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Estimating the Value of Groundwater in Irrigation

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1 Introduction and Motivation

Transboundary and water conflict issues have given rise to increasing regulation of agricultural water use. In order to develop effective policy tools to achieve water conservation, the value of irrigation water needs to be estimated accurately. Irrigated land is more profitable than dryland because of increased crop yields. This increased profitability of irrigated land should be capitalized into the sales price of the land. Previous papers on surface water rights have found this to be the case. Xu et al. (1993) found that irrigation in Washington State had a positive effect on land price and Faux and Perry (1999) found similar positive results for irrigated farmland sales in Oregon. On the other hand, studies on irrigation dependent on groundwater have found mixed results. Some studies have found a significant positive effect of irrigation (Torell et al. 1990), but others find no effect on the sale price of agricultural parcels (Hartman and Taylor 1989, Sunderland et al. 1987). One explanation for such results may be that in areas that have no restrictions on groundwater use, there exists the option to implement irrigation in the future and thus sales prices may not be affected by existing irrigation. Petrie and Taylor (2007) find this to be the case in the southeastern United States. They look at differences in land prices before and after a moratorium on water-use permits in Georgia and find that value is only added to the land after the moratorium is in effect.

Another issue that arises in modeling the value of irrigation is that the decision to irrigate a parcel is not random, but is based on underlying observable and unobservable characteristics of the land and its owners. Failure to account for sample selection may result in biased estimates when using a standard hedonic method, as is commonly used in the literature. In this paper, we use both a standard hedonic model and a propensity score matching model to evaluate the value of groundwater in an area where pumping restrictions are in place.

Our study area is Chase County, Nebraska which is part of the Republican River Basin. The county covers an area of 584,000 acres and the population is about 4,000. The majority of the land is used for agricultural production: only six sections out of 912 do not have agricultural land (Figure 1).[1] The Republican River Basin has been the source of long-term litigation between Colorado, Kansas and Nebraska. In 2002, the Supreme Court decided that groundwater pumping by Nebraska contributed to reduced instream flows in Kansas. As a result, groundwater management districts in Nebraska were forced to introduce a variety of restrictions, such as moratoria on new wells (introduced in 1999), metering of existing ones, and volumetric pumping restrictions.

We use a geospatial database that includes arms length sales, tax assessor's data, and hydrologic and climatic variables of parcels that sold in Chase Country between 2000 and 2008. There are 330 observations, where each parcel contains sale prices along with the sales date obtained from the Chase County tax assessor's website
(http://chase.assessor.gisworkshop.com/Assessor/index.jsp). In addition, other characteristics of the parcel, such as the presence of outbuildings and the square footage and age of residences are included. Each observation also has the distribution of agricultural land (irrigated, dryland, or grassland) and four soil quality types in each type of land. We also assembled georeferenced data on estimated depth to water, the rate at which a well can pump water, precipitation and growing degree days.

[1] A section is one square mile, which is an area of 640 acres.

First, we estimate an Ordinary Least Squares Regression Model to characterize the sale price per acre of the land. Several alternative specifications are considered, including year dummies, interaction terms between year dummies and irrigation, and dummies between irrigation and hydrologic variables. The main results are that (i) irrigation has a significant and positive effect on the sale price of land, (ii) the rate at which a well can pump water is important in determining the sale price, (iii) depth to water does not have a significant effect on the sale price per acre of land, and (iv) the climatic variables considered do not have an effect. From the preferred OLS model, the value of groundwater irrigation is found to be $712 per acre.

Second, we estimate a propensity score model which involves two steps. First, we estimate the probability of a parcel of land being irrigated using a probit model. The results from the probit show that farmers are more likely to irrigate on lands that are of intermediate quality, suggesting that irrigation is land-quality augmenting. This follows previous studies on irrigation technology adoption (Lichtenberg 1989). However, unlike results from the OLS model, depth to water and climatic variables do affect the decision to adopt irrigation with expected signs.

In the second step, we match pairs of non-irrigated and irrigated parcels that have the same probability of being irrigated and analyze whether there is a difference in the sales price. Results show that once again there is a positive and significant value associated with groundwater irrigation rights, but the difference is larger than the hedonic analysis at $839 per acre.

We find that, controlling for selection, estimates for the value of groundwater irrigation obtained with propensity score matching are higher than estimates obtained with the standard hedonic model. The difference between models appears to be driven by preferential adoption of irrigation on intermediate quality land. Presumably, irrigation is adopted on intermediate quality land because the difference in profitability from irrigation is higher on these lands than on both high and low quality lands. Given that irrigation technology is generally considered to be land quality augmenting, an important policy implication is that simple hedonic analysis may generally underestimate the value of groundwater in irrigation.

This paper is laid out as follows. First, we provide some background of my study area. This includes the relevant regulatory history of the Republican River Basin and the Upper Republican Natural Resource District in which Chase County is located. Second, we present both the Ordinary Least Squares and Propensity Score Matching models. In the following section, we describe the economic, physical, hydrologic, and climatic data we use in the analysis. we then present the results obtained using both methods of estimation and compare them. Finally, we provide a conclusion with policy implications and future research possibilities in this area.

2 Background

In this section we describe (i) previous work that has been done using hedonic analysis to estimate the value irrigation water and (ii) the institutional background of my study area.

2.1 Previous Literature

Irrigating land increases crop yields and this should be capitalized into the sale price of agricultural land. Irrigation can be either from surface water or groundwater sources. Surface water studies find that irrigation increases the sale price of land. For example, Xu et al. (1993) analyze agricultural land sales in Washington state and find that irrigation systems have a positive effect. Their model includes three types of irrigation systems: center pivot, sprinkler, and rill irrigation in areas where available. Their results show that center pivot irrigation adds most value to the sale price, followed by sprinkler irrigation and finally rill irrigation. Faux and Perry (1999) also find surface water irrigation to have a positive effect on the price of farmland in Malheur County, Oregon. They stress the importance of including separate land classes as opposed to an averaged composite index as soil class is not a continuous variable and averaging may result in loss of information. In both Oregon and Washington States, agricultural production is diverse. Conversely, in our study area, irrigated corn and dryland wheat dominate production.

Studies that use hedonic analysis to estimate the value of groundwater irrigation find mixed results. Hartman and Taylor (1989) find that groundwater does not have a significant effect on the sale price of land in Colorado. Sunderland, Libbin, and Torell (1987) find the same result in New Mexico, when analyzing land that uses groundwater from the Ogallala aquifer. Torell et al. (1990) expanded their previous study area from New Mexico to include Oklahoma, Nebraska, Kansas, and Colorado (all of which use the Ogallala) to estimate the value of groundwater. They found a positive effect of irrigation on the sale price. They suggest that the difference in results from previous studies is a result of regional differences that were not included previously. In particular, they found that saturated thickness of the aquifer and measures of farm income were significant determinants in irrigated land values. They also found declining price differentials between irrigated and non-irrigated land over time.

Another reason that may explain these mixed results is that in general, groundwater is private property and its use is not regulated. Without regulations in place there is the option to implement irrigation in the future and so the potential value of irrigation may be capitalized into the price of both currently irrigated land and dryland. Petrie and Taylor (2007) did a study that is the closest to my analysis. They estimated the value of water in Dooly County, Georgia before and after a moratorium on water use permits. They found that before the moratorium on water use permits there was no difference in the prices of agricultural land with or without permits. However, after the moratorium, land with water use permits attached sold for about 30 percent more than land without permits. Petrie and Taylor's (2007) interpretation was that the moratorium added value of the land with permits; an alternative interpretation is that the moratorium reduced the value of parcels without permits. The moratorium in our study area is different than that in Dooly County, Georgia: permits in the latter allow unlimited pumping from a source whereas in our area there are also volumetric pumping restrictions even with a permit.

To the best of our knowledge, there are no published papers using propensity score matching (PSM) for hedonic analysis. However, several working papers use the PSM methodology in a hedonic context. Cutter et al. (2009) use PSM to estimate the hedonic value of open space land and Lynch et al. (2009) estimate the difference in land price due to preservation programs. The PSM method is applicable to our study as we observe both parcels that are irrigated and those that are not irrigated, and we also have data on the variables that should affect the decision to irrigate. This allows for the estimation of propensity scores for both irrigated and non-irrigated parcels in order to match and compare them with each other.

2.2 Institutional Background

The Republican River is formed by the merging of the North Fork Republican River and the South Fork Republican River, both of which originate in northeastern Colorado. It flows eastward for approximately 445 miles through southeast Nebraska and further south entering into the Smoky Hills Region of Kansas where it eventually becomes the Kansas River. The Nebraska portion of the River is known as the Republican River Basin and its watershed constitutes about 24,900 square miles. In 1943 Colorado, Nebraska and Kansas agreed to the Republican River Compact which allocated the "virgin water supply" equitably among the three states. The "virgin water supply" is the "water supply within the Basin undepleted by the the activities of man" (Hinderlider et al. 1942). The compact also stated that the best use of the water was "beneficial consumptive use" which was defined as "that use by which the water supply of the Basin is consumed through the activities of man, and shall include water consumed by evaporation from any reservoir, canal, ditch or irrigated area" (Hinderlider et al. 1942).

