors are reported in parenthesis. For the coefficient of the CRP acreage change, † † †, ††, and † indicate significant difference from -1 at the 99th, 95th and 90th percentiles, respectively. For the coefficient of the other covariates, ***, ** and * indicate significant difference from zero at the respective percentiles.

Table 7: Slippage Estimates from the 1982-1992 Long Panel by Production Support Program Participation and Base-Year Cropped Acreage Share

	Coefficient Estimate	Slippage Rate	Share of CRP Participants out of 1251 Observations
	(1)	(2)	(3)
	A. By Production Support Program Participation		
Non-participants	-0.907 ††	9.3% **	21%
	(0.039)		
Participants	0.098	19.1%**	79%
	(0.092)		
	B. By Cropped Acreage Share in 1982		
50% $\leq$ Share of cropped acres	-0.956 †	4.4% *	82%
	(0.024)		
Share of cropped acres < 50%	0.383 ***	42.7%***	18%
	(0.103)		

Note: In panel A, a slippage rate is estimated by subsidy recipient status in 1992 by including the interaction of the CRP acreage change and the 1992 setaside acreage dummy variable (with non-recipients as a reference). In panel B, a slippage rate is estimated by groups of different cropped acreage shares over total farmland in 1982 by including the interaction of the CRP acreage change and indicator variables of categorical groups. The sample is divided into two groups: (i) cropped acreage share in 1982 is above 50% (as a reference) and (ii) below 50%. Estimation is conducted with full specification, i.e., with all covariates and all sets of fixed effects. A dependent variable is the change in cropped acreage over 1982-1992. See notes to table 5 for the definition of cropped acres. Heteroskedasticity-robust standard errors are reported in parenthesis. Column (1) reports coefficient estimates of CRP acreage change and its interaction terms with respective group indicator variables. Slippage rates in column (2) are computed from those estimated coefficients. † † †, ††, and † indicate significant difference from -1 at the 99th, 95th and 90th percentiles, respectively. Column (3) reports the share of CRP participants in each category out of 1251 observations. ***, ** and * indicate significant difference from zero at the 99th, 95th and 90th percentiles, respectively.

Table 8: Slippage Estimates from the 1982-1992 Long Panel by Region

	Coefficient Estimate	Slippage Rate
	(1)	(2)
Other Regions	-0.976	2.4%
	(0.081)	
Corn Belt	0.072	9.7%***
	(0.082)	
Lake States	0.129	15.4%***
	(0.084)	
Northern Plains	0.128	15.3%***
	(0.087)	
Southern Plains	0.324	34.9%*
	(0.202)	
Mountain	0.119	14.3%
	(0.117)	
Total		13.6%

Note: Region-specific slippage rates are estimated by including the interaction of the CRP acreage change and region indicator variables (with other regions as a reference). The Corn Belt region includes Illinois, Indiana, Iowa, Missouri and Ohio, the Lake States include Michigan, Minnesota and Wisconsin, the Northern Plains include Kansas, Nebraska, North Dakota and South Dakota, the South Plains include Oklahoma and Texas, and the Mountain region includes Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming. Estimation is conducted with full specification, i.e., with all covariates and all sets of fixed effects. A dependent variable is the change in cropped acreage over 1982-1992. See notes to table 5 for the definition of cropped acres. Heteroskedasticity-robust standard errors are reported in parenthesis. Column (2) reports coefficient estimates of CRP acreage change and its interaction terms with respective group indicator variables. Slippage rates in column (3) are computed from those estimated coefficients. † † †, ††, and † indicate significant difference from -1 at the 99th, 95th and 90th percentiles, respectively. ***, ** and * indicate significant difference from zero at the 99th, 95th and 90th percentiles, respectively.

Table 9: Distribution of Slippage Estimates from the 1982-1992 Long Panel by Farm Types

