The Implicit Value of Irrigation Through Parcel Level Hedonic Price Modeling

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Abstract

This paper relies on data associated 2,100 agricultural land sale transactions across two major Nebraska Watersheds (the Republican and Central Platte) over the 2000 to 2008 time period. The sales were spatially referenced (digitized into a GIS) in order to quantify and geo-spatially predict and map the implicit values of irrigation through the use of hedonic price modeling. Marginal implicit prices vary substantially across sub-watersheds (natural resource districts), and the contribution of irrigation to sale prices is directly related to the extent to dependency of production agriculture on irrigation.
This information is now currently being used to evaluate the economic efficiency of recent irrigation retirement programs and to help ensure that current and future retirement programs are cost-effective through targeting that retires irrigation land with the greatest hydrologic impact on water resources for the lowest cost.

Introduction:

The need to quantify the economic value of irrigation associated with production agriculture has become essential in evaluating the economic feasibility of various water management policy options in many Central and Western U.S. States with water scarcity issues. The approaches used to quantify irrigation depend greatly on the location and type of irrigation being valued. In many western states relying almost exclusively on surface water irrigation sources, and which have an active market for trading water surface water supplies, economists and appraisers simply report observed selling prices (usually from auction and/or exchange data) while adjusting for transaction costs.

However, in other central and western states (such as Nebraska and Kansas) that rely either on groundwater or a mix of groundwater and surface water supplies for irrigation, and where there is often not a formal market for trading surface water rights, agricultural economists have generally relied on two alternative approaches to value irrigation: The 'Change in Net Income Approach; and the 'Land Value Approach'.

The principal assumption underlying the 'Land Value' approach for determining the contributory value of irrigation is that buyers and sellers of agricultural land are able to differentiate the factors of production as they relate to future profits when agreeing to sale prices for agricultural land. Therefore real estate prices reflect revealed preferences for particular land characteristics.

This present research focuses on valuing irrigation in two Nebraska watersheds (the Republican and the Central Platte) each of which exemplify water scarcity conflicts across the upper Great Plains where pivot irrigation has over last two decades dramatically increased the extent and productivity of corn production which in turn has greatly intensified both *intra* and *inter*-state disputes over the management of water resources. These conflicts are between groundwater irrigators and surface water users, natural resource management districts and the four States (Nebraska, Kansas, Colorado and Wyoming) who compete for water rights associated with the Republican and Platte River Basins along with Environmental groups and the Federal Government) who are concerned with maintaining river flows (particularly on the Platte River) for the purposes of protecting several endangered species and migratory waterfowl populations.

After reviewing previous attempts to quantify the value of irrigation using hedonic price models in two other (non-Great Plain) States, the paper focuses on the procedures for obtaining, editing, mapping (digitizing into a Geographic Information System or GIS database) land sale transaction data. Of particular concern are the accuracy, reliability, and usefulness of land sale transaction data collected by County governments.

Second the paper develops strategies to integrate digitized sale parcels with a wide variety of bio-physical, administrative and infrastructure related characteristics contained in GIS databases compiled by local, state and Federal agencies. Of particular interest is the usefulness and reliability of alternative soil productivity measures, identifying irrigation acreage, and measuring irrigation potential (both field slopes, and well pump

Finally a series of hedonic price models are estimated with the land sale prices specified to be a function of the quantity of irrigated and non-irrigated acreage associated with a sale, parcel level soil quality characteristics, location, and the ability to irrigate The marginal price of irrigation (both rights and potential bundled together) on sale prices is indicated by the coefficient of a variable measuring the percentage of a sold parcel that is irrigated. This can be considered the price differential between an irrigated versus a non-irrigated parcel while taking into account (controlling) for other factors (productivity measures). This irrigation value represents buyers and sellers opinions regarding the discounted net (contributory) value of irrigation over time.

