Impact Analysis of the Walnut Creek Intensive Groundwater Use Control Area.

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EXECUTIVE SUMMARY

In 1992, an intensive groundwater-use control area (IGUCA), including portions of Barton, Rush and Ness Counties, was established in the Walnut Creek Valley in central Kansas. This IGUCA was instituted to address streamflow depletions resulting from excessive withdrawals of groundwater. The Walnut Creek IGUCA stopped the authorization of new water rights and cut back groundwater withdrawals by existing water right holders. The purpose of this research is to provide policy makers, producers, and other stakeholders with a quantitative analysis of the economic impacts related to the restrictions on groundwater usage associated with the Walnut Creek IGUCA.

Impact Analysis for Planning (IMPLAN) software was used to provide the *ex-anti* (before the fact) estimate of secondary economic impacts to the regional economy, based on an estimate of direct economic impacts to irrigated agriculture. Two *ex-anti* estimates of direct impacts, based on average values, were provided, both of which were higher than the estimated *ex-post* (after the fact, or observed) direct impact. This suggests that the use of regional average budgets and crop mixes may overestimate the direct economic impacts and supports the idea that if producers choose to convert irrigated crop production to nonirrigated they may convert their least profitable irrigated cropland.

The evidence suggests that producers were able to mitigate the initial economic losses by maintaining/expanding the production of higher valued crops such as corn and alfalfa and by adopting more efficient irrigation technologies and practices. It is hypothesized that the ‘certainty’ of water use restrictions, prescribed by the IGUCA allowed the economic impacts to diminish. The fore-knowledge that water use would be restricted into the foreseeable future allowed producers to develop long-run strategies to mitigate economic damages. This research does not suggest that short-run unexpected interruptions in the irrigation water supply, such as are being experienced in several areas that rely on surface water, will see the economic impacts diminish over time.

The Walnut Creek IGUCA gave producers a 5-year allocation period. It can be hypothesized that this feature gave producers the needed flexibility to better manage the available water supply, making better use of natural precipitation. Additionally, the IGUCA allowed the marketing or transfer of water right allocations between users. This ‘Cap and Trade’ policy option was designed to facilitate the most profitable use of irrigation water. Additional research is needed to identify the pros and cons of both the 5-year allocation period and the ‘Cap and Trade’ features of the IGUCA.

The overall production conditions prevailing in Kansas are similar to those in the neighboring Ogallala states and other semi-arid regions in the West. All of this suggests that our results should be informative for policy makers in other states in the High Plains region and somewhat beyond. A portion of the micro-level (farm level) econometric method used in this study is only feasible in Kansas due to data availability. The WRIS database on water-use is a unique outcome of Kansas water law, which (unlike other Ogallala states) requires all water-right holders to annually report the data used in this analysis. Analyzing the Walnut Creek IGUCA provides an opportunity for community leaders, researchers, and market participants to gain insights into the impact that mandated water use restrictions have on the water resource as well as the local economy.

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INTRODUCTION

For the majority of the 20th century, federal and state water policies in the western United States were aimed at encouraging settlement and developing surface water and groundwater natural resources for use by agriculture. As an example, the Desert Land Act in 1877 discounted the price of a full 640 acre-section of land to settlers on the Great Plains who would irrigate their land (Opie, 2000). These societal goals were extremely successful. Today, approximately 43 million acres of agricultural land are irrigated in the West. These lands produced 72% of crop sales on only 27% of the total harvested crop acreage. Irrigated agriculture currently consumes approximately 90% of the freshwater resources in the West (Gollehon and Quinby, 2000).

As we move into the 21st century, societal goals for our water resources are gradually changing. Public concerns over aquifer decline rates, diminishing streamflow, decreasing wildlife populations, the desire for more water-oriented recreational facilities, the water needs of an expanding industrial sector, and increased population concentration call into question the current allocation of water resources. With increasing frequency, policy makers are asked to decide how to equitably transfer water rights from the agricultural sector to competing sectors. When these situations occur, policy makers, agricultural producers, and other stakeholders are concerned about the likely negative economic impacts that the agricultural community will incur as water resources are shifted away from the production of irrigated crops, the cost of the policy, and the benefits to the water resource. Unfortunately, there is little economic literature and less empirical data that is capable of providing guidance on the likely impacts.

In 1992, an Intensive Groundwater-Use Control Area (IGUCA), including portions of Barton, Rush and Ness Counties, was established in the Walnut Creek Valley in central Kansas (Figure 1). This IGUCA was instituted to address streamflow depletions resulting from excessive withdrawals of groundwater. The Walnut Creek IGUCA stopped the authorization of new water rights and cut back groundwater withdrawals by existing water right holders. The purpose of this project is to provide policy makers, producers, and other stakeholders with a quantitative analysis of the economic impacts associated with transferring water resources from agriculture to other uses or for conservation purposes. This will be accomplished by applying both *ex-anti* (beforehand) and *ex-post* (after the fact) case study techniques to the Walnut Creek situation. A portion of the micro-level econometric method used in this study is only feasible in Kansas due to data availability. The Water Rights Information System (WRIS) database on water-use is a unique outcome of Kansas water law, which (unlike other Ogallala states) requires all water-right holders to annually report the data used in this analysis.[1] These data are collected and made available to the public by the Kansas Division of Water Resources.

The *ex-anti* input-output models developed in this research assume that many factors will remain constant. Given fixed sector-to-sector relationships, industrial sectors, workers, and landowners are expected to change in predictable ways to accommodate water conservation schemes. Models of this type estimate the potential size of the adjustments that economies will face rather than the actual outcome of a policy change (ERS, 2004). Input-output analysis can be characterized as a short-run static analysis. The ex-post analysis provides input on what the actual impacts were after economic adjustments. The quasi-experimental control group analysis used in this study can be characterized as a long-run dynamic analysis. According to ERS (2004), both approaches are useful, but each alone provides an incomplete picture of economic

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[1] The WRIS data is available at http://hercules.kgs.ku.edu/geohydro/wimas/index.cfm

effect on rural regions. By combining results from both models, stakeholders will obtain a more complete picture of the economic impacts of water conservation policy.

Background on Cheyenne Bottoms

Cheyenne Bottoms is the largest marsh in the interior of the U.S., and has been officially designated a Wetland of International Importance. The area is considered the most important shorebird migration point in the western hemisphere (Cheyenne Bottoms, 2008). The 19,857-acre Cheyenne Bottoms Wildlife Area is part of a 41,000-acre natural land sink just northeast of Great Bend, Kansas. During the 1940s and1950s, the State of Kansas acquired the land, and constructed dikes to impound water. Canals and dams were built to divert water from the Arkansas River and Wet Walnut Creek into the Cheyenne Bottoms (Kansas Department of Wildlife and Parks, 2008). A lack of continuous flow in the Arkansas River and Walnut Creek makes management of the state land difficult. By 1992, over-appropriation of the regional water resources resulted in Cheyenne Bottoms being completely dry with no water for migratory birds. Kansas Department of Wildlife and Parks (KDWP), which maintains Cheyenne Bottoms, argued that the situation was the result of farmers in the area using more than their entitled share of water for irrigation.

The Walnut Creek IGUCA

Kansas water law, as established in the Kansas Water Appropriation Act and consistent with the rest of the water laws of the western U.S., is based on “first in time, first in right”. When a more senior (earlier) water right is impaired, the owner can ask the Chief Engineer of Kansas Department of Agriculture’s Division of Water Resources (DWR) to provide relief by curtailing the junior (less senior or later) water right withdrawals. One option available to the Chief Engineer to meet these types of needs is to develop a special management plan referred to as an IGUCA. An IGUCA is defined in the Kansas Statutes by the Groundwater Management District Act (Kansas Government, 2008). While IGUCAs provide flexible solutions, when adopted they have the force and effect of law. Recognizing the relationship between stream flow and groundwater pumping, and as a result of the process set forth in the Groundwater Management District Act for establishing an IGUCA, the Chief Engineer created an IGUCA and curtailed groundwater pumping in the Walnut Creek area. The IGUCA order stopped the appropriation of water for new water rights and reduced withdrawals by other water right holders.

Testimony presented at the IGUCA hearing suggested that total average annual aquifer withdrawals were approximately 45,000 acre-feet while the safe yield was 22,700 acre-feet (Pope, 1992). Using the safe yield[2] as a benchmark, the IGUCA left all vested rights at their then-authorized quantities. The IGUCA reduced the annual pumping of all other groundwater water rights, to achieve safe yield in the basin. Surface water rights, including KDWP’s Cheyenne Bottoms water right, were required to implement conservation plans (Pope, 1992).

The IGUCA defined the ‘reasonable’ average annual amount of water needed for irrigation as 12 inches per acre for Barton County, 13 inches per acre for Rush County, and 14 inches per acre for Ness County. In addition to vested water rights, two classes of water rights were defined: senior rights were defined as those with priority dates on or prior to October 1, 1965 and junior rights were defined as those since that date.[3] Senior water rights for irrigation

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[2] A safe yield policy is essentially balancing groundwater pumping with the average annual recharge.

[3] The IGUCA determined the point where the basin became over-appropriated and any water rights after that date would be considered junior and before that time were senior.

had their appropriation reduced to the allocation deemed ‘reasonable’ for the area which was a reduction in appropriated quantity of between 22 percent and 33 percent, depending on their location in the basin. Junior water rights were allocated the remaining portion of the approximate 22,700 acre-feet. This resulted in junior water rights receiving approximately 44 percent of the allocations of senior rights (Barton 5.25 inches per acre; Rush 5.75 inches per acre; and Ness 6.25 inches per acre). Junior rights for irrigation use had their appropriated quantity curtailed by 64 percent to 71 percent, again depending on location. Total irrigated acreage was limited to either the maximum number of acres actually irrigated in any one year from 1985 through 1990 or the maximum acres authorized, whichever was less (Pope, 1992).

To allow producer flexibility, The IGUCA authorized the new allocations to be enforced based on a 5 year average, assuming that water use in any one year could not exceed the original appropriated quantity. The IGUCA allowed producers to carry over a part of the allocation unused in the five year period to the next five year period, not to exceed the maximum annual quantity authorized under the water right and allowed more flexibility on shifting water-use among wells. The carryover amount was limited to the authorized amount of the water right if the unused portion exceeded the authorized amount. Additionally, the IGUCA provided additional flexibility for water right holders to transfer all or a portion of their water right allocations among other allocations for water rights (Pope, 1992).

EX-ANTI IMPLAN ANALYSIS

When irrigation water use is restricted, in all likelihood crop yields will decline and crop revenues will be reduced. Input-output (I-O) analysis is often used to estimate the impacts that policy induced changes in revenue have on regional economies (Lamphear, 2005; Pritchett et al., 2005; Leatherman et al., 2006; Supalla, Buell, and McMullen, 2006; Golden, Peterson, and O’Brien, 2008). Given estimates of direct economic impacts, software such as Impact Analysis for Planning (IMPLAN) estimates endogenous linkages between production, labor and capital income, trade, and household expenditures providing estimated effects on sector output (total sales), value-added (essentially profits), household income, and employment (MIG, 1999). The process captures not only the direct and indirect effects in production, but induced effects, as well. Direct effects represent the initial impacts of an outside shock on a particular sector. Indirect effects refer to the economic impacts on a particular sector’s demands for intermediate goods. Induced effects refer to changes in those demands for goods and services made by households spending their altered income.

