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EXPLAINING PARTICIPATION IN THE COLORADO REPUBLICAN RIVER AND NEBRASKA PLATTE-REPUBLICAN RESOURCES AREA CONSERVATION RESERVE ENHANCEMENT PROGRAMS

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ABSTRACT

EXPLAINING PARTICIPATION IN THE COLORADO REPUBLICAN RIVER AND NEBRASKA PLATTE-REPUBLICAN RESOURCES AREA CONSERVATION RESERVE ENHANCEMENT PROGRAMS

Agricultural land retirement is increasingly used to conserve groundwater resources, reduce challenges associated with the conjunctive use of water resources, and meet streamflow compliance. This study explores the factors that influence the participation of agricultural producers in the Colorado Republican River and Nebraska Platte-Republican Resources Area Conservation Reserve Enhancement Programs (CREP). A better understanding of what leads agricultural producers to enroll in CREP could be used to inform program managers on how changing the incentives offered or expanding eligible area would impact enrollment and ultimately groundwater conservation. We develop a theoretical model of CREP participation using a random utility framework that contains the incentives offered for participation, measures approximating the opportunity costs of participation, and aquifer and soil characteristics. We then construct a dataset of participating wells and eligible non-participating wells and generate spatial measures of the explanatory variables. We empirically investigate participation using Probit models, which are estimated with data from the three basins aggregated and also each basin separately. The sign on many of our estimated significant coefficients varies across the three models. For the three participation models, we find that an increase in saturated thickness decreases the probability of participating in CREP.

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INTRODUCTION

Groundwater rights have been overappropriated in several basins of the Great Plains. This has depleted rivers and creeks to the extent that some states have experienced difficulty complying with interstate streamflow compacts. The USDA, states, and local water conservation districts have utilized agricultural land retirement programs to conserve groundwater resources, reduce challenges with the conjunctive use of water resources, and meet streamflow compliance. One such agricultural land retirement program is the Conservation Reserve Enhancement Program (CREP). CREP pays farmers to convert land to a conservation practice and temporarily or permanently restricts producers from irrigating. Significant financial resources are currently devoted to retire agricultural land and reduce water use through Conservation Reserve Enhancement Programs in Colorado, Nebraska, Kansas, and Idaho.[1]

This paper explores the factors that influence agricultural producers to participate in the Colorado Republican River and Nebraska Platte-Republican Resources Area Conservation Reserve Programs. Many economic studies have explained landowners' enrollment decisions in the Conservation Reserve Program or similar land retirement programs. Kingsbury and Boggess (1999), Armstrong et al. (2011), and Yeboah, Lupi, and Kaplowitz (2015) use survey methods to assess the determinants of hypothetical participation in conservation programs. Lynch and Brown (2000) use an optimization model to simulate an agricultural producer's decision to enroll land in the Maryland Chesapeake Bay CREP. Konyar and Osborn (1990), Cooper and Keim (1996), Parks and Schorr (1997), Plantinga, Alig, and Cheng (2001), and Suter, Poe, and Bills

[1] Conservation Reserve Enhancement Programs have been implemented with different objectives throughout the United States. CREPs in the Northeast and Midwest are generally aimed at reducing runoff into streams while CREPs in the Great Plains and Mountain region have the goal of reducing water use. The general objective of CREPs in California and the Northwest is to improve wildlife habitat.

(2008) use county-level data to estimate limited dependent variable models of enrollment in land retirement programs. To our knowledge, this is first study to incorporate microdata in participation models and the first to model the participation of landowners in a land retirement program with the objective of reducing water consumption. A better understanding of what leads producers to participate will be useful for predicting how changing the incentives or expanding the eligible area will impact enrollment.

This paper begins with a summary of the Colorado and Nebraska Conservation Reserve Enhancement Programs and a review of economic studies of participation in land retirement programs. Next, we develop a theoretical model of participation, describe the model we estimate and the variables used in the model, and detail how the variables in the study were generated. Finally, we present and discuss our results and conclude by noting some of the limitations of our study and potential areas for further research.

SUMMARY OF COLORADO AND NEBRASKA CONSERVATION RESERVE ENHANCEMENT PROGRAMS

The Nebraska Platte-Republican Resources Area and Colorado Republican River Conservation Reserve Enhancement Programs are state-federal cooperative programs that remove land from agricultural production to improve environmental conditions and reduce ground and surface water use. The Nebraska Platte-Republican CREP was implemented in 2005 and the Colorado Republican CREP was implemented in 2006. This section will discuss the relationship between CREP and the Conservation Reserve Program, the area and land eligible for enrollment in the Colorado Republican and Nebraska Platte-Republican Conservation Reserve Enhancement Programs, the conservation practices that are adopted, and the incentives offered to producers for participation in these programs.

Relationship to the Conservation Reserve Program

The Conservation Reserve Enhancement Program is a subsidiary program to the larger Conservation Reserve Program (CRP). The CRP is the primary program in the United States that removes land from agricultural production. The CRP was established in 1985 and has grown to enroll 24.2 million acres of agricultural land as of August 2015. Approximately 1.6 billion dollars in annual rental payments were made in 2015. The land eligible for enrollment, conservation practices established by participants, and the payment incentives offered in the CREP are very similar to those in the CRP. The individual Conservation Reserve Enhancement Programs generally target more specific areas and conservation issues than the CRP. The CREPs are partnerships between the USDA and state or local organization involved whereas the Conservation Reserve Program is solely administered by the USDA.

Eligibility for Enrollment

The land eligible for enrollment in both the Nebraska and Colorado CREPs must be located within specified areas and meet prior irrigation criteria. Administrators of the Colorado Republican CREP have an objective of enrolling 35,000 acres of cropland throughout the Republican River Water Conservation District (RRWCD). This includes all or portions of Kit Carson, Logan, Phillips, Sedgwick, Washington, and Yuma counties (Figure 1). The area eligible to enroll in the Nebraska Platte-Republican Program includes land within 2.5 miles of the Republican River and several of its tributaries[2] and area along the Platte River where surface and groundwater has been designated as over appropriated (Figure 2).[3] Land is eligible for enrollment in the Colorado and Nebraska programs if at least six acre-inches of water have been applied in four of the six years prior to enrollment and the land is capable of being planted and irrigated in a "normal manner" (FSA 2005). The Republican program also requires that land be irrigated with at least six acre-inches within the 24 months prior to application. The Platte-Republican CREP allows the enrollment of irrigated land and the corners associated with a center-pivot while the Republican CREP allows only irrigated land to be enrolled.

Conservation Practices

Land enrolled in the program must not be irrigated for the duration of the contract (except for applying six acre-inches in the first year for the establishment of the conservation practice). Participants in the Colorado Republican program are also required to cancel the associated

[2] Including sections of Frenchman Creek, Spring Creek, Stinking Water Creek, Red Willow Creek, Fox Creek, Muddy Creek, Turkey Creek, Spring Creek, Beaver Creek, Driftwood Creek, Buffalo Creek, Rock Creek, Indian Creek, and North Branch Indian Creek with perennial stream flow and all sections of Medicine and Saapa Creeks.

[3] Defined as where "pumping a well for 40 years will deplete the North Platte River, South Platte River, Platte River, or base flow tributary by 28 percent of the amount pumped in that time." Source: State of Nebraska, Department of Natural Resources Order.

groundwater well permits and abandon the well in perpetuity. Land in both programs must be converted from agricultural production to conservation practices for the duration of the contract (14 to 15 years for the Republican program and 10 to 15 years for the Platte-Republican program). The eligible conservation practices are very similar between the two programs. Both programs allow for the following practices: establishment of permanent native grasses, permanent wildlife habitat, filter strips, and wetland buffers and restoration of wetlands. Establishing rare and declining habitat and wildlife food plots are also included in the Platte-Republican program. Each program contains a specific goal for the number of acres converted for each of the conservation practices. The most frequent conservation practices are the establishment of permanent native grasses and permanent wildlife habitat. These two practices represent 96 percent of the total acreage in the Republican program and 85 percent of acreage in the Platte-Republican program. None of the enrollment caps on conservation practices have been met. After the contract has ended, land in the Nebraska Platte-Republican CREP can be returned to irrigated agricultural production, while land previously enrolled in the Colorado Republican CREP can only return to dryland production because the associated well has been permanently retired.

Incentives for Participation

Eligible landowners are offered annual and one-time payments for participation in the Conservation Reserve Enhancement Program. For the Republican and Platte-Republican CREPs, the largest incentive is the annual rental payment. This payment is based on the irrigated cropland rental rate (and the dryland rental rate if enrolling a dryland corner in the Platte-Republican program) in Nebraska and the irrigated rental rate and distance from river in Colorado. The annual rental payment varies by watershed in the Nebraska Platte-Republican

Resources Area CREP and ranges from 110 dollars per acre in the Middle North Platte, Horse Creek, and Pumpkin Creek watersheds to 125 dollars per acre for the Middle Platte and certain watersheds within the Republican Basin. In the Colorado CREP, the annual rental payment is 140 dollars per acre for participants less than one mile from the North or South Fork of the Republican River, 130 dollars per acre for participants greater than or equal to one mile but less than two, 120 per acre for participants greater than or equal two miles but less than four miles, and 115 dollars per acre for participants greater than or equal to four miles. Table 1 displays annual rental payment in the Colorado CREP by distance from North or South Fork of the Republican River. Table 2 shows annual rental payment for each watershed in the Nebraska CREP. Because annual rental payment varies by distance from the river in the Republican River CREP and by watershed in the Platte-Republican Resources Area CREP, we are able to observe enrollment at different annual rental payments.