The original Compact did not include groundwater in the calculation of the "virgin water supply". Disputes over Nebraska's consumptive water use in the Basin finally resulted in Kansas filing an original action against the states of Nebraska and Colorado in 1998. The United States Supreme Court appointed a Special Master who concluded that groundwater use should be included in the calculations for the virgin water supply and the allocations for each state. On May 19, 2003 the three states entered into a Settlement Agreement and adopted the Special Master's recommendation, as stipulated by the Supreme Court (Nebraska Department of Natural Resources and Upper Republican Natural Resource District 2008).

In Nebraska, water management is undertaken by natural resource districts (NRDs). These NRDs began operation in 1972. The four NRDs in the Republican River Basin are the Upper Republican, Middle Republican, Tri Basin, and Lower Republican NRDs. The NRDs are bounded by the natural boundaries of the Republican River (URNRD fact sheet, 2008). The Upper Republican NRD consists of Perkins, Chase and Dundy counties and covers 435,337 irrigated acres.[2] The goals of the URNRD are to make sure that it is in compliance with the Republican River Compact, that users of water in the

[2]There are no surface water rights in the study area of Chase County and as a result, all irrigated farmland uses groundwater irrigation only.

URNRD are only responsible for their share in complying with the Compact, and to help to sustain compliance through regulation and incentive programs (Nebraska Department of Natural Resources and Upper Republican Natural Resource District 2008).

In order to comply with the Settlement Agreement, the Nebraska legislature passed LB 962 in 2004; this required NRDs that were over or fully-appropriated in their water use to develop and implement integrated water management plans. One of the methods to help control use was allowing irrigation on only certified acres. A certified acre is any acre of land that has an allocation of groundwater for irrigation allocated to it (Nebraska Department of Natural Resources and Upper Republican Natural Resource District 2008). The certification process used historical and tax assessors' rewards to determine the extent of irrigation.

The Upper Republican River Basin has required that all ground water use be metered and the data to be reported since 1978. From these data, the NDNR determined that the URNRD pumping volume for the years 1998-2002 was 531,763 acre-feet. It also estimated that for the same time period the URNRD's depletion to stream flow was 74,161 acre-feet. For the URNRD, these numbers mean a depletion proportion of 44 percent. In 2005, the NDNR and URNRD adopted an integrated water management plan that provided regulations starting in 2005 and running until 2007. According to this plan, the URNRD was allowed a groundwater allocation of 13.5 inches per year per certified acre. This plan was implemented to reduce water usage by 5 percent from the 1998-2002 baseline that was calculated. Furthermore, the NDNR and URNRD agreed that a 20 percent reduction in pumping from the 1998-2002 baseline would be enough to keep the total depletions within the 44 percent URNRD share until 2020 (Nebraska Department of Natural Resources and Upper Republican Natural Resource District 2008). In 2008, the URNRD further reduced the allocation to 13 acre inches per year per certified acre.

Note that in the URNRD, if farmers did not face any restrictions on water use, it is estimated that they would use up to 18 acre inches of water per year per irrigated acre (Palazzo 2009). Thus, the current allocation of 13 inches per acre per year is binding on almost all farmers.

3 Model and Estimation

We use two different techniques for the estimation process. Below, we describe the theory behind each of these models, the assumptions made, and the application to my study area.

3.1 Ordinary Least Squares

Hedonic price theory for an agricultural parcel of land is explained below. In the basic model an individual receives utility from the consumption of a commodity X, which is a parcel of land in this case. This commodity or parcel is composed of a vector of hydrologic and climatic characteristics, Q, a vector of physical characteristics, S, and a vector of structural characteristics, N. An individual can choose to purchase any parcel of land and increase their consumption of a particular characteristic by buying a parcel that has more of that characteristic. For example, a person can choose a parcel that receives more rain if that is the desired characteristic.

In this paper, the commodity X is a parcel of land. The vector Q contains the depth to water, pump rate, precipitation, and beneficial and harmful degree days. The vector S includes the different soil types and N is composed of a dummy for outbuildings, house size, and age of any house on the parcel.

Mathematically, this model can be represented as:

$$P_{Li} = P_i(S_i, N_i, Q_i) \tag{1}$$

where the price of the ith parcel of land is a function of the vectors of characteristics. This function can be linear or non linear.

To estimate the hedonic price function, we use an Ordinary Least Squares (OLS) regression. The dependent variable is the sale price of land per acre. Recent hedonic studies (Faux and Perry 1999, **?**) use the per acre sale price. This is because there is such a high range in the total acres of the parcels. The independent variables included in the model are a dummy variable for irrigation, the proportions of each soil quality type, the pump rate (gallons per minute per acre), the house size (square feet per acre), the assessed value of outbuildings ($ per acre), depth to water (feet), precipitation, beneficial growing degree days, and harmful growing degree days. Irrigation is captured with a dummy variable equal to one if the parcel is irrigated and zero if non-irrigated.

Soil qualities were included as better soil qualities are expected to lead to higher yields and so higher profitability. The pump rate is the rate at which a well can pump water in gallons per minute, as reported by the Nebraska DNR wells database. The coefficient on pump rate is expected to be positive because a faster rate of pumping would allow a farmer to irrigate more land. we include the pump rate per parcel as well as per acre. The per parcel value provides information about the decision to irrigate an entire parcel while the pump rate per acre contains information about how much of the parcel the farmer could to irrigate. Structures such as houses and outbuildings also add value to a parcel of land and so positive coefficients are also expected for these. The more recently a house was built, the better condition it should be in, and so we also expect a negative effect of increasing house age on the sales price of land. Depth to water measures the distance to the top of the aquifer.

A lower depth would make the water more easily accessible and so a negative coefficient is expected for this variable. Beneficial degree days are those that are conducive to the growing of crops and lead to higher yields. Therefore, the coefficient on this variable should be positive. On the other hand, the coefficient on harmful degree days should be negative as more harmful days will lead to lower crop yields and lower profitability. More detail on each variable is provided in the Data section.

3.2 Propensity Score Matching

The second model we use estimates the causal effect of irrigation on the sales price of a parcel of land. Propensity score matching allows for the evaluation of an outcome on particular units (sale price of land, in this project) based on exposure to a program or treatment. The theory is that each unit of interest can be exposed to different levels of treatment and the focus is on a comparison of units that are exposed and those that are not exposed to the treatment (Imbens and Wooldridge 2009). An issue with this is that most often we do not observe different levels of the treatment on a single unit. We only observe the unit being exposed to one level of treatment. Therefore, comparisons must be made between distinct units that have been exposed to different levels of treatment. In the economics literature the focus has been on endogeneity or self selection which means that items that are treated are by definition different that those that are not.

There are two main assumptions that have to be made in order to estimate a PSM model. The first is the conditional independence assumption. This states that the selection into treatment is based on observable characteristics. Therefore, selection into irrigation must be explained by observable variables in the model. The variables that explain selection in this model are soil type, pump rate, depth to water, precipitation and growing degree days. The second is the common support assumption. Having common support means that the treated and untreated groups must have an overlap of propensity scores in order to match them for comparison. Probabilities of the irrigated parcels must overlap probabilities for the non-irrigated parcels.

Propensity score matching is a two-step process. In the first step, a probit regression model is estimated. It estimates the probabilities of the treated and non treated variables. For this paper, it measures the probability that a parcel of land will be irrigated. The dependent variable is a dummy variable that is equal to one if the parcel is irrigated and zero if not irrigated. The independent variables includes in the model are the proportions of soil types, the pump rate (in gallons per minute per acre and in gallons per minute), depth to water (feet), precipitation, beneficial degree days and harmful degree days. The soil qualities are included because irrigation is a land augmenting technology and we expect to see a positive coefficient for poorer quality soils (Lichtenberg 1989). The pump rate and pump rate per acre are included and expected to have a positive effect on irrigation adoption (Savage and Brozović 2009). Depth to water should have a negative coefficient as it would be more expensive to reach water that was deeper underground. Studies have shown that heat increases crop yields but extreme heat decreases yields (Schlenker and Roberts 2009). The range of temperatures for beneficial and extreme heat are discussed in more detail in the data section. Precipitation and beneficial degree days should have a negative coefficient as more precipitation and better growing degree days increase crop yields without the need for irrigation. However, extreme degree days should have a positive effect. Housing and structure data are not included as they should not effect the decision to irrigate.

In the second step of PSM, the “average treatment effect of treatment on the treated” (ATT) values are calculated. This is calculated as the difference between the variables of interest in the treated versus the non treated group that have the same probability of being treated. The control group of untreated variables can be constructed in several ways. Here, we chose nearest neighbor matching that matches a treated observation to an untreated one based on the closest propensity score estimated. The results of the ATT provide the difference in the average of the variables between the treated and control group. PSM controls for the selection into treatment, in this case selection into irrigation, and allows us to compare how the sales price and other variables differ if endogeneity is accounted for. The ATT estimates the difference in all variables of interest. Therefore, the results for variables such as housing data and structural data can also be estimated although they are not included in the first-stage probit.