I-O model development is often conceptualized as having two components; the descriptive model and the predictive model. The descriptive model contains the social accounts and I-O accounts and describes the transfer of money between industries and institutions (MIG, 1999). The descriptive model is for a specified geographic area for a selected time period. This IMPLAN analysis uses 1992 economic data. The appropriate geographic scope used in the analysis should reflect the researcher’s belief in where the reduction in agricultural output, associated with reduced water-use, impacts the economy. The intent of this analysis is to identify those impacts that affect market participants and households within that area. It is assumed that stakeholders are not concerned with economic impacts that may affect the state or US economy. MIG (1999) suggest the use of the concept of a ‘functional economic area’ to define the study area. This area is semi self-sufficient economic unit that includes the places where people live, work, and shop, and accounts for the locations of buyers and sellers of goods and services important to the analysis. According to Thorvaldson and Prichett (2007), in order to isolate the effects of an economic impact it is desirable to make the study area as small as possible while still including areas necessary to capture all important effects. For this research, the I-O study area includes Barton, Ness, and Rush Counties. Table 1 reports the basic demographic information for the study region. Within the study region there are 155 industries. Table 2 reports economic information on select industries within the study region.

The IMPLAN software generates several types of outputs that describe the economy and can be used to quantify the total economic impact (all of which are broken down into the direct, indirect, and induced effects). 'Total Industry Output' is the total value of industry output for a given time frame (MIG, 1999). It can be loosely interpreted as the value of sales. 'Value Added' consist of four components: 1) employment compensation (wage, salary, and benefits paid by the employers), 2) proprietor income (payments received by self-employed individuals as income), 3) other property income (payments to individuals in the form of rents), and 4) indirect business taxes (basically all taxes with the exception of income tax). IMPLAN also generates sector 'Employment' impacts. A final note on economic impacts; while total industry output, value-added, and employment impacts are reported, the reader is cautioned that the impacts are not additive. The wages associated with any employment change are included in the estimated value-added, which is itself a portion of the total industry output.

The predictive model estimates the economic impacts associated with a given economic shock. Purchases for final use (final demand), for an industry, drive an I-O model. Changes in final demand represent a direct economic impact to the affected industry. 'Direct effects' are the changes in the industries to which the final demand change was made (MIG, 1999). For our case, the direct impacts are those that directly impact the producer's revenues and impact the grain and oil seed farming sector. Accurately identifying and quantifying the direct economic impact is critical to I-O analysis. The researcher defines the magnitude of the direct economic impact and typically, IMPLAN then estimates the indirect and induced impacts. If the direct impacts are erroneous then the indirect and induced impacts also will be incorrect. When water resources are shifted from agricultural production, a variety of economic impacts may occur. Reduced revenues from irrigated crop production will negatively impact the community through both backwards and forwards industry linkage. In most cases, the lost revenues from irrigated crop production will be offset, to some extent, by the increased revenues generated from dryland crop production.

In all likelihood, an industry that experiences a direct economic impact, purchases goods and services from other industries which may indirectly experience economic impacts. 'Indirect effects' are the changes in inter-industry purchases as they respond to the new demands of the directly affected industries (MIG, 1999). When irrigated cropland is retired, the demand for goods and services will diminish. Major inputs for agricultural production (equipment, replacement parts, fuel, seed, fertilizer, herbicides, and insecticides) are purchased from local suppliers. The reduction in demand experienced by these local suppliers is referred to as the first-round indirect impacts. The firms that experience first-round indirect impacts will in-turn reduce their demand for goods and services which will create subsequent rounds of indirect impacts. As the direct and indirect economic impacts ripple through the economy household consumer income may be affected. 'Induced effects' typically reflect changes in spending from households as income increases or decreases due to the changes in industry production (MIG, 1999), resulting from the direct and indirect impacts. Indirect and induced effects are often referenced in the literature as secondary impacts and/or third party costs.

Typically, a researcher defines the magnitude of a direct impact to industry output and the sector which is impacted. IMPLAN then uses the sector's production function to define the magnitude of the indirect impact and the distribution of the indirect impact across the supply chain. During the IGUCA process, interested parties provided testimony as to the likely impacts of restricting irrigation water use. Portions of these testimonies were reproduced in Pope (1992). Pope (1992) reports that "the potential loss in commodity sales under the assumption that no irrigation is permitted in that portion of the IGUCA in Rush and Barton Counties is $6.32 million".[4] At the time, concern was expressed that the irrigated land that was converted to nonirrigated production would be fallowed every other year, supposedly raising the expected economic impact.

It is unlikely that all the irrigated land would be converted to nonirrigated production. First, we assume that 12,000 acres of irrigated corn, sorghum, soybeans, and wheat would be converted to nonirrigated production. Applying the average crop budgets reported in Table 3 and Table 4 and the average crop mix reported in Table 5, and assuming that the irrigated land that was converted to nonirrigated production would be fallowed every other year, leads to an alternative estimate of $3.54 million in lost revenue. This estimate of the direct impact on industry output can be broken down into an impact of $3.12 million on the feed grain sector and $0.42 million in the oil seed sector.

Estimating the indirect effects of a decline in agricultural production revenue presents a number of analytic challenges. If we simply pull the value of production from the regional economy, the model will calculate the number of jobs associated with this value of revenue and permanently remove both the production and jobs. This overstates the impact because it implies no alternative use for the land and labor. To illustrate, we report the impacts associated with the estimated $3.54 million reduction in feed grains and oil seed crops revenues in Table 6. There, we observe a significant impact to the agricultural sector. This is because the total value of production and the associated labor is assumed to be permanently lost. While the income is, in fact, lost, the labor will more than likely adjust. Most of the affected producers remained in business and continued production, albeit producing a reduced level of output. A better approach, in our view, is to consider the effect to household income, an impact that did occur.

The practical effect of a reduction in production revenue will be a reduction in household consumption by producers and their hired workers. Without compensating payments, these individuals have no choice but to forgo the purchase of an amount to household goods and services. From the information in Tables 3 and 4 and applying assumptions regarding the labor content of various input categories, we estimate that total household income declined by $1,520, 614. Applying this reduction in household spending to a middle income household expenditure pattern yields the regional economic impacts reported in Table 7.

When modeling change in household consumption, the entire impact is considered an induced effect. Thus, we report only total impacts. We first note that the scale and distribution of impacts across the two scenarios is quite different, with considerably less impact accruing to the agriculture sector. Total regional output was projected to decline by a little less than $1.1 million annually. This amount of economic activity is closely tied to about 33 jobs spread throughout the economy. These are average jobs without consideration of whether they are full- or part-time jobs, and the job loss is a one-time reduction. Finally, after we add the initial loss of income back, total income in the region was projected to have decline by about $2.2 million annually.

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[4] This was based on a report from R. Stukenohltz titled "The Economic Impact of Irrigation Water for Crop Production in Rush and Barton Counties, Kansas. Effective Water Loss in Rush and Barton Counties."

EX-POST QUASI-EXPERIMENTAL CONTROL GROUP ANALYSIS

Introduction

This portion of the research relies heavily on the quasi-experimental control group analysis method. This method defines a socioeconomic parameter of interest, a target area, a control area, and a treatment. Preferably, the only difference between the target area and the control area is that the target area received the treatment and the control area did not receive the treatment. For our case, the treatment is the implementation of the IGUCA, the target area is the Wet Walnut Creek sub-basin (the portions of Barton, Ness, and Rush Counties within the IGUCA boundary), the control area is comprised of surrounding counties (which will be discussed in greater detail later) and the socioeconomic parameters of interest are metrics such as population, employment, water use, irrigation technology, crop mix, irrigated acreage, land values etc. If the socioeconomic parameters in the target and control areas are comparable (magnitude and growth pattern) before the treatment occurs, then any statistically significant difference in the socioeconomic parameters of interest after the treatment occurs represents the effect of the treatment. As an example, if the target area and control area had comparable irrigated acreage and growth in irrigated acreage before the IGUCA was implemented, and the target area had statistically fewer acres than the control area after the IGUCA was implemented then it is assumed that the IGUCA caused a reduction in the number of irrigated acres in the target area.

A strong association between the target and control counties simplifies the statistical modeling by comparing the temporal processes in a similar framework. By minimizing the effects of other factors, the effects of the IGUCA should be easier to identify. The benefits of this approach are its intuitive appeal, transparency, and the fact that it is less dependent on assumptions regarding functional forms of structural models and reduced-form relationships. Since the target and control areas are similar, the use of a linear model to control for potentially convoluting factors should give a good approximation (ERS, 2004).

The quasi-experimental control group analysis has been used extensively in economic/impact analysis (ERS, 2004; Bohm and Lind, 1993; Reed and Rogers, 2003; Eklund, Jawa, and Rajala, 1999; Huff et al., 1985). Similar to quasi-experimental control group analysis, Supalla (2006) suggests that employment and population effects (of water policy) can be best determined by looking at rural areas that increased agricultural acreage and assume that the loss of irrigated acres will have a comparable negative impact.

The Control Group

Developing an appropriate control group is at the heart of quasi-experimental control group analysis (ERS, 2004). The use of control group analysis relies on two major assumptions. First, that there are counties outside the target area that are similar to the target area, and second, that those counties can serve as a counter-factual for what would have happened in the target area had there been no IGUCA. The similarity between the control group and the target group can be based on spatial distances, by a comparison of one or two key characteristics, or by using a statistical measure of similarity, such as a propensity score or the Mahalanobis distance metric (ERS, 2004). While no two areas are exactly the same, the Mahalanobis distance metric is often used in control group analysis (Isserman and Rephann, 1995; and ERS, 2004) and is applied in this research to match areas with similar characteristics.

The Mahalanobis distance function takes into account the covariance among the variables in calculating an ‘abstract’ distance measure. With this measure, problems of scale and correlation are minimized. Consider a target area that has multiple socio-economic characteristics (population, population growth rate, unemployment level, proportion of cropland that is irrigates, property tax receipts, etc). Let T represent this vector of socio-economic characteristics for the target group, T_i represent the i^{th} characteristic, and $\overline{T}$ represent the mean of the vector of socio-economic characteristics. Now consider a possible control group. Let C represent this vector of socio-economic characteristics, C_i represent the i^{th} characteristic, and $\overline{C}$ represent the mean of the vector of socio-economic characteristics. The covariance between T and C ($COV_{T,C}$) is a measure of how the two vectors change together. Given these definitions, the Mahalanobis distance (MD_C) from vector C to vector T can be defined as

$$(1) \qquad MD_C = \sqrt{(C-T)'COV_{T,C}^{-1}(C-T)} \, .$$

The smaller the Mahalanobis distance metric is, the more similar vector C is to vector T. Given the vector $\overline{T}$, the Mahalanobis distance metric can be calculated for each county in the target group, each county that is a possibility for the control group, and for the aggregated control group.