In addition, participating land owners are eligible to receive one-time signing incentive payments, practice incentive payments, and cost-sharing for certain conservation practices. Ten dollars per acre for each year of the contract is paid up front for the establishment of filter strips, riparian buffers, and wetland restoration for Platte-Republican Resources Area CREP. Ten to 35 dollars per acre, depending on distance from river, is paid for participating in the Republican CREP. There are also practice incentive payments offered to participants. These practice incentive payments are equal to 40 percent of the total eligible costs for installing filter strips and riparian buffers and restoring wetlands in Platte-Republican CREP and 40 percent of total eligible costs for installing riparian buffers in Republican CREP.[4] Fifty percent of eligible

[4] This Practice Incentive Payment is included in the Republican CREP Fact Sheet but not on the Republican River Water Conservation District website.

reimbursable costs are covered for all conservation practices in the Platte-Republican CREP. In the Republican CREP, 50 percent of eligible reimbursable costs for establishing riparian buffers are covered and 55 to 80 percent of eligible reimbursable costs are covered (depending on distance from river) for all other conservation practices. In the Republican CREP, enrollees are also paid 33 to 133 dollars in the 5^{th}, 10^{th}, and 15^{th} years.[5] Table 3 summarizes the incentive payments offered for enrollment in the Republican and Platte-Republican CREPs.

[5] The payments differ based on distance from river.

LITERATURE REVIEW

Previous economic studies of participation in agricultural land conservation programs employ surveys of hypothetical participation, simulations of a landowner's choices, and county-level enrollment data to determine the factors that influence participation. The following section reviews articles that attempt to explain participation in conservation programs—focusing on methods and variables used in each study and highlighting the advantages and shortcomings of each.

Surveys of hypothetical participation ask a respondent if he or she would enroll land in a given conservation program over a specific period for a specified annual payment. These surveys also gather information on farm and farmer characteristics and, in some cases, environmental and conservation values. Kingsbury and Boggess (1999) use a survey on hypothetical CREP participation in Union and Washington Counties in Oregon. Participation is modeled as a function of annual payment, acres, acreage planted with high value crops, acreage planted with low value crops, and percentage of income from farming, expectations (including planned retirement within ten years and importance of land use flexibility), environmental and program preferences and perceptions, demographic variables, and knowledge or past experience with conservation programs. The coefficient on the incentive payment is positive for Union County, but negative for Washington County. Placing a greater importance on flexibility of land use decreases the probability of enrolling while the availability of cost-sharing incentives increases the likelihood of participating. Perceiving an environmental problem and placing a higher importance on environmental quality is also found to increase participation.

Armstrong et al. (2011) survey agricultural producers in the Cannonsville Watershed Area on current or planned participation in the New York City CREP program. Current or future participation is a function of farmer attributes (education, proportion of known farmers within one mile radius presence of other sources of income, and political ideology), farm characteristics (dairy cattle on farm, crop acres, and pasture acres), and farmer attitudes that include resentment towards New York City and attitudes towards the opportunity cost of enrollment. Farmer attitudes towards the opportunity cost of enrolling land and resentment towards water management policies and institutions are found to significantly impact enrollment. In addition, the estimated coefficient on crop acres is positive and significant, implying that landowners with greater acreage are more likely to participate.

Yeboah, Lupi, and Kaplowitz (2015) survey agricultural landowners in the Saginaw River watershed (Michigan) about hypothetical participation in the Conservation Reserve Enhancement Program.[6] The survey the authors use varies contract length, one-time bonus payments, and cost-sharing incentives in addition to varying the annual incentive payment. Measures of environmental values and attitudes towards filter strips are also included along with the farmer characteristics (age, education, conservation experience, gender, and percentage income from farming). The authors find that higher annual payments and shorter contract lengths increase the probability of enrolling in the program, but one-time signing bonuses and reimbursement for installing filter strips do not have a significant impact on the decision to enroll. Farmer age, experience, and knowledge of conservation programs increase the stated

[6] The Saginaw River Valley CREP already exists so the survey samples only landowners who are currently not enrolled.

likelihood of enrollment. Positive attitudes and values towards filter strips and protecting the environment also are associated with higher probabilities of participation.

Another technique for determining the factors that affect participation in agricultural land conservation programs is numerical simulation. Lynch and Brown (2000) use an optimization model to simulate a representative[7] agricultural producer's decision to use land for production, sell for development, or enroll in the Maryland Chesapeake Bay CREP program. The authors then model the optimal acreage to enroll and whether to plant trees or grasses as a riparian buffer. The authors vary crop price, annual rental payment, land price, one-time incentive and cost-share payments, stumpage prices, and discount rates to determine where enrollment decisions change. At existing crop, stumpage, land prices, and incentive levels, the average farmer enrolls the maximum number of acres in the CREP program (assumed to be ten acres) and the enrolled acreage would be used to plant a forest buffer. As land prices increase because of development pressure, the optimal decision changes from planting a forest buffer and enrolling the land in a contract for 30 years to enrolling land for 15 years in a grass buffer. At high land prices, the optimal decision for the landowner is to not enroll any acreage in CREP. The model used by authors assumes that landowners can renew CREP contracts and that land enrolled in the program does not increase in productivity after remaining idle for 15 years.

Several studies use county-level enrollment data to estimate limited dependent variable models on participation. Konyar and Osborn (1990) model the proportion of acres in a Major Resource Land Area enrolled in the Conservation Reserve Program as a function of the difference in net returns between participation and production returns, land value, percentage of

[7] The representative farm for the Maryland Chesapeake Bay CREP produces corn on 100 acres.

land rented, farm size, average age of producers, and average annual soil loss. All variables included in the model are significant at the five percent level. As net returns to agricultural production decrease or as payment incentives for enrollment increase, the proportion of acres participating in the program increases. If average land value, farm size, and age of farmer increase, participation in the program is expected to decline. Counties with greater percentages of rented farms or greater erosion rates are associated with higher enrollment rates.

Parks and Schorr (1997) model Conservation Reserve Program enrollment for metropolitan and non-metropolitan counties in the Northeast. The proportion of eligible area enrolled in a county is modelled as a function of the maximum allowable rental rate, value of crops, crop production costs, value of land, change in land value between 1982 and 1987, proportion of land designated as of limited agricultural value, proportion of land idle, proportion of farms with annual crop sales less than 10,000 dollars, and proportion of high-value crop sales. The authors reject the hypothesis that the regression coefficients for metropolitan and non-metropolitan counties are equal by using a Chow Test and run separate regressions for metropolitan and non-metropolitan counties. Counties with a greater maximum allowable rental rate, crop production costs, proportion of low quality agricultural land, and proportion of idle land is associated with greater enrollment rates in non-metropolitan counties. A greater proportion of sales of high-value crops in a county is associated with lower enrollment rates. In non-metropolitan counties, an increase in production costs or an increase in the proportion of low quality land is estimated to increase the proportion of land enrolled. Increases in land values and in the proportion of farms with crop sales under 10,000 dollars decrease county enrollment rates.

Plantinga et al. (2001) estimate supply functions for agricultural conservation land for nine major US regions. For each region, county acres enrolled is modeled as a function of rental payments, eligible land, average land quality, population density, median household income, and dummy variables for states in the region. Regressions are run for each region and each year from 1987 to 1990. For most years and regions, the coefficients on payment, eligible area, and average land capability class are positive and statistically significant. In the North Plains (North Dakota, South Dakota, Nebraska, and Kansas) region, the coefficient on payment is positive but not statistically different from zero and in the Lakes States region (Minnesota, Wisconsin, and Michigan) the coefficient on average land capability class is negative. Agricultural conservation land supply curves are constructed for each region and year and an average of each region for 1987 to 1990. Supply curves for the East Coast region are the most inelastic followed by supply curves for the Lake States, Cornbelt, and South Plains. An increase in CRP payments in the Mountain and North Plains regions are associated with an over proportional increase in agricultural land offered for conservation.

Suter et al. (2008) model CREP enrollment decisions at the county-level as a function of payment incentives, opportunity costs, and county-level factors. The authors begin by highlighting flaws with the incentive variables used in other articles. Using the average incentive payment to enrollees instead of the average offered creates selection bias issues in Konyar and Osborn (1990).[8] The use of the maximum allowable rental rate to represent the incentive payment in Parks and Schorr (1997) may lead to truncation issues. To obtain unbiased estimates, a payment incentive variable is constructed that is an average of the soil rental rates weighted by the percentage of soil in the area eligible for enrollment. This soil rental rate is then multiplied by the percentage incentive rate to generate the average annual payment offered to the eligible landowners in a given county. The authors also note that estimates of eligible land from the

[8] Plantinga et al. also suffers from this problem.

NRCS National Resource Inventory data used in Parks and Schorr are inaccurate, and instead the land eligible for enrollment is determined by adding together buffer areas surrounding streams for each county. The percentage of eligible acres enrolled as riparian buffers in each county is modeled as a function of annual rental payment, one-time payments and cost-share incentives, average farm income, farm size, percentage irrigated cropland, number of cattle per acre, percentage of owner-operated farms, an urban influence index, average property tax, acreage enrolled in CRP, and FSA payroll per farm. The authors use a Tobit method to avoid truncation bias.[9] The estimated coefficients on annual and one-time payment incentives are positive while the coefficient on urban influence index is negative which indicates that urban development lowers participation and acreage enrolled in the CREP program. Increasing annual and one-time payments increases the percentage of eligible land enrolled while an increase in urban influence decreases enrollment rates.