Background: The two Study Watersheds

The Republican River Watershed is of major economic importance to Colorado, Nebraska and Kansas. From its headwaters in Colorado to its mouth in Kansas the Republican provides water to irrigate hundreds of thousands of acres in Colorado, Nebraska, and Kansas. In 1943 under the Kansas-Nebraska-Colorado Republican River Compact (1943) these states agreed upon an appropriation of water throughout the basin. In the spring of 1998 a complaint was filed with United State Supreme Court by the state of Kansas. The complaint alleged that Nebraska had violated the compact by allowing the use of groundwater hydraulically connected to the river. On December 15, 2002 a settlement was reached. The settlement essentially allowed Nebraska to continue at its present rate of water use, except in short-water years, which occur 25% - 33% of the time, during which time Nebraska would be required to limit its water use (NE DNR 2003). The Republican River settlement is currently under dispute and is heading to the U.S. Supreme Court. In the meantime state and local officials in Nebraska are evaluating strategies to reduce irrigation in the Watershed trough both conservation measures and irrigation retirement programs.

The Platte River which crosses Colorado Wyoming and Nebraska is an internationally significant staging area for migratory water birds of the Central Flyway and critical habitat for the whooping crane. In the last hundred years the watershed has been transformed by major reservoirs and water diversion projects, and extensive dry land irrigation activities all of which have changed the river channel flows and local ecosystems

The states of Nebraska, Wyoming, and Colorado and the U.S. Department of the Interior (Interior) signed a Cooperative Agreement in July of , 1997, to address several Endangered Species Act (ESA) issues affecting water development in the Platte River Basin. The initiative has two main purposes: To develop and implement a Platte River Recovery Implementation Program (Program) to maintain, improve and conserve habitat for four threatened and endangered species that use the Platte River in Nebraska: whooping crane, piping plover, interior least tern, and pallid sturgeon. And, to enable existing and new water uses in the Platte River Basin to proceed without additional ESA requirements for the four target species.

The Platte River Recovery Implementation Plan, the states of Nebraska, Colorado and Wyoming to reduce groundwater consumption to increase in-stream flows on the Platte River for the purpose of threatened and endangered species protection. The voluntary retirement of irrigation rights is emerging as a viable and likely approach for reducing irrigation in these States, particularly in Nebraska. However, the success of irrigation retirement programs from the dual perspective of cost-effectiveness and landowner participation is not fully understood particularly from a spatial perspective. Much of the focus in Nebraska is on the Central Platte Watershed which contains a high concentration of irrigated agriculture and large concentrations of much critical migratory waterfowl habitat.

Previous Studies that Have Valued Irrigation:

The most reliable and widely accepted approach among economists to value irrigation is the multiple regression based ‘Hedonic Valuation Method’ (HVM). The HVM is also known as a hedonic price model (the terminology used for the remainder of this present study), or a ‘price attribute model’ or a ‘mass appraisal technique’. The hedonic approach was formerly established by Rosen (1974) and has been used to value a full range of factors influencing real estate prices. The approach was refined and applied specifically to agricultural land sale prices by Palmquist (1989 and 1991) and is based on the assumption that producers are able to differentiate factors of production as they relate to profits when purchasing agricultural land under the following conditions:

$$P(q,s,z,i) = \int_0^\infty R(q,s,z,i)e^{-rs}ds$$

where the price of agricultural land (P) is specified to be function of agricultural rent *R* based on soil quality characteristics q, location *z*, time *s*, the ability to irrigate *i*, and the interest rate *r*. To determine the effect of irrigation on real property sales or the net present value of a string of returns from irrigation this study utilizes a hedonic model:

$$(Price / Acre)_i = \beta_0 + \sum_{i=1}^{n} \beta_q Q_{ij} + \beta_s S_{ij} + \beta_z Z_{ij} + \beta_c I_i + u$$

where the of price per acre is a function of a vector of physical characteristics **Q**, a time trend matrix of dummy variables **S**, location dummies **Z**, a vector representing the presence of a irrigation rights and ability **I**, and a random error term u.