4 Data

For this analysis we synthesized economic, physical, hydrologic, and climatic data. The dataset used includes all agricultural parcels in Chase County, Nebraska that sold between 2000 and 2008. First we will describe data from the Chase County tax assessor's office, and then hydrologic and climatic data. Descriptive statistics for the data are reported in Table 1.

4.1 Tax Assessor's Data

Chase County is made up of mostly agricultural land. Out of 912 sections in the county (each one square mile in size), 908 contain some type of agricultural land. The total area of the county is 583,680 acres and the population is 4,381 *(http://www.co.chase.ne.us/about.html)*. Agricultural land sales in the area remain in farmland; there is currently no suburbanization or development pressure for agricultural land.

The Chase County tax assessor's office maintains records of all parcels in the county. There are 2257 agricultural parcels. From 2000 to 2008 there were 554 sales of agricultural parcels. The price range for sales was zero to $4,241,000 with the mean at $146,986. Out of the 554 sales, 190 had sale prices of zero which likely represent transfers from one family member to another. There were also 16 sales which were under $1,000.

The tax assessor's data also include information regarding the type of land in each parcel. Agricultural land is divided into three types: irrigated, dryland, and grassland. Given current crop prices, irrigated land is used mostly used for growing corn as it is the most profitable alternative, and dryland is used to grow wheat. Grassland is not used to grow crops but as pasture. However, in any year a farmer has the choice either to irrigate (if he has the right to do so via certified acres) or to be in dryland production. Certified acres are ones that have the right to irrigate. Also, in this region there are no surface water rights, thus all irrigation uses ground water. The tax assessor's office reports acreages in each soil class in each parcel. The soil classes range from one to four with soil class one being the best quality and soil class four the worst. The total acreage of the parcel is the total acreage found by adding averages for all the soil types. Each parcel of land can contain more than one soil type and many contain all four.

Housing data are also provided by the tax assessor. These include the square footage of houses on agricultural parcels along with how old such houses are. There are 287 houses in the complete dataset of 2257 parcels in the county, with a mean square footage of 1550. The size of houses ranges from 384 to 4000 square feet. The age of these houses ranges from one year to 128 years with a mean age of 66 years. Other structures reported are outbuildings. There are 407 parcels with outbuildings.

For the purposes of the analysis in this paper, we dropped the 206 observations which had sales prices of either zero or under $1,000 as these do not appear to be arms length sales. We calculated the sale price per acre by dividing these by the total acreage. This left 348 sales out of which eight had sale price per acre values of greater than $6,000 and four had total acreages of less than four. These 12 observations were also dropped from the final analysis. Parcels with sale prices per acre above

$6,000 were dropped as such high prices are inconsistent with agricultural use. One of the parcels was purchased by an energy company in California and is likely to be for an ethanol plant.[3] The price of another can be attributed to a feedlot on the property. Parcels of less than four acres were dropped because such small acreages may not represent land whose primary purpose is agricultural production. These changes left a total of 330 observations with a mean price per acre of $1178. Descriptive statistics for these 330 observations are presented in Table 2. Note the clustering of parcels around 160 acres in size, equal to one quarter section of land (Figure 2).

The soil data were summed up across the four different types (soil 1 through soil 4) and divided by the total acreage to obtain proportions of each type for the analysis. For the parcels that sold, the average proportions of soil 1 and soil 4 were similar at 31 and 33 percent, respectively. The average proportion of soil 2 was 15 percent and soil 3 about 20 percent. In addition, a dummy variable for irrigation was also created. The dummy equaled one if irrigated land was present in the parcel and zero otherwise. Out of the 330 observations, 163 were included some irrigated land and 167 had no irrigated land. Figure 3 shows the distribution of irrigated and dryland in the county with the sale price per acre. Note that the figure shows more irrigated land in the west of the county. This may be due in part to a large precipitation gradient across the county with lower precipitation in the west.

There were 34 observations with houses in the final data set, with a mean square footage of 1514. These were divided by the total acreage and the square feet per acre value was used in the estimation. This follows Xu et al. (1993) and Torell et al. (1990). Butsic (2007) and Parsons (1990) have also argued that weighting of the variable by parcel size is the right specification.[4] The mean house size per acre was about 2 square feet. There were 53 parcels in the final dataset with outbuildings.

Year dummies were also constructed to estimated year fixed effects. The year dummies were equal to one if there was a sale in that year and zero otherwise. Interaction terms between the year dummies and irrigation dummy were also included. These were equal to one if there was an irrigated sale in that year and zero otherwise. The number of irrigated and non-irrigated sales in each year are shown in Figure 4.

4.2 Hydrologic and Climatic Data

Hydrological data included in the model are depth to water and the rate at which a well can pump water (the pump rate in gallons per minute). Both the depth to water and pump rate data were obtained from the Nebraska Department of Natural Resources *(http://www.dnr.state.ne.us)* wells database (Palazzo 2009). Well-level observations were aggregated up to the section level and spatial interpolation was used to estimate values at section centroids for all parcels, whether irrigated or not as these values do not exist for non-irrigated parcels (Savage and Brozović 2009). The depth to water measures the distance in feet from the land surface to the top of the aquifer. Figure 5 shows the distribution of depths in the county. The shallowest depths, that is water that is more easily reachable, are

[3] The parcel ID for this purchase is 150002513 and it sold in December 2007.

[4] To test if this specification was accurate, the model was also tested using a housing dummy; the sign and significance of the coefficients remained unchanged.

found in the west. Depth to water ranges from about 3 feet to 390 feet with a mean of 143 feet, for the parcels that sold.

The pump rate is measured in gallons per minute. The rate is an inherent characteristic of the land and does not depend on the equipment used. Figure 6 shows the distribution of pump rates and pump rates per acre. Values were calculated at the section level as described above. The mean pump rate is 1643 gallons per minute and the mean pump rate per acre 18 gallons per minute. Note that there appears to be less spatial correlation in pump rates than in depth to water (compare figures 5 and 6).

Interaction terms between pump rate and pump rate per acre and the irrigation dummy were also constructed. These variables were included to capture incremental value of pump rate specifically on irrigated land. Similarly, an interaction term between depth to water and the irrigation dummy was constructed.

Precipitation and minimum and maximum temperature data obtained from the National Weather Service are included *(http://cdo.ncdc.noaa.gov)*. The precipitation data collected were annualized from total monthly precipitation (Savage and Brozović 2009). The temperature data were used to calculate beneficial and harmful growing conditions. Schlenker and Roberts (2009) found that crop production is non linear in heat: heat is beneficial up to a certain point but then it is harmful at higher levels. Schlenker and Roberts estimated that beneficial heat ranges from 8 to 29 degrees Celsius and harmful heat is anything greater than 29 degrees Celsius. Both beneficial and harmful degree days are calculated as lagged three year averages over the growing season, which is from March to August (Savage and Brozović 2009).

5 Results

In this section we analyze and discuss the results of both the Ordinary Least Squares model and its variations and the Propensity Score Matching model.

5.1 Ordinary Least Squares Regression Results

To help with interpretation of results, we present several different models. The simplest model uses Ordinary Least Squares to measure the hedonic value of irrigation (Table 3). Three variations of the model are presented. The first model does not have year fixed effects, the second includes year dummies and the third includes year dummies as well as interaction terms between the year dummies and the irrigation dummy. Each of the variations of the model is discussed below.[5]

In general, OLS results follow expected coefficients (Table 3). The coefficient for the irrigation dummy in the first model is 712 and is statistically significant at the one percent level. This means that an irrigated parcel of land has a sale price that is $712 per acre of the parcel more than that of a non-irrigated parcel, holding everything else constant. This is the implicit price of groundwater in irrigation. The mean sale price for a parcel of land is $1178. The value of irrigated land at $712 dollars is about 60 percent more than non-irrigated land at the mean price. This result is comparable with that found by Faux and Perry (1999) but is higher than values found by Petrie and Taylor (2007) at 30 percent. The pump rate is positive and significant at the five percent level. The coefficient of 0.18 implies that a one gallon per minute increase in the pumping rate would cause the sale price of land to increase by 18 cents per acre. The house size per acre had a coefficient of 33 and was statistically significant at the one percent level. This indicates that an increase of one square foot per acre would increase the sale price by $33. The dummy for outbuildings is statistically different from zero at the five percent level and is a positive coefficient of 307, implying that if there is an outbuilding on the parcel the sale price per acre of land would increase by $307. As hypothesized in the model section, depth to water is expected to have a negative coefficient because deeper water is associated with higher variable pumping costs. However, my results find no significant effect of depth on the sale price. Climatic variables also do not have an impact on the sale price.

