Determinants of Voluntary Conservation: The USDA Conservation Reserve Program

Jacob N. Brimlow*

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Abstract

The United States Department of Agriculture's (USDA) Conservation Reserve Program (CRP) is the largest U.S. land conservation program, distributing about $1.8 billion dollars each year to keep 36 million acres of cropland out of production. The CRP generates both market and non-market environmental benefits; USDA estimates indicate that CRP benefits exceed program costs, with $464 million in benefits coming from added fresh water recreation, pheasant hunting, and wildlife viewing alone. The CRP relies on voluntary participation by landowners, who agree to retire land from production for 10-15 years in return for annual per-acre rental payments. There is evidence that CRP payments confer windfall rents to enrolling landowners, and it has been suggested that redesigning the CRP enrollment mechanism may significantly decrease the cost of conserving land under the program (Kirwan et al. [2005]). Despite the central role landowner decisions play in CRP enrollment, and the importance of these decisions to the administration of the program, there is little consensus in the literature about the sign and magnitude of the major determinants of landowner decisions to participate in CRP(Konyar and Osborn [1990], Parks and Schorr [1997], Esseks and Kraft [1988],Isik and Yang [2004]). This paper presents a parcel-level structural model of landowner decisions to enroll all, some, or none of their land in the CRP, and uses enrollment data for farms in Minnesota to estimate the impact of land characteristics and non-CRP government payments on participation decisions. The estimation contributes to the literature by using parcel level data in an econometric framework that explicitly accounts for censoring in the enrollment data. The results offer the first parcel-level evidence of the association between lower land productivity and increased CRP enrollment and has implications for the ex-ante estimation of the costs and benefits of this large land conservation program.

Keywords: Conservation; Land Productivity; Conservation Reserve Program; Censored Normal.

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*The author is a PhD Candidate in the Department of Economics at North Carolina State University. Correspondence: jnbrimlo@ncsu.edu
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Introduction

I find that parcel level increases in land productivity and non-conservation government payments are associated with decreased enrollment in the United States Department of Agriculture's Conservation Reserve Program (CRP). The result adds a robust parcel level estimate to a mixed literature by addressing misspecification and censoring in CRP enrollment data. The CRP is one of the United States largest land conservation programs. The CRP distributes about $1.8 billion a year in payments to conserve over 36 million acres of agricultural land(U. S. Department of Agriculture [2006]). Market and non-market benefits of the CRP include improvements in air and water quality, which enhance recreation value and decrease industrial operations costs, and improvements in bird and other wildlife habitats, which enhance hunting and wildlife viewing. Fresh water recreation, pheasant hunting, and wildlife viewing benefits directly attributed to CRP were estimated at $464 million annually by the USDA Economic Research Service. However, Shoemaker [1989] and Kirwan et al. [2005] have found evidence that payments for CRP enrollment may exceed private opportunity costs, raising questions about the efficiency of the CRP as a conservation program, and generating discussions about alternative enrollment mechanisms. These discussions highlight a need for agreement regarding the drivers of CRP enrollment.

Previous empirical studies indicate that land quality, payments, and landowner characteristics contribute to CRP enrollment decisions (Konyar and Osborn [1990], Parks and Schorr [1997], Parks and Kramer [1995], Isik and Yang [2004], Goodwin and Smith [2003]), but the studies differ in geographic location, empirical approach, and estimation results, offering little to no consensus. The studies use Major Land Resource Area (MLRA) and county level data that allow estimation of the effects of erodibility, productivity, landowner characteristics, and CRP bid cap and payment variables on CRP enrollment. The inclusion of CRP bid caps and payment variables as explanatory variables may explain the weak and counterintuitive results found in previous work because CRP metrics can be highly correlated with land characteristics. Motivated by a parcel level structural model of landowner enrollment in the CRP, I estimate a parcel level empirical model using data on Minnesota farmland parcels. The parcel level data represent a significant improvement in data resolution, allowing the determinants of enrollment in the CRP to be estimated at the same resolution those decisions occur. I address specification concerns by limiting the to the effects of non-CRP government payments and a uniquely comprehensive index of land productivity, and use a censored normal regression framework to accommodate censoring in the participation data.

The USDA's Conservation Reserve Program

The USDA's Conservation Reserve Program (CRP) is a voluntary land use restriction program originally established in 1985 "to assist owners and operators in conserving and improving soil, water, and wildlife resources on their farms by converting highly erodible and other environmentally sensitive cropland and marginal pasture to long-term resource conserving covers." The CRP was established as a supply control program, but amendments in 1990, 1996, and 2002, have transformed it into an environmental program with 30 approved practices aimed at reducing soil erosion, enhancing water quality, and expanding and improving wildlife habitat and wetlands. CRP achieves its conservation goals primarily through $10-15$ year contracts that pay landowners to convert productive cropland to alternative covers such as native grasses or forest.

