Does Pumping Pay: Groundwater Management Institutions and Cropland Values in Nebraska

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Conflicts over agricultural water use have been an issue in the western United States and worldwide since the widespread development of irrigation. Water management institutions serve to ration scare water resources, but can impose costs on water uses. These costs can be difficult to measure as water rights are often not tradable. The option value of irrigation, or the costs imposed when producers lose the unused right to irrigate, is especially difficult to measure. This study measures the value of pumping rights under different management institutions in Nebraska. We take advantage of temporal and spatial variation in water management across the state, as well as unique plot level data that incorporate information on cropland values, irrigation status, and physical characteristics. Preliminary results indicate that irrigation rights substantially increase cropland values, and hence likely contribute significantly to farm income.

Introduction

Irrigation water is a key input for many farming systems, and the effects on costs to agricultural water users of different water management strategies have important policy implications. Conflicts over agricultural water use have been an issue in the western United States since widespread development of irrigation began in the latter half of the nineteenth century. Globally, access to agricultural water is an increasing source of conflict. The increase in extreme temperature and adverse weather events predicted by many global climate models could exacerbate such conflicts. Effective systems for allocation of irrigation water can mitigate such conflicts while ensuring sustainable use. Various water management institutions serve to ration scarce water resources, but can impose costs on water uses. These costs can be difficult to measure, as water or water-use rights are often not tradable. When pumping rights are transferrable, transactions costs to trading are often quite high (Palazzo 2009). Further, the option value of irrigation, or the costs imposed when producers lose the unused right to irrigate, is especially difficult to measure. This study measures the value of irrigation and the option value of irrigation under different water management institutions in Nebraska. We take advantage of temporal and spatial variation in water management institutions in Nebraska over the past two decades, as well as unique plot-level data on cropland values, irrigation status, and physical characteristics. In this article, we review irrigation systems in Nebraska and the literature on the costs of groundwater irrigation, and estimate the value that irrigation adds to cropland values in Nebraska. Subsequent research will estimate the option value of groundwater irrigation and the costs of different regulatory regimes.

Background and Literature Review

Nebraska overlies parts of six river basins: Niobara, Upper Platte, Lower Platte, Blues, Republican, and Missouri. Most of the state is underlain by the High Plains, or Ogallala, aquifer.

Groundwater is managed by local conservation districts in Nebraska. Since 1972, groundwater in Nebraska has been managed by Natural Resource Districts (NRDs), which are responsible for managing a wide range of natural resources(Stephenson 1996). Among the responsibilities of NRDs are to protect aquifers from overuse and pollution. Boundaries of the NRDs follow the natural boundaries of sub-watersheds within the river basins; there are 23 NRDs in the state. In the NRDs overlying the Republic River Basin (RRB) and the Platte River Basins, the resources must also be managed to comply with interstate water use compacts.

Allocations of water within interstate river basins have been a source of long-term conflict between Nebraska and its neighbors. The North Platte River, for example, flows though

Colorado, Wyoming, and Nebraska. Major irrigation development of the North Platte began in the 1880s, and conflicts arose among competing water users shortly thereafter. In 2001, the North Platte Decree between the United States, Nebraska, Wyoming, and Colorado ended litigation that began in the 1930s. Concern over habitat degradation for endangered species is driving the ongoing Platte River Recovery Implementation Program in Nebraska.

The Republican River Basin (RRB) of Colorado, Nebraska, and Kansas is another source of active conflict among the states. A particularly contentious issue has been the extent to which ongoing pumping of water from the Ogallala Aquifer leads to reduced flows in streams and rivers close to pumping sites. When surface water flows were allocated between the states in the 1940s, irrigation technology suitable to the sandy soils and rolling hills of the area did not exist. However, as center pivot irrigation technology has developed over the last fifty years, pumped groundwater has become an extremely important input supporting agricultural production in the region.

Following decades of litigation, in 2002 the Supreme Court decided that groundwater pumping by Nebraska farmers in the RRB reduced the availability of instream flows to downstream users in Kansas. As a result groundwater management districts in Nebraska were required to introduce a variety of agricultural water use restrictions to reduce their impacts on stream flow. A moratorium on new wells was extended; this effectively removed the future option to irrigate land that was currently in dryland production. Annual volumetric restrictions were placed on all existing wells, based on certification of historical irrigated area, and well metering was completed in the Nebraska portion of the RRB. Trading of water rights is now allowed in some portions of the basin, but institutional barriers have resulted in relatively few water sales or leases over the last few years.