The Mahalanobis distance metric for each county in the target group reflects how similar each target county is to the mean of all target group counties. Possible control counties were selected based on the criteria that their individual Mahalanobis distance from the target group’s mean vector was less than or equal to the maximum Mahalanobis distance from any of the individual target counties to the target group’s mean vector. This process insures that the individual counties within the control group are similar to the individual counties within the target group. Given the possible control counties that met the previously described criteria, the control group was selected based on the composition that minimized the Mahalanobis distance from the target group mean to the control group mean. This process insures that the mean vector for the control group is similar to the mean vector for the target group. Based on this procedure Edwards, Kiowa, Pawnee, Pratt, Rice, and Stafford Counties were designated as the control group. In addition, the portions of Barton, Ness, and Rush Counties outside the IGUCA boundary are included in the control group.

The Mahalanobis distance metric provides a statistical measure of similarity. The measure is based on a vector of socio-economic characteristics. The socio-economic characteristics used in this study to calculate the Mahalanobis distance metric include population, population growth rate, employment in the agriculture sector, per capita personal income, average wage per job, unemployment rate, nominal taxable retail sales, total annual payroll, total property tax, annual precipitation, proportion of cropland in the conservation reserve program, and the proportion of cropland that is irrigated. The characteristics are based on 1991 data obtained from the U. S. Census Bureau’s County Business Pattern, the United States Department of Agriculture’s National Agricultural Statistic Service, the United States Department of Agriculture’s Economic Research Service, the United States Department of Agriculture’s Farm Service Agency, and the Kansas Weather Library. The resulting Mahalanobis distance metric implicitly assumes that these characteristics define similarity. A different vector of socio-economic characteristics would lead to different Mahalanobis distance metrics and possibly a different specification for the control group.

The Conceptual Quasi-Experimental Model

Broder, Taylor, and McNamara (1992) define a time-series linear regression discontinuity model that is suitable for this analysis. The model is estimated using binary variables (dummy variables) to test trends associated with a treatment for significant intercept shifts or discontinuities. Under the assumption that the IGUCA caused a change in the socio-economic variable of interest ($SV_{T,i}$), the statistical model for the target area can be defined as

$$(2) \qquad SV_{T,i,t} = \beta_0 + \beta_1 D1_t + \beta_2 D2_t + \sum_{j=3}^{n} \beta_j X_{j,t} \,,$$

where *i* indexes the socio-economic variable, *t* indexes time, *X* is a vector of explanatory variables that impact the socio-economic variable other than the IGUCA, *D1* and *D2* are binary variable that takes the value of either zero or one for all *t*. When appropriate, this model will be used to focus specifically on the target group.

Similarly, the statistical model for the control area can be defined as

$$(3) \qquad SV_{C,i,t} = \beta_0 + \sum_{j=1}^{n} \beta_j X_{j,t} \,.$$

The model used in this analysis, for comparing the target and control group, is defined by subtracting the target area model from the control area model

$$(4) \qquad SV_{C,i,t} - SV_{T,i,t} = \Delta SV_{i,t} = \lambda_0 + \lambda_1 D1_t + \lambda_2 D2_t + \sum_{j=1}^{n} \lambda_j \Delta X_{j,t} \,,$$

where Δ designates the difference in the variables value between the control and target area.[5]

Some of the effects of reducing groundwater use may be evident quickly while other effects may not be apparent for some time. Additionally, it has been hypothesized that many of the negative impacts may diminish over time (Supalla, Buell, and McMullen, 2006; Leatherman et al., 2006). To capture both the short-run and long-run effects, the model incorporates two binary variables. *D1* will take a value of zero for *t* greater than 1991 and less than 1996 and a value of one otherwise. This specification will capture the short-run impacts (the 3 years following the implementation of the IGUCA). *D2* will take a value of zero for *t* less than or equal to1995 and a value of one otherwise. This specification will capture the long-run impacts. If the parameter estimates for either λ_1 or λ_2 is positive and statistically significant then the interpretation is that the implementation of the IGUCA statistically caused a reduction in the socio-economic variable in the target area for the time period considered.

In the following sections, models for each socio-economic variable of interest will be developed and the results reported and discussed. In most cases, data from the target and control areas will be graphed to provide a visual depiction of the data being discussed. Making direct comparisons of socio-economic variable across the target and control area is problematic. While the data are statistically similar the magnitude will not be identical. Indexed values will be used

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[5] Given the definition in Equation 4, a negative impact to the Target area will be reflected as a positive parameter estimate in the regression model results.

to make relative comparisons. When applied to a time series, indexed values are obtained by dividing each annual value by the starting value. When multiplied by 100, an indexed value represents the percent of staring values that occurs in each year.

Impacts on Irrigated Acreage and Water Use

Data from the WRIS for the years 1985 through 2005 were used in this analysis. Each irrigator is required to report his annual water use, irrigated acreage, crop selection, and irrigation technology into the WRIS system. These data were aggregated based on the target and control group designation. The WRIS system identifies those points of diversion located within the IGUCA boundaries. The Walnut Creek IGUCA included portions of Barton, Rush and Ness Counties but not the entire counties. As such, those points of diversion located in Barton, Rush and Ness Counties outside the IGUCA boundaries are included in the aggregation of the control group.

Figures 2 thru Figure 4 illustrate the indexed time trends for total groundwater use, irrigated acres, and average water use per irrigated acre, respectively. Visually, it appears that there was a short-run and long-run decline in total water use, average water use per acre, and irrigated acreage after the implementation of the IGUCA. For all variables, the short-run reductions were larger than the long-run, which is somewhat surprising, for irrigated acreage, because of the higher than average rainfall in 1992 and 1993 as illustrated in Figure 5.

The econometric model for the difference in the indexed values of total water use ΔTWU_t can be specified as

$$(5) \qquad \Delta TWU_t = \lambda_0 + \lambda_1 D1_t + \lambda_2 D2_t \,.$$

The model results are reported in Table 8. These results suggest that the IGUCA resulted in a statistically significant short-run and a statistically significant long-run reduction in total water use. The short-run impact was greater than the long-run reduction in total water use. This may be due to producers reacting to the IGUCA 5-year allocation period in a very conservative manner during the short-run.

The econometric model for the difference in the indexed values of water use per acre ΔWUA_t can be specified as

$$(6) \qquad \Delta WUA_t = \lambda_0 + \lambda_1 D1_t + \lambda_2 D2_t + \lambda_3 \Delta AP_t \,.$$

Golden and Peterson (2006) suggest that annual precipitation (*AP*) has a significant impact on water use per acre and has been included as an explanatory variable in this model. The model results are reported in Table 9. These results suggest that the IGUCA resulted in a statistically significant short-run and a statistically significant long-run reduction in water use per acre. The short-run impact was greater than the long-run reduction. This may be due to producers 'learning-by doing' and developing strategies that require less water. It is interesting to note that the difference in precipitation did not prove to be statistically significant. This may be because the Mahalanobis distance metric included annual precipitation as one of the variables which defined similar regions.

The econometric model for the difference in the indexed values of total irrigated acreage ΔTIA_t can be specified as

$$(7) \qquad \Delta TIA_t = \lambda_0 + \lambda_1 D1_t + \lambda_2 D2_t \, .$$

The model results are reported in Table 10. These results suggest that the IGUCA resulted in a statistically significant short-run and a statistically significant long-run reduction in annual irrigated acreage. The short-run impact was greater than the long-run reduction in total irrigated acreage. This may be due to producers reacting to the IGUCA 5-year allocation period in a very conservative manner in the short-run. It should be noted that this does not imply a permanent reduction in the number of acreage that could be irrigated within the IGUCA boundaries. Since the IGUCA allowed a 5-year allocation period it is possible that producers would choose a rotation scheme that incorporated dryland production for a portion of the 5-year period. Additionally, during the period immediately preceding the IGUCA, irrigated acreage increased by approximately 20%, which is similar in magnitude to the long-run reduction.

Impacts on Revenue from Irrigated Crop Production

As reported in the previous section, the Walnut Creek IGUCA restricted total water use, which resulted in a short-run reduction in irrigated acreage, and a long-run reduction in per-acre water use. Both factors would be expected to reduce revenues from irrigated crop production. Data on irrigated crop acreage from WRIS, and crop prices and yields from the National Agriculture Statistic Service (NASS) were used to construct a time series of revenues for both the Target and Control areas. These data are illustrated in Figure 6.

The econometric model for the difference in the indexed values of total irrigated crop revenue ΔTIR_t can be specified as

$$(8) \qquad \Delta TIR_t = \lambda_0 + \lambda_1 D1_t + \lambda_2 D2_t \, .$$

The model results are reported in Table 11. These results suggest that the IGUCA resulted in a statistically significant short-run and a statistically insignificant long-run reduction in annual irrigated crop revenue. The parameter estimate for the short-run impact was greater than the long-run. While the long-run parameter estimate reflects a negative impact, it is not statistically different from zero. The short-run parameter estimate implies a short run reduction in revenues generated from irrigated cropland of approximately $2.5 million. As reflected in Figure 3 and Table 10, the IGUCA resulted in a statistically significant short-run and a statistically significant long-run reduction in annual irrigated acreage. It is possible that idled irrigated acres generated nonirrigated crop revenues. Due to the uncertainty in crop rotation, as noted in Pope (1992), possible nonirrigated crop revenues generated from previously irrigated cropland were not included in this analysis. Had they been included, both the short-run and long-run estimated impacts to crop revenue would be reduced.

When irrigation water use is restricted, crop production becomes more dependent on rainfall which may increase yield variability or production risk. An increase in production risk would be expected to increase the risk or variability in revenue and profits. The increased variability in revenues can be observed in Figure 6. The coefficient of variation (CV) is often used to compare the relative risk between two groups. After the implementation of the IGUCA the Target group had a revenue CV of 28% while the Control group had a revenue CV of 14%. The implication is that while the IGUCA may not have decreased mean revenues in the long-run, it may have increased the risk associated with irrigated crop production. Additional research is needed to verify this finding.

Producer's Reaction to Water Use Restrictions

When water-use is restricted, producers of irrigated crops develop and implement strategies to mitigate potential revenue losses (Amossom et al., 2009). Buller (1988) and Wu, Bernardo, and Mapp (1996) suggest that producers will change crop mix by shifting from high water-use crops, such as corn, into crops with lower consumptive use. Taylor and Young (1995), BBC Research & Consulting et al. (1996) suggest that higher valued, possibly more water intensive crops will remain in production and lower valued crops on marginal land will be the first to be retired. Burness and Brill (2001) and Williams et al. (1996) suggest that in such cases, producers will adopt more efficient irrigation technology. Harris and Mapp (1986) and Klocke (2004) suggest that computer-aided technologies and improved irrigation scheduling might provide a solution. Schlegel, Stone, and Dumler (2005) report significant water savings with the adoption of limited irrigation management strategy.