The data on sales are from 2000 to 2008, which includes the boom in corn ethanol production. For this reason we might expect to see higher land prices in more recent years. To test if such a time trend exists the second model includes year dummies (Tables 3 and 4). For this model, the value of irrigation is $723 per acre. It is statistically significant at the one percent level. Similar to the first model, the pump rate is statistically significant at the five percent level and a one gallon per minute increase cause the sale price to increase by 18 cents per acre. An increase in the house size also causes the sale price to go up by $34. The dummy for outbuildings is statistically significantly positive at the five percent level. If a parcel has an outbuilding the sale price per acre increases by $300. None of the year dummies are statistically different from zero, suggesting that there is no strong time trend in sale price per acre of land (Table 4). However, some of the year dummies are statistically different from each other. Years 2001, 2002, 2003, and 2005 are different from 2007 and 2008 at the five percent

[5]The results presented are for the dataset which includes 330 sales where total agricultural acreage is greater than four and the sale price per acre is less than $6,000. Different cutoff values were tested to check the robustness of the model.

level. Year 2001 is different from 2004 at the ten percent significance level.[6] One reason why no significant trend is observed may be the relatively low number of sales per year.

The ethanol boom caused prices for crops to increase overall. However, relative to other crops, corn prices increased the most. In Chase County, where corn is grown on irrigated land, we might thus expect to see a more pronounced time trend in the sale price of irrigate land. Model three includes both year dummies and year dummies interacted with the irrigation dummy to test for this. The results are reported in Tables 3 and 4. The irrigation dummy is dropped from the model to enable direct interpretation of the year irrigation dummy interaction terms. The sign, magnitude and significance of most coefficients is unchanged from the previous model. Again, the year dummies are not statistically different from zero, indicating no trend in the sale price of all land. As there was a boom in ethanol and corn prices leading up to 2007, we would expect to see a trend as corn dominates the irrigated agriculture in the area. Each year is also not statistically different from the others. The year dummies interacted with the irrigation dummy allow for the estimation of the value of irrigation in each of the eight years represented by the model. The interaction terms are significantly different from zero from 2003 to 2008. In 2003, the sale price of irrigated land was \$716 more than that of non-irrigated land (significant at the five percent level). The range in the difference of the sale price per acre in each year is from \$514 in 2005 to \$1,051 in 2007. In addition, each of the interaction terms are not significantly different from each other except for 2002 and 2005 compared to 2007. Thus, overall, there is some weak evidence that sale prices of irrigated land were higher in the last few years.

The OLS model was also estimated with the pump rate, pump rate per acre, and depth to water interacted with the irrigation dummy. These variables were included as we would expect these variables to matter on land that was being irrigated and not necessarily on land which was not, given the moratorium on new wells. These results are reported in Tables 5 and 6. This model was also run with the year dummies and with year dummy and irrigation dummy interaction terms. Most previous models of groundwater do not include the pump rate. However, Palazzo (2009) found that the pump rate is an important factor in determining per acre returns to irrigation in the Republican River basin.

In all models the interaction term between pump rate per acre and the irrigation dummy is significant. This implies that a higher pump rate per acre increases the sales price of irrigated land only. For non-irrigated land, pump rate per acre is not significant. The significance of the pump rate interaction term is consistent with the results of Petrie and Taylor (2007), as following a moratorium on new wells, we would expect no additional value on non-irrigated parcels from variables associated with groundwater availability.

For models with irrigation interaction terms, the value of irrigation must be calculated as it is no longer the coefficient on the irrigation dummy. The value of irrigation can be calculated by adding the value of the irrigation dummy coefficient to the pump rate per acre irrigation interaction term multiplied by the mean pump rate for irrigated land and then subtracting the pump rate multiplied by the mean value of pump rate on irrigated land and the depth to water irrigation interaction term multiplied by the mean depth to water on irrigated land. For the first model, without year dummies, the

[6]The models were also estimated using a time trend and a shift variable. The time trend was found to be significant and also the shift variable which was equal to one after 2006 and zero before. Other coefficients remained the same.

value of irrigation is calculated to be $729 and for the second model it is $747. In all the models, the pump rate per acre irrigation dummy interaction term and house size per acre are statistically different from zero. An increase in the pump rate of one gallon per minute per acre increases the sale price of irrigated land by $24.

In the third model, the irrigation dummy is removed from the estimation and the value of irrigation is estimated for each year. we test the joint significance of the year irrigation dummy interaction term with the irrigated depth to water, irrigated pump rate, and irrigated pump rate per acre dummies. we find the dummies to be jointly significantly different from zero starting in 2003. The range of values of irrigation were from $563 in 2005 per acre to $1083 per acre in 2007. Once again, this provides some evidence that sale prices of irrigated land have been increasing over time.

5.2 Propensity Score Matching Results

In addition to Ordinary Least Squares, we used propensity score matching (PSM) to estimate the value of irrigation water. The decision to irrigate a parcel of land is not random but is based on the characteristics of that parcel. Thus, the endogeneity in the choice of whether to irrigate or not may result in biased OLS estimates. PSM is able to tackle this problem by matching each irrigated parcel to non-irrigated parcels with equivalent propensity scores.

The first step of PSM involves running a probit regression where the dependent variable is a binary variable (treatment variable). For my model, the treatment is irrigation and the dependent variable is equal to one if the parcel is irrigated and zero if non-irrigated. Independent variables included in the PSM model were soil 2, soil 3, soil 4, pump rate, pump rate per acre, depth to water, precipitation, beneficial degree days, and harmful degree days. The housing and structural data are not included in this model as they are not expected to affect the decision to irrigate a parcel of land.

Marginal effects of the probit regression are reported in Table 7. These are useful in describing how each independent variable effects adoption into irrigation. The marginal effect of soil 3 is 0.691. All else equal, a parcel that consists of soil 3 only is 69.1 percent more likely to be irrigated then one that consists of soil 1 only. As the soil types are estimated as proportions and soil 1 is dropped from the model, these results on soil 3 and soil 4 are relative to soil 1. This implies that irrigation is more likely to be implemented on intermediate quality soil, so it is a land-quality augmenting technology (Lichtenberg 1989). However, unlike the results of Lichtenberg (1989), my results suggest that irrigation is least likely on the poorest quality soils, implying that there are limits on the productivity goal of irrigation.

The marginal effect of pump rate is positive at 0.0002. This means that at the average pump rate and increase in one gallon per minute would result in an increase in the probability of irrigation by 0.0002. The effect of pump rate per acre is -0.012. This negative coefficient is not what we would expect. One possibility is that there are errors in estimating the pump rates for parcels that are wholly non-irrigated. The beneficial degree days variable has a marginal effect of -0.031. This means that if growing degree days increase by one day at the average level, the probability of irrigation will decrease by 0.0267. The harmful degree days variable has a positive marginal effect of 0.031. This means that an increase in harmful degree days, which is extreme heat, will increase the probability of adoption into irrigation by 0.5195.

Depth to water and climatic variables are significant in the probit results, which is different from what we found using OLS. Overall these results suggest that depth to water is important in the decision to irrigate, but once that decision has been made, depth to water no longer matters in land value. Some support for this argument is given by Palazzo (2009), who found that high well pump rates were a more important factor in per acre profits than low depth to water. Note that even though Chase County is relatively small, there is a large rainfall gradient, and this may help to explain the significance of the climatic variables.

A hit or miss table of the probit results shows that the probit model has a good fit (Table 8). The dataset has 163 irrigated parcels of land and 167 non-irrigated parcels. To measure the goodness of fit, the irrigated parcels would be considered non irrigated as there are more non-irrigated parcels. Thus, the fit would be about 50 percent. The probit model predicts 128 of the non-irrigated parcels and 105 of the irrigated parcels correctly. This means that the goodness of fit is 70 percent, which is higher than what would have been estimated without the probit model.

The average treatment effects results are reported in Table 9. The coefficient on sale price per acre is positive and highly significant for the unmatched as well as the matched results. However, the unmatched results estimate a difference of $721 between irrigated and non-irrigated land while the difference in the matched results is higher at $839. Thus, with PSM, the value of irrigation is estimated to be higher than that found with the OLS regression. Soil 3, soil 4, pump rate, house size, value of outbuildings, house age, depth to water, and precipitation were significantly different from zero for the unmatched data but these differences disappear when they are matched.

The values of irrigated land estimated above measure the price per acre of an irrigated parcel. However, in order to calculate the price of a fully irrigated acre, these estimated must be divided by the proportion of the parcel on average that is irrigated. Only 83 percent of irrigated land is irrigated on average and thus all results must be divided by 0.83 to obtain the value of a fully irrigated acre.

My results show that irrigation is being adopted more on intermediate quality soil and not on the highest or lowest quality. As irrigation is a land-quality augmenting technology, the profits from adopting irrigation on the intermediate quality soil is the greatest (Lichtenberg 1989). This may explain the higher value of irrigation that are estimated using the PSM methodology.