In part to comply with the Republican Settlement, the Nebraska legislature passed LB 962 in 2004, which required NRDs that were over- or fully-appropriated in their water use to develop and implement integrated water management plans. Note that any NRD may implement an integrated management plan. The purposes of integrated water management are to understand how water moves through the regional hydrologic regimes and to manage supplies at the basin scale (Schellpeper 2012). In over- or fully-appropriated basins, an NRD may implement regulations to reduce water withdrawals such as those in place in the RRB, including well metering and volumetric restrictions, well-drilling moratoria, and certifying irrigated acres. By certifying irrigated acres, the right to irrigate is limited to a particular field. Additionally, the remaining basins not declared fully- or over-appropriated are reviewed prior to January 1 of each year to ensure an adequate water supply.

The institutional history of management varies by NRD. The Upper Republican NRD has the longest history of regulation in the state: well metering took place from 1978—1982 and volumetric restrictions on pumping were implemented once metering was complete. In the Lower and Middle Republican NRDs and the Tri-Basin NRD, metering began in 1998 and volumetric restrictions were not in place until 2004. In the portions of the state that overlie the North Platte and Platte River Basins, metering and volumetric restrictions began in over-appropriated sub-basins as early as 2002 and well drilling moratoria were implemented as early as 2001. In areas of the state that have not faced interstate litigation over water, groundwater irrigation wells are not metered and farmers may drill new wells, though all active wells must be registered with the local NRD. The state Department of Natural Resources (DNR) uses the information from NRDs to maintain an active wells database for the state. All wells must be registered with the local NRD at the time drilling commences. The information required for registration includes the locational coordinates of the well, owner and contractor information, and groundwater pumping characteristics including acres irrigated, pumping water level, and yield of water well. Data on pumping water levels and well yields are not updated, so these data represent conditions at the time the well was registered. The DNR compiles information from each NRD to maintain an active wells directory for the state.

Studies of surface water rights consistently find that the presence of irrigation rights significantly increase agricultural land values. Xu et al. (1993) found that surface-water supplied irrigation in Washington State had a positive effect on the sale price of agricultural land while Faux and Perry (1999) found similar positive results in Oregon. Studies of groundwater and land values however have been mixed. In a study of the Ogallala Aquifer, Torell et al. (1990) found the value of irrigation to be positive. On the other hand, no significant value was found in New Mexico (Sunderland et al. 1987) or Colorado (Hartman and Taylor 1989). One explanation for these differences is that in areas where groundwater use is unrestricted, the option to irrigate in the future is also reflected by land values. Petrie and Taylor (2007) lend support to this idea of option values. They study the effects of a moratorium on surface water use permits in Dooly County, Georgia and find that permits added value to agricultural land only after the restriction was implemented. Similar results are found for Chase County, Nebraska, which lies in the Upper Republican NRD (Brozovic and Islam 2010).

Data and Methodology

We use a standard hedonic model to estimate the value of irrigation for Nebraska cropland. The hedonic model recognizes that the value of an agricultural parcel reflects the expected present value of future rents from the parcel (Palmquist 1989). Farmland is treated as a differentiated factor of production, with n characteristics, $\{\mathrm{z}_1, \dots, \mathrm{z}_\mathrm{n}\}$, affecting the productivity and thus the land value, R, or $\mathrm{R} = \mathrm{R}(\mathrm{z}_1, \dots, \mathrm{z}_\mathrm{n})$. The value of the characteristic can be implicitly estimated using hedonic analysis even though we do not observe a market for that characteristic (Freeman 2003). The standard estimating equation for hedonic farmland value models is in the form $\mathrm{R} = \beta\mathrm{Z} + \varepsilon$, where R is the observed or estimated per acre land value, Z is a vector of observable farmland characteristics $(\mathrm{z}_1, \dots, \mathrm{z}_\mathrm{n})$, β is a vector $(\mathrm{b}_1, \dots, \mathrm{b}_\mathrm{n})$ of the (implicit) present value of observable farmland characteristics $(\mathrm{z}_1, \dots, \mathrm{z}_\mathrm{n})$, and ε is an error term that encapsulates unobserved factors that can influence farmland values. Our estimating equation, which follows the standard hedonic model, is

$$\mathrm{R}_{\mathrm{it}} = \beta_1 Z_i + \beta_2 X_i + \beta_3 \mathrm{I}_{\mathrm{irr}} + \mathrm{t} + \varepsilon.$$

Our variable of interest, $\mathrm{I}_{\mathrm{irr}}$, is an indicator variable for whether or not land is irrigated. Z_i is a vector of plot level characteristics that includes plot size, soil moisture capacity, slope, standard deviation of slope and soil quality. X_i is a vector of operator characteristics that may be correlated with the adoption decision, including sales volume and operator age. The dependent variable, R_i, is the cropland value per acre, and we also control for changes in land value over time (t).