Both alfalfa and corn are considered highly profitable and high water use crops. As a result it was of interest to analyze how the acreage devoted to these crops varied over time. Data on irrigated crop acreage from WRIS were used to construct a time series for both the Target and Control areas. These data are illustrated in Figure 7 and Figure 8 for alfalfa and corn respectively.

The econometric models for the difference in the indexed values irrigated crop acreage ΔIA_t can be specified as

$$\Delta IA_t = \lambda_0 + \lambda_1 D1_t + \lambda_2 D2_t \,. \tag{9}$$

The model results are reported in Table 12 and Table 13 for alfalfa and corn respectively. These results suggest that the IGUCA resulted in a statistically significant long-run increase in irrigated alfalfa acreage, but no statistically significant change was observed in irrigated corn acreage. While not reported, a reduction in the irrigated acreage devoted to wheat and grain sorghum was observed. These findings are consistent with those suggested by Taylor and Young (1995), and BBC Research & Consulting et al. (1996).

Figure 9 illustrates the indexed time trends for acres irrigated with center pivot technology. Data on irrigation technology from WRIS were used to construct these series. The econometric models for the difference in the indexed values of acres irrigated with center pivot technology ΔCPT_t can be specified as

$$\Delta CPT_t = \lambda_0 + \lambda_1 D1_t + \lambda_2 D2_t \,. \tag{10}$$

Table 14 reports the regression results. These results suggest that the IGUCA resulted in a statistically significant long-run increase in acres irrigated with center pivot technology. While not reported, a similar analysis for acres irrigated with flood technology suggests that the majority of the short-run total irrigated acreage reduction (Figure 3) came from parcels of land irrigated with flood technology. These findings are consistent with those suggested by Burness and Brill (2001) and Williams et al. (1996). Referencing back to Figure 4 and Table 9, a statistically significant short-run and a statistically significant long-run reduction in water use per acre was observed. This suggests that producers reduced water use on high water use crops such as corn and alfalfa without experiencing a comparable reduction in revenues. These findings are consistent with those suggested by Schlegel, Stone, and Dumler (2005). It is unclear whether computer-aided technologies and improved irrigation scheduling, as suggested by Harris and Mapp (1986) and Klocke (2004), enabled producers to reduce water consumption as data on these practices are unavailable.

Impacts on Land Values and Property Tax

When irrigated cropland is converted to nonirrigated cropland there may be a change in land values which may in turn impact local property tax revenues. To determine the IGUCA's impact on land prices, this research relied on a model developed by on Tsoodle, Golden, and Featherstone, (2006). This hedonic appraisal technique allows for the unbiased estimation of the value of irrigated cropland based both on the conventional site-specific characteristics of the land as well as hydrological and related characteristics of the water right.

The linear hedonic model for irrigated cropland can be conceptualized as

$$P = \beta_0 + \sum_{i=1}^{n} \beta_i EV_i + \sum_{i=n+1}^{j} \beta_i BV_i \tag{11}$$

where P is the logged per acre price for the land sale, EV is a vector of site-specific explanatory variables, and BV is a vector of binary variables representing the year of the sale. The vector of binary variables quantifies the yearly change in land price and will be used to compare the time path of land prices in the Control and Target areas.

The data in this analysis consists of all 'arms length transaction' sales of irrigated agricultural land in Kansas between 1986 and 2000. The Property Valuation Division (PVD) of the Kansas Department of Revenue (KDR) collected this information and verified by personal contact the fair market nature of the sale. Kansas statutes require any land transaction to be reported to the KDR. The County Appraiser, using a standardized method, collects this data and provides it to KDR on an annual basis. The data contains information on sales location, sales date, the parcels agriculture use types, soil mapping unit contained in the parcel, total acres in the parcel, the agricultural tax value, the tax value of all buildings, topographical codes, utility codes, and access codes. Definitions and descriptions of these codes are contained in KSCAMA Residential/Agricultural Data Collection Course 1-104-2.

Figure 10 illustrates the time trends for binary variables estimated with Equation 11. Given Equation 4 and Equation 11, the econometric models for the difference in binary variables ΔBV_t can be specified as

$$\Delta BV_t = \lambda_0 + \lambda_1 D1_t + \lambda_2 D2_t \,. \tag{12}$$

Table 15 reports the regression results. These results suggest that the IGUCA resulted in no statistically significant short-run or long-run decrease in irrigated cropland values. However, it should be noted that only parcels that were sold as irrigated cropland were in the dataset. While on average there was no difference in observed irrigated land price, this does not imply that some unsold parcels may have experienced a reduction in value or that previously irrigated land that was sold as nonirrigated cropland did not experience a loss.

In 1985, concern over rapidly escalating land prices prompted a shift from fair-market appraisal of agricultural land to use-value appraisal for property tax appraisal purposes in the State of Kansas. These valuations were established for each parcel of land devoted to agricultural use upon the basis of the agricultural income or productivity attributable to the inherent capabilities of such land. In order to stabilize the appraisal process multi-year averages for acreage, revenue, and costs are incorporated into the process. In 1989 and 1999, major changes were made to the appraisal process. In1997, those irrigated parcels within the IGUCA boundaries that were classified as either senior or junior water rights were assessed based on nonirrigated land use values.

County level data from PVD on total agricultural assessed valuations were collected for 1989 through 2005. Figure 11 illustrates the indexed time trends for these valuations. The econometric models for the difference in the indexed values of total agricultural assessed valuations $\Delta TAAV_t$ can be specified as

$$(13) \qquad \Delta TAAV_t = \lambda_0 + \lambda_1 D1_t \,.$$

This model specification includes only one binary variable which takes the value of one for the period 1997 through 2005. Table 16 reports the regression results. These results suggest that the IGUCA may not have resulted in a statistically significant increase in total agricultural assessed valuations. The true impact of the reduction in senior and junior water rights assessments may be masked due to the fact that the Target area PVD was aggregated at the county level as opposed to the IGUCA boundaries, and also may have been impacted by the changes in appraisal process that were previously mentioned.

Impacts on the Natural Resources

The goal of water conservation policy is obviously to conserve water. While the economic impacts of policy are important to all participants, one metric of success is whether or not the policy actually resulted in a reduction in the primary water usage. Since the implementation policy requires the expenditure of taxpayer dollars, the investment of other State resources, and the financial burdens placed on other stakeholders, it is imperative that research be expended to quantify the impacts on the water resources.

Concerns over the lack of continuous streamflow motivated the 1992 Walnut Creek IGUCA. Pope (1992) reported that the combination of declining streamflows and declining groundwater levels indicated that the hydrologic system was out of balance, and that the balance needed to be restored to achieve the goal of sustainability. While this research primarily focuses on the economic impacts associated with the IGUCA, it is nevertheless appropriate to ask the question: Did the IGUCA meet its environmental objectives?

Recognizing the hydraulic connectivity between streamflow and the aquifer, the Walnut Creek IGUCA focused on aquifer recovery as the means to restore streamflow. Pope, (1992) indicated that the aquifer should be allowed to recharge and be maintained in an essentially full state such that total average annual groundwater withdrawals were limited to the long-term sustainable yield. In order to monitor groundwater elevation changes, the Kansas Department of Agriculture's Division of Water Resources (DWR) began monitoring observation wells within the IGUCA's boundaries. Table17 provides the summary statistics on groundwater elevation changes for the observation wells during the period 1993 – 2008. On average, the groundwater elevation has increased during the observation period (conversely the depth to water has decreased). However, what has happened since 1993 may not tell the full story. It is of interest to look at the pre-1993 decline rates. Of the wells monitored by the DWR, within the IGUCA's boundary, six can be matched to historical data sets maintained by the United States Geological Survey (USGS) and suitable for statistical analysis. Figure 12 illustrates the historical data for these six wells.

The annual change in the depth to groundwater is a function of annual temperature and precipitation which influences evaporation and recharge, the time it takes for the recharge to reach the area of saturated thickness, and annual groundwater withdrawals for irrigation. Unfortunately, this research could not identify the annual groundwater withdrawals for the six well in the WRIS system. The econometric model for depth to groundwater (*DTG*) can be specified as

$$(14) \qquad DTG_t = \lambda_0 + \lambda_1 P_t + \lambda_2 P_t^2 + \lambda_3 D1_t$$

where *P* is the annual precipitation and *D*1 is a binary variable that takes the value of one for all years after 1992. The regression results are reported in Table 18. The dependent variable in this model is the depth to groundwater. As a result, the negative parameter estimates on the binary variables indicate that on average the depth to groundwater was less for the period after the IGUCA as compared to the time period before the IGUCA. These results suggest that the IGUCA may have resulted in a statistically significant increase in the aquifer's water table elevation.

Referring to Figure 12, it is important to note that there was a rapid decrease in the depth to water during the 1992 -1994 period. Referring to Figure 5, we note higher than normal precipitation, while referring to Figure 2, we note a large reduction in total groundwater use during the same period. These rapid changes in variables that impact depth to water may influence regression analysis. As such this research concludes, that while the depth to water decreased with certainty, the influence of higher than normal precipitation may be understated and the influence of the IGUCA overstated. The influence of higher than normal precipitation and its relationship to the IGUCA is not well defined. Additional research by qualified hydrologist is needed in this area.

Pope, (1992) reported that streamflow in Walnut Creek declined from 1959 through 1985 based on the gauged flow at the Albert gauging station. Figure 13 illustrates the historical data set for the Albert gauging station.[6] Several factors can impact streamflow including groundwater elevation, precipitation quantity and intensity, soil conservation structures within the watershed, land use and vegetation. Analyzing all factors that impact streamflow (*SF*) goes beyond the scope of this project, and is best conducted by a qualified hydrologist. However, a rather simplistic model can be defined as

$$(15) \qquad SF_t = \lambda_0 + \lambda_1 P_t + \lambda_2 D1_t$$

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[6] The data was obtained from http://waterdata.usgs.gov/nwis/monthly?referred_module=sw&site_no=07141900&por_07141900_7=92617,00060,7,1958-06,2009-03&format=html_table&date_format=YYYY-MM-DD&rdb_compression=file&submitted_form=parameter_selection_list

where P is the annual precipitation and $D1$ is a binary variable that takes the value of one for all years after 1992 and implicitly accounts for all factors not explicitly modeled. The regression results are reported in Table 19. Assuming that all other factors that impact streamflow were similar for the pre- and post-1992 period, these results suggest that the IGUCA resulted in a statistically significant increase in the streamflow.

The evidence suggests that water use restrictions associated with the IGUCA may have allowed the water table elevation in the aquifer to rise, which in turn allowed the streamflow to increase. While this research suggests a statistically significant improvement in groundwater elevations and streamflow associated with the IGUCA, additional research by qualified hydrologists is required to verify the findings.

SUMMARY and CONCLUSIONS

This research relies heavily on the quasi-experimental control group analysis method. This method defines a socioeconomic parameter of interest, a target area, a control area, and a treatment. In this case, the treatment has been defined as the implementation of the IGUCA. Preferably, the only difference between the target area and the control area is that the target area received the treatment and the control area did not receive the treatment. The Mahalanobis distance function was used to define similarity between the target and control group, and ultimately determine which counties were included in the control group. The Mahalanobis distance metric provides a statistical measure of similarity based on a vector of socio-economic characteristics which are based on the researcher's subjective opinion. Given the distance metric the researcher's subjective opinion is used to define the tolerances that define similarity. A different vector of socio-economic characteristics and tolerances could lead different specification for the control group.