The marginal price of irrigation (both rights and potential bundled together) on sale prices is indicated by the coefficient of a variable measuring the percentage of a sold parcel that is irrigated. This can be considered the price differential between an irrigated versus a non-irrigated parcel while taking into account (controlling) for other factors (productivity measures). This irrigation value represents buyers and sellers opinions regarding the discounted net value of irrigation over time. Therefore, to convert such irrigation values to an annual basis, it is necessary to multiply hedonic based irrigation values by a capitalization rate (the ratio of annual rental rates to sale prices).

Hedonic based estimates of irrigation include Crouter (1987) who relied a linear regression equation for 53 real property sales near Greeley, CO with water variables represented by acre-feet of surface water delivered to the parcel and a dummy indicating the presence of a well. An index of soil quality available from the NRCS was used to proxy for the physical characteristics of the parcel. Overall, the value of an acre-foot of delivered water was shown to be just under $100 depending on the model used. Torell, Libbin, and Miller (1990) extend this research to the agricultural production in areas served by the Ogallala Aquifer and determined that irrigation was on average worth $545 per acre-foot. Faux and Parry (1999) using hedonic pricing found that irrigation values in Oregon ranged from $514 to $2,551 per acre with the highest values being associated with the highest quality land. Finally, Petrie and Taylor (2007) used hedonic pricing to determine that irrigation well moratoriums and pumping restrictions had significant impacts on irrigation values in Georgia.

Methods and Data

Before the hedonic price models could be estimated it was necessary to spatially reference (digitize) sale parcels and collect sale transaction data and characteristics. Sales were obtained from the Nebraska Property Tax Assessment Division as a database of legal descriptions and prices for 'arms length' real property sales.[1] The legal descriptions were used to digitize the exact field boundaries of the sales into a Geographic information System based database as polygons.

Various bio-physical and locational characteristics associated with sold agricultural land were quantified through the following GIS techniques: Distance measurements, spatial overlays (unions, intersects, and zonal statistics). These parcel characteristics later are used as explanatory variables in the hedonic price models and include the following:

- Soil Productivity (soil rating for plant growth based on USGS SSURGO data)
- Field Slope (based on USGS digital elevation models)
- Precipitation (from CALMIT)
- Parcel size
- Cropping patterns (from the NASS cropland data layer)
- Well pumping capacity (a DNR database of registered wells)
- Distances to elevators and towns
- The percentage of sales parcels that were irrigated Irrigation status (both from State sale records and the CALMIT irrigation database called COHYST)

The specific explanatory variables used in the hedonic price models are defined along with their expected signs (impact on land sale prices) in Table 1. Of particular interest are the variables representing the % of a sold parcel that is irrigated either through pivot or gravity systems. Since the dependent variable in the hedonic models is the sale price of parcels adjusted for irrigation equipment inclusions, these estimated coefficient of these variables will represent the marginal price of an additional acre of irrigation on the sale price per acre of sold land

[1] 'Arms Length' sales are sale of real estate sold on a true market i.e. sales between family members or to and from non-profit organizations are removed from the sample.

Table 1 Explanatory Variables in the Hedonic Price Models (Descriptions and Expected Signs)

Variable	Description	Expected Sign
LN Acres	The acres of the parcel logged to account for diminishing marginal effect of economies of scale	-
% Crop	The percentage of the parcel farmed with an implement (Row Crops, Small Grains, Hay)	+
SRPG	Soil Rating for Plant Growth- a unit-less index created by the Natural Resource Conservation Service to measure the ability of the soil to support plants.	+
% Slope	The average percent slope of the parcel	-
Precipitation	The average yearly precipitation in Inches	+
D Loess Soil	If the dominant soil parent material is Loess	+
Mile Elevator	Distance in Miles to the nearest Grain Terminal	-
Miles Interstate	Distance in Miles to the Nearest Interstate	-
Miles Major Road	Distance in Miles to the Nearest Major Road	-
Pumping Level Ft	The Depth to Water for the parcel if it is irrigated	-
Gallons/ Minute	The Water yield of the nearest well for irrigated parcels	+
% Gravity	Percentage of the parcel Gravity Irrigated	+
% Pivot	Percentage of the parcel Pivot Irrigated	+
Year	Dummy Matrix Representing the Year a Parcel Was Sold After the base year of 2000	+
NRD	Dummy Matrix Indicating the Location of the Sale in Reference to Natural Resource District	?