This study employs confidential, nationally representative, and geo-coded panel data on field (tract) level cropland values from the NASS-USDA June Area Survey (JAS). The JAS is conducted annually in early June and collects land value data that underpin the official USDA land values published in August. The survey uses an area-frame sampling methodology in which approximately one square mile “segments” are randomly sampled. Once sampled, a segment remains in the sample for five years, and is then replaced. The operators of all parcels of land or tracts within each segment are interviewed, and detailed data on land use and value are collected. JAS also indicates parcel size and whether a parcel is irrigated. Plot- or field- level cropland values, irrigation status, plot size, sales volume, operator age variables are aggregated to the segment level using survey weights for our analysis. Various land characteristics (Z_i) were matched with each segment using segment centroids (latitude and longitude).

To estimate our model, we use Ordinary Least Squares (OLS). The reported standard errors are robust to correlation at the county level, and survey weights are applied to our estimates. To address potential segment-level correlation in errors over time due to the JAS being a rolling panel, we only include three years in the analysis: 1999, 2005 and 2012. Future analyses will take advantage of the panel element of JAS data. While this preliminary analysis does not control for all factors that might be correlated with the irrigation status of cropland, we do control from many key factors. Biophysical traits such as slope, pumping capacity, and total acres irrigated are commonly missing from hedonic studies (Shultz 2010). We control many of these variables in our current study, including various indicators of land quality (Z_i). We also control for many of the factors associated with the irrigation adoption decision by including key plot and operator characteristics. We will incorporate additional plot-level irrigation and well data into our analysis in extensions of this work. Inclusion of plot-level characteristics precludes use of plot or segment fixed effects. The variables used in our analysis are summarized in Table 1.

Results and Future Research

Results of our basic regression analysis can be found in Table 2. Because data on operator age were not collected in 1999, we excluded this variable from our initial analysis (column 1). We find that irrigation (or moving from 0% share of irrigated cropland to a 100% share) is associated with a $1,275 increase in average cropland value per acre. Variables that measure urban influence, both in terms of population and distance to major urban centers, have a statistically significant impact on cropland values. Likewise, sales class is highly significant, although its effect is small. The impact of various soil characteristics is mixed, with only water holding capacity having a statistically significant impact.

Irrigation was associated with an $1,843 increase in average cropland value per acre when we included operator age and excluded 1999 data (column 2). This stronger result is likely related to commodity prices, especially for corn and wheat, which increased between 2005 and 2012. Farm incomes also increased during this period. Irrigation became more restricted in several Nebraska NRDs between 2005 and 2012, and this might influence the results. We will explore these relationships in future research. The impact of other key variables is similar. Like irrigation status, this is likely related to structural changes in the agricultural sector and changes in irrigation regulations during the study period.

Our regression analysis indicates that irrigation is associated with higher cropland values, and this result is robust to the inclusion of key factors related to both cropland values and irrigation status in our analysis. However, a variety of econometric issues arise in estimating hedonic models of farmland value, including sample selection, spatial autocorrelation, and questions of functional form and model specification. In future analysis we will address sample selection, since irrigation is not randomly distributed across observations but is based on the underlying biophysical characteristics of the parcel. Failure to account for this relationship using the conventional OLS hedonic model may bias the hedonic estimates the value of irrigation. Brozovic and Islam (2010) analyze the value of irrigation rights in Chase County, Nebraska, an area with pumping restrictions, using both OLS and a propensity score matching model. Estimates from the propensity score model, which accounts for endogeneity between the decision to irrigate and the value of irrigation, are significantly higher than those obtained from the standard OLS model. Koundouri and Pashardes (2003) account for simultaneity between hedonic valuation and sample selection in a study of water salinity effects on the demand for agricultural land in Kiti, Cyprus. Using the standard OLS model, the estimated marginal willingness-to-pay for fresh groundwater has a positive significant effect on land values, but estimates using Heckman's two step estimation to correct for selection bias are not significant.

A second problem arises because spatial autocorrelation is likely in the empirical estimation of hedonic models. The empirical model is likely to have omitted variables that may be spatially correlated. In the case that omitted variables are exogenous, this results in inefficient estimates (Anselin 1988). However, endogenous omitted variables will be spatially correlated with the error term, which results in parameter estimates that are inconsistent and inefficient. This is because the presence of spatial autocorrelation usually implies heteroskedastic disturbances as well as spatially correlated errors (Mcmillen 1995).

Econometric methods incorporating autocorrelated errors have been developed and applied to hedonic models that estimate the value of various environmental amenities (Bell and Bockstael 2000; Leggett and Bockstael 2000; Boxall, Chan, and McMillan 2005; Irwin 2002). In future analysis we will test and correct, if necessary, for spatial autocorrelation.