Data were gathered from several sources, and, where available, multiple data sets for the same socio-economic variable were obtained. An econometric method which compared the differences in indexed values over time, and employed binary variables to define short-run and long-run were applied. In most cases, the time period analyzed was from 1985 through 2005. Economists have long known that the application of different data sources, econometric techniques, model specifications, and time periods may lead to different conclusions. The results presented in this report were robust when compared to different model specifications and different data sets.

Due to a variety of limitations, most economic studies encounter some hurdles. Specific to this research, the ability to accurately specify and estimate the econometric models depends on the ability to adequately correct for the econometric problems inherent in spatially-linked data. Several socio-economic variables associated with secondary economic impacts (such as on farm employment, farm wages, retail agricultural sales, etc.) were considered. The model results associated with these variables were not robust to variations in model specifications, time period analyzed, or data source and as such are not reported. This is not to say that secondary impacts do not occur. Obviously, if a producer uses less fertilizer the fertilizer dealer will experience reduced revenues.

IMPLAN was used to provide the *ex-anti* estimate of secondary impacts, based on an estimate of direct impacts. Two *ex-anti* estimates of direct impacts, based on average values, were provided, both of which were higher than the estimated *ex-post* direct impact. Many researchers assume that the crops grown on retired irrigated acres have cropping patterns similar to the regional average. Golden et al. (2008), Thorvaldson and Prichett (2007), BBC Research & Consulting et al. (1996), and Norvell and Kluge (2005) applied this technique. However, BOR (1999) suggest that in a willing-seller market, water would be transferred from crop patterns that cost the least, in terms of foregone crop revenue. Thorvaldson and Prichett (2007) suggest that while their study assumed that crops were taken out of production in proportion to the observed crop mix, it was more likely that some crops would be taken out of production in greater proportion than others based on relative profitability. Taylor and Young (1995) and BBC Research & Consulting et al. (1996) suggest that lower valued crops on marginal land will actually be the first to be retired based on crop profitability, soil characteristics, and aquifer profiles. Leatherman et al. (2006) developed a model to predict which acreage would be retired first, based on cropping system profitability. This research suggests that the use of regional average budgets and crop mixes may overestimate the direct economic impacts and supports the idea if producers choose to convert irrigated crop production to nonirrigated they may convert their least profitable irrigated cropland.

I-O impact analysis is a valuable tool for evaluating the economic consequences of policy decisions. The method provides a static snap-shot in time of probable impacts, but does not estimate the dynamic adjustment process. However, implicit in economic theory is the notion that policy implementation influences individual and market behavior creating dynamic reactions. Recognizing this factor, several researchers have applied ad-hoc (best guess for the case at hand) correction factors to conventional I-O impact analysis. Pritchett et al (2005) applied impact analysis to the case of water rights retirement in Colorado. He noted that this type of analysis has limitations; in particular, the analysis does not capture the dynamic adjustments of businesses that pursue new activities in lieu of the business traditionally used to support irrigated cropping. He suggested that despite this limitation, the analysis does provide a basis for policy discussion. Supalla, Buell, and McMullen (2006) applied I-O analysis to various water conservation policy scenarios in Nebraska. Recognizing that rural economies make dynamic adjustments, the authors diminished a portion of the economic impacts in an ad-hoc linear fashion over 10 years. Leatherman et al. (2006) evaluated the proposed CREP program in southwest Kansas with I-O analysis. The research team assumed that people generally are innovative in their response to economic change, and that an economy is never static in the way it responds to change. They suggested that it is likely that the negative impacts associated with the program would in fact diminish over time and developed an ad-hoc non-linear response function. This research is consistent with the notion that direct impacts do in fact diminish over time. For the case of the Walnut Creek IGUCA the direct economic impact diminished even quicker than hypothesized in previous studies.

While the direct economic impact diminished over time, the initial shock was quite severe. It has been suggested that the short-run severity was in-part due to producers over reacting to the perceived magnitude of the water use restrictions and only achieved previous levels of revenue after a period of ‘learning-by doing’. This gives rise to the hypothesis that the short-run magnitude of economic impacts could have been reduced had the IGUCA phased-in the water use restrictions over a period of years. As an example, had the IGUCA implemented 50% of the reduction in year1 and the remaining 50% in year 6, producers would have had a longer period to develop and implement their new management strategies and mitigate some of the short-run impacts.

The evidence suggests that producers were able to mitigate the initial economic losses by maintaining/expanding the production of higher valued crops such as corn and alfalfa and by adopting more efficient irrigation technologies and practices. However, the evidence also suggests that producers were also exposed to more revenue risk as the result of using less water. Additional research on the risk associated with deficit irrigation is needed.

It is hypothesized that the 'certainty' of water use restrictions allowed the economic impacts to diminish. The fore-knowledge that water use would be restricted into the foreseeable future allowed producers to develop long-run strategies to mitigate economic damages. This research does not suggest that short-run unexpected interruptions in the irrigation water supply, such as are being experienced in several areas that rely on surface water, will see the economic impacts diminish over time.

In evaluating the long-run revenue losses associated with the IGUCA, this analysis implicitly assumed that water use could have remained at pre-1992 levels had the IGUCA not been implemented. This may not have been the case. This research did not ask the question – What would have happened if water use was not restricted and the aquifer continued to decline. Testimony presented in Pope (1992) suggests that water shortages due to aquifer depletion were imminent and may have generated revenue losses more severe than the IGUCA. Recent research by Golden et al. (2008) and Amosson et al. (2009) suggest that conservation policies that restrict per-acre water use are less costly to society than those which achieve a comparable reduction in water use by land retirement. This research did not ask the question – What would have happened if Kansas Department of Wildlife and Parks had insisted that their senior water right be protected by retiring irrigated land.

The Walnut Creek IGUCA gave producers a 5-year allocation period. It can be hypothesized that this feature gave producers the needed flexibility to better manage the available water supply, making better use of natural precipitation. Additionally, the IGUCA allowed the marketing or transfer of water right allocations between users. This 'Cap and Trade' policy option could insure that irrigation water is used for the most profitable purposes. Additional research is needed to identify the pros and cons of both the 5-year allocation period and the 'Cap and Trade' features of the IGUCA.

The overall production conditions prevailing in Kansas are similar to those in the neighboring Ogallala states and other semi-arid regions in the West. All of this suggests that our results should be informative for policy makers in other states in the High Plains region and somewhat beyond. A portion of the micro-level econometric method in this study is only feasible in Kansas due to data availability. The WRIS database on water-use is a unique outcome of Kansas water law, which (unlike other Ogallala states) requires all water-right holders to annually report the data used in this analysis. Analyzing the Walnut Creek IGUCA provides an opportunity for community leaders, researchers, and market participants to gain insights into the impact that mandated non-voluntary water use restrictions have on the water resource.

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TABLES

Table 1. Input-Output Study Region: Basic Demographics in 1992

Item	Value
Population	37,000
Households	14,834
Income per Household	$43,169
Total Personal Income*	$640.30
Number of Industries	155
Total Industry Output*	$1,454.19
Total Industry Value Added*	$752.38
Total Industry Employment	24,391

Data Source: 1992 IMPLAN data
*Millions of dollars; expressed in 1992 dollars

Table 2. Input-Output Study Region: Select Industry Economic Demographics in 1992

Industry	Industry Output*	Employment	Value Added*
Meat Packing Plants	$126.27	338	$4.09
Cattle Feedlots	$81.01	515	$31.13
Nonferrous Wire Drawing and Insulating	$60.71	351	$18.09
Wholesale Trade	$58.30	1,031	$43.67
Owner-occupied Dwellings	$54.06	0	$38.73
Pipe Lines, Except Natural Gas	$49.60	69	$41.24
Food Grains	$47.96	710	$30.95
Natural Gas & Crude Petroleum	$38.83	542	$25.28
Electric Services	$38.55	151	$24.30
Banking	$36.52	382	$15.93
Motor Freight Transport and Warehousing	$34.27	478	$17.07
State & Local Government - Education	$32.79	1,811	$32.79
Gas Production and Distribution	$31.20	76	$9.89
Hospitals	$29.92	754	$20.94
Insurance Carriers	$29.66	247	$6.45
Maintenance and Repair Oil and Gas Wells	$29.07	2,445	$23.83
Maintenance and Repair Other Facilities	$29.00	400	$14.77
Automobile Repair and Services	$27.53	271	$7.98
State & Local Government - Non-Education	$27.49	1,368	$27.49
Eating & Drinking	$26.69	1,127	$14.43
Fluid Power Cylinders & Actuators	$25.96	260	$8.51
Doctors and Dentists	$25.81	403	$22.03
Ranch Fed Cattle	$21.59	690	$9.27
New Industrial and Commercial Buildings	$21.04	285	$9.93
Legal Services	$19.35	273	$14.14
Automotive Dealers & Service Stations	$18.33	471	$15.29
New Residential Structures	$17.44	242	$6.62
Feed Grains	$17.03	200	$11.15
Petroleum Refining	$14.29	13	$2.44
Farm Machinery and Equipment	$12.13	117	$3.57
All Other Industries	$371.78	8,371	$200.38
Total Industry Output	$1,454.19	24,391	$752.38

Data Source: 1992 IMPLAN data
*1992$ millions of dollars

Table 3. Nonirrigated Crop Budgets for Central Kansas in 1992

			Crop		
Category	Alfalfa	Corn	Sorghum	Soybeans	Wheat
Data Source*	1992 MF574	1992 MF993	1992 MF575	1992 MF994	1992 MF574
Yield	4	85	55	25	35
Price	$78.20	$2.50	$2.30	$5.75	$3.25
Crop Revenue	$273.70	$212.50	$126.50	$143.75	$113.75
Net Government Payment	$0.00	$14.79	$11.80	$0.00	$19.12
Total Revenue	$273.70	$227.29	$138.30	$143.75	$132.87
Labor	$4.32	$2.40	$1.44	$1.64	$1.36
Seed	$5.20	$23.75	$2.10	$10.00	$6.00
Herbicide	$29.81	$25.23	$22.95	$23.94	$9.77
Fertilizer	$18.85	$21.55	$11.55	$8.25	$9.00
Fuel and Oil	$17.65	$8.80	$8.10	$7.65	$8.20
Fuel and Oil - Pumping	$0.00	$0.00	$0.00	$0.00	$0.00
Equipment Repairs	$26.65	$17.20	$15.70	$16.85	$12.40
Irrigation Equipment Repairs	$0.00	$0.00	$0.00	$0.00	$0.00
Crop Insurance	$0.00	$5.85	$4.20	$3.70	$2.75
Drying	$0.00	$8.50	$5.50	$0.00	$0.00
Crop Consulting	$0.00	$0.00	$0.00	$0.00	$0.00
Miscellaneous	$5.00	$5.00	$5.00	$5.00	$5.00
Interest on Variable Expenses	$3.22	$3.55	$2.30	$2.31	$1.63
Total Variable Cost	$110.70	$121.83	$78.84	$79.34	$56.11
Real Estate Tax	$5.75	$5.25	$5.75	$5.25	$5.75
Interest on Land	$17.03	$15.54	$17.03	$15.54	$17.03
Interest on Equipment	$16.00	$23.39	$20.66	$23.21	$19.70
Interest on Irrigation Equipment	$0.00	$0.00	$0.00	$0.00	$0.00
Insurance on Equipment	$0.46	$0.67	$0.59	$0.66	$0.56
Total Fixed Expenses	$39.24	$44.85	$44.03	$44.66	$43.04
Total Expenses	$149.94	$166.68	$122.87	$124.00	$99.15
Profit	$123.76	$60.61	$15.43	$19.75	$33.72