6 Conclusion and Policy Implications

Growing environmental concerns regarding depletion of groundwater resources along with interstate conflicts have led to increased restrictions in agricultural water use. In order for the water management regulations to be cost-effective, the value of water must be estimated correctly. In this paper, we compare a standard hedonic model and a propensity score matching model to estimate the value of groundwater in an area where groundwater use is permitted and there is a moratorium on new wells. We use propensity score matching in order to account for selection issues in the hedonic method, as an irrigated parcel is by definition different from a non-irrigated one and this may cause bias in the results from the first model. Our data are from Chase County, Nebraska and consist of tax assessor's data, physical, hydrologic, and climatic variables related to 330 sales of agricultural land between 2000 and 2008. We compare the results of the two models and find that irrigation does have a significant and positive effect on land prices. However, the propensity score matching methodology gives estimates of the value of water over 15 percent higher than those estimated using standard hedonic analysis.

We find that the value of water estimated using Ordinary Least Squares ranges from \$712 to \$723 per acre, depending on the exact specification used. The pump rate is an important determinant of the value of sale price using both OLS and PSM. Conversely, depth to water and climate are only important in the decision to irrigate, but variations are not capitalized into land value. There is weak evidence to suggest that prices of land were higher in the last few years than in earlier years for the period analyzed. The time trend may not be visible due to the small number of sales in each year. Using a five percent discount rate along with the allocation of 13 inches per acre per year in the Upper Republican NRD (Nebraska Department of Natural Resources and Upper Republican Natural Resource District 2008) gives an annual value of about \$34 per acre foot of water. For the propensity score matching, the value is \$40 per acre foot of water per year.[7] Note that only 83 percent of irrigated land is irrigated on average. In order to calculate the value of a fully irrigated acre, the annual value calculated above is divided by 0.83. Therefore, the estimated value of an acre foot of water per year in Chase County is \$41 using OLS and \$48 using PSM. These values are lower than those found by Palazzo (2009) in the same area but this may be because of the high commodity prices used in that analysis.

The higher value of irrigation that results from the PSM estimation may be because irrigation adoption is taking place preferentially on intermediate quality soil and not the best quality soil. This is because irrigation is a land-quality augmenting technology, so that the highest profit difference between irrigated and dryland agriculture is not on the highest quality soil (Lichtenberg 1989). Irrigation is expected to be land-quality augmenting in general and thus the result that OLS may bias values of irrigation downwards is not limited to just Chase County. Standard hedonic methods that do not account for selection issues may be biased in other areas as well.

Future work could include analyzing the value of water for other counties in the region to verify the results obtained here. Most groundwater models use depth to water as an important determinant of irrigated production and technology and do not consider well yield at all. Similarly, PSM is only

[7] $a = rC/1 + r$ where r=annual interest rate, C=capitalized value, and a=annual value

one method to correct for selection issues. The Heckman selection model could also be used and the results compared to those obtained here. My results suggest that pump rate is the more important variable in determining profits and may need to be modeled explicitly.

The results of this paper have important policy implications in areas such as Nebraska where there is debate on how to reduce water use cost-effectively. The analyses presented here suggest that future reductions may be costlier than previous research suggests, and that the standard hedonic method may not be best in estimating the value of water. In particular, if policy analyses use a standard hedonic methodology, the reductions will be more expensive than anticipated to both the government and farmers. In Nebraska, the government has tried to reduce water use by buying permits from farmers. There has been a lot of resistance to this and one explanation for this may be that the government is not offering enough compensation for the permits.

7 Tables and Figures

Table 1: Description of Data

Data	Source	Description
Soil 1 Irrigated	Chase County Tax Assessor	Proportion of Soil type 1 that is irrigated in the parcel
Soil 2 Irrigated	Chase County Tax Assessor	Proportion of Soil type 2 that is irrigated in the parcel
Soil 3 Irrigated	Chase County Tax Assessor	Proportion of Soil type 3 that is irrigated in the parcel
Soil 4 Irrigated	Chase County Tax Assessor	Proportion of Soil type 4 that is irrigated in the parcel
Soil 1 Dryland	Chase County Tax Assessor	Proportion of Soil type 1 that is in dryland in the parcel
Soil 2 Dryland	Chase County Tax Assessor	Proportion of Soil type 2 that is in dryland in the parcel
Soil 3 Dryland	Chase County Tax Assessor	Proportion of Soil type 3 that is in dryland in the parcel
Soil 4 Dryland	Chase County Tax Assessor	Proportion of Soil type 4 that is in dryland in the parcel
Soil 1 Grassland	Chase County Tax Assessor	Proportion of Soil type 1 that is in grassland in the parcel
Soil 2 Grassland	Chase County Tax Assessor	Proportion of Soil type 2 that is in grassland in the parcel
Soil 3 Grassland	Chase County Tax Assessor	Proportion of Soil type 3 that is in grassland in the parcel
Soil 4 Grassland	Chase County Tax Assessor	Proportion of Soil type 4 that is in grassland in the parcel
Sales Price	Chase County Tax Assessor	The sale price of a parcel of land
Sales Year	Chase County Tax Assessor	The year the parcel of land sold
House Size	Chase County Tax Assessor	The size, in square feet per acre, of a house
House Age	Chase County Tax Assessor	The age, in years, of the most recent house on a parcel
Value of Outbuildings	Chase County Tax Assessor	The assessed value, in dollars, of outbuildings
Depth to Water	2008 Nebraska DNR database	The depth, in feet, to the top of the groundwater source. Filled empty entries with nearest neighbor information (Palazzo 2009)
Pump Rate	2008 Nebraska DNR database	The rate at which a well can pump water in gallons per minute. Filled empty entries with nearest neighbor information (Palazzo 2009)
Precipitation	National Weather Service	Annualized monthly precipitation in inches (Savage and Brozović 2009)
Growing Degree Days	Raw data from the National Weather Service	Calculated beneficial growing degree days and harmful growing degree days using raw three year moving average minimum and maximum temperatures(Savage and Brozović 2009, Schlenker and Roberts 2009)

Table 2: Descriptive Statistics: Parcels that Sold, Chase County 2000-2008

	Mean	Std. Dev.	Min	Max
Sale Price (per acre)	1178.293	952.183	63.291	5031.25
Irrigation Dummy	0.494	0.501	0	1
Soil 1 Irrigated	0.117	0.255	0	1
Soil 2 Irrigated	0.067	0.164	0	0.886
Soil 3 Irrigated	0.139	0.243	0	1
Soil 4 Irrigated	0.088	0.206	0	0.895
Soil 1 Dryland	0.192	0.345	0	1
Soil 2 Dryland	0.056	0.157	0	1
Soil 3 Dryland	0.052	0.125	0	0.949
Soil 4 Dryland	0.035	0.107	0	0.783
Soil 1 Grassland	0.005	0.022	0	0.189
Soil 2 Grassland	0.024	0.094	0	0.828
Soil 3 Grassland	0.017	0.065	0	0.784
Soil 4 Grassland	0.209	0.351	0	1
Soil 1	0.314	0.391	0	1
Soil 2	0.146	0.245	0	1
Soil 3	0.207	0.279	0	1
Soil 4	0.332	0.383	0	1
Pump Rate (gallons per minute)	1642.598	681.559	297.715	3205.91
Pump Rate (gallons per minute per acre)	17.908	51.629	1.133	658.518
House Size (sq. feet per acre)	1.926	10.267	0	129.335
House Age (years)	7.23	23.784	0	118
Assessed Value of Outbuildings ($ per acre)	41.475	239.077	0	3057.318
Depth to Water (feet)	143.063	86.254	2.988	389.86
Precipitation (inches)	200.877	12.759	138.73	207.947
Beneficial Degree Days	3492.019	46.24	3005.693	3496.441
Harmful Degree Days	72.162	2.435	44.697	72.394
Acres	192.719	131.222	4.600	651.04

Notes: There are four land classes. Soil 1 is the best quality and Soil 4 the worst. The soil data are presented as proportions of the total acreages in agricultural use in the parcel.

Table 3: Ordinary Least Squares, n=330

Variables	(1) Model	(2) Model	(3) Model
Irrigation Dummy	712.41***	723.34***	
	(104.452)	(104.662)	
Soil 2	-92.15	8.94	-28.70
	(218.781)	(218.544)	(224.104)
Soil 3	142.04	120.96	59.87
	(211.612)	(210.372)	(218.511)
Soil 4	163.15	224.75	217.59
	(150.029)	(149.232)	(152.569)
Pump Rate (gallons per minute)	0.18**	0.18**	0.18**
	(0.071)	(0.071)	(0.072)
Pump Rate (gallons per minute per acre)	-0.76	-0.65	-0.78
	(0.938)	(0.938)	(0.953)
Depth to Water (feet)	-0.27	0.04	0.01
	(0.712)	(0.717)	(0.721)
House Size (sq. feet per acre)	33.32***	33.69***	33.68***
	(5.141)	(5.141)	(5.198)
House Age (years)	-5.49**	-5.40**	-5.78**
	(2.369)	(2.365)	(2.409)
Outbuildings Dummy	307.36**	299.95**	295.87**
	(145.419)	(145.250)	(147.875)
Precipitation	1.20	0.89	1.54
	(4.293)	(4.300)	(4.403)
Beneficial Degree Days	1.41	-2.78	-5.77
	(18.746)	(19.020)	(19.281)
Harmful Degree Days	-14.97	56.94	114.05
	(356.045)	(360.643)	(365.817)
Constant	-3,646.01		
	(39,816.144)		
Year Dummies	NO	YES	YES
Year Dummy and Irrigation Interaction Terms	NO	NO	YES

Standard errors in parentheses

*10% significance; ** 5% significance; *** 1% significance.