Since 1990, the majority of enrollment in the CRP has been governed by a bidding system based on the Environmental Benefits Index (EBI). A landowner's EBI score is comprised of five environmental factor scores and a cost factor score. The environmental factors reflect the history of the CRP as an erosion control program as well as the current environmental focus: wildlife, water quality, erosion, enduring benefits, and air quality.[1] The scores from environmental factors are added to the following cost factor that penalizes higher proposed rents and requests for cost share assistance:

$$CostFactor = \omega(1 - r/HIGH)) + 10(1 - s) + Min(15, r^m - r). \tag{1}$$

In equation 1, r is the rental rate proposed by the landowner, r^m is the parcel's soil-based maximum rental rate,[2] $HIGH$ is the highest soil specific rental rate allowed for all bids received, ω

[1]A brief description of the EBI categories are provided in the appendix.
[2]Bidding rules require that $r \leq r^m$.

is a scaling parameter set by the government after all bids are submitted, and s=1 if the farmer chooses to request cost share assistance, and 0 otherwise. [3] The first term in equation 1 gives landowners more EBI points for proposing low rental rates, with the value of ω determining the weight of the cost factor in the overall EBI score.[4] The second term in equation 1 gives landowners a 10 point bonus if they do not request cost share assistance.[5] The final term in equation 1, added for sign-up 16 in 1997, adds one point to a landowner's score - up to 15 - for every dollar they bid below the maximum allowed, r^m. The maximum yearly rental rates allowed are determined by a formula that uses the relative productivity of soils within each county, the prevalence of the three most prominent soil types on the subject parcel, and the average county dryland cash rent. The rental rate proposed by each landowner determines the annual payments received over the life of a CRP contract if the bid is accepted; rental rates are not adjusted during the contract period. Bids are ranked nationally according to EBI score, and after each general sign-up period has ended, the FSA determines a national EBI score cutoff, and enrolls qualifying contracts USDA [2007].[6]

General[7] CRP sign-ups begin with a bidding period during which eligible landowners submit bids to receive cost share and yearly rental payments in return for installing conservation practices on land for 10−15 year contract periods. Eligibility is determined by active ownership and operation of land offered for enrollment; landowners are required to own and operate the land the offer, and to have cropped the land in several years prior to enrollment. Bids are collected by the Farm Service Agency (FSA) and ranked according to EBI score. After bids have been collected, the FSA determines an EBI score threshold; landowners submitting bids that exceed the threshold EBI score are enrolled in the CRP and paid their proposed rental rate.

The EBI shows an explicit link between land characteristics and CRP payments that is impor-

[3] Some notation is borrowed from Kirwan et al. [2005]

[4] The scale parameter ω has been constant at 125 since sign-up 15.

[5] The government typically pays half the cost of establishing the proposed conservation practice if landowners request cost share assistance.

[6] No information about how EBI cutoffs are determined is released by FSA, but presumably they are set in accordance with program goals and budgets.

[7] There are two types of CRP enrollment: general and continuous. The vast majority of CRP contracts fall under general enrollment, with continuous sign-ups being targeted at specialized areas and practices.

tant to the choice of exogenous variables in estimations of the determinants of CRP enrollment. The data used in my estimation cover CRP enrollments that occurred as early as 1988, but the large sign-up in 1997, sign up 15, likely covers the most acres. I do not include measures of CRP payments and maximum bid caps in my estimation to avoid the possible misspecification they could introduce.

Review of Existing Evidence

The institutional structure of the CRP under the EBI scoring system informs estimation of the determinants of enrollment vis a vis previous studies. The EBI score explicitly links land characteristics that affect the opportunity cost of enrolling in CRP and land productivity to the likelihood of acceptance and the CRP payment received. Previous researchers have estimated the effects of soil erodibility and productivity in models that also include CRP rental rates, government payments, and landowner characteristics, and have obtained mixed results. A summary of these studies is shown in table 1, and described below.

Konyar and Osborn [1990] use data aggregated to Major Land Resource Area's (MLRA) and Weighted Two-Stage Least Squares to estimate a discrete choice model of the effects of differential land use returns, land value, farm size, landowner tenure and age, and land erodibility on CRP enrollment in the first 3 sign-ups in 1986. The authors find results consistent with their a priori expectations: the proportion of land enrolled in the CRP increases when land is less productive and alternatives to cropping are less likely to compete with returns to CRP, and larger farms, older farmers, and farmers with less tenure enroll a smaller proportion of land in CRP.

Parks and Kramer [1995] and Parks and Schorr [1997] use grouped logit estimation at the county level. Parks and Kramer [1995] examine the impact of land benefits, land attributes, and owner attributes on national county level participation in CRP wetland restoration practices. As expected, the authors find that increases in net agricultural benefits and net CRP benefits (rental rate) are associated with decreased and increased participation, respectively. However, increased land quality, expected to be strongly associated with decreased participation, is found to be positive and statistically insignificant. Increased government payments, expected to increase opportunity costs and decrease participation,[8] are associated with increases in participation. Parks and Kramer postulate that the counterintuitive land quality result may be due to non-linear land quality impacts being modeled linearly, and that increased government payments proxy for landowner awareness of federal programs. Ownership of land and older age are associated strongly with increased participation; the result for age conflicts directly with Konyar and Osborn [1990]. Parks and Schorr [1997] conduct a county level analysis of CRP participation in the Northeast. The authors' main finding is that the CRP does not affect landowner decisions in metropolitan[9] counties, likely because payments from the CRP were not large enough to induce landowners to forgo development. This result highlights the possible importance of considering development options when estimating determinants of CRP enrollment. Parks and Schorr [1997] also find that 'hobby farms,' small farms owned and operated for pleasure rather than business, influence enrollment in metropolitan counties. In a study similar in spirit to Parks and Kramer [1995] and Parks and Schorr [1997], Esseks and Kraft [1988] use data from the midwest and find a negative relationship between participation in the first four CRP sign-ups and income from farming, and a positive relationship between CRP participation and the percentage of land with erodible soils.