	Coefficient Estimate	Slippage Rate	Mean acres enrolled in the CRP
	(1)	(2)	(3)
	A. By Farm Size (Acreage)		
Farmland < 100 acres	-0.734 † † †	26.6% ***	19.1
	(0.093)		
100 acres ≤ Farmland < 250 acres	-0.118	14.8% ***	46.3
	(0.095)		
250 acres ≤ Farmland < 500 acres	-0.136	13.0% ***	97.8
	(0.100)		
500 acres ≤ Farmland	-0.131	13.5% **	260.5
	(0.111)		
	B. By Farm Type and Farm Size (Sales)		
Part-time farm with sales < $10,000	-1.103	-10.3%	33.4
	(0.179)		
Part-time farm with sales ≥ $10,000	0.148	4.5%	77.1
	(0.188)		
Full-time farm with sales < $10,000	0.365 *	26.2% **	56.3
	(0.210)		
Full-time farm with $10,000 ≤ sales < $50,000	0.263	16.0% ***	125.0
	(0.186)		
Part-time farm with sales ≥ $50,000	0.241	13.8% *	194.6
	(0.194)		

Note: Panel A and panel B report slippage estimates by two different farm size definitions. In panel A, the slippage estimate is allowed to vary across farmland size (with the smallest farmland size group as a reference). In panel B, the slippage estimate is allowed to vary across operator's principal occupation and farm sales categories (with smaller non-farm farms as a reference). Estimation is conducted with full specification, i.e., with all covariates and all sets of fixed effects. A dependent variable is the change in cropped acreage over 1982-1992. See notes to table 5 for the definition of cropped acres. Heteroskedasticity-robust standard errors are reported in parenthesis. Column (1) reports coefficient estimates of CRP acreage change and its interaction terms with respective group indicator variables. Slippage rates in column (2) are computed from those estimated coefficients. Column (3) reports mean acreage enrolled in the CRP for each group. † † †, ††, and † indicate significant difference from -1 at the 99th, 95th and 90th percentiles, respectively. ***, ** and * indicate significant difference from zero at the 99th, 95th and 90th percentiles, respectively.

Table 10: Distribution of Slippage Estimates from the 1982-1992 Long Panel by CRP Signup Periods

CRP Enrollment Period	Coefficient Estimate (1)	Slippage Rate (2)	Mean acreage enrolled in the CRP (3)
Enrollment during 1986	-0.873 ††	13.7%**	94.1
	(0.057)		
Enrollment during 1987-91	-0.055	12.2%*	101.9
	(0.069)		
Enrollment during 1986 and 1987-91	0.145	28.2%***	164.5
	(0.091)		

Note: An enrollment-specific slippage rate is estimated by including the interaction of the CRP acreage change and indicator variables of the enrollment status of CRP participants. The enrollment status is classified into three categories: (i) 82-87 enrollees who enrolled in the CRP only prior to 1987 (reference); (ii) 87-92 enrollees who enrolled in the CRP only after 1987; and (iii) 82-92 enrollees who enrolled in the CRP during both of the 1982-1987 and 1987-1992 periods. Estimation is conducted with full specification, i.e., with all covariates and all sets of fixed effects. A dependent variable is the change in cropped acreage over 1982-1992. See notes to table 5 for the definition of cropped acres. Heteroskedasticity-robust standard errors are reported in parenthesis. Column (1) reports coefficient estimates of CRP acreage change and its interaction terms with respective group indicator variables. Slippage rates in column (2) are computed from those estimated coefficients. Column (3) reports mean acreage enrolled in the CRP for each group. † † †, ††, and † indicate significant difference from -1 at the 99th, 95th and 90th percentiles, respectively. ***, ** and * indicate significant difference from zero at the 99th, 95th and 90th percentiles, respectively.

Table 11: Regression Results for Grain Farms from the 1982-1987 and 1987-1992 Panel Data

Panel Period	1982-1987	1987-1992 with only new CRP	1982-1992
	(1)	(2)	(3)
Change in CRP acres	-0.755 † † †	-0.875 † † †	-0.864 † † †
	(0.093)	(0.043)	(0.048)
Farm characteristics	YES	YES	YES
Base-year farm characteristics	YES	YES	YES
Farm fixed effects	YES	YES	YES
County-year fixed effects	YES	YES	YES
SIC fixed effects	YES	YES	YES
Observations	28286	18504	12074
Adjusted R2	0.33	0.69	0.63

Note: Estimation results from 1982-1987 and 1987-1992 panel data are compared with the 1982-1992 estimation result. Estimation is conducted with full specification, i.e., with all covariates and all sets of fixed effects. A dependent variable for each panel data is the change in cropped acreage over the respective panel period. See notes to table 5 for the definitions of cropping acreage. The 1987-1992 panel data analysis in column (2) uses only participants enrolling after 1987 to avoid the measurement error of the dependent variable as discussed in section 5.2. Heteroskedasticity-robust standard errors are reported in parenthesis. For the coefficient of the CRP acreage change, † † †, ††, and † indicate significant difference from -1 at the 99th, 95th and 90th percentiles, respectively. For the coefficient of the other covariates, ***, ** and * indicate significant difference from zero at the respective percentiles.