Notes: The dependent variable is sales price per acre.

Table 4: Ordinary Least Squares continued

Variables	(2) Model	(3) Model
Year Dummy 2000	5,796.18	12,289.96
	(40,456.289)	(40,987.382)
Year Dummy 2001	5,478.53	11,796.29
	(40,417.675)	(40,961.927)
Year Dummy 2002	5,579.86	11,918.79
	(40,454.499)	(40,990.005)
Year Dummy 2003	5,616.87	11,831.73
	(40,455.449)	(40,993.049)
Year Dummy 2004	5,868.01	12,008.73
	(40,456.396)	(40,990.445)
Year Dummy 2005	5,646.47	11,982.34
	(40,469.850)	(41,026.755)
Year Dummy 2006	5,765.50	11,923.38
	(40,454.944)	(40,990.070)
Year Dummy 2007	6,008.51	12,058.77
	(40,455.095)	(40,991.136)
Year Dummy 2008	6,105.69	12,267.30
	(40,455.897)	(40,994.504)
Year Dummy 2000*Irrigation Dummy		341.45
		(476.352)
Year Dummy 2001*Irrigation Dummy		419.45
		(365.632)
Year Dummy 2002*Irrigation Dummy		358.05
		(316.081)
Year Dummy 2003*Irrigation Dummy		715.60**
		(277.329)
Year Dummy 2004*Irrigation Dummy		841.69***
		(228.944)
Year Dummy 2005*Irrigation Dummy		514.30*
		(261.954)
Year Dummy 2006*Irrigation Dummy		848.68***
		(266.129)
Year Dummy 2007*Irrigation Dummy		1,051.21***
		(230.349)
Year Dummy 2008*Irrigation Dummy		844.34**
		(328.645)

Standard errors in parentheses

*10% significance; ** 5% significance; *** 1% significance.

Notes: The dependent variable is sales price per acre.

Table 5: Ordinary Least Squares with Pump Rate and Depth to Water Dummies, n=330

Variables	(4) Model	(5) Model	(6) Model
Irrigation Dummy	486.07	555.61*	
	(311.534)	(309.487)	
Soil 2	-47.08	40.98	-5.04
	(219.221)	(218.805)	(224.490)
Soil 3	183.85	151.59	91.93
	(212.080)	(210.871)	(218.852)
Soil 4	208.61	260.55*	249.98
	(150.655)	(149.805)	(153.054)
Pump Rate (gallons per minute)	0.11	0.13	0.12
	(0.105)	(0.104)	(0.105)
Pump Rate*Irrigation Dummy	-0.01	-0.04	-0.03
	(0.155)	(0.154)	(0.156)
Pump Rate (gallons per minute per acre)	-0.79	-0.73	-0.85
	(0.951)	(0.953)	(0.966)
Pump Rate (per acre)*Irrigation Dummy	24.41**	24.22**	23.53**
	(10.087)	(10.103)	(10.227)
Depth to Water (feet)	0.04	0.28	0.16
	(0.815)	(0.819)	(0.825)
Depth to Water*Irrigation Dummy	-0.07	-0.03	0.25
	(1.178)	(1.169)	(1.196)
House Size (sq. feet per acre)	32.68***	33.26***	33.22***
	(5.136)	(5.137)	(5.199)
House Age(years)	-5.37**	-5.31**	-5.60**
	(2.357)	(2.355)	(2.401)
Outbuildings Dummy	327.39**	321.28**	308.93**
	(145.113)	(145.073)	(147.691)
Precipitation	1.66	1.11	1.93
	(4.339)	(4.353)	(4.461)
Beneficial Degree Days	0.80	-3.22	-5.30
	(18.721)	(18.975)	(19.253)
Extreme Degree Days	-2.83	66.48	105.93
	(355.555)	(359.789)	(365.293)
Constant	-2,433.72		
	(39,761.950)		
Year Dummies	NO	YES	YES
Year Dummy and Irrigation Interaction Terms	NO	NO	YES

Standard errors in parentheses

*10% significance; ** 5% significance; *** 1% significance.

Notes: The dependent variable is sales price per acre.

Table 6: Ordinary Least Squares with Pump Rates and Depth to Water continued

	(5)	(6)
Year Dummy 2000	6,639.79	11,174.96
	(40,357.313)	(40,925.350)
Year Dummy 2001	6,310.81	10,693.75
	(40,320.044)	(40,898.464)
Year Dummy 2002	6,400.53	10,822.37
	(40,355.691)	(40,925.282)
Year Dummy 2003	6,443.21	10,742.00
	(40,356.793)	(40,928.396)
Year Dummy 2004	6,653.91	10,905.61
	(40,357.787)	(40,927.229)
Year Dummy 2005	6,482.46	10,874.31
	(40,370.353)	(40,962.788)
Year Dummy 2006	6,576.42	10,815.12
	(40,356.357)	(40,926.595)
Year Dummy 2007	6,835.72	10,952.00
	(40,356.381)	(40,928.163)
Year Dummy 2008	6,924.90	11,164.40
	(40,356.921)	(40,931.039)
Year Dummy 2000*Irrigation Dummy		160.40
		(555.604)
Year Dummy 2001*Irrigation Dummy		222.86
		(471.543)
Year Dummy 2002*Irrigation Dummy		115.53
		(461.896)
Year Dummy 2003*Irrigation Dummy		473.75
		(425.235)
Year Dummy 2004*Irrigation Dummy		558.41
		(376.330)
Year Dummy 2005*Irrigation Dummy		325.96
		(381.690)
Year Dummy 2006*Irrigation Dummy		614.61
		(391.256)
Year Dummy 2007*Irrigation Dummy		845.95**
		(365.670)
Year Dummy 2008*Irrigation Dummy		612.24
		(440.711)

Standard errors in parentheses

*10% significance; ** 5% significance; *** 1% significance.

Notes: The dependent variable is sales price per acre.

Table 7: Probit Regression Results, Marginal Effects, n=330

Variables	Coefficient	Std. Error
Soil 2	0.097	(0.139)
Soil 3	0.691***	(0.144)
Soil 4	-0.182*	(0.099)
Pump Rate (gallons per minute)	2E-04***	(0.000)
Pump Rate (gallons per minute per acre)	-0.012***	(0.004)
Depth to Water (feet)	-0.001**	(0.000)
Precipitation	-2E-04	(0.003)
Beneficial Degree Days	-0.031***	(0.001)
Harmful Degree Days	0.595***	(0.026)

Standard errors in parentheses
*10% significance; ** 5% significance; *** 1% significance.

Table 8: Goodness of fit of probit model

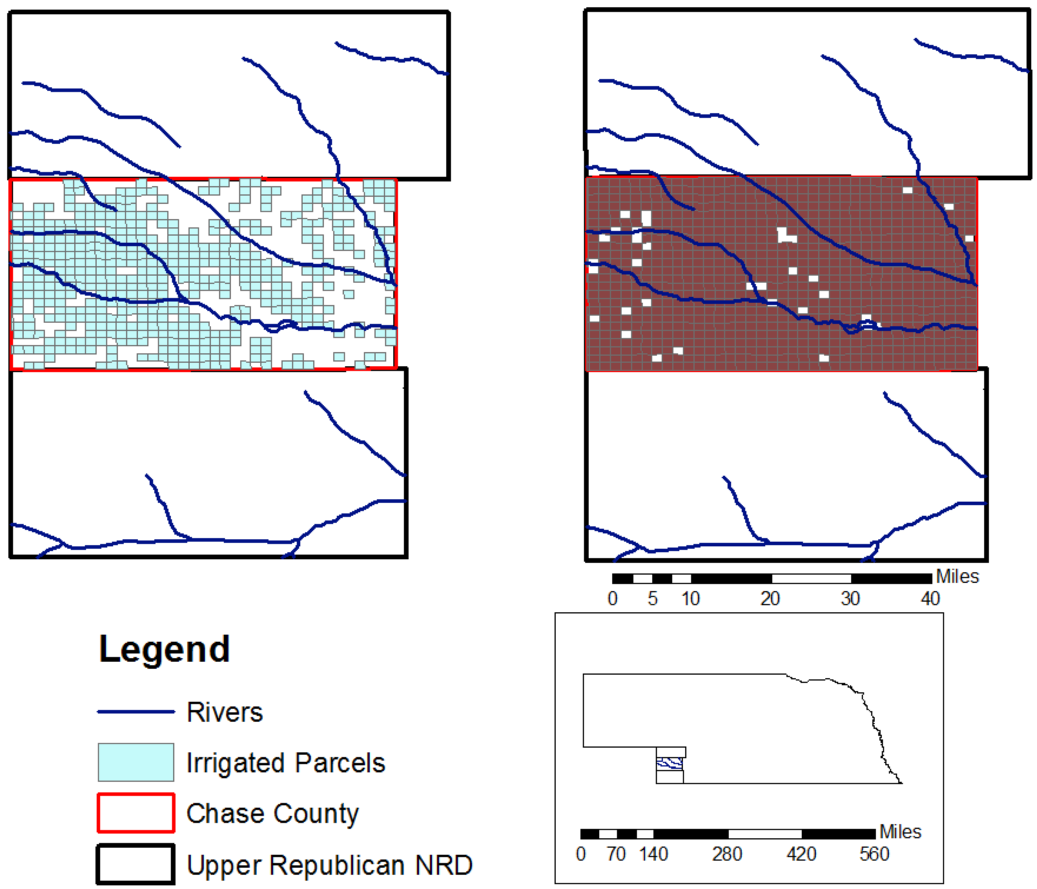
		Predicted		
		Non-Irrigated	Irrigated	
Actual	Non-Irrigated	128	39	167
	Irrigated	58	105	163
		186	144	