The general specification of the hedonic model to be estimated is:

$$\text{Price/Acre} = f(X, T, L, W)$$

Where, the sale price of an acre of land is specified to be a function of a vector of physical characteristics X, a time trend vector represented by T, a vector of location characteristics L, and a vector of irrigation potential characteristics W, of which the most important is an interaction term that measures the percentage of cropland within a sale parcel that is irrigated.

Expected hedonic-based irrigation values are defined as the combined rights and ability (physical potential) associated with irrigation. Hedonic modeling assumes that the buyers and sellers of agricultural land assess the value of irrigation when negotiating sale contract prices.

Alternative models will be estimated using various combinations of explanatory variables (all measured at the parcel level of analysis). These include: soil productivity measures, topography precipitation, parcel size, cropping patterns, topography, well pumping capacity, distances to elevators and towns, and alternative measures of groundwater supplies and available for irrigation and their relative pumping costs (from collaboration with a USGS scientist).

Explanatory variables are interpreted as marginal implicit prices (MIP), namely a one-unit change in the dependent variable price (P) associated with a one-unit change in the explanatory variable:

$$MIP(X_j) = \partial P / \partial X_j = \beta_j$$

Results

A total of 2,125 arms-length agricultural land sales across the two watersheds over the 2000 to 2008 period were successfully digitized within a GIS. This represents approximately 95% of all arms-length sales over this period as some sales (around 5%) could not be successful digitized due to erroneous legal descriptions of sale boundaries.

The locations of these sales mapped by price on per acre basis across different sub-watershed boundaries (natural resource districts) in each of the two watersheds are shown in Figure 1 and he characteristics of these sale parcels reported by whether by whether they were not irrigated, i.e., dry (n = 576) or partially irrigated (n=-1,550) are summarized in Table 2.

Figure 1. Digitized Sale Locations and Values ($/Acre) Across Natural Resource Districts in Central Platte and Republican Watersheds, 2000-2008