Data Source: Kansas State University Extension Budgets

Table 4. Irrigated Crop Budgets for Central Kansas in 1992

	Crop				
Category	Alfalfa	Corn	Sorghum	Soybeans	Wheat
Data Source*	1992 MF574	1992 MF574	1992 MF574	1992 MF574	1993 MF574
Yield	6.5	150	85	50	55
Price	$78.20	$2.50	$2.30	$5.75	$3.25
Crop Revenue	$508.30	$375.00	$195.50	$287.50	$178.75
Net Government Payment	$0.00	$27.40	$15.14	$0.00	$28.69
Total Revenue	$508.30	$402.40	$210.64	$287.50	$207.44
Labor	$2.60	$2.52	$1.80	$1.80	$1.80
Seed	$7.80	$33.38	$3.15	$12.50	$10.80
Herbicide	$24.99	$71.73	$25.75	$23.94	$7.57
Fertilizer	$18.40	$32.35	$16.25	$9.20	$15.70
Fuel and Oil	$8.64	$8.36	$7.17	$5.92	$7.31
Fuel and Oil - Pumping	$43.20	$34.80	$17.40	$26.10	$17.40
Equipment Repairs	$21.50	$21.50	$15.80	$15.05	$15.40
Irrigation Equipment Repairs	$7.20	$4.80	$2.40	$3.60	$2.40
Crop Insurance	$0.00	$6.25	$2.95	$5.35	$5.15
Drying	$0.00	$15.00	$8.50	$0.00	$0.00
Crop Consulting	$5.50	$6.00	$5.50	$5.50	$5.00
Miscellaneous	$6.00	$6.00	$6.00	$6.00	$6.00
Interest on Variable Expenses	$4.97	$7.28	$3.38	$3.45	$2.84
Total Variable Cost	$150.80	$249.97	$116.05	$118.41	$97.37
Real Estate Tax	$7.98	$8.01	$8.01	$8.01	$8.01
Interest on Land	$23.63	$23.72	$23.72	$23.72	$23.72
Interest on Equipment	$9.67	$18.29	$15.30	$14.86	$14.86
Interest on Irrigation Equipment	$6.07	$6.07	$6.07	$6.07	$6.07
Insurance on Equipment	$1.21	$0.70	$0.61	$0.60	$0.60
Total Fixed Expenses	$48.56	$56.79	$53.71	$53.26	$53.26
Total Expenses	$199.36	$306.76	$169.76	$171.67	$150.63
Profit	$308.94	$95.64	$40.88	$115.83	$56.81

Data Source: Kansas State University Extension Budgets

Table 5. Crop Mix in the Target Area

Category	Alfalfa	Corn	Sorghum	Soybeans	Wheat
Nonirrigated Crop Mix	4.74%	0.00%	9.65%	0.00%	85.61%
Irrigated Crop Mix	27.94%	33.98%	14.06%	8.63%	15.39%

Data Source: National Agricultural Statistic Service

Table 6. Regional Economic Impacts on Total Industry Output, Employment, and Value Added Due to Revenue Losses from a Decrease in Irrigated Crop Acreage

Industry	Total Output[a]	Total Employment[b]	Total Value Added[a]
Agriculture	-3,632,121	-44	-2,313,724
Mining	-4,608	-0.1	-3,000
Construction	-59,971	-0.9	-30,679
Manufacturing	-69,861	-0.5	-20,429
TCPU[c]	-141,763	-1.6	-74,771
Trade	-100,253	-2	-75,120
FIRE[d]	-95,475	-1.2	-45,387
Services	-47,898	-1.2	-29,888
Government	-371,802	-7.9	-260,821
Total	-4,523,752	-59.3	-2,853,819

Data Source: IMPLAN output

[a] Expressed in 1992 dollars

[b] Expressed in number of workers

[c] TCPU is transportation, communication, and public utilities

[d] FIRE is finance, insurance, and real estate

Table 7. Regional Economic Impacts on Total Industry Output, Employment, and Value Added Due to Decreased Household Spending from a Decline in Irrigated Crop Acreage

Industry	Total Output[a]	Total Employment[b]	Total Value Added[a]
Agriculture	-12,669	-0.2	-5,863
Mining	-5,265	-0.1	-3,427
Construction	-23,256	-0.4	-11,920
Manufacturing	-52,685	-0.2	-10,516
TCPU[c]	-88,126	-0.7	-48,584
Trade	-207,835	-6.9	-147,581
FIRE[d]	-166,838	-1.1	-92,683
Services	-265,237	-6.7	-171,099
Government	-171,372	-3.5	-119,134
Other	-57,092	-13.8	-57,092
Institutions	-38,315	0	0
Initial Income	0	0	-1,520,614
Total	-1,088,690	-33.6	-2,188,513

Data Source: IMPLAN output

[a] Expressed in 1992 dollars

[b] Expressed in number of workers

[c] TCPU is transportation, communication, and public utilities

[d] FIRE is finance, insurance, and real estate

Table 8. Regression Results for the Difference in Total Water Use

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.045
D1	Short-Run Impact	0.600*
D2	Long-Run Impact	0.476*
R^2	Degree of Fit	0.757

* Statistically significant at the 10% level

Table 9. Regression Results for the Difference in Annual Water Use per Acre

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.013
D1	Short-Run Impact	0.412*
D2	Long-Run Impact	0.339*
ΔAP	Change in Annual Precipitation	-0.019
R^2	Degree of Fit	0.712

* Statistically significant at the 10% level

Table 10. Regression Results for the Difference in Irrigated Acres

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.050
D1	Short-Run Impact	0.434*
D2	Long-Run Impact	0.152*
R^2	Degree of Fit	0.594

* Statistically significant at the 10% level

Table 11. Regression Results for the Difference in Irrigated Crop Revenue

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.055
D1	Short-Run Impact	0.490*
D2	Long-Run Impact	0.094
R^2	Degree of Fit	0.571

* Statistically significant at the 10% level

Table 12. Regression Results for the Difference in Irrigated Alfalfa Acreage

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.123
D1	Short-Run Impact	0.256
D2	Long-Run Impact	-1.971*
R^2	Degree of Fit	0.648

* Statistically significant at the 10% level

Table 13. Regression Results for the Difference in Irrigated Corn Acreage

Variable	Description	Parameter Estimate
Intercept	Intercept	0.107
D1	Short-Run Impact	-0.493
D2	Long-Run Impact	-0.119
R^2	Degree of Fit	0.045

* Statistically significant at the 10% level

Table 14. Regression Results for the Difference in Center Pivot Irrigated Acreage

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.050
D1	Short-Run Impact	0.247
D2	Long-Run Impact	-1.794*
R^2	Degree of Fit	0.531

* Statistically significant at the 10% level

Table 15. Regression Results for the Difference in Regression Binary Variables

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.055
D1	Short-Run Impact	-0.004
D2	Long-Run Impact	0.066
R^2	Degree of Fit	0.165

* Statistically significant at the 10% level

Table 16. Regression Results for the Difference in Total Agricultural Assessed Valuations

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.055
D1	Short-Run Impact	0.020
R^2	Degree of Fit	0.118

Table17. Summary Statistics for the Change in Water Table Elevation for 1993 - 2008

County	Number of Wells	Maximum Increase in Elevation	Minimum Increase in Elevation	Average Increase in Elevation	Standard Deviation of Elevation Change
Barton	19	13.75	-0.08	6.72	3.58
Ness	16	11.28	-3.76	1.23	3.65
Rush	20	22.13	1.55	7.78	5.56

The 1993 measurements were made in February and the 2008 measurements were made in October. Only wells that had both 1993 and 2008 data were used in this analysis The spatial location and identifier for the wells used in the analysis for Ness County were: 18 21W 25 AAB, 18 21W 27 CBC, 18 21W 31 CCA, 19 21W 06 BBC, 18 22W 36 ACA, 19 22W 05 DCD, 19 23W 06 AAA, 19 23W 08 CBB, 19 23W 11 BBD, 19 23W 14 DBA, 19 24W 16 DCC, 18 24W 27 ADB, 19 24W 08 DCC, 18 25W 05 AAC, 18 25W 33 BBC, 19 25W 02 DBC. The spatial location and identifier for the wells used in the analysis for Rush County were: 18 16W 08 DCD, 18 16W 15 DAD, 18 16W 20 BAB, 18 16W 23 DCC, 18 16W 23 DCC, 18 17W 14 CCC, 18 17W 21 CBB, 18 17W 21 CCB, 18 17W 23 BCC, 18 17W 27 AAB, 18 17W 28 BCC, 18 18W 27 CCB, 18 18W 34 BBB, 18 19W 18 CDD, 18 19W 19 CCA, 18 19W 23 CCD, 18 19W 36 BAA, 18 20W 16 DDB, 18 20W 19 BDA, 18 20W 21 CAA. The spatial location and identifier for the wells used in the analysis for Barton County were: 19 13W 06 ACB, 19 13W 15 CDB, 19 13W 22 CCB, 18 14W 28 DDC, 18 14W 30 CCA, 18 14W 32 BAC, 18 14W 35 AAA, 19 14W 02 CBB, 19 14W 05 DCB, 19 14W 09 ABA, 19 14W 12 DAA, 19 14W 24 DCB, 18 15W 18 CCC, 18 15W 20 CCC, 18 15W 21 CCD, 18 15W 27 DDC, 18 15W 28 CCB, 18 15W 33 ADA, 18 15W 36 BBA

Table18. Regression Results for the change in Depth to Groundwater

USGS Well Number	County	Intercept	P	P^2	D1	N	R^2
382506098470501	Barton	15.180*	0.179	0.000	-2.547*	27	0.385
382601098550102	Barton	19.047	-0.134	0.007	-7.067*	18	0.487
382756099033302	Rush	18.033*	0.218	0.008	-12.787*	18	0.719
382822099104601	Rush	63.779*	-3.017*	0.076*	-13.215*	23	0.804
382447099534801	Ness	19.688*	0.073	0	-2.874*	27	0.506
382749099352001	Ness	30.452*	-0.017	-0.002	-2.639*	27	0.659

Table 19. Regression Results for the Change in Streamflow

Variable	Description	Parameter Estimate
Intercept	Intercept	-859.580*
P	Precipitation	13.962*
D1	Impact	240.454*
R^2	Degree of Fit	0.689