Issues of functional form and model specification are common to all hedonic analyses. In general, economic theory offers little guidance regarding model specification or restrictions on the functional form. Instead, model specification is dictated by data availability and a priori beliefs about the type of attributes of agricultural land parcels that matter to producers. Because of the lack of theoretical guidance regarding the choice of functional form, empirical evidence typically informs the specification choice. Baltagi and Li (2001) developed Lagrangian multiplier (LM) tests to jointly test for functional form and spatial autocorrelation that may be used to compare the goodness-of-fit criteria of linear and log-linear models. In future analysis we will use alternative functional forms and test for goodness-of-fit.

We will also incorporate additional data into future analysis. The Nebraska DNR maintains data on active irrigation wells in the state. The DNR Wells Database gives data on current owner, spatial location, and pumping characteristics, which can be matched with JAS data. Irrigation rights are tied to a specific parcel. However, since groundwater pumping for agriculture historically has not been regulated, detailed well information generally is difficult to obtain. Agroclimatological factors affect crop yields in average years and the field's vulnerability during drought years. Our current analysis accounts for various soil characteristics, and in future analysis we will account for local precipitation and temperature.

Future analysis will also account for various institutional settings for groundwater management. We can exploit the differences in groundwater management practices that vary at a sub-basin level. In the Republican River Basin, which overlies four NRDs, pumping restrictions were first implemented as early as 1982. With the passage of LB 962 in 2004 by the Nebraska Legislature, NRDs that manage fully or over-appropriated river basins are required to impose restrictions on irrigation development such as well moratoria, a certification of irrigated acres, integrated water management plan adoption, and other management actions deemed necessary by the NRD. To date, thirteen of the 23 NRDs that cover Nebraska contain at least some areas declared fully- or over-appropriated. In addition to the moratoria on new wells and on expansion of irrigated acres, NRDs in the Republican River Basin and portions of the Platte River Basin have imposed volumetric pumping restrictions. Thus, by examining land values from farms located in different NRDs, but in agricultural areas of similar productivity, we can identify the effects of changes in water management programs on cropland values. Prior to the imposition of groundwater use restrictions, we would expect cropland values to be unaffected by pumping rights, controlling for characteristics describing irrigation potential and cropland productivity. While adopting groundwater-irrigated production was not costless prior to the imposition of pumping restrictions, the option to irrigate a parcel was embedded in the value of cropland. After the moratorium on irrigation development was implemented, we would expect the value of irrigation rights to be capitalized into land values. We would expect this to be especially the case for fields in fully- and over-appropriated basins, but not necessarily for cropland outside of these basins. This hypothesis will be the focus of the final version of this paper and beyond.

Conclusion

We find that irrigation is associated with substantial increases in cropland values, and hence likely contributes significantly to farm income in Nebraska. By reducing the potential profitability of irrigated land, regulation of groundwater use within Nebraska imposes potentially large costs on farmers. Our future analysis will further refine estimates of the value of irrigation and groundwater regulation on Nebraska cropland. Estimates of the value of groundwater irrigation rights are an important component of the ongoing policy debate on protecting instream flows, both in the Republican River Basin and elsewhere in the western United States. By combining unique land values panel data with detailed physical data and accounting for changes in water use policy, we will be able to make a substantial contribution to the literature on the value of groundwater in agriculture. Although several studies have considered the impact of irrigation on farmland values, the option value of irrigation has not been previously estimated and more generally the impact of water use institutions on land values has not been adequately considered.

Table 1. Summary Statistics

Variable	Mean	Standard Deviation	Source
Cropland Value	\$2340	\$2713	June Area Survey
Share Irrigated	0.41	0.41	June Area Survey
Soil Productivity	4.35	1.72	NCCPI, scale of 0-1
Mean slope	2.47	1.72	SURGO
Std. dev. slope	1.02	0.75	SURGO
Water holding capacity	171.1	40.6	Mean available water storage (mm) in the top meter of soil

Population Intensity Index	6145	8669	ERS analysis of US Census data
Urban influence	204.3	97.3	Distance from a city with population greater then 250,000
Sales class	8.49	1.55	JAS; categories 1-13; 1=smallest, 13=largest
Operator age class	4.25	0.87	JAS; categories 1-6; 1=youngest, 6=oldest

Table 2. Regression Results

	(1) Cropland Value	(2) Cropland Value
Share Irrigated	1274.7***	1842.9***
	(179.0)	(191.8)
Soil Productivity	38.5	151.7***
	(61.2)	(57.3)
Mean slope	34.0	38.5
	(53.9)	(50.2)
Std. dev. slope	-19.6	112.4
	(131.1)	(119.8)
Water holding	7.0***	7.6***
capacity	(1.4)	(1.8)
Population	0.05***	0.03***
Intensity Index	(0.01)	(0.01)
Urban influence	-6.0***	-6.7***
	(1.1)	*1.0)
Sales class	152.0***	135.1***
	(35.2)	(46.1)
Operator age		-39.0
class		(66.3)
2005, 2012 only		X
Observations	1006	649
R-squared	0.40	0.75

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