Table 12: Trend of Regional Slippage Incidence during the 1982-1992 Period

Panel Period	1982-1987	1987-1992 with only new CRP	1982-1992
	(1)	(2)	(3)
Corn Belt	16.3%***	15.1%***	9.7% ***
Lake States	19.7%***	23.0%***	15.4%***
Northern Plains	17.5%***	7.8%	15.3%***
Southern Plains	29.6%***	43.8%***	34.9%*
Mountain	28.3%***	14.9%	14.3%
Other regions	37.4%***	1.1%	2.4%
Total	24.5%***	12.5%***	13.6%

Note: Region-specific slippage rates are computed from each of the 1982-1987, 1987-1992, and 1982-1992 panel data estimations by including the interaction of the CRP acreage change and region indicator variables. The Corn Belt region includes Illinois, Indiana, Iowa, Missouri and Ohio, the Lake States include Michigan, Minnesota and Wisconsin, the Northern Plains include Kansas, Nebraska, North Dakota and South Dakota, the South Plains include Oklahoma and Texas, and the Mountain region includes Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming. Estimation is conducted with full specification, i.e., with all covariates and all sets of fixed effects. A dependent variable is the change in cropped acreage over 1982-1992. See notes to table 5 for the definition of cropped acres. The 1987-1992 panel data analysis in column (2) uses only participants enrolling after 1987 to avoid the measurement error of the dependent variable as discussed in section 5.2. ***, ** and * indicate significant difference from zero at the 99th, 95th and 90th percentiles, respectively.

Table 13: Regression Results for All Farms from the 1982-1992 Long Panel Data

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Change in CRP acres	-0.863 † † †	-0.856 † † †	-0.854 † † †	-0.859 † † †	-0.856 † † †	-0.865 † † †	-0.859 † † †
	(0.045)	(0.047)	(0.055)	(0.051)	(0.051)	(0.046)	(0.043)
Change in CRP acres X Non-grain farms	0.094	0.113 *	0.267 ***	0.098	0.110	0.247 ***	
	(0.064)	(0.066)	(0.080)	(0.065)	(0.067)	(0.074)	
Change in CRP acres X Non-grain crop farms							0.093
							(0.121)
Change in CRP acres X Livestock farms							0.319 ***
							(0.078)
Farm characteristics	NO	YES	YES	NO	YES	YES	YES
Base-year farm characteristics	NO	NO	YES	NO	NO	YES	YES
Farm fixed effects	YES	YES	YES	YES	YES	YES	YES
County-year fixed effects	NO	NO	NO	YES	YES	YES	YES
SIC fixed effects	NO	NO	NO	YES	YES	YES	YES
Observations	84155	84155	84155	84155	84155	84155	84155
Adjusted R2	0.24	0.25	0.32	0.35	0.35	0.42	0.43

Note: A dependent variable is the change in cropped acreage over 1982-1992. See notes to table 5 for the definition of cropped acres. Heteroskedasticity-robust standard errors are reported in parenthesis. For the coefficient of the CRP acreage change, † † †, ††, and † indicate significant difference from -1 at the 99th, 95th and 90th percentiles, respectively. For the coefficient of the other covariates, ***, ** and * indicate significant difference from zero at the respective percentiles.