Isik and Yang [2004] provide the only study explicitly estimating the impact of uncertainty and irreversibility on participation in the CRP. The authors condition on a set of explanatory variables similar to that in Parks and Kramer [1995] and Parks and Schorr [1997], with the addition of a variable accounting for the value of "real options"[10] forfeited by landowners when they choose to enter the CRP. Isik and Yang find that irreversibility and uncertainty play a significant role in landowner decisions to enter the CRP; as option values increase, participation decreases. This study reinforces the importance of controlling for variables that affect option values such as proximity to to urban

[8] Acres placed in the CRP are not eligible for government payments.

[9] Counties considered metropolitan statistical areas by the Census of Population taken by the U.S. Department of Commerce, Bureau of Census.

[10] See Dixit and Pindyck [1994] for a description of real options, and Brimlow et al. [2008] for an application of real options models to land conservation decisions.

areas.

Also working with CRP enrollment prior to 1990, Plantinga et al. [2001] use county data and linear regression to estimate CRP supply functions for nine U.S. regions. As in Parks and Kramer [1995] and Parks and Schorr [1997], Plantinga, et al. find that increases in program payments and decreases in land capability tend to increase participation in the CRP, although their results are not consistent in all regions. Increases in population density and median household income are found to decrease participation. Goodwin and Smith [2003] use county level data between 1982 and 1992 to estimate a set of simultaneous equations describing CRP participation, soil erosion, crop insurance participation, conservation effort, and fertilizer usage. The authors find an expected result - that increases in CRP rental rates are associated with increased participation - but report several statistically significant results that have signs that conflict with previous work. Increases in cost share assistance are associated with decreased participation, more erodible soil is associated with decreased participation, and increases in government payments, one of the opportunity costs of CRP participation, are associated with increased participation.

Roberts and Lubowski [2007] include an estimation of CRP participation in a study of CRP contract expiration between 1995 and 1997. Several variables found to be significant in other studies, including prime soil and erodibility, are insignificant in Roberts and Lubowski's model, but this may be explained by the fact that the model is the first stage in a two-stage selection model, and may over specified due to the authors' attempt to capture selection bias. Coefficients with statistical significance, such as changes in government payments, have the expected signs.

Before 1990, 33.9 million acres were enrolled in the CRP under 10 year contracts, so the vast majority of early CRP contracts were set to begin expiring around 1996. Contracts written before 1990 were not subject to the competitive EBI bidding process, and many landowners were likely being paid significantly more than their opportunity costs. Consequently, several studies focused on the determinants and effects of land use choices made by landowners facing the decision to return their land to non-conservation uses or to compete to re-enter the CRP (Cooper and Osborn [1998], Johnson et al. [1997], Skaggs et al. [1994], Kalaitzandonakes and Monson [1994]). The studies of re-enrollment decisions use survey and land use data, and are broadly consistent with the literature covering initial CRP enrollment: land characteristics such as productivity and location are the primary drivers of land use decisions (Kalaitzandonakes and Monson [1994], Cooper and Osborn [1998], Johnson et al. [1997]), with increases in land productivity and/or market value decreasing the likelihood of reenrollment. Landowner characteristics and conservation considerations play a secondary role in Cooper and Osborn [1998] and are insignificant in Kalaitzandonakes and Monson [1994].

If payments exceed the private opportunity cost of restriction, landowners enrolled in CRP may be earning windfall profits, providing motivation for policy makers to examine the enrollment process, and possibly to change the bidding structure of the program. The auctions literature has investigated how landowner bids submitted under the CRP's EBI auction mechanism shed light on the motivations of participants, and how well the bidding structure forces landowners to reveal the true opportunity cost of enrollment (Vukina et al. [2008], Cason and Gangadharan [2004], Kirwan et al. [2005]). Vukina et al. [2008] analyze farmer bids to enter the CRP and find that farmers value the environmental benefits of the CRP, especially when those benefits increase the future productivity of their land. This suggests that the EBI auction mechanism may be rewarding farmers, through higher EBI scores and increased probability of acceptance, for actions they may have undertaken anyway. Kirwan et al. [2005] estimate the difference between willingness to pay and willingness to accept in the CRP. Their estimates indicate that landowners were paid10-40% more than a rent that would just compensate them for adopting conservation practices. This premium could represent windfall gains to landowners, or could just represent the payment required to convince landowners to reveal private information and enroll in CRP.