Each method used in the articles detailed above has advantages and shortcomings. Hypothetical participation surveys elicit the environmental perceptions and values and experience with and knowledge of land conservation programs that may affect the participation of a landowner but are not included in studies that use actual enrollment data. As pointed out in Suter et al. (2008), studies using hypothetical surveys often do not predict the acreage enrolled. These surveys also often cover a small geographic area and as a consequence, the findings might not generalize to other areas. Numerical simulation can provide useful insights of a typical farmer's decision to enroll provided that the model accurately represents the actual decision-making. Because non-typical producers might be more likely to participate, understanding the

[9] The authors also note that none of the counties included approached the upper limit on maximum enrollment so there was no need to use a doubly censored Tobit model.

factors that explain enrollment for non-typical producers is of greater interest to policymakers than those that influence a typical farmer. Models using county-level enrollment data do not rely on hypothetical participation but are unable to use detailed information on environmental values and knowledge of conservation programs that may explain participation.

Several themes from the literature are used to guide this study. We avoid issues of using the average payment received by enrollees by using spatially explicit microdata to determine the annual rental payment offered at each eligible well. The data also allow us to exclude wells that are not eligible for the program by generating a spatially explicit representation of the area eligible for enrollment. This study is the first of our knowledge to use microdata to model enrollment in CREP. Using microdata will enable more detailed prediction of agricultural producers' participation in CREP which is a useful initial step for policymakers in designing similar programs. The results from our study will provide program managers a better understanding of how changing incentives or the area eligible will impact enrollment.

THEORETICAL MODEL AND MODEL ESTIMATED

In this section, we develop a theoretical model of enrollment, describe the variables we use and the model we estimate, and detail our identification strategy. Let $\boldsymbol{\pi}_i^{enroll}$ be the sum of discounted net returns from enrolling for producer i which consist of the discounted sum of net returns from CREP participation and discounted sum of net returns from dryland production in the 15th year and forward through the future.

$$\boldsymbol{\pi}_i^{enroll} = \pi_{i,0}^{CREP} + \pi_{i,15}^{dryland} \quad (1)$$

The net returns to CREP participation, $\pi_{i,0}^{CREP}$, are a function of the annual rental payment and eligibility for signing incentive payments or cost-share payments. Net returns to dryland production, $\pi_{i,15}^{dryland}$ are assumed to be impacted by the dryland rental rate and percentage sand. Increases to the dryland rental rate approximate net returns to dryland production. Soils containing a greater percentage of sand are poorer at holding nutrients and water and are therefore associated with lower returns to dryland production.

Let $\boldsymbol{\pi}_i^{produce}$ be the sum of discounted net returns from production for producer i which include the sum of discounted of net returns from irrigated production up to year T, $\pi_{i,0}^{irrigated}$, when the landowner converts from irrigated to dryland production, and the sum of discounted net returns from dryland production from Tonward, $\pi_{i,T}^{dryland}$.

$$\boldsymbol{\pi}_i^{produce} = \pi_{i,0}^{irrigated} + \pi_{i,T}^{dryland} (2)$$

Net returns from irrigated production, $\pi_{i,0}^{irrigated}$, are assumed to be a function of aquifer and soil characteristics and soil productivity measures. Saturated thickness is the distance from the base to the top of the aquifer, specific yield is the amount of water that drains from a volume of the aquifer, hydraulic conductivity is the volume of water flows through the aquifer within a given time under a gradient. Landowners with greater saturated thickness, hydraulic conductivity, and specific yield have more water available for production and are able to irrigate for a longer duration, earning greater net returns. These landowners also have greater well capacity and are able to apply more water and earn greater yields, revenues, and profits. Wells irrigating land with greater potential yield should earn greater net returns. Producers that have soil with greater available water capacity, the amount of water held by the soil made available to the crop, experience greater yields and need to apply less water. These landowners earn greater revenues, experience lower costs, and generate greater profits from production. An increase to depth to groundwater increases the cost of applying an acre-foot of water decreasing the net returns to irrigated production. Increasing the net irrigation requirement increases the volume of water necessary for production and the cost of irrigated production and decreases the profits from irrigated production.

Net returns from dryland production beginning in T, $\pi_{i,T}^{dryland}$, are again approximated by the dryland rental rate and affected by the percentage sand. Producers with a greater dryland rental rate earn greater net returns from dryland production. Landowners engaged in dryland production on soil with a greater percentage of sand earn lower revenues and profits than those producing on soil with a lower percentage of sand.

Let $U\left(\boldsymbol{\pi}_i^{enroll}\right)$ represent the utility from enrolling in CREP, such that $V\left(\boldsymbol{\pi}_i^{enroll}\right)$ is the observable component of utility from enrolling and ε_{enroll} is the unobservable component of utility from enrollment.

$$U\left(\boldsymbol{\pi}_i^{enroll}\right) = V\left(\boldsymbol{\pi}_i^{enroll}\right) + \varepsilon_i^{enroll} \quad (3)$$

Similarly, let $U\left(\boldsymbol{\pi}_i^{produce}\right)$ be the utility from production, with $V\left(\boldsymbol{\pi}_i^{produce}\right)$ the observable component of utility from production, and $\varepsilon_i^{produce}$ be the unobservable component. An eligible producer is expected to enroll acreage if $U(\boldsymbol{\pi}^{enroll}) > U(\boldsymbol{\pi}^{produce})$. Next, define $\Pr(Enroll)$ as the probability of enrollment.

$$\Pr(Enroll) = \Pr\left(U\left(\boldsymbol{\pi}_i^{enroll}\right) > U\left(\boldsymbol{\pi}_i^{produce}\right)\right) \quad (4)$$

$$= \Pr\left(V\left(\boldsymbol{\pi}_i^{enroll}\right) + \varepsilon_i^{enroll} > V\left(\boldsymbol{\pi}_i^{produce}\right) + \varepsilon_i^{produce}\right)$$

$$= \Pr\left(V\left(\boldsymbol{\pi}_i^{enroll}\right) - V\left(\boldsymbol{\pi}_i^{produce}\right) > \varepsilon_i^{produce} - \varepsilon_i^{enroll}\right)$$

$$= \Pr\left(\varepsilon_i^{produce} - \varepsilon_i^{enroll} < V\left(\boldsymbol{\pi}_i^{enroll}\right) - V\left(\boldsymbol{\pi}_i^{produce}\right)\right)$$

$$= F\left(V\left(\boldsymbol{\pi}_i^{enroll}\right) - V\left(\boldsymbol{\pi}_i^{produce}\right)\right)$$

$$= F\left(\pi_{i,0}^{CREP} + \pi_{i,15}^{dryland} - \pi_{i,0}^{irrigated} - \pi_{i,T}^{dryland}\right)$$

If we assume that $\varepsilon_i^{produce} - \varepsilon_i^{enroll}$ is distributed normally then $F\left(\pi_{i,0}^{CREP} + \pi_{i,15}^{dryland} - \pi_{i,0}^{irrigated} - \pi_{i,T}^{dryland}\right)$ is equivalent to the cumulative normal distribution and we can estimate the probability of enrollment with a probit model.

We estimate the following econometric model:

$$\Pr(Enroll) = \Phi(\beta_0 + \beta_1 ARP_i + \beta_2 Within1{,}895_i + \beta_3 Distance_i + \beta_4 Acres_i + \beta_5 IrrYld_i + \beta_6 DRR_i + \beta_7 IrrLCCI + \beta_8 IrrLCCII + \beta_9 IrrLCCIII + \beta_{10} ST_i + \beta_{11} \%ST_i + \beta_{12} K_i + \beta_{13} SY_i + \beta_{14} D_i + \beta_{15} AWC_i + \beta_{16} \%Sand_i + \beta_{17} NIR_c + \beta_{18} Age_c) \quad (5)$$

In equation 5, ARP is the annual rental payment offered to the producer. A landowner offered a greater annual rental payment earns greater net returns from enrollment and is more likely to enroll in the program. We are unable to determine wells that are eligible for signing incentive or cost-sharing payments. Distance to nearest stream and a dummy variable if the well is located within 1,895 feet of a stream are included to identify wells that could be eligible for cost-sharing and signing incentive payments.[10] All else equal, eligibility for cost-sharing incentives or signing incentive payments is expected to increase the probability of enrollment because these incentives increase the net returns to enrollment.

$IrrYld$ represents the irrigated corn yield in bushels. Increasing the irrigated yield while holding all else constant would increase the revenues and net returns from irrigated production and decrease the probability of participating in the program. DRR, dryland rental rate, is included in the model to approximate the returns from dryland production. An increase in dryland rental rate increases the returns from dryland production. A greater percent of sand, $\%Sand$, is expected to decrease the net returns from dryland production. The impact of an increase in dryland net returns on the probability of enrollment is ambiguous in our theoretical model. If T is greater than 15, greater dryland net returns increase the net returns from enrolling relative to the net returns from producing and increase the probability of enrollment. If T is less than 15, an

[10] 1,895 feet is the diagonal of a quarter-quarter section. We assume if a stream is borders a quarter-quarter section that the land and associated well received a cost-sharing or signing incentive payment.

increase to dryland net returns increases the opportunity cost of enrollment and decreases the probability that land is enrolled in the program. Dummy variables are included for wells located in soil with irrigated land capability class I, II, and III (irrigated land capability IV is the reference group). Soils with a greater irrigated capability class are more limiting or require conservation practices for management. Landowners with greater irrigated capability class experience smaller net returns from irrigated production and are less likely to participate in CREP.