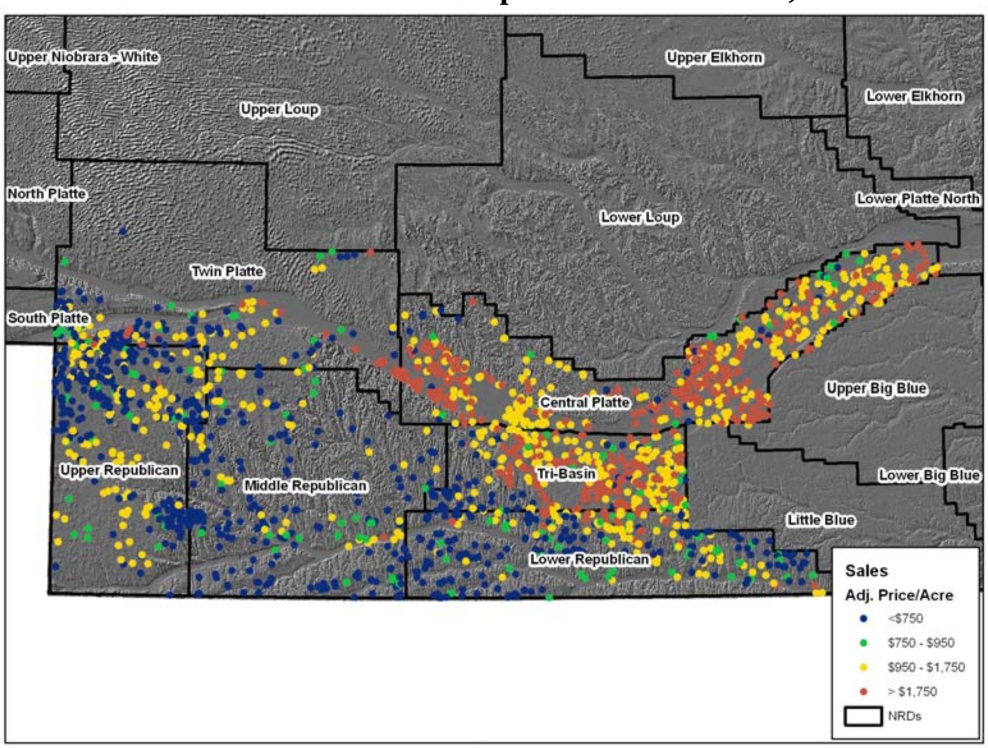

Table 2 Summary Statistics of Irrigated, Non-irrigated Sale Parcels (2000-2008)

Variable	Dry (n=576)				Irrigated (n=1550)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
LN Acres	5.0	0.6	3.1	7.2	4.9	0.6	3.0	7.1
% Crop	0.71	0.17	0.40	1.00	0.84	0.15	0.40	1.00
SRPG	54.7	10.5	11.0	73.4	52.9	12.8	17.0	74.8
Slope	2.5	1.7	0.0	9.3	1.6	1.5	0.0	8.4
Precipitation	21.4	3.1	17.0	29.0	22.9	3.0	17.0	29.0
D Loess Soil	0.71	0.45	0.00	1.00	0.49	0.50	0.00	1.00
Mile Elevator	6.0	2.8	0.5	15.0	5.0	2.8	0.2	18.9
Miles Interstate	31.1	17.2	0.1	60.3	17.3	13.9	0.1	60.7
Miles Major Road	3.4	2.3	0.0	14.1	2.6	2.2	0.0	16.6
Gallons/ Minute	0.0	0.0	0.0	0.0	1053.5	446.5	40.0	2902.0
% Gravity	0.00	0.00	0.00	0.00	0.29	0.37	0.00	1.00
% Pivot	0.00	0.00	0.00	0.00	0.51	0.36	0.00	1.00
D 2001	0.13				0.12			
D 2002	0.13				0.15			
D 2003	0.14				0.16			
D 2004	0.11				0.17			
D 2005	0.13				0.12			
D 2006	0.16				0.11			
D 2007	0.08				0.05			
D Central	0.07	0.26	0.00	1.00	0.38	0.48	0.00	1.00
D Lower Republican	0.23	0.42	0.00	1.00	0.12	0.32	0.00	1.00
D Middle Republican	0.20	0.40	0.00	1.00	0.08	0.27	0.00	1.00
D Tri-Basin	0.10	0.29	0.00	1.00	0.20	0.40	0.00	1.00
D Upper Republican	0.33	0.47	0.00	1.00	0.12	0.33	0.00	1.00

The average sale price of dry parcels was $616 and acre versus $1,425/acre for partially irrigated parcels. And as expected, soil productivity measures and suitability for irrigation (as measured by slope and well pumping capacity) were markedly higher for irrigated parcels.

The estimated hedonic model results are summarized in Table 3. All of the explanatory variables are statistically significant except the dummies for the 2001 and 2002 years and the Lower, Middle, and Upper Republican NRD in the model using soil descriptors. The coefficient for the gravity and pivot irrigated percentages are significant at the 1% level. The F value for the model is sufficiently high indicating that all variables considered jointly have a statistically significant effect on the dependant variable irrespective of specification. In the model using soil proxies such as slope, precipitation, and loess parent material the value for gravity and pivot irrigation is $781 and $786 per acre respectively. Since gravity irrigation associated with surface water supplies is relatively infrequent in the watersheds, the remainder of this paper will only focus on pivot irrigation values associated with groundwater supplies.