Auction studies suggest that the CRP may be conferring windfall rents to enrolled landowners. If institutional changes are needed to increase the cost-effectiveness of the CRP auction mechanism, it would be helpful to have firm understanding of the factors influencing landowner decisions to enroll in the CRP. However, the literature reports contradictory effects of erodible soil and higher non-CRP government payments, and several studies find that land quality has an insignificant effect on CRP enrollment. The mixed and sometimes counterintuitive results may be due in part to specification errors. Factors influencing landowner participation in CRP are often the same factors determining CRP program metrics such as the maximum allowable rental rate. Parks and Kramer [1995] find that the proportion of land in Land Capability Classes (LCC) I and II has an insignificant effect on participation in the CRP. Because land in LCC's I and II is the most productive land, a higher proportion of land in LCC's I and II indicates higher opportunity costs and, therefore, would be expected to decrease CRP enrollment. The Parks and Kramer result is less surprising once it is noted that the the maximum rental rate allowed by the CRP, largely determined by the productivity of land in the region, is also included in the regression. Misspecification introduced by the correlation between maximum CRP rental rates and LCCs could explain the result; this example illustrates the importance of considering the CRP enrollment process when estimating of the determinants of CRP enrollment, and of carefully selecting explanatory variables to avoid misspecification.

Theory

Assume landowners are profit maximizers, so they accept land use restrictions only when expected returns under restriction exceed returns without restriction.[11] Further, assume that conservation program payments are broken into constant annual per acre payments that do not vary over the life of the contract and compensate landowners for transactions costs.

Figure 1 plots the yearly value of productive acreage, net of production costs (net productiv-

[11] While nonpecuniary returns are not included in the estimation section, returns under restriction could include pecuniary returns as well as nonpecuniary returns due to conservation preference or bequest motive. Anderson and King (2004) and Vukina, Zheng, Marra, and Levy (2008) find that landowners do not place considerable weight on the public benefits of conservation; landowners participate in conservation programs if the private benefits of participation (monetary compensation, personal satisfaction, etc.) outweigh the private opportunity costs (foregone income, option values). Therefore, a model of landowner participation in the CRP that accounts for the primary sources of private benefits and costs is likely sufficient.

ity), for each of two farmland properties of the same size. Acreage of each parcel is arrayed from least to most productive along the horizontal axis, with the size of each full parcel represented by $\bar{A}$. The net productivity of a parcel of land can be written

$$NP_i = a_0 + a_1' \cdot \mathbf{z_i} + a_2 \cdot A, \tag{2}$$

where z_i is a vector of variables that shift net productivity, i indexes parcels, and A is acres. Parcel 1 is assumed to have higher net productivity than parcel 2 (due to the values in z_2 relative to z_1), so NP_1 lies above NP_2.[12] Because land is arrayed from least to most productive along the horizontal axis, the net productivity of the first acre in each parcel is less than the net productivity of the last acre; the model being developed here allows for land quality that is heterogeneous both within and across parcels.

If a conservation program offers landowners a constant yearly per acre payment to retire land from production, landowners will restrict acres, from least to most productive, until the payment just offsets the opportunity cost of restriction. In Figure 1, the opportunity cost of restriction for each property is represented by its net productivity curve. If a yearly payment of $\bar{c}$ is offered, Parcel 1 will be unrestricted because the value of the annual per acre payment is below the net productivity of the parcel's least productive acre. For parcel 2, $\bar{c}$ is greater than the net productivity of all acres up to A^*, so some of the acreage in parcel 2 is offered for restriction. In general, landowners will restrict all, some, or none, of parcel acreage, depending on parcel productivity and program payments.

With the introduction of the EBI bidding system in 1990, offering land for participation in the CRP was an increasingly strategic decision by landowners, and the structural model presented here can be viewed as representing those decisions. As discussed above, landowners choose the land they offer (A^*), the conservation practices they will adopt, and the rental rate they request ($\bar{c}$). Evidence of strategic behavior of landowners found by Shoemaker [1989], Cason and Gangadharan [2004], and Kirwan et al. [2005] indicate that the exogenous characteristics of a parcel of land will

[12]The parcels are assumed to share values for the parameters a_0, a_1, and a_2.

affect the joint determination of the conservation practices adopted, the amount of land offered for conservation, A^*, and the yearly rental rate, $\bar{c}$.

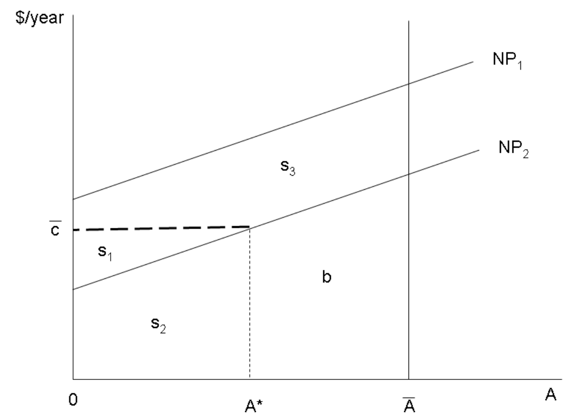

Figure 1: Conservation Payments and Land of Varying Productivity

It is well understood that land characteristics affect land use choices (Lichtenberg [1989] Plantinga [1996]), and several studies discussed above (Skaggs et al. [1994], Parks and Kramer [1995], Parks and Schorr [1997]) have found evidence that landowner characteristics (age, tenure) also impact land use decisions. It could be argued that the model presented here should be modified to accommodate landowner characteristics. The parcel level data I use in this study does not include landowner attributes, and aggregated measures such as county level census information would not yield enough variation to justify their use. Roberts and Lubowski [2007] address this issue by appealing to equilibrium sorting a la Tiebout [1956]: heterogeneous individuals sort into different locations, and characteristics of individuals are mapped to the characteristics of land and to prices in equilibrium. This implies that landowner characteristics are ultimately endogenous, and should not be included in the analysis. I will appeal to this argument here, omitting landowner characteristics from the model and estimation.