Saturated Thickness (ST), hydraulic conductivity (K), and specific yield (SY) are included in the econometric model. Landowners with higher saturated thickness, specific yield, or hydraulic conductivity have more groundwater for application and greater well capacity. These landowners earn greater net returns from production and are therefore expected to be less likely to participate in the program. Percentage change in saturated thickness since 1980, $\%ST$, is also included in the model to represent changes in volume available for application. Landowners experiencing a sizable percentage loss in saturated thickness might be more concerned with decreases in water availability and might be more likely to retire land than landowners who experienced smaller percentage losses in saturated thickness. An increase in available water content,AWC, is expected to increase yields and the net returns from irrigation and decrease the likelihood of a producer enrolling in the program.

Depth to water, $D,$ and the county-level net irrigation requirement for corn, $NIR,$ are also included in the model. The cost of irrigation is greater for landowners with greater depth to water or a greater net irrigation requirement, these landowners experience lower net returns to irrigation, and are more likely to enroll in CREP as a result. County-level median age is included in the model to approximate the difficulty of selling land. We expect that land in areas with a greater median age is more likely to be enrolled because it may be more difficult to sell or rent land in these areas and thus the landowners may choose to retire the land instead of selling or renting.

The effect of the annual rental payment on participation is identified in our models due to the inclusion of a broad set of variables that control for the opportunity costs of enrollment. Because the annual rental payment offered varies by sub-watershed and distance from the river and the area of the payment bands are relatively small, we should observe multiple wells with similar opportunity characteristics offered different rental payments. Because the large size of the eligible area and watersheds in the Nebraska CREP, there might not be sufficient heterogeneity in the non-incentive payment variables in each watershed or we may not sufficiently measure all of these variables to fully identify the effect of annual rental payment in our Nebraska models. For example, some low annual rental payment watersheds might not have high quality land to compare to the same quality land in a watershed with high annual rental payments. In Colorado, the identification of incentive payments is stronger due to the fact that the rental payments vary only based on distance from the river, which is more likely to be exogenous of the variables that may impact enrollment.

DATA

The spatial data used in this study are obtained from a variety of sources. Retired wells are identified using data provided by the Republican River Water Conservation District and the Nebraska Department of Natural Resources (DNR). The wells eligible for the Colorado Republican CREP are determined by selecting irrigation wells from a Colorado Division of Water Resources database that are within the Republican River Water Conservation District. Wells eligible for the Nebraska-Platte Republican CREP are determined by subsetting a Nebraska DNR spatial dataset of irrigation wells by the Platte overappropriated area[11] or buffers surrounding the Republican River and eligible tributaries.[12] The payment incentive offered to producers in the Colorado Republican CREP is generated by calculating the distance from each well to the North or South Fork of the Republican River using the USGS National Hydrography Data. Payment incentives offered in the Nebraska Platte-Republican CREP are created by determining the watershed for each well using USGS Watershed Boundary Data. Irrigated land capability class and irrigated yield is generated using the USDA NRCS Soil Survey Geographic Database (SSURGO).[13,14] The SSURGO data and soil posting data from the USDA FSA are combined to determine the dryland rental rate in 2005 and 2006. SSURGO data is also used to generate available water content and percent sand. Saturated thickness for 2005, depth to water in 2000, percentage change in saturated thickness since 1980, hydraulic conductivity, and specific yield at each well are generated using USGS Water Resources Spatial Data. County-

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[11] Spatial data of the overappropriated area was provided by the Nebraska DNR.
[12] Using the USGS National Hydrography Data for the Republican River.
[13] We are unable to determine land associated with wells so we use dryland rental rate, irrigated land capability class, irrigated yield, percent sand and available water capacity of the map soil unit in which the well is located to represent the same variables of the associated land.
[14] A sizable percentage of wells are missing dryland rental rate and irrigated corn yield in Colorado and Nebraska. Values for these variables were imputed and if missing, the imputed value is used in the regression models.

level median age of operator for 2002 is generated from the USDA NASS Census of Agriculture. Net irrigation requirement at the county-level is generated from data provided by the USDA Risk Management Agency.

Table 4 displays CREP enrollment by year for the Colorado Republican, Nebraska Republican, and Nebraska Platte basins. The year of enrollment was determined by the year the contract began in Nebraska or the year the well permit was cancelled or the well was abandoned in Colorado. We consider enrollments that occurred in 2005, 2006, and 2007 as participants and enrollments that occurred after 2007 as non-participants in our analysis of the Nebraska Platte-Republican CREP. Similarly, we consider enrollments in 2007, 2008, and 2009 as participants and enrollments after 2009 as non-participants in the Colorado Republican CREP. We restrict those counted as participating to the first three years of participation. It is also important to note that both CREPs allow the enrollment of surface water, but we have excluded surface water retirements from our analysis.[15]

[15] Approximately, 13 percent of land enrolled in the Nebraska CREP was previously irrigated with surface water.

SUMMARY STATISTICS

Table 5 displays the participation rates for the three regions. Approximately 9.17 percent of eligible wells participated in the Nebraska Republican basin, 2.47 percent of eligible wells participated in the Colorado Republican region, and 0.94 percent of eligible wells participated in the Nebraska Platte region.

Summary statistics for the explanatory variables for the Colorado Republican, Nebraska Republican, and Nebraska Platte areas are displayed in Tables 6, 7, and 8. The mean annual rental payment offered in the Nebraska Republican basin is slightly greater than in the Colorado Republican and Nebraska Platte basins. Land productivity amongst eligible wells is greater in the Nebraska Platte and Republican basin than the Colorado Republican basin. The average irrigated corn yield and dryland rental rate is much lower for land in the Colorado Republican area than in the Nebraska basins. Average irrigated land capability class is greater in Colorado than in the Nebraska basins. Saturated thickness is greater in the Nebraska Platte region than the other two basins. The mean value of depth to groundwater, percentage change in saturated thickness, and net irrigation requirement is greater in the Colorado Republican basin the in the two Nebraska areas. The lower opportunity costs of retirement and saturated thickness in the Colorado Republican basin may lead to a higher participation rate than in the Nebraska Platte basin.

Table 9, 10, and 11 display pairwise correlations between explanatory variables for the Colorado Republican, Nebraska Republican, and Nebraska Platte models. The correlation between annual rental payment and the explanatory variables is much greater in the Nebraska Republican and Platte regions than in the Colorado Republican region. This is because annual rental payment is determined by distance from river in the Colorado Republican, while in the

Nebraska regions the irrigated rental rate in the watershed is used to determine the annual rental payment. Percent sand and available water content have a very high correlation in the Colorado Republican region. This might signal potential collinearity issues so we will conduct post-estimation collinearity checks on the Colorado Republican model results.

RESULTS

The first column in Table 12 displays estimated coefficients from the model that includes eligible wells in both Colorado and Nebraska.[16] The estimated coefficient on acres and the dummy variable on the Middle Republican NRD are positive and statistically significant, while the estimated coefficients on dummy variables for irrigated land capability class I and II, saturated thickness, and hydraulic conductivity are negative and statistically significant. The sign on the significant coefficients in this model matches our prior expectations. We expect that increasing saturated thickness and hydraulic conductivity would decrease the probability of enrollment all else equal. We also expect that land in irrigated capability class I and II is less likely to be enrolled. Marginal effects for the variables included in this model are shown in the second column of Table 12. The marginal effects represent the change in the probability of enrollment associated with a unit increase in the explanatory variable for the typical landowner. The estimated probability that an eligible well will enroll in CREP in the three regions is 2.4 percent. A 10 percent increase in saturated thickness or hydraulic conductivity decrease the probability that a typical landowner enrolls from 2.4 to 2.1 percent.

A likelihood ratio test is conducted to determine if it is appropriate to use a pooled model with aggregated data from the three regions. The chi-squared statistic for the likelihood ratio test is $LR = -2(LL_{Pooled} - (LL_{CO\ Republican} + LL_{NE\ Republican} + LL_{NE\ Platte}) = -2(-2068.81 - (-377.58 - 1244.79 - 288.37)) = 316.15$. We reject the hypothesis of pooling the data from the three regions based on these values ($P < 0.0001$). Likelihood ratio tests also reject the pooling the Colorado Republican and Nebraska Republican data, the Nebraska Republican and

[16] Standard errors are clustered at the watershed level.

Platte data, and the Colorado Republican and Nebraska Platte data.[17] Based on the results of these tests, probit regression models are run for each region.

Estimated coefficients from the regression of Colorado eligible wells are displayed in the first column of Table 13. In the Colorado Republican participation model, the coefficients on annual rental payment and irrigated yield are positive and statistically significant from zero, while the coefficients on acres, saturated thickness, and percent change in saturated thickness are negative and statistically significant. The sign on these coefficients[18] except irrigated yield match our prior expectations. All else equal, increasing the annual rental payment are expected to increase the probability of participation and increasing saturated thickness or the percent change in saturated thickness should decrease the probability of participation. We would expect that an increase in irrigated yield should decrease the probability of enrollment holding everything else constant. The first column of Table 14 shows the marginal effects for the variables used in the regression at mean values. Marginal effects represent the increase in probability of enrollment for a one unit change in an independent variable holding all other independent variables constant at mean values. The probability that an eligible well is enrolled in the Colorado Republican region is approximately 0.01. The probability that a typical well is enrolled would approximately double if the annual rental payment increased by ten dollars (ten percent increase). An increase of saturated thickness of 10 percent (13 feet) would decrease the probability that a well is enrolled by approximately two-tenths of a percent. A one percent change in saturated thickness is expected to decrease the probability of enrollment by six-tenths of a percent.

[17] The chi-squared test statistic for these hypothesis tests are 174.51, 123.86, and 81.80 respectively. The 95 percent critical value for 19 degrees of freedom is 30.144.