* Statistically significant at the 10% level

FIGURES

Figure 1. Map of the Wet Walnut Creek Area

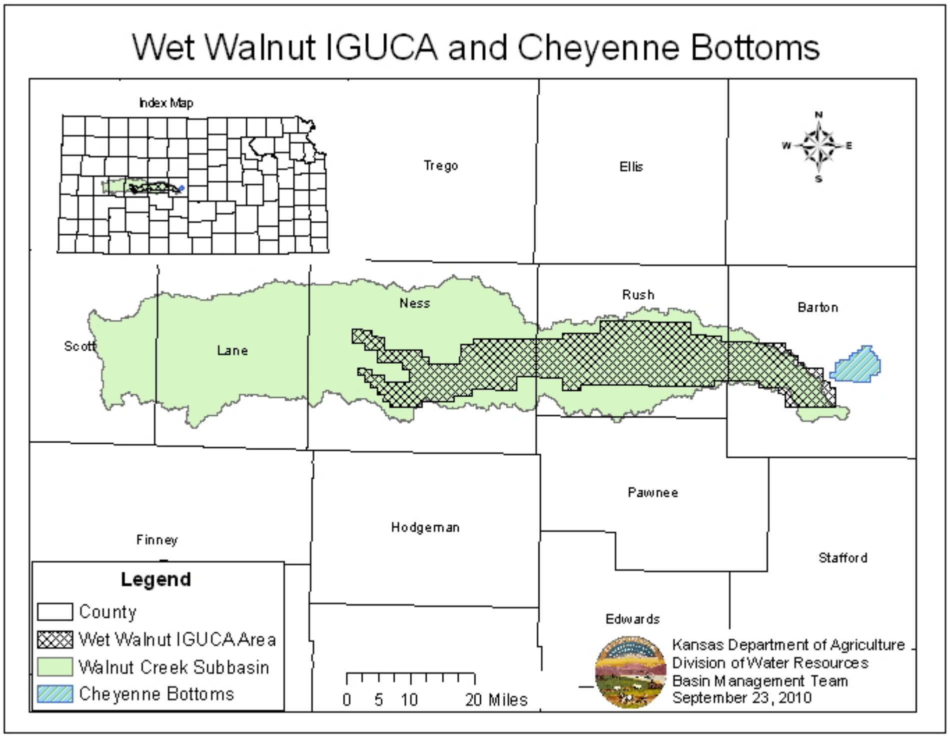


Figure 2. Time Series Comparison of the Indexed Values of Total Groundwater Use

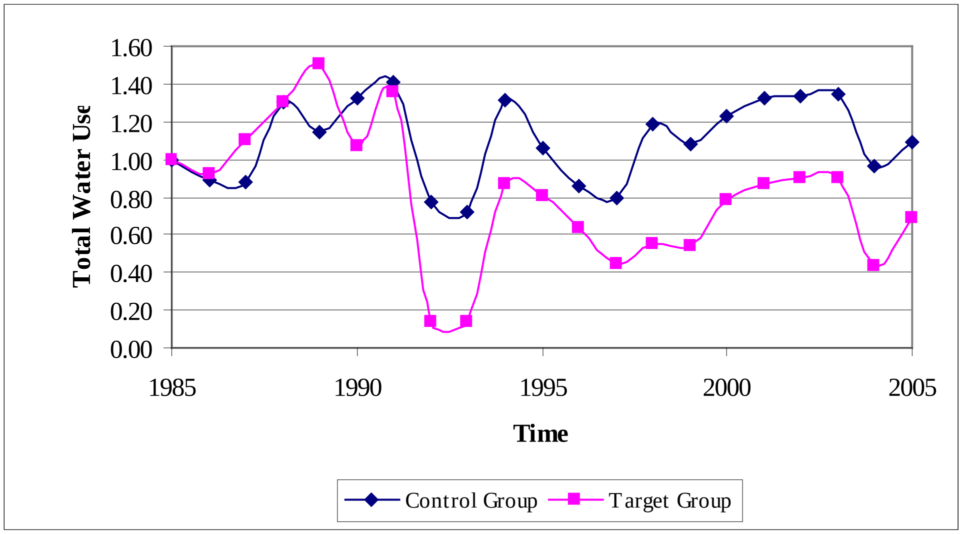


Figure 3. Time Series Comparison of the Indexed Values of Irrigated Acreage

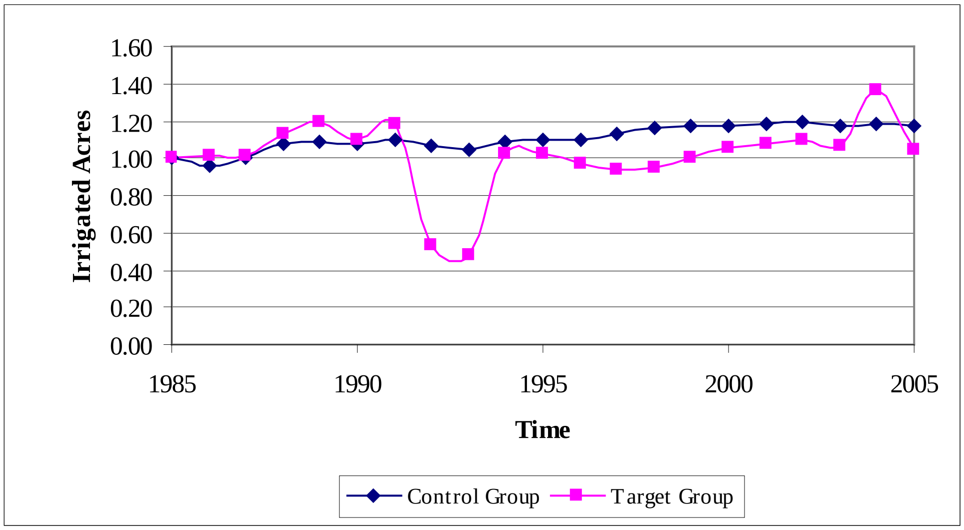


Figure 4. Time Series Comparison of the Indexed Values of Water Use per Acre

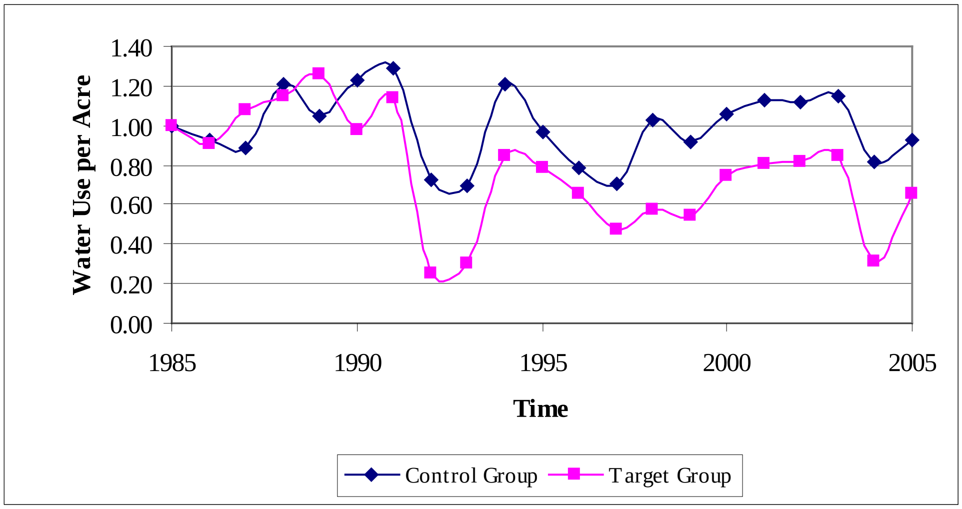
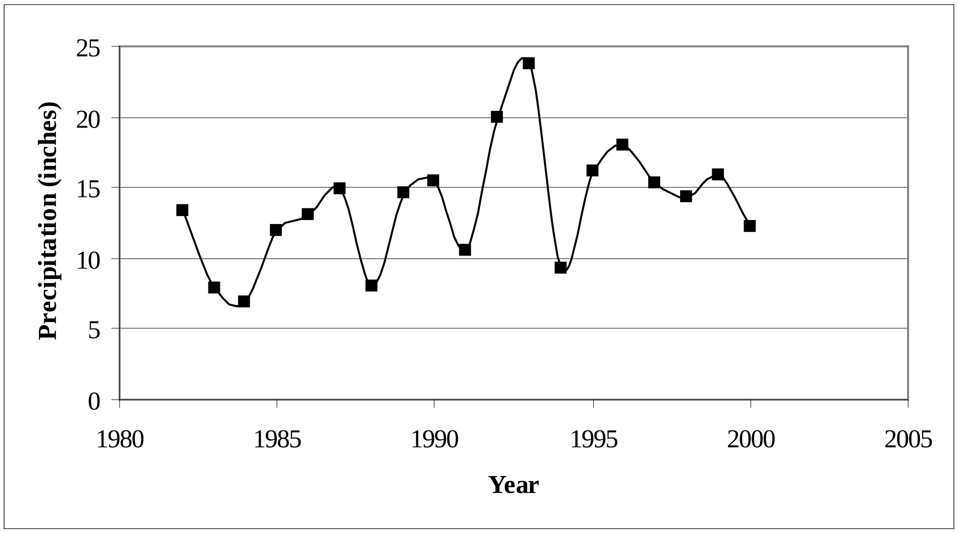


Figure 5. Time Series Target Area Summer Time Precipitation



Data Source: Kansas Weather Library. The average is 13.8 inches.
Summer time is defined as May through August

Figure 6. Time Series Comparison of the Indexed Values of Irrigated Crop Revenue

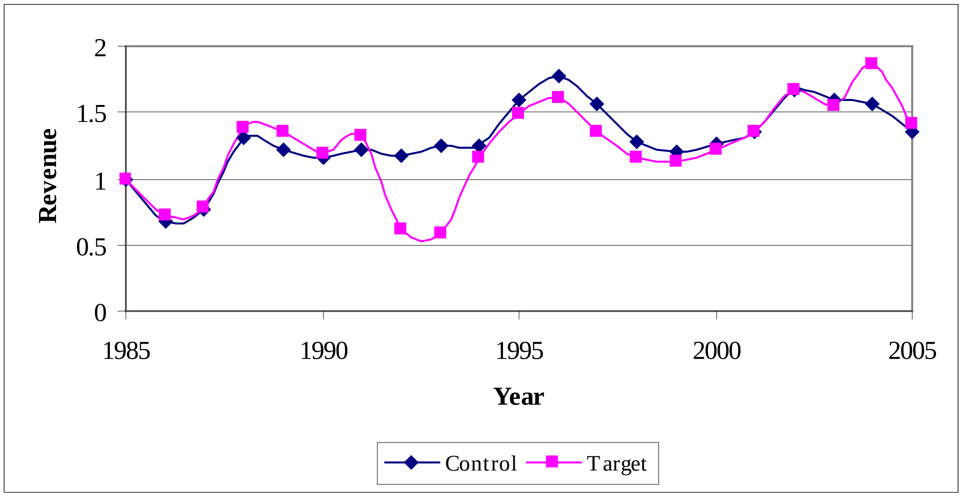


Figure 7. Time Series Comparison of the Indexed Values of Irrigated Alfalfa Acreage