Estimation

Empirical Model

The main implication of the structural model presented above is that the amount of land enrolled in a conservation program will decrease as the net productivity of that land - representing the private opportunity cost of restriction - rises. In Figure 1, the quantity of enrolled land, A^*, is determined by the intersection between the conservation payment, $\bar{c}$, and net productivity, so enrollment is determined by

$$A^* = \frac{\bar{c} - a_0 + a_1 \cdot \mathbf{z}}{a_2}. \tag{3}$$

This enrollment equation can be estimated using

$$A^* = \alpha_0 + \alpha_1 \cdot \mathbf{z} + \alpha_{\mathbf{2}} \cdot \bar{\mathbf{c}} + \eta \tag{4}$$

to identify model parameters and gain insight into the behavior of optimizing landowners. The structural model of figure 1 shows that landowners owning land of very high or very low productivity would enroll less than zero or more than the total acreage in the parcel if they could. Therefore, at the parcel level, enrollment can be censored from below by zero, or from above by the acreage of each parcel. A two-sided censored normal model is used to estimate equation 4 to accommodate fixed lower and varying upper censoring points. The two-sided censored normal model is:

$$A_i^* = \alpha^{'} \mathbf{x_i} + \eta_{\mathbf{i}}$$

where A_i^* is the latent dependent variable of acres enrolled in CRP. The vector $\mathbf{x_i}$ contains independent variables such as productivity and CRP payments, α is the vector of parameters to be estimated, and the η_i are residuals assumed to be independently and normally distributed, $\eta \sim N(0, \sigma^2)$. The observed dependent variable, A_i, can be represented as

$$
\begin{aligned}
A_i &= 0 && \text{if} A_i^* \leq a_i \\
&= \alpha^{'}\mathbf{x_i} + \varepsilon && \text{if} A_i < A_i^* < b_i \\
&= 1 && \text{if} A_i^* \geq b_i,
\end{aligned}
$$

where a_i and b_i are the upper and lower censoring points for each observation, respectively. Following Maddala (1983), the parameters β are estimated by maximizing the likelihood function

$$
L(\alpha, \sigma) = \prod_{A_i=0} \Phi\left(\frac{a_i - \alpha'\mathbf{x_i}}{\sigma}\right) \prod_{A_i=A*_i} \frac{1}{\sigma}\phi\left(\frac{A_i - \alpha'\mathbf{x_i}}{\sigma}\right) \prod_{A_i=1}\left(b_i - \Phi\left(\frac{1-\alpha'\mathbf{x_i}}{\sigma}\right)\right),
$$

where Φ and ϕ are the normal distribution and density function, respectively. The two-sided Tobit model results if a and b are constant across observations.

How censored normal regression coefficients are interpreted depends on the purpose of the estimates. For data that are always censored, as is the case for CRP enrollment data (negative enrollment or enrollment above the maximum size of the parcel are never observed), impacts on the censored population are relevant. Following Greene [1997], marginal effects on the censored dependent variable in a two-sided censored normal model are obtained using

$$
\frac{\partial E[A_i|\mathbf{x}_i]}{\partial \mathbf{x}_i} = \alpha \times \Pr(a \leq A_i^* \leq b) = \alpha[\Phi((b - \alpha^{'}\mathbf{x}_i)/\sigma) - \Phi((a - \alpha^{'}\mathbf{x}_i)/\sigma)], \tag{5}
$$

where a and b are the upper and lower censoring points, respectively. A two-sided censored normal model is used to estimate equation 4.

Data

Estimating equation 4 requires parcel level data for CRP enrollment, per-acre CRP payments, and variables likely to shift the net productivity of land, such as soil productivity and non-CRP government payments. Data for Minnesota farm parcels were obtained from Dr. Steve Taff at the University of Minnesota Department of Applied Economics. The University of Minnesota maintains a substantial database of arms-length sales data for all land types. Data from a pooled cross section of sales occurring between 2002 and 2006 were used for this estimation. The data include information about land characteristics (productivity, size, tillable acreage), location, and acres enrolled in the CRP at the time of sale.[13] As of September 30, 2006, Minnesota contained nearly 1.8 million of the 36.8 million acres enrolled nationally in the CRP. The acreage is concentrated in the western and southern parts of the state where agriculture is a prevalent land use. Although enrollment data for this analysis comes from both general and continuous CRP sign-ups, the vast majority of Minnesota's CRP acreage, 1.4 million acres, entered the program through the general sign up process, and 1.6 million acres falls into the Prairie Pothole Conservation Priority Area (CPA). [14] The data used for this analysis exclude parcels with no tillable acreage, and parcels smaller than 35 acres that contain structures.[15]

The CRP places productive acreage under conservation restriction, so the dependent variable is constructed using only the tillable acreage of each parcel. Models are estimated using the level and log of tillable acreage enrolled, as well as the proportion of tillable acreage enrolled, as the dependent variable. If *tillacre* represents the total tillable acreage in a parcel, and *crp* represents the number of acres in each parcel restricted by CRP, tillable acreage enrolled in CRP is calculated as $\min[tillacre, crp]$, and the proportion of tillable acreage enrolled as $\min[\frac{crp}{tillacre}, 1]$.[16] The dependent variable is considered to be censored from below if the parcel is not enrolled in CRP,[17] and

[13]Taff [2004] and Taff and Weisberg [2007] utilize this set, but the data used in this paper were updated with sales through 2006.