[18] We do not have an expectation on the sign of the acres variable.

The second column of Table 13 displays the estimated coefficients from the model of eligible wells in the Nebraska Republican region. Estimated coefficients on irrigated yield, irrigated land capability class dummy variables, saturated thickness, and hydraulic conductivity are negative and statistically significant while the coefficients on acres and the Middle Republican dummy variable are positive and statistically significant. The sign of the statistically significant coefficients match our prior expectations. Marginal effects for the variables used in the regression are displayed in the second column of Table 14. A typical well in the region has an 8.9 percent probability of enrollment. The probability that a typical well is enrolled would decrease by about one percent if hydraulic conductivity were to increase by 10 percent. An increase in saturated thickness of ten percent is expected to decrease the probability of enrollment by three-tenths of a percent.

Estimated coefficients from the model for the Nebraska Platte region are displayed in the third column of Table 13. The estimated coefficient on percentage sand is positive and significant while the coefficients on annual rental payment, distance from stream, dryland rental rate, saturated thickness and net irrigation requirement are negative and significant. The estimate signs on annual rental payment and net irrigation requirement do no match our prior expectations. We expect that increasing annual rental payment and net irrigation requirement would increase the probability of participation all else equal. The third column of Table 10 shows the marginal effects of the variables used in the regression at the mean levels. The probability of enrollment for a typical well is 0.007, which is notably smaller than for the other two regions, and given the small enrollment percentage the changes to the probability of enrollment from unit increases in the variables used in the regression are quite small.

Comparing results across the three regions, saturated thickness is the only estimated coefficients to be statistically significant and have the same sign in each region (see Table 13). Distance from stream, dryland rental rate, the irrigated land capability class dummy variables, hydraulic conductivity, percentage sand, net irrigation requirement, and age are significant in one of the three regression models. The sign on annual rental payment, acres, and irrigated yield vary between two of the three models.

The sign on estimated coefficients from the Colorado Republican and Nebraska Republican models align better with prior expectations than the Nebraska Platte models. Table 15 displays the expected sign and estimated sign on the coefficients used in our models. None of the significant coefficients in the Nebraska Republican participation model have signs that conflict with prior expectations (see the second column of Table 13). Three out of the four significant coefficients estimated in the Colorado Republican participation model are of the expected sign (first column of Table 13). Two out of the five significant coefficients estimated in the Nebraska Platte participation model do not match our prior expectation of sign (third column of Table 13).

Several of the variables used in our model have sizable marginal effects on the probability of enrollment (see Table 14) considering the very small probability that a well is enrolled. If the annual rental payment were to increase by ten dollars in the Colorado Republican region, the probability that a typical well is enrolled is predicted to increase from 0.01 to 0.02. In the Nebraska Republican region, the marginal effect from a 10 percent increase in hydraulic conductivity decreases the probability of enrollment by almost one percent. A ten percent increase in the saturated thickness would decrease the probability of enrollment by three-tenths of one percent.

Table 16 displays the estimated variance inflation factors from the Colorado Republican CREP participation model. The estimated variance inflation factors of available water capacity and percent sand are greater than 10 which indicates multicollinearity issues with these two variables. As a consequence of this multicollinearity, our standard errors are larger and we are less likely to find statistical significance for these variables than otherwise.

DISCUSSION

This section discusses two important findings from our study and how our results could be used by CREP program administrators. In the Colorado Republican model, our estimated coefficient on annual rental payment is positive and matches our prior expectations. This estimate could be used to predict an increase in enrollment that results from raising the annual rental payment. We unexpectedly find that an increase in the annual rental payment has no statistically significant effect on the probability of enrollment in the Nebraska Republican basin and decreases the probability of participation in the Nebraska Platte basin. We are unsure what drives these unexpected results. Perhaps we are unable to fully identify the annual rental payment variable because a lack of within watershed heterogeneity in the other variables used in our model or we have omitted a variable from our Probit model that affects participation and is correlated with the annual rental payment. The permitted allocation for Pumpkin Creek watershed was substantially reduced around when the Nebraska CREP was implemented and this watershed also has a very high participation rate and a low annual rental payment. Unfortunately, we were only able to include NRD dummy variables and not groundwater permitted allocations (which sometimes vary within the NRD) in our Nebraska models. Perhaps adding permitted allocation to our models would change the sign of the estimated coefficient on annual rental payment.

Another important finding is that several of our aquifer, soil, and climactic variables affect the probability of enrollment. Increasing saturated thickness decreases the probability of enrollment in all three of our models. Percent of saturated thickness lost and hydraulic conductivity also have a statistically significant impact on enrollment in at least one of the models. Of the soil characteristics, irrigated land capability class dummy variables, and percent sand are also statistically significant from zero in one of our three models. The aquifer, soil, and climate characteristics faced by a producer impact the probability of participation in CREP. These estimates would be very useful to a program manager choosing among potential areas for CREP expansion with the goal of increasing enrollment.

LIMITATIONS

There are several aspects of this study that may limit our findings. We do not observe groundwater pumping prior to or during the enrollment period and are thus unable to determine which wells extracted the required volume of groundwater to be eligible for the program. Wells that used water for irrigation and that were not decommissioned as of 2005 in Nebraska and 2006 in Colorado were considered eligible, non-participating wells. We also cannot associate a groundwater well with the irrigated land so we use the soil characteristics at the well location as those of the land irrigated. If the soil characteristics at the well location and the actual irrigated land differ along another variable, our estimates could be biased. Another limitation is that we are not able to include crop price into our analysis. Price is not included because very few producers enroll after the first three years of the program and we assume producers' expectation of future price does not change from another year of information. Predictions from our model might only apply to years or areas with similar returns to irrigated land as those in Colorado in 2007, 2008, and 2009 and Nebraska in 2005, 2006, and 2007. Another limitation of our study is that there are only four annual rental payment levels in both Colorado and Nebraska and the range of annual rental payments for participation is relatively narrow. The annual rental payments vary from 115 to 140 dollars in Colorado and from 110 to 125 in Nebraska. Few payment levels and a narrow range of payments limit our predictions to small changes in the annual rental payments. Selection bias issues may arise in our analysis if farmers on poorer quality land are more likely interact with the Farm Service Agency (FSA), know more about the CREP, and are more likely to enroll as a result of their better understanding of CREP rather than land quality. Since we do not include a measure of interaction with the FSA in our model, our estimated coefficient on land quality would be biased if this is what actually occurs. Using a dynamic model could capture the effect of changes in price expectations and net returns to irrigated production, but because we do not have sufficient data to capture these expectations we have focused instead on a static model.

FURTHER RESEARCH

There are several areas for further research on the Colorado and Nebraska Conservation Reserve Enhancement Programs. Spatial patterns of well ownership could be incorporated into the model. Well owners near retired wells may experience greater well capacity or lower depth to water than if the well had not been retired. If wells owners are able to internalize this spillover from retirement, they may be more likely to retire wells. Producers in Nebraska and Colorado also may enroll wells and land in the Environmental Quality Incentives Program and the Agricultural Water Enhancement Program. These programs restrict producers from irrigation but allow dryland production. We could construct a model where producers choose to retire land and groundwater, retire groundwater, or retire neither. Estimating potential slippage from the CREP program is also an interesting potential research area. Landowners near retired wells may extract more groundwater or landowners in Nebraska who retired wells may extract more water after the expiration of CREP contract. Understanding if slippage from the CREP occurs would lead to a better understanding of the benefits from retiring wells. Upcoming increases to the annual rental payment in Colorado will provide an opportunity to test the predictions of the model estimated in this study. Modeling the commodities produced on previously retired land is another interesting area for potential research, once the contracts on enrolled acreage begin to expire.

TABLES AND FIGURES

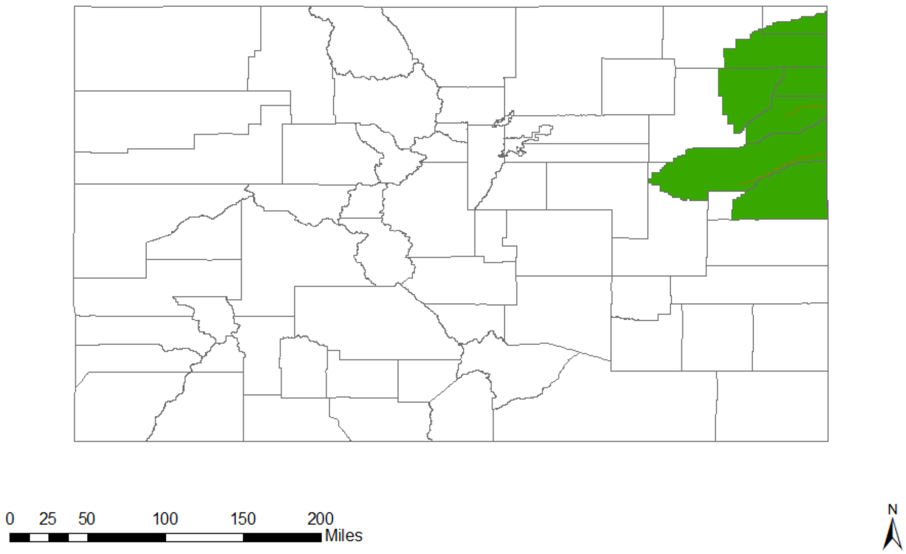

Figure 1. Area Eligible for Colorado Republican River Conservation Reserve Enhancement Program