Table 9: Average Effect of Treatment on the Treated, n=330

Variable	Sample	Treated	Controls	Difference	Std. Error.
Sale Price (per acre)	Unmatched	1543.392	821.938	721.454***	97.149
	ATT	1543.392	703.977	839.414**	115.671
Soil 2	Unmatched	0.162	0.131	0.031	0.027
	ATT	0.162	0.153	0.009	0.057
Soil 3	Unmatched	0.325	0.093	0.233***	0.028
	ATT	0.325	0.347	-0.021	0.053
Soil 4	Unmatched	0.242	0.420	-0.178***	0.041
	ATT	0.242	0.277	-0.035	0.079
Pump Rate (gallons per minute)	Unmatched	1777.863	1510.572	267.291***	73.694
	ATT	1777.863	1783.349	-5.486	134.459
Pump Rate	Unmatched	11.031	24.620	-13.588**	5.644
(gallons per minute per acre)	ATT	11.031	11.864	-0.833	1.573
Depth to Water (feet)	Unmatched	123.276	162.375	-39.099***	9.263
	ATT	123.276	123.436	-0.160	16.935
House Size (sq. feet per acre)	Unmatched	0.543	3.275	-2.733**	1.122
	ATT	0.543	0.700	-0.158	0.646
House Age	Unmatched	5.000	9.407	-4.407	2.611
	ATT	5.000	8.883	-3.883	5.799
Outbuildings Dummy	Unmatched	.160	.162	-.002	.041
	ATT	.160	.086	.074	.075
Precipitation	Unmatched	203.022	198.783	4.240***	1.387
	ATT	203.022	202.851	0.171	2.579
Beneficial Degree Days	Unmatched	3493.470	3490.602	2.867	5.097
	ATT	3493.470	3496.441	-2.971	2.971
Harmful Degree Days	Unmatched	72.244	72.082	0.162	0.268
	ATT	72.244	72.394	-0.150	0.150

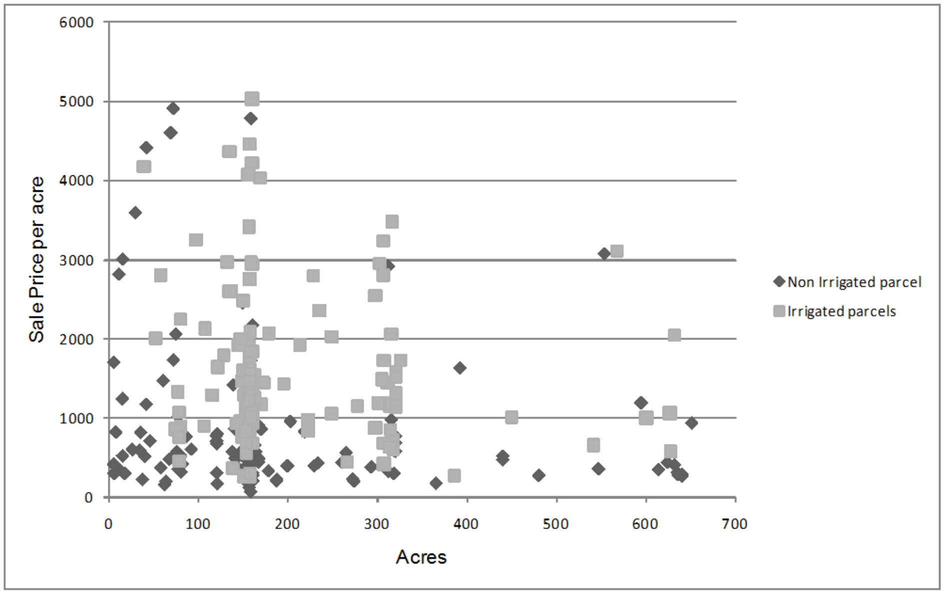
*10% significance; ** 5% significance; *** 1% significance.

Figure 1: Chase County, Nebraska: Irrigated and Non-Irrigated Land



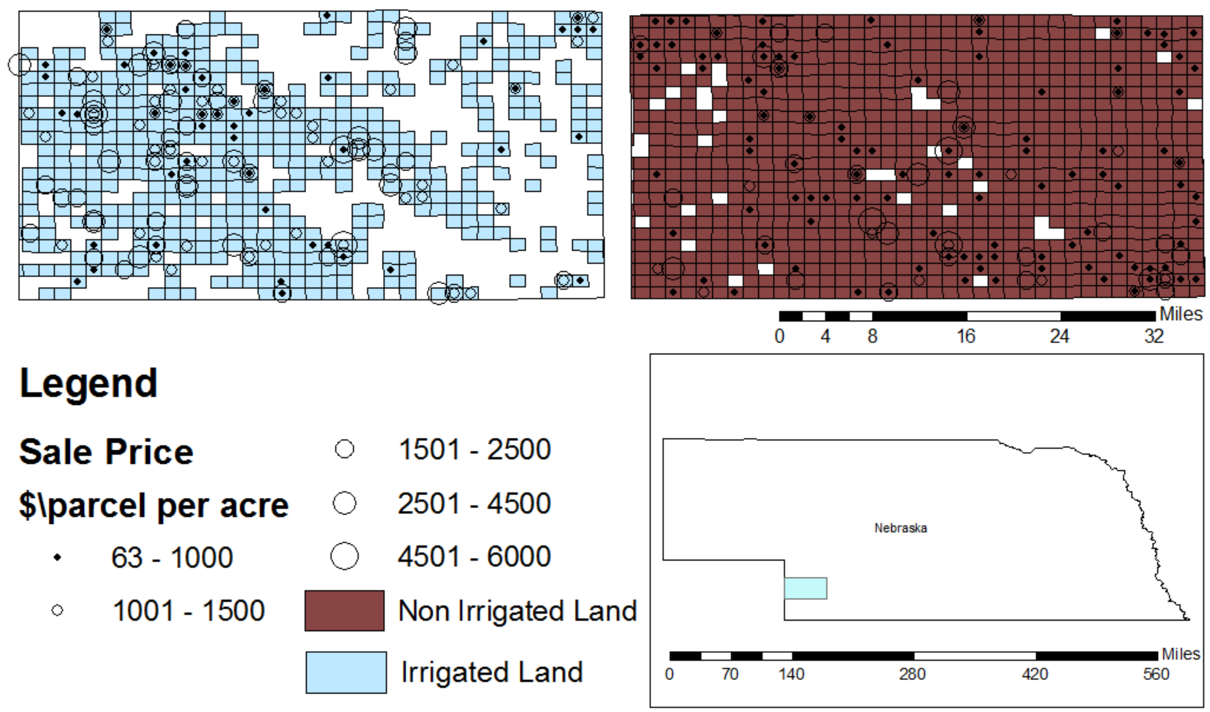
Notes: Each square is a Section which measures one mile by one mile and is equal to 640 acres. The shaded squares in the panel on the left are land that is irrigated and the shaded panels on the right are those that are non irrigated. Note that many sections include both irrigated and non irrigated parcel of land.