[14]Parcels in National Conservation Priority Areas, such as the Prairie Pothole, receive bonus points during contract sign ups because they have been deemed more sensitive by the USDA.

[15]This addresses the issue of 'hobby farms,' noted by Anderson and Weinhold [2005], where farmland is used as a place of residence but not actively farmed due to landowner preference. Landowners who live on 'hobby farms' have a preference for untilled land, and would be expected to enroll more land in CRP because they receive payments for idling land they plan to idle anyway.

[16]The acreage enrolled in CRP exceeded the tillable acreage in 42 of 288 parcels. For all but 5 of the parcels enrolled in CRP, CRP exceeded tillable acreage by less than 20 acres; the mean was 10 acres. The CRP enrollment in these parcels likely exceeded tillable acreage because of measurement error or the enrollment of wildlife habitat under the continuous CRP.

[17]This assumes that for parcels not enrolled in CRP, the value of the least productive acre is higher than the payment the landowner could receive from CRP. This assumption could be violated if county acreage caps restricted enrollment, if landowners submitted bids that were not accepted, or if landowners did not know about the CRP. If all observations with no enrollment are thrown out, the coefficient estimates reported below decrease in value, but are qualitatively the same.

censored from above if the parcel is fully enrolled.

In equation 4, the vector **z** contains variables that affect the net productivity of land. For this estimation, Minnesota's Crop Equivalency Rating (CER), non-CRP government payments, and fixed effects for county and region are included in **z**.[18] Minnesota's measure of productivity, the Crop Equivalent Rating (CER), is a broad proxy for land productivity. According to the Agricultural Extension Service of the University of Minnesota, CERs reflect the net economic return per acre of soil when the soil is used for cultivated crops, permanent pasture, or forest, whichever provides the highest net return. The CER for each parcel is computed using soil, climate, and management variables, and provides a relative ranking of parcels on a scale of 1 (lowest) to 100 (highest). CER data are computed by individual counties, and were not available for every observation; over 4000 sales in 41 counties, including 288 CRP-restricted parcels, had CER data and are used for this analysis.[19] Using CER data to proxy for productivity introduces measurement error for at least two reasons. First, CER values were calculated in some parts of Minnesota as early as 1972, and the majority were computed in the 1980s, so recent changes in a parcel's relative or absolute productivity will not be reflected in the measure. Second, CERs are computed using the distribution of soils on each parcel, but only one number is recorded for each parcel. This means each parcel's CER is an average across the parcel, and does not provide information about the distribution of productivity across acres. Measurement error will bias the coefficient estimate on CER downward in the estimation of equation 4. CER is a parcel specific rating of property productivity, so the model of figure 1 predicts that increases in CER will decrease the proportion of a property enrolled, *ceteris paribus*.

Non-CRP government payments are also included in the estimation. Non-CRP government payments and subsidies to agricultural land represent a cost of CRP enrollment because enrolling land

[18]Time dummies are not included in the estimation because none of the variables are affected by the year when the sale occurred.

[19]A comparison between parcels with CER data and parcels parcels without showed that parcels with CER data sold for higher average per acre prices. This could reflect the value of the productivity information to sellers, or to a systematic difference in the types of properties for which CER's are recorded. If parcels with CER data are systematically different from parcels without, the results of this estimation will only be applicable to similar types of parcels.

in CRP decreases the acreage eligible for these types of payments. Non-CRP government payment data were not included in the sales dataset. County average per-acre direct government payments in Minnesota over the years 1993-2000 were obtained from FINBIN, an online farm financial database that gathers data using individual farm surveys, and average government payments to land managed primarily for corn were used.[20] County fixed effects cannot be used in conjunction with the county averages for non-CRP government payments, so National Agricultural Statistical Service (NASS) region dummies were constructed for use as fixed effects in models that include non-CRP government payments. The model of figure 1 predicts that higher non-CRP government payments will decrease CRP enrollment. However, non-CRP payments are based on agricultural productivity, and are correlated with CER.[21] For this reason, models are run with and without this variable.

CRP rental payments to individual parcels, $\bar{c}$ in equation 4, were not available. The structural model suggests that CRP payments are an important determinant of participation, but the CRP sign-up process, discussed in section 2, may make their inclusion unnecessary or even problematic. Payments from the CRP are designed to compensate landowners for foregone crop profits, and the maximum allowable rental rate increases with the productivity of land. Therefore, excluding payment information may be acceptable for at least two reasons: first, the maximum rent paid in each county is used to determine the cost factor for each bid, so county fixed effects may capture some of the variation in payments; second, payments are determined by both landowner choice and the relative productivity of the land offered for restriction, so CER is likely correlated with CRP payments, and inclusion of both could confound estimation results. This latter point may explain some the weak and counterintuitive results found in studies that include measures of productivity as well as CRP payment information.