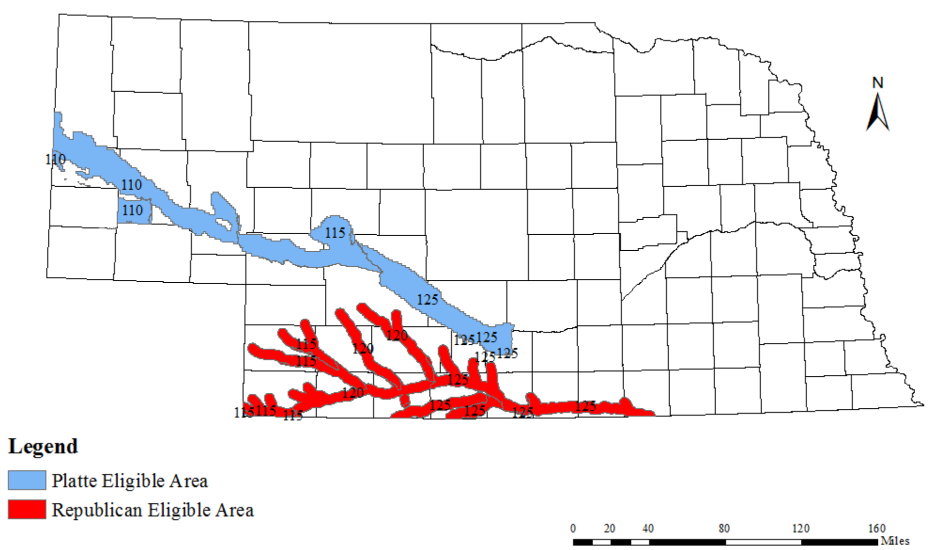

Figure 2. Area Eligible for Nebraska Platte-Republican Resources Area Conservation Reserve Enhancement Program

Table 1. Colorado Republican River Conservation Reserve Enhancement Program Annual Rental Payments

Distance from North or South Fork of Republican River	Payment	Eligible Wells	Participation Rate
Less than one mile	140	100	10.00
Greater than or equal to one mile and less than two miles	130	61	11.48
Greater than or equal to two miles and less than four miles	125	188	6.38
Greater than four miles	115	3,571	1.90

Table 2. Nebraska Platte-Republican Resources Area Conservation Reserve Enhancement Program Annual Rental Payments

Watersheds	Payment	Eligible Wells	Participation Rate
Republican Basin			
Arikaree	115	8	12.50
Frenchman	115	540	15.00
North Fork Republican	115	160	14.38
South Fork Republican	115	8	0.00
Stinking Water	115	213	9.39
Medicine	120	226	8.85
Red Willow	120	174	7.47
Upper Republican	120	968	8.57
Beaver	125	333	3.90
Harlan County Reservoir	125	956	8.79
Lower Sappa	125	258	10.08
Middle Republican	125	438	6.16
Prairie Dog	125	1	0.00
Platte Basin			
Middle North Platte-Scotts Bluff	110	1,851	1.30
Horse	110	30	0.00
Pumpkin	110	201	2.99
Lower North Platte	115	642	2.02
Middle Platte-Buffalo	125	3,277	0.43
Harlan County Reservoir	125	34	0.00
Middle Republican	125	15	0.00

Table 3. Summary of Incentives in the Colorado Republican and Nebraska Platte-Republican CREP

Incentives	Colorado Republican	Nebraska Platte-Republican
One-time		
Signing Incentive Payments	10 to 35 dollars per acre (depending on distance from river)	10 dollars per acre per year (for filter strips, riparian buffers, or wetland restoration)
Practice Incentive Payments	40 percent of total eligible costs for installing riparian buffers	40 percent of total eligible costs for installing filter strips or riparian buffers
Cost-sharing	50 percent of eligible reimbursable costs for riparian buffers and 55 to 80 percent for all other practices (depending on distance to river)	50 percent of eligible reimbursable costs for all conservation practices
Recurring		
Annual Rental Payment	115 to 140 dollars per acre (depending on distance to river)	110 to 125 dollars per acre (depending on watershed)
Direct Payments	33 to 133 dollars per acre (in the 5th, 10th, and 15th year of the contract)	

Table 4. Conservation Reserve Enhancement Program Enrollment by Year

Year	Colorado Republican	Nebraska Republican	Nebraska Platte
2005	0	266	34
2006	0	116	20
2007	18	9	3
2008	20	5	0
2009	59	0	2
2010	27	2	1
2011	6	0	0
2012	0	0	8
Missing	12	28	1

Table 5. Conservation Reserve Enhancement Program Participation Rates by Basin

	Colorado Republican		Nebraska Republican		Nebraska Platte	
	Number	Percent	Number	Percent	Number	Percent
Total	3,920	-	4,283	-	5,993	-
Enrolled	97	2.47	391	9.13	57	0.94
Not Enrolled	3,823	97.53	3,892	90.87	6,050	99.06

Table 6. Summary Statistics of Variables used in Colorado Republican CREP Participation Model

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Annual Rental Payment (dollars) (based on distance from river)	3,920	116.35	4.74	115.00	140.00
Within 1,895 of Stream	3,920	0.24	0.42	0.00	1.00
Distance to Stream (feet)	3,920	15,175.50	17,421.24	0.28	73,068.79
Acres	3,749	172.59	71.54	4.00	965.00
Irrigated Yield (Bushels of Corn) (map soil unit)	3,894	118.44	38.88	4.25	172.40
Dryland Rental Rate (dollars) (map soil unit)	3,919	30.37	6.72	13.00	50.00
Irrigated Land Capability Class I (map soil unit)	3,920	0.00	0.07	0.00	1.00
Irrigated Land Capability Class II (map soil unit)	3,920	0.44	0.50	0.00	1.00
Irrigated Land Capability Class III (map soil unit)	3,920	0.29	0.45	0.00	1.00
Saturated Thickness (feet)	3,919	130.20	74.41	5.14	309.14
Percentage Change in Saturated Thickness since 1980	3,919	-0.13	0.09	-0.60	1.14
Hydraulic Conductivity (feet per day)	3,920	85.69	18.70	35.05	138.86
Specific Yield (feet per day)	3,920	15.17	2.24	8.48	21.08
Depth to Water (feet)	3,920	143.34	43.90	48.27	223.17
Available Water Capacity (centimeters of water/centimeters of soil)	3,919	0.14	0.04	0.04	0.20
Percentage Sand	3,919	47.73	29.18	9.74	95.32
Net Irrigation Requirement (inches) (county-level)	3,920	15.44	0.33	14.93	16.82
Age (county-level)	3,920	53.56	1.03	52.70	56.40

All variables except for annual rental payment, irrigated yield, dryland rental rate, irrigated land capability class, net irrigation requirement, and age vary by well.

Table 7. Summary Statistics of Variables used in Nebraska Republican CREP Participation Model

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Annual Rental Payment (dollars) (based on distance from river)	4,283	121.23	3.94	115.00	125.00
Within 1,895 of Stream	4,283	0.81	0.39	0.00	1.00
Distance to Stream (feet)	4,283	1,411.61	1,831.18	0.21	13,085.10
Acres	3,955	122.52	88.43	1.00	867.74
Irrigated Yield (Bushels of Corn) (map soil unit)	4,272	131.89	19.18	30.00	165.00
Dryland Rental Rate (dollars) (map soil unit)	4,275	44.87	12.06	25.00	76.00
Irrigated Land Capability Class I (map soil unit)	4,283	0.29	0.45	0.00	1.00
Irrigated Land Capability Class II (map soil unit)	4,283	0.47	0.50	0.00	1.00
Irrigated Land Capability Class III (map soil unit)	4,283	0.12	0.32	0.00	1.00
Saturated Thickness (feet)	4,283	94.75	91.63	5.64	474.73
Percentage Change in Saturated Thickness since 1980	4,283	-0.04	0.06	-0.41	0.21
Hydraulic Conductivity (feet per day)	4,283	125.33	62.46	23.43	250.69
Specific Yield (feet per day)	4,283	15.35	2.49	9.78	20.24
Depth to Water (feet)	4,283	86.27	33.56	16.13	196.79
Available Water Capacity (centimeters of water/centimeters of soil)	4,283	0.17	0.04	0.05	0.22
Percentage Sand	4,283	35.76	27.67	6.76	95.32
Net Irrigation Requirement (inches) (county-level)	4,283	12.91	0.97	10.88	14.41
Age (county-level)	4,283	54.77	1.26	50.30	57.40

All variables except for annual rental payment, irrigated yield, dryland rental rate, irrigated land capability class, net irrigation requirement, and age vary by well.

Table 8. Summary Statistics of Variables used in Nebraska Platte CREP Participation Model

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Annual Rental Payment (dollars) (based on distance from river)	6,050	118.78	7.02	110.00	125.00
Within 1,895 of Stream	6,050	0.64	0.48	0.00	1.00
Distance to Stream (feet)	6,050	1,859.12	1,885.15	0.70	25,666.36
Acres	5,897	127.45	84.92	0.70	999.00
Irrigated Yield (Bushels of Corn) (map soil unit)	5,985	124.79	21.08	2.10	165.00
Dryland Rental Rate (dollars) (map soil unit)	6,038	43.71	17.94	16.00	76.31
Irrigated Land Capability Class I (map soil unit)	6,050	0.35	0.48	0.00	1.00
Irrigated Land Capability Class II (map soil unit)	6,050	0.30	0.46	0.00	1.00
Irrigated Land Capability Class III (map soil unit)	6,050	0.20	0.40	0.00	1.00
Saturated Thickness (feet)	6,050	280.83	137.90	1.36	651.17
Percentage Change in Saturated Thickness since 1980	6,050	-0.01	0.05	-0.40	1.76
Hydraulic Conductivity (feet per day)	6,050	53.08	24.16	18.65	127.27
Specific Yield (feet per day)	6,050	18.44	2.60	11.35	24.83
Depth to Water (feet)	6,050	33.76	26.65	6.22	178.42
Available Water Capacity (centimeters of water/centimeters of soil)	6,050	0.16	0.05	0.03	0.22
Percentage Sand	6,050	43.72	29.92	5.50	95.73
Net Irrigation Requirement (inches) (county-level)	6,050	13.50	1.66	11.27	16.09
Age (county-level)	6,050	53.39	1.89	50.30	57.60

All variables except for annual rental payment, irrigated yield, dryland rental rate, irrigated land capability class, net irrigation requirement, and age vary by well.