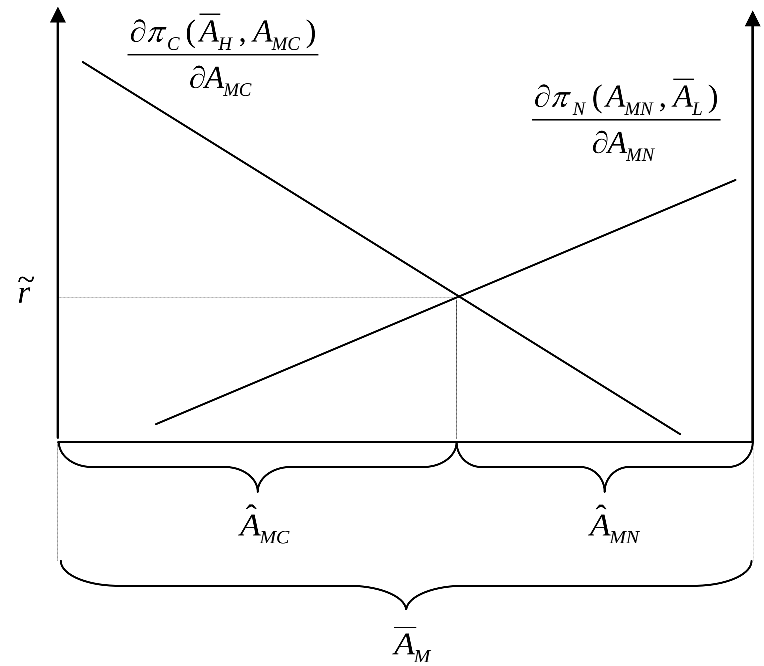

Figure 1: Farmland allocation decision for medium-quality land

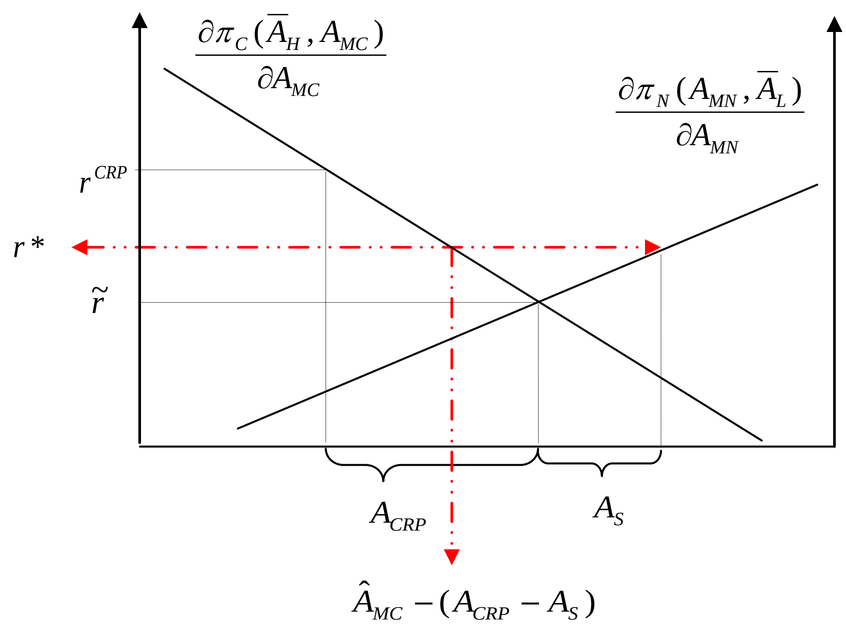

Figure 2: Impact of CRP enrollment on subsequent land allocation for medium-quality land

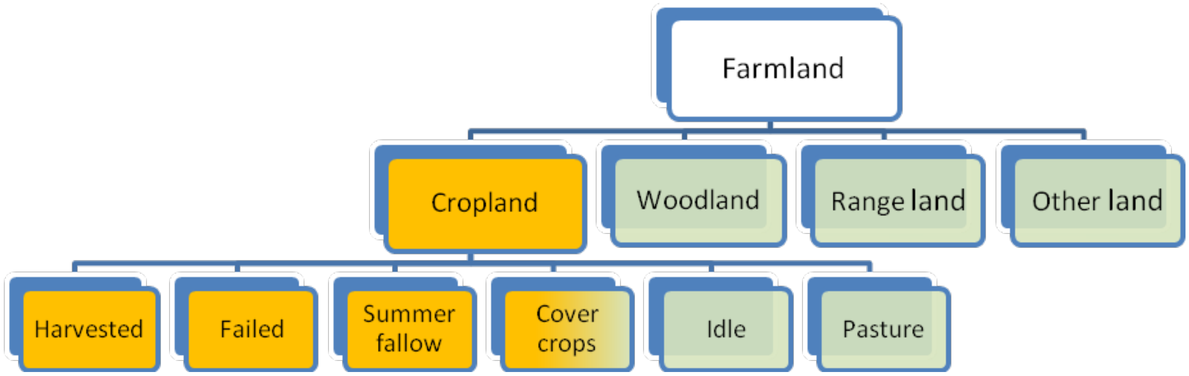

Figure 3: Land use categories in the Census of Agriculture