Summary statistics for the data used are presented in table 2.

[20]Minnesota farmers in the study region generally rotate corn and soybean crops.
[21]The simple correlation coefficient between the two variables in the data is .45.

Results

Table 3 reports results for censored normal regressions of the level of acres enrolled in CRP on productivity and other variables, and table 4 reports results for regressions using the log of acres enrolled. The log specification is preferred if marginal increases in the productivity of additional acres of land decline with increased acreage. The coefficient on *CER*, the relative productivity of each parcel, is negative and statistically significant across both models and all specifications, indicating that increased productivity is associated with decreased enrollment. The result is consistent with intuition and the structural model presented above. Plugging the mean value for each of the explanatory variables into equation 5, the coefficient estimate under the log specification (table 4) when county fixed effects are included imply that a one unit increase in *CER* decreases acres enrolled by approximately .73 percent, *ceteris paribus*. Thus, a one standard deviation change in productivity results in about a 9.5 % change in enrollment. In the log specification, the coefficient on county average non-CRP government payments is negative and significant when NASS region fixed effects are not included. The estimate implies that a one dollar increase in government payments reduces enrollment by approximately .43 percent, or that a one standard deviation change reduces enrollment by around 3%, ceteris paribus. When NASS region fixed effects are included, the coefficient estimate remains negative but is no longer statistically significant. The negative relationship between government payments and enrollment is consistent with the interpretation that government payments increase the opportunity cost of restriction, decreasing CRP enrollment.

The proportion of tillable acres enrolled was also used as the dependent variable to estimate equation 4. Using the proportion of tillable acres enrolled imposes the requirement that the first and last acre of large and small parcels with the same CER have the same productivity. With fixed censoring points, the censored normal model becomes a two-sided Tobit, as described above. This alternative model specification estimates smaller marginal effects of productivity and non-CRP government payments on enrollment, but the sign and significance of the estimates remain the same. Results are reported in table 5. Again using equation 5 and the mean values of the explanatory variables, the coefficient estimates for Model 2 in table 5 imply that a one unit increase in productivity decreases the proportion of land enrolled by approximately .0014, *ceteris paribus*. The coefficient on government payments indicates that a one dollar increase in government payments reduces the proportion enrolled by approximately .0007, *ceteris paribus*. The effect of non-CRP government payments is again statistically significant only in the absence of NASS region fixed effects.

The estimations show a significant negative relationship between land quality and CRP enrollment; selection into CRP is made based partially on productivity as measured by *CER*. The result is robust to model specification, and is obtained despite the likely presence of measurement error, which would bias the estimate downward (toward zero).

Conclusion

I find that increases in parcel net productivity have a negative and significant effect on the proportion of land enrolled in the USDA's Conservation Reserve Program. The result adds a robust parcel level result to mixed empirical evidence that has important policy implications. My finding that increases in non-CRP government payments decrease CRP enrollment is evidence of non-trivial interaction between USDA Farm Bill programs. The strongly significant association between enrollment and productivity has important implications for testing the hypothesis that CRP confers windfall rents to enrolled landowners advanced byKirwan et al. [2005], among others. One way to test for the existence of windfall rents is to estimate the difference in land value between land enrolled and not enrolled in CRP. This approach has been used in several studies of the CRP and other conservation programs (Anderson and Weinhold [2005], Nickerson and Lynch [2001], Taff [2004], Taff and Weisberg [2007]), and mixed and counterintuitive results have been reported. Selection bias will confound regressions of land value on CRP enrollment if CRP is enrollment is driven by factors that also affect land value. Therefore, my finding that CRP enrollment is significantly affected by land productivity, a strong determinant of land value, indicates that selection bias must be considered. Incomplete consideration of selection bias may explain the mixed results in previous studies of the effect of enrollment in conservation programs on land value.

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Appendix

EBI point scores are the sum of the point values earned in six EBI categories:

N1(Wildlife) - habitat cover, enhancement; bonus if in priority area

N2(Water Quality) - improvements to ground and surface water due to decreased erosion; bonus if in priority area

N3(Erosion) - weighted average of wind and water Erodibility Index (EI); based on 3 predominant soils

N4(Enduring Benefits) - points for establishing enduring cover

N5(Air Quality) - improvements to air quality due to decreased wind erosion; also includes carbon sequestration

N6(Cost) - based on landowner bid; bonus if bid is below max payment rate for region/practice)

Table 1: Literature Summary: Determinants of Participation in the CRP[a]

	Estimation Method	Data Aggregation	Higher Land Quality	Erodible Soil	Higher CRP Rental Rate	Higher non-CRP Government Payments	Larger Farms (Hobby Farm)	Higher Population Density	Longer Tenure	Older Landowner	Own Land	Option Value
Konyar and Osborne 1990	Weighted OLS	MLRA	-	+	+	-	-	n/a	+	-	n/a	n/a
Parks and Kramer 1995	Grouped Logit	county	?	n/a	+	+	n/a	n/a	n/a	+	+	n/a
Parks and Schorr 1997	Grouped Logit	county	-	n/a	+	n/a	-	n/a	n/a	n/a	n/a	n/a
Esseks and Kraft 1988		county	-	+	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Plantinga, et al. 1990	OLS	county	-/?	n/a	+/?	n/a	n/a	-	n/a	n/a	n/a	n/a
Goodwin and Smith 2003	Bootstrapped 2SLS	county	n/a	-	+	+	n/a	n/a	n/a	n/a	n/a	n/a
Isik and Yang 2004	Grouped Logit	county	-	n/a	+	-	n/a	n/a	n/a	+	+	-
Roberts and Lubowski 2007	2SLS	farm/county	?	?	+/?	-/?	n/a	n/a	n/a	n/a	n/a	n/a

[a] +, -, ? are used to indicate positive, negative, and insignificant effects, respectively. If results were mixed, / is used to separate the effects.