Table 9. Correlation between explanatory variables used in the Colorado Republican CREP Participation Models

Variables	Ann. Rental Pay.	W/in 1,895 ft.	Dist. from Strm.	Acres	Irrig. Yield	Dry. Rental Rate	Irrig. LCC I	Irrig. LCC II	Irrig. LCC III	Sat. Thk.	Per. Sat. Thk. Lost	Hydr. Cond.	Specific Yield	Depth to Water	Avail. Wat. Cap.	Per. Sand	Net Irrig. Req.	Age
Ann. Rental Pay.	1.00																	
W/in 1,895 ft.	0.24	1.00																
Dist. from Strm.	-0.19	-0.45	1.00															
Acres	-0.09	-0.16	0.08	1.00														
Irrig.Yield	-0.08	-0.04	-0.10	0.04	1.00													
Dry. Rental Rate	-0.12	0.10	-0.27	-0.02	0.14	1.00												
Irrig. LCC I	-0.02	0.00	0.03	0.02	0.00	0.02	1.00											
Irrig. LCC II	-0.07	0.14	-0.35	0.00	0.35	0.55	-0.06	1.00										
Irrig. LCC III	0.05	-0.10	0.16	-0.05	-0.18	-0.02	-0.04	-0.58	1.00									
Sat. Thickness	-0.11	-0.36	0.53	0.10	-0.14	-0.18	-0.06	-0.30	0.12	1.00								
Per. Chg. Sat. Thk.	0.12	0.19	-0.18	-0.10	-0.16	-0.01	-0.04	-0.06	0.05	0.12	1.00							
Hydr. Cond.	0.05	-0.16	0.10	-0.02	-0.23	0.01	-0.04	-0.25	0.19	0.21	0.14	1.00						
Specific Yield	-0.10	-0.33	0.48	0.05	-0.07	-0.20	-0.02	-0.34	0.16	0.41	0.03	0.37	1.00					
Depth to Water	-0.22	0.05	-0.34	0.07	0.24	0.26	0.00	0.39	-0.17	-0.40	-0.15	-0.11	-0.10	1.00				
Avail. Wat. Cap.	-0.04	0.25	-0.49	-0.01	0.16	0.60	0.06	0.64	-0.20	-0.51	-0.05	-0.33	-0.44	0.49	1.00			
Percent Sand	0.03	-0.24	0.48	-0.02	-0.19	-0.54	-0.06	-0.65	0.26	0.52	0.08	0.42	0.45	-0.47	-0.95	1.00		
Net Irrig. Req.	0.01	0.09	-0.15	-0.02	0.23	-0.13	0.04	0.09	-0.04	-0.43	-0.02	-0.29	-0.27	0.19	0.25	-0.29	1.00	
Age	-0.08	0.14	-0.37	-0.03	0.38	0.10	0.06	0.23	-0.08	-0.44	0.08	-0.23	-0.17	0.44	0.38	-0.38	0.44	1.00

Table 10. Correlation between explanatory variables used in the Nebraska Republican CREP Participation Models

Variables	Ann. Rental Pay.	W/in 1,895 ft.	Dist. from Strm.	Acres	Irrig. Yield	Dry. Rental Rate	Irrig. LCC I	Irrig. LCC II	Irrig. LCC III	Sat. Thk.	Per. Sat. Thk. Lost	Hydr. Cond.	Specific Yield	Depth to Water	Avail. Wat. Cap.	Per. Sand	Net Irrig. Req.	Age
Ann. Rental Pay.	1.00																	
W/in 1,895 ft.	0.32	1.00																
Dist. from Strm.	-0.34	-0.73	1.00															
Acres	-0.07	-0.15	0.12	1.00														
Irrig.Yield	0.36	0.18	-0.20	-0.08	1.00													
Dry. Rental Rate	0.64	0.27	-0.31	-0.13	0.54	1.00												
Irrig. LCC I	0.09	0.10	-0.13	-0.10	0.31	0.35	1.00											
Irrig. LCC II	0.16	0.15	-0.19	0.01	0.18	0.12	-0.59	1.00										
Irrig. LCC III	-0.12	-0.08	0.12	0.07	-0.33	-0.23	-0.23	-0.35	1.00									
Sat. Thickness	-0.52	-0.32	0.37	0.19	-0.31	-0.41	-0.19	-0.04	0.13	1.00								
Per. Chg. Sat. Thk.	0.14	0.20	-0.21	-0.09	0.04	0.23	0.00	0.09	-0.05	0.06	1.00							
Hydr. Cond.	0.36	0.27	-0.32	-0.21	0.33	0.44	0.28	-0.01	-0.14	-0.64	0.01	1.00						
Specific Yield	0.21	0.13	-0.14	-0.12	0.14	0.36	0.14	0.02	-0.07	-0.19	0.04	0.65	1.00					
Depth to Water	0.01	-0.01	-0.01	0.03	-0.10	-0.09	-0.05	0.12	-0.02	0.38	-0.05	-0.28	0.03	1.00				
Avail. Wat. Cap.	0.29	0.31	-0.41	-0.02	0.46	0.40	0.21	0.25	-0.14	-0.15	0.16	0.22	0.08	0.08	1.00			
Percent Sand	-0.26	-0.22	0.30	-0.03	-0.38	-0.31	-0.20	-0.20	0.17	0.08	-0.12	-0.12	-0.05	-0.15	-0.87	1.00		
Net Irrig. Req.	-0.86	-0.35	0.36	0.09	-0.32	-0.74	-0.09	-0.18	0.10	0.41	-0.23	-0.40	-0.41	-0.06	-0.30	0.26	1.00	
Age	-0.72	-0.25	0.25	-0.03	-0.29	-0.58	-0.04	-0.17	0.00	0.08	-0.20	-0.11	-0.16	-0.15	-0.36	0.32	0.80	1.00

Table 11. Correlation between explanatory variables used in the Nebraska Platte CREP Participation Models

Variables	Ann. Rental Pay.	W/in 1,895 ft.	Dist. from Strm.	Acres	Irrig. Yield	Dry. Rental Rate	Irrig. LCC I	Irrig. LCC II	Irrig. LCC III	Sat. Thk.	Per. Sat. Thk. Lost	Hydr. Cond.	Specific Yield	Depth to Water	Avail. Wat. Cap.	Per. Sand	Net Irrig. Req.	Age
Ann. Rental Pay.	1.00																	
W/in 1,895 ft.	0.07	1.00																
Dist. from Strm.	-0.09	-0.71	1.00															
Acres	-0.09	-0.03	0.03	1.00														
Irrig.Yield	0.33	-0.07	0.02	-0.05	1.00													
Dry. Rental Rate	0.81	-0.02	-0.04	-0.05	0.47	1.00												
Irrig. LCC I	0.47	-0.06	-0.01	-0.03	0.43	0.57	1.00											
Irrig. LCC II	-0.13	-0.02	0.02	-0.01	0.23	-0.07	-0.48	1.00										
Irrig. LCC III	-0.11	0.10	-0.08	0.05	-0.32	-0.22	-0.36	-0.32	1.00									
Sat. Thickness	0.83	-0.03	0.03	-0.06	0.31	0.70	0.41	-0.12	-0.10	1.00								
Per. Chg. Sat. Thk.	0.37	0.03	-0.07	-0.05	0.13	0.36	0.22	-0.10	-0.06	0.41	1.00							
Hydr. Cond.	-0.84	-0.05	0.04	0.07	-0.25	-0.66	-0.41	0.20	0.04	-0.79	-0.34	1.00						
Specific Yield	-0.84	-0.09	0.11	0.04	-0.27	-0.69	-0.41	0.19	0.06	-0.74	-0.42	0.93	1.00					
Depth to Water	0.13	-0.07	0.05	0.12	0.07	0.22	0.08	0.04	-0.09	0.24	0.10	-0.15	-0.23	1.00				
Avail. Wat. Cap.	0.48	-0.02	-0.07	-0.02	0.48	0.61	0.51	0.10	-0.18	0.40	0.17	-0.33	-0.36	0.13	1.00			
Percent Sand	-0.60	0.01	0.09	0.00	-0.46	-0.75	-0.56	0.01	0.19	-0.51	-0.27	0.43	0.48	-0.21	-0.87	1.00		
Net Irrig. Req.	-0.94	-0.05	0.06	0.11	-0.34	-0.85	-0.47	0.16	0.11	-0.79	-0.40	0.86	0.86	-0.10	-0.42	0.56	1.00	
Age	-0.59	-0.01	0.04	0.05	-0.34	-0.69	-0.38	-0.01	0.15	-0.45	-0.23	0.31	0.34	-0.03	-0.43	0.54	0.56	1.00