Table 3 Hedonic Regression Results for the Entire Watershed (n = 2,125, R^2 value of 0.64)

Variables	Coef.	Std. Err.	P>t
LN Acres	-66.104	17.994	0.000
% Crop	599.102	67.344	0.000
SRPG	9.047	0.873	0.000
% Slope			
Precipitation			
D Loess Soil			
Mile Elevator	-18.861	4.146	0.000
Miles Interstate	-1.925	0.795	0.016
Miles Major Road	0.439	4.765	0.927
Pumping Level Ft	-0.776	0.152	0.000
Gallons/ Minute	0.028	0.024	0.247
% Gravity	781.484	52.046	0.000
% Pivot	768.191	50.885	0.000
D 2001	-20.600	31.910	0.519
D 2002	43.715	34.470	0.205
D 2003	91.160	30.178	0.003
D 2004	116.022	31.962	0.000
D 2005	267.091	35.815	0.000
D 2006	355.867	35.068	0.000
D 2007	456.393	50.187	0.000
D Central	488.694	44.292	0.000
D Lower Republican	78.933	44.151	0.074
D Middle Republican	47.578	45.749	0.298
D Tri-Basin	379.225	43.218	0.000
D Upper Republican	45.874	41.049	0.264
Intercept	-70.625	119.922	0.556

Note: Limited to parcels with greater than 40% crop to remove non-cropland or pasture sales
Note: If within 5 miles of a city greater than 5k observation is dropped
Note: Dummy for Twin Platte Removed to Prevent Dummy Variable Trap

The hedonic models for each of five sub-watersheds (Natural Resource Districts) generated R^2 values ranging from 0.46 to 0.72, with statistically significant f-tests, and statistically significant coefficients for irrigation values in all models. The resulting marginal implicit prices for irrigation along with mean irrigated sale prices on a dollar per acre basis are summarized in Table 4. These marginal irrigation values vary substantially across the watersheds and the contribution of irrigation to land sale prices also varies (from 25% to 75%). As expected, irrigation plays a greater role on land prices on the more western NRD's where precipitation is noticeably lower meaning that production agriculture in these areas is not generally possible without irrigation.

Table 4 Marginal Prices of Irrigation by Natural Resource District and Compared to Irrigated Land Sale Prices

NRD	Marginal Price of	Mean Irrigated	The Contribution of

	Irrigation	Sale Price ($/Acre	Irrigation to Sale Prices
Central Platte	460***	$1,860	25%
Lower Republican	413***	$1,190	35%
Middle Republican	508***	$865	58%
Upper Republican	795***	$1,054	75%
Tri-Basin	536***	$1,715	31%

*** Significant at the 1% level

Conclusions

This geo-spatial approach to valuing the contribution of irrigation to agricultural land values was very much focused on methodological issues (GIS database development and hedonic model specifications that would result in reliable implicit values for irrigation across two large watersheds with highly heterogeneous levels of productivity. This information is now currently being used to evaluate the economic efficiency of recent irrigation retirement programs and to help ensure that current and future retirement programs are cost-effective through targeting that retires irrigation land with the greatest hydrologic impact on water resources for the lowest cost.

These hedonic based irrigation values are currently being used to evaluate cost-effective strategies to implement irrigation retirement programs that are currently being conducted in these two watersheds. This includes estimating price premiums required for irrigation retirement by comparing prices paid for implemented retirements with the estimated value of irrigation for these same parcels. It also involves estimating mapping irrigation values across all the parcels in the watersheds through the use of common land units of the Farm Service Agency as a unit of analysis. Spatial overlays of irrigation land values and areas identified as optimal for irrigation retirement from a hydrological perspective should result in cost-effective targeting of irrigation retirements.

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