Table 2: Summary Statistics for all Parcels and Parcels Enrolled in CRP

Variable	Obs	Mean	Std. Dev.	Min	Max
All Parcels					
Tillable Acreage in CRP	4528	3.02	16.51	0	207
CER	4528	66.47	13.53	5	99
Cty Ave Govt Pay 1993-2000	4528	23.63	7.11	1.39	36.91
Total Acreage in Parcel	4528	114.54	85.21	1	1360
Total Tillable Acreage in Parcel	4528	100.82	78.72	1	1278
Parcels Enrolled in CRP					
Tillable Acreage in CRP	288	47.41	46.79	1	207
CER	288	56.23	12.20	5	85
Cty Ave Govt Pay 1993-2000	288	20.07	7.01	1.39	36.31
Total Acreage in Parcel	288	142.88	100.88	14	687
Total Tillable Acreage in Parcel	288	116.48	88.99	5	601

Table 3: Censored Normal Estimation Results - Acres Enrolled in CRP

	Model 1	Model 2	Model 3	Model 4
CER	-3.437***	-2.987***	-3.139***	-2.979***
	(-11.41)	(-8.66)	(-10.17)	(-9.34)
Cty Ave Gov't Pay			-1.636***	-1.277*
			(-3.21)	(-1.84)
nassregn== 4				-12.627
				(-0.95)
nassregn== 5				-33.675**
				(-2.26)
nassregn== 7				11.272
				(0.96)
nassregn== 8				-68.533***
				(-4.02)
nassregn== 9				-31.317
				(-1.64)
Constant	35.323**	-77.730***	52.749***	53.712**
	(2.30)	(-2.83)	(3.22)	(2.42)
Cty Fixed Effects	N	Y	N	N
N	4528	4528	4528	4528
Sigma	117.186***	102.950***	117.169***	113.975***
	(17.93)	(18.26)	(17.93)	(17.97)
Log–Likelihood	-2214.742	-2082.169	-2209.415	-2187.070
Chi–Squared	193.003	458.147	203.657	248.346

Note: t-stats in parentheses; * $p< 0.1$, ** $p< 0.05$, *** $p< 0.01$

Table 4: Censored Normal Estimation Results - Log of Acres Enrolled in CRP

	Model 1	Model 2	Model 3	Model 4
CER	-0.207***	-0.180***	-0.186***	-0.179***
	(-10.95)	(-8.38)	(-9.64)	(-8.94)
Cty Ave Gov't Pay			-0.111***	-0.070
			(-3.51)	(-1.61)
nassregn== 4				-0.038
				(-0.05)
nassregn== 5				-1.347
				(-1.45)
nassregn== 7				1.098
				(1.47)
nassregn== 8				-3.860***
				(-3.62)
nassregn== 9				-1.450
				(-1.22)
Constant	1.874**	-4.959***	3.039***	2.320*
	(1.97)	(-2.93)	(3.00)	(1.68)
Cty Fixed Effects	N	Y	N	N
N	4528	4528	4528	4528
Sigma	7.320***	6.414***	7.292***	7.141***
	(17.16)	(17.40)	(17.18)	(17.21)
Log–Likelihood	-1545.888	-1414.325	-1539.475	-1518.878
Chi–Squared	183.430	446.556	196.257	237.451

Note: t-stats in parentheses; * p< 0.1, ** p< 0.05, *** p< 0.01

Table 5: Tobit Estimation Results - Proportion of Tillable Acres Enrolled

	Model 1	Model 2	Model 3	Model 4
CER	-0.040***	-0.036***	-0.037***	-0.035***
	(-11.15)	(-8.84)	(-10.05)	(-9.33)
Cty Ave Gov't Pay			-0.018***	-0.010
			(-3.06)	(-1.29)
nassregn== 1				0.259
				(1.18)
nassregn== 4				0.230
				(1.02)
nassregn== 5				0.057
				(0.24)
nassregn== 7				0.427**
				(2.17)
nassregn== 8				-0.451*
				(-1.93)
Constant	0.439**	-0.811**	0.629***	0.243
	(2.50)	(-2.55)	(3.35)	(0.71)
Cty Fixed Effects	N	Y	N	N
N	4528	4528	4528	4528
Sigma	1.337***	1.196***	1.337***	1.321***
	(16.58)	(16.79)	(16.58)	(16.59)
Log–Likelihood	-1109.563	-984.158	-1104.704	-1086.917
Chi–Squared	197.523	448.333	207.240	242.815

Note: t-stats in parentheses; * $p< 0.1$, ** $p< 0.05$, *** $p< 0.01$