Figure 2: Irrigated and Non-Irrigated Sales



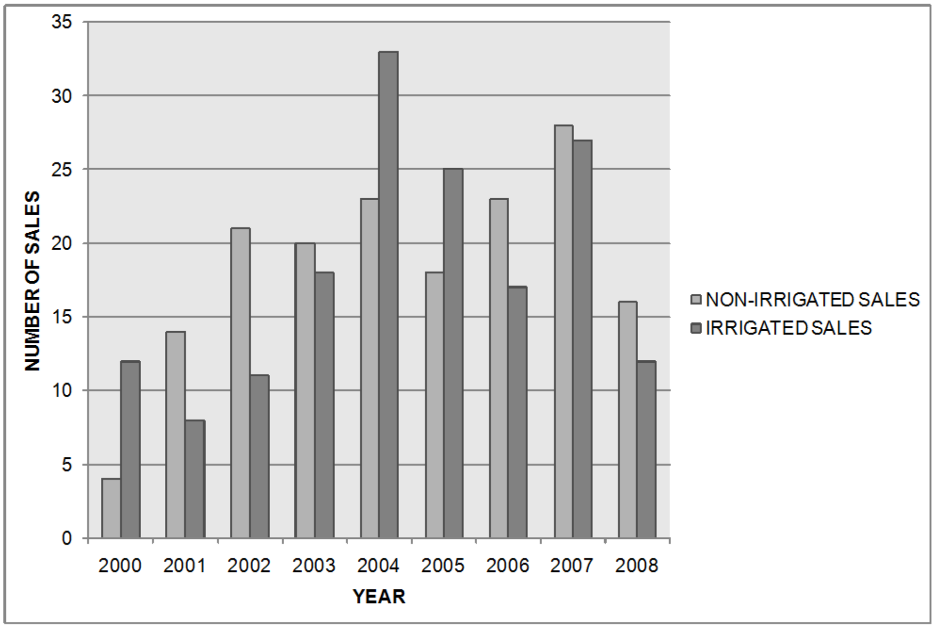
Notes: This is a scatter plot of the sale price per acre and total acreage. Non-irrigated parcels are represented by the darker diamonds and irrigated parcels by lighter squares. Note the clusters of sales at 160 acres, representing a parcel size of one quarter section.

Figure 3: All Arms Length Sales in Chase County from 2000 to 2008



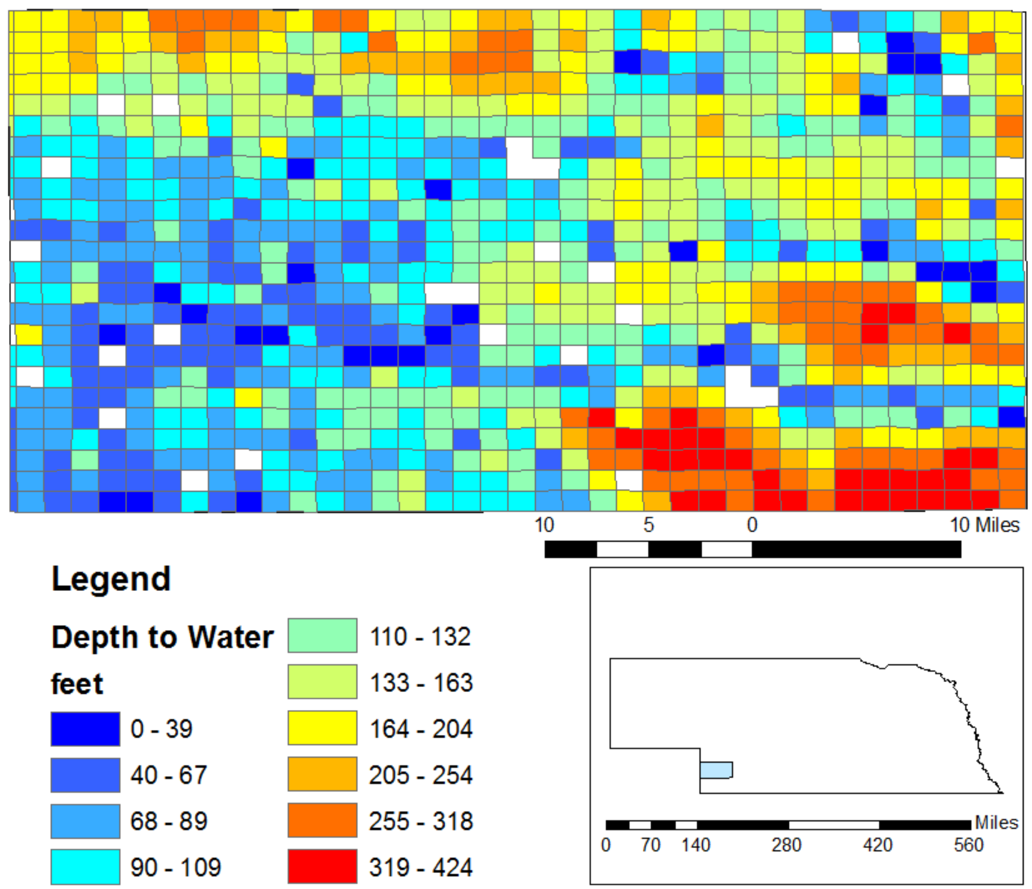
Notes: The panel on the left shows land which is irrigated and the sales that took place on irrigated land. The panel on the right shows non irrigated land and sales that occured on that land. Each circle represents sale of a parcel and larger circles represent higher per acre sale prices (n=330).

Figure 4: Distribution of Irrigated and Non-Irrigated Sales by Year



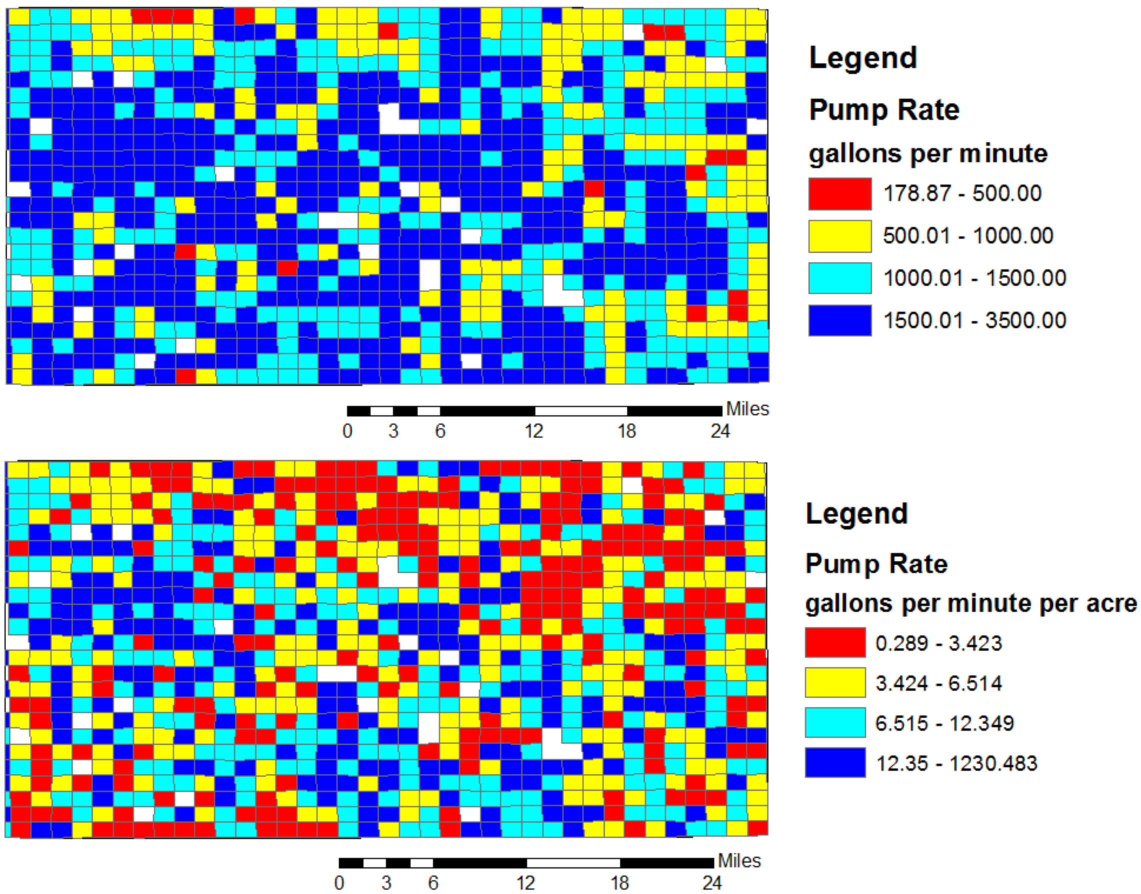
Notes: This figure shows the distribution of irrigated and non-irrigated sales in each year. The lighter bars represent non-irrigated sales and the darker bars represent irrigated sales.

Figure 5: Depth to Water



Notes: The depth to water shows the distance in feet from the surface of the land to the groundwater source. Blue colored squares represent water that is closer to the surface and thus has lower variable cost associated with pumping, and red colored squares represent water that is deeper from the surface.

Figure 6: Pump Rate



Notes: The figure on top panel shows the pump rate in gallons per minute. Blue colored squares represent faster pump rates that allow users to access water more quickly and red colors represent lower pump rates. The bottom panel shows the pump rate per acre in gallons per minute per acre. Again, blue colored squares represent faster rates.

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