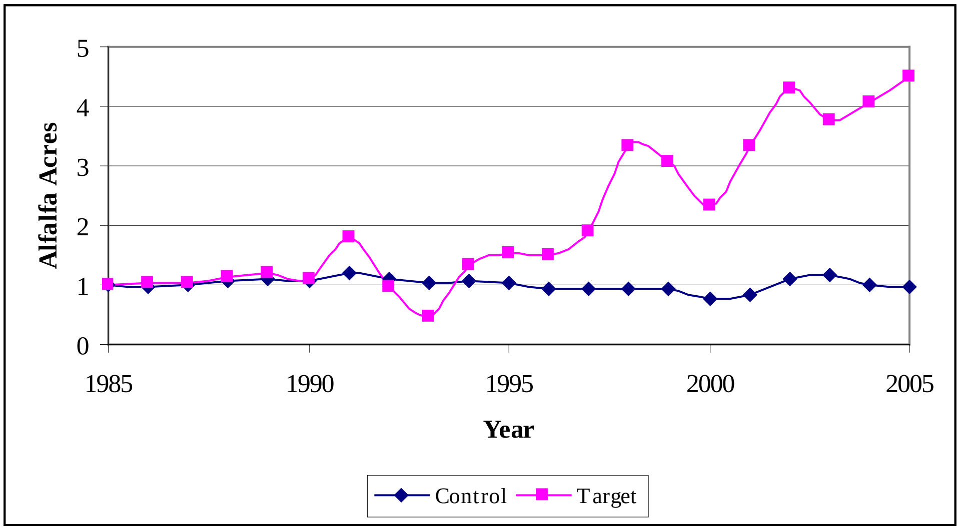


Figure 8. Time Series Comparison of the Indexed Values of Irrigated Corn Acreage

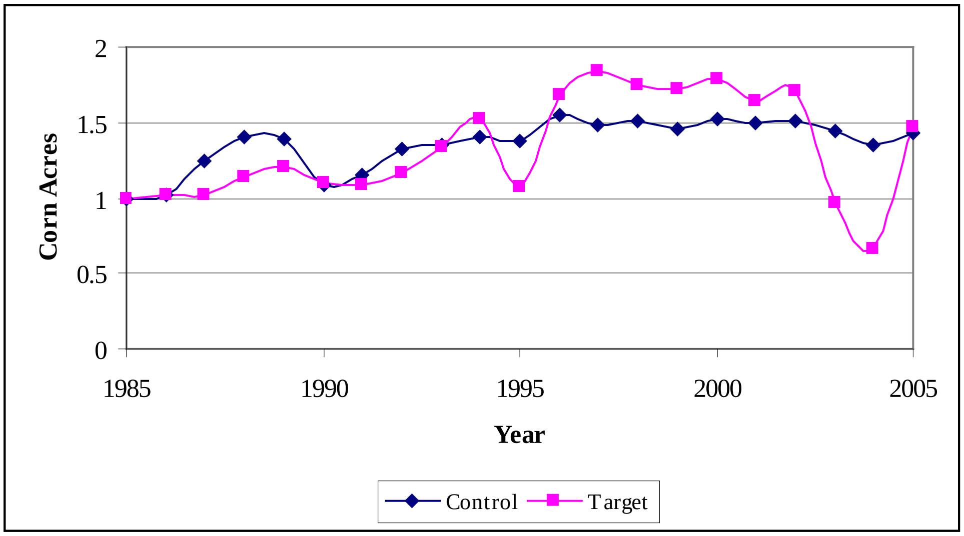


Figure 9. Time Series Comparison of the Indexed Values of Center Pivot Irrigated Acreage

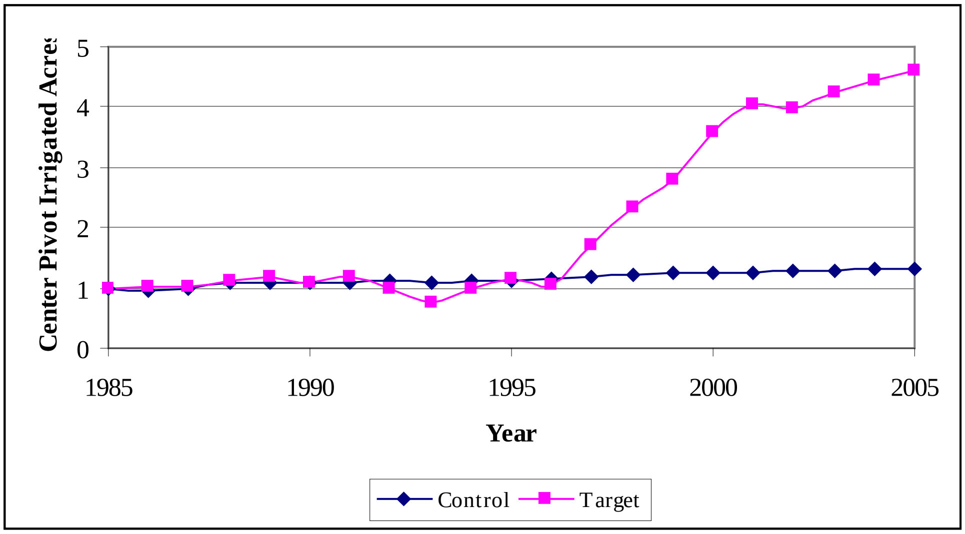


Figure 10. Time Series Comparison of Regression Binary Variables

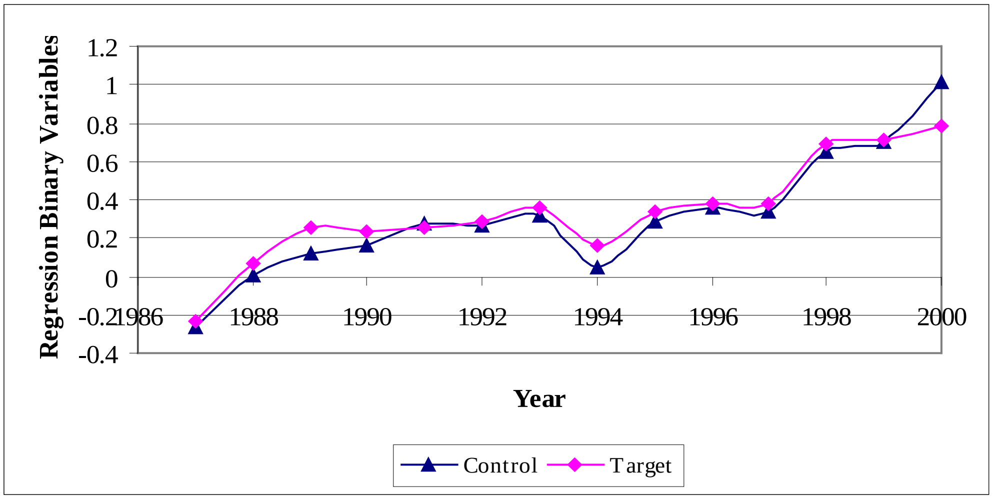


Figure 11. Time Series Comparison of Total Agricultural Assessed Valuations

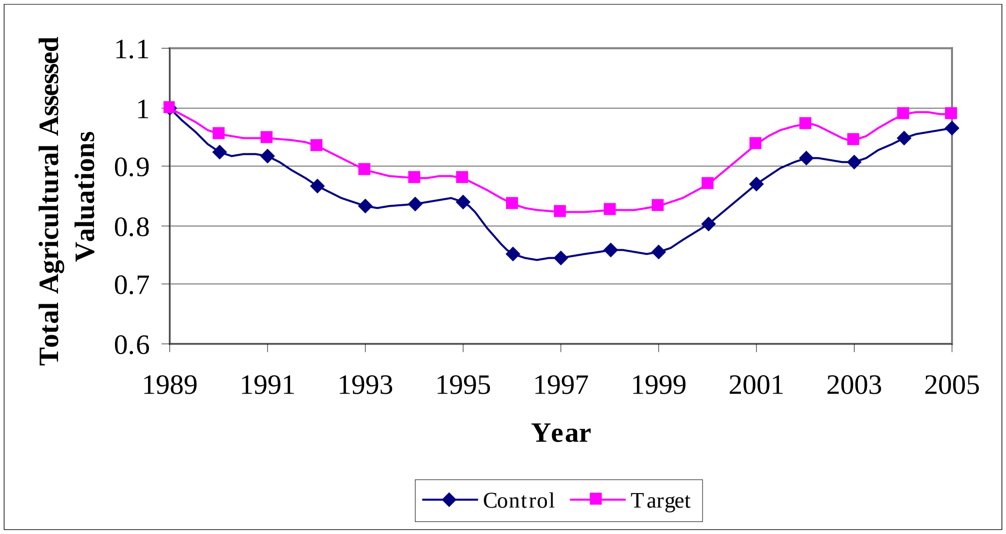


Figure 12. Time Series of the Depth to Groundwater for USGS Observation Wells

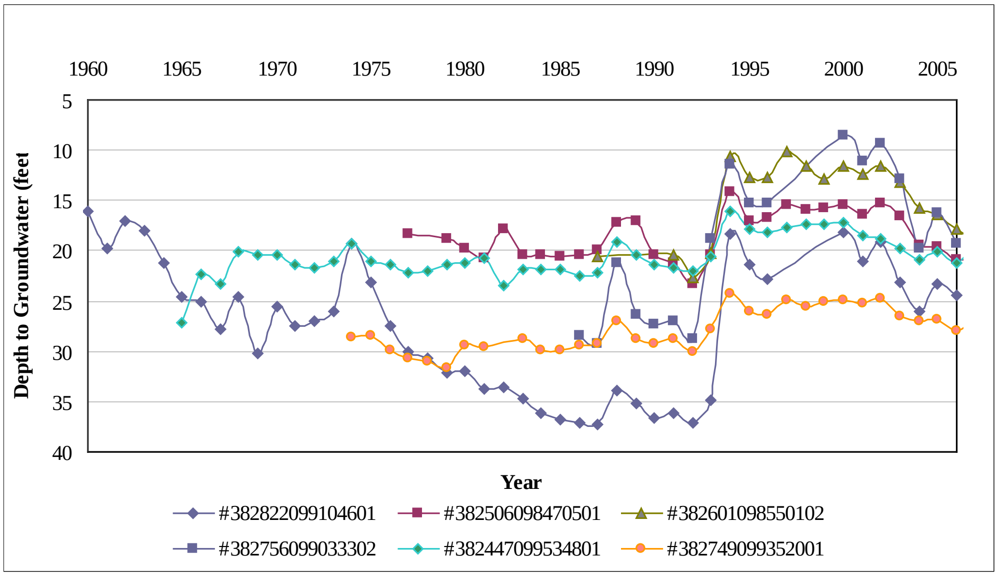