Table 12. CREP Participation Model and Marginal Effects

VARIABLES	Coefficients	Marginal Effects
Ann. Rental Payment	0.0182	0.00101
	(0.0148)	(0.000878)
W/in 1,895 feet	0.122*	0.00677*
	(0.0639)	(0.00380)
Dist. From Stream	-2.97e-06	-1.65e-07
	(4.85e-06)	(2.72e-07)
Acres	0.000910***	5.05e-05**
	(0.000342)	(1.98e-05)
Irrigated Yield	-0.00110	-6.10e-05
	(0.00167)	(9.22e-05)
Dryland Rental Rate	0.00192	0.000107
	(0.00644)	(0.000354)
Irr. LCC I	-0.308***	-0.0171***
	(0.113)	(0.00652)
Irr. LCC II	-0.228**	-0.0126**
	(0.0959)	(0.00521)
Irr. LCC III	-0.203*	-0.0113*
	(0.118)	(0.00664)
Saturated Thickness	-0.00232***	-0.000129***
	(0.000669)	(3.80e-05)
Percent Change in Sat. Thk.	-0.570	-0.0316
	(0.841)	(0.0460)
Hydraulic Conductivity	-0.00413***	-0.000229***
	(0.00103)	(5.36e-05)
Specific Yield	0.0390*	0.00216*
	(0.0231)	(0.00127)
Depth to Water	0.000770	4.28e-05
	(0.000950)	(5.34e-05)
Avail. Wat. Capacity	2.096	0.116
	(1.356)	(0.0732)
Percentage Sand	0.000847	4.71e-05
	(0.00199)	(0.000108)
Net Irrigation Requirement	0.102	0.00566
	(0.146)	(0.00806)
Age	0.0640	0.00356
	(0.0471)	(0.00268)
Nebraska	0.258	0.0143
	(0.545)	(0.0302)
Lower Republican NRD	0.504	0.0280*
	(0.328)	(0.0166)
Middle Republican NRD	0.745***	0.0413***
	(0.268)	(0.0135)
Upper Republican NRD	0.503	0.0279
	(0.345)	(0.0189)
Central Platte NRD	0.149	0.00829
	(0.279)	(0.0151)
North Platte NRD	-0.591	-0.0328
	(0.576)	(0.0321)
Twin Platte NRD	-0.267	-0.0148
	(0.337)	(0.0186)
Constant	-9.528**	
	(3.791)	
Observations	13,834	13,834
Pseudo-R^2	0.126	
Log-likelihood	-2007	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 13. CREP Participation Models with Clustered Standard Errors

VARIABLES	CO Republican	NE Republican	NE Platte
Ann. Rental Payment	0.0370**	-0.0465	-0.114**
	(0.0153)	(0.0331)	(0.0491)
W/in 1,895 feet	0.217*	-0.152	0.0934
	(0.122)	(0.128)	(0.0965)
Dist. From Stream	-2.56e-06	-4.77e-05	-6.94e-05***
	(4.53e-06)	(3.11e-05)	(1.95e-05)
Acres	-0.00206***	0.00102**	0.000375
	(0.000500)	(0.000424)	(0.000677)
Irrigated Yield	0.00572***	-0.00626***	-0.00123
	(0.00192)	(0.00218)	(0.00293)
Dryland Rental Rate	-0.00168	0.0122*	-0.0153***
	(0.0197)	(0.00672)	(0.00555)
Irr. LCC I	0.130	-0.354***	-0.176
	(0.537)	(0.130)	(0.292)
Irr. LCC II	-0.443	-0.311***	0.0122
	(0.282)	(0.0952)	(0.122)
Irr. LCC III	-0.0677	-0.424**	-0.222
	(0.129)	(0.166)	(0.270)
Saturated Thickness	-0.00558***	-0.00234***	-0.00139**
	(0.00125)	(0.000716)	(0.000587)
Percent Change in Sat. Thk.	-2.217***	-0.546	1.402
	(0.399)	(1.109)	(1.194)
Hydraulic Conductivity	0.00409	-0.00480***	0.000496
	(0.00592)	(0.00146)	(0.00984)
Specific Yield	0.0275	0.0549	-0.00256
	(0.0293)	(0.0375)	(0.0931)
Depth to Water	0.00145	0.00160	-0.00209
	(0.00183)	(0.00218)	(0.00211)
Avail. Wat. Capacity	0.597	3.440*	2.127
	(5.616)	(2.067)	(2.114)
Percentage Sand	-0.00746	0.00104	0.00481***
	(0.00719)	(0.00361)	(0.00173)
Net Irrigation Requirement	0.222*	0.286*	-0.501**
	(0.129)	(0.154)	(0.223)
Age	-0.347**	0.0213	-0.0267
	(0.169)	(0.0364)	(0.0631)
Lower Republican NRD		0.747	
		(0.494)	
Middle Republican NRD		0.550**	
		(0.216)	
Tri-Basin NRD		0.574	-0.234
		(0.536)	(0.655)
Central Platte NRD			0.596
			(0.472)
North Platte NRD			0.0186
			(0.386)
Constant	8.200	-1.262	19.89**
	(7.406)	(3.715)	(9.441)
Observations	3,731	3,944	5,820
Pseudo-R^2	0.162	0.0495	0.115
Log-likelihood	-376.7	-1207	-283.4

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 14. Conservation Reserve Enhancement Program Participation Model Marginal Effects

VARIABLES	CO Republican	NE Republican	NE Platte
Ann. Rental Payment	0.00105***	-0.00748	-0.00138***
	(0.000254)	(0.00542)	(0.000423)
W/in 1,895 feet	0.00618	-0.0245	0.00113
	(0.00434)	(0.0209)	(0.00113)
Dist. From Stream	-7.29e-08	-7.68e-06	-8.39e-07**
	(1.22e-07)	(5.19e-06)	(3.27e-07)
Acres	-5.85e-05**	0.000164**	4.54e-06
	(2.51e-05)	(6.62e-05)	(7.84e-06)
Irrigated Yield	0.000163***	-0.00101***	-1.48e-05
	(5.45e-05)	(0.000319)	(3.51e-05)
Dryland Rental Rate	-4.78e-05	0.00197*	-0.000185***
	(0.000566)	(0.00114)	(6.05e-05)
Irr. LCC I	0.00370	-0.0569**	-0.00213
	(0.0160)	(0.0228)	(0.00346)
Irr. LCC II	-0.0126*	-0.0501***	0.000148
	(0.00667)	(0.0164)	(0.00149)
Irr. LCC III	-0.00193	-0.0682**	-0.00269
	(0.00348)	(0.0267)	(0.00320)
Saturated Thickness	-0.000159***	-0.000376***	-1.68e-05**
	(3.29e-05)	(0.000122)	(7.73e-06)
Percent Change in Sat. Thk.	-0.0631***	-0.0879	0.0169
	(0.0162)	(0.178)	(0.0124)
Hydraulic Conductivity	0.000116	-0.000773***	5.99e-06
	(0.000193)	(0.000252)	(0.000119)
Specific Yield	0.000782	0.00884	-3.09e-05
	(0.000745)	(0.00621)	(0.00113)
Depth to Water	4.13e-05	0.000258	-2.52e-05
	(4.55e-05)	(0.000350)	(2.67e-05)
Avail. Wat. Capacity	0.0170	0.554*	0.0257
	(0.158)	(0.330)	(0.0223)
Percentage Sand	-0.000212	0.000167	5.81e-05***
	(0.000234)	(0.000580)	(1.53e-05)
Net Irrigation Requirement	0.00631	0.0460*	-0.00605**
	(0.00426)	(0.0259)	(0.00251)
Age	-0.00987***	0.00342	-0.000323
	(0.00265)	(0.00581)	(0.000729)
Lower Republican NRD		0.120	
		(0.0811)	
Middle Republican NRD		0.0885**	
		(0.0365)	
Tri-Basin NRD		0.0923	-0.00282
		(0.0874)	(0.00801)
Central Platte NRD			0.00720
			(0.00524)
North Platte NRD			0.000225
			(0.00466)
Observations	3,731	3,944	5,820

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

Table 15. Expected and Actual Sign on Coefficients from CREP Participation Models

	Expected Sign	Actual Sign			
VARIABLES		CO Republican	NE Republican	NE Platte	All Wells
Annual Rental Payment	+	+		-	
W/in 1,895 feet	+				
Distance From Stream	-			-	
Acres		-	+		+
Irrigated Yield	-	+	-		
Dryland Rental Rate				-	
Irrigated LCC I	-		-		-
Irrigated LCC II	-		-		-
Irrigated LCC III	-		-		
Saturated Thickness	-	-	-	-	-
Percentage Change Sat. Thickness	-	-			
Hydraulic Conductivity	-		-		-
Specific Yield	-				
Depth to Water	+				
Available Water Capacity	-				
Percentage Sand				+	
Net Irrigation Requirement	+			-	
Age		-			

Note: This table does not include dummy variables for the Nebraska or the Nebraska NRDs.

Table 16. Collinearity Diagnostics for Variables used in the Colorado Republican Regression

Variable	Variance Inflation Factor
Annual Rental Payment	1.23
Within 1,895 feet	1.46
Distance from Stream	2.24
Acres	1.07
Irrigated Yield	1.48
Dryland Rental Rate	2.42
Irrigated Land Capability Class I	1.06
Irrigated Land Capability Class II	3.87
Irrigated Land Capability Class III	2.07
Saturated Thickness	2.17
Percent Change Saturated Thickness	1.30
Hydraulic Conductivity	1.62
Specific Yield	1.74
Depth to Water	1.79
Available Water Capacity	13.16
Percent Sand	12.76
Net Irrigation Requirement	1.66
Age	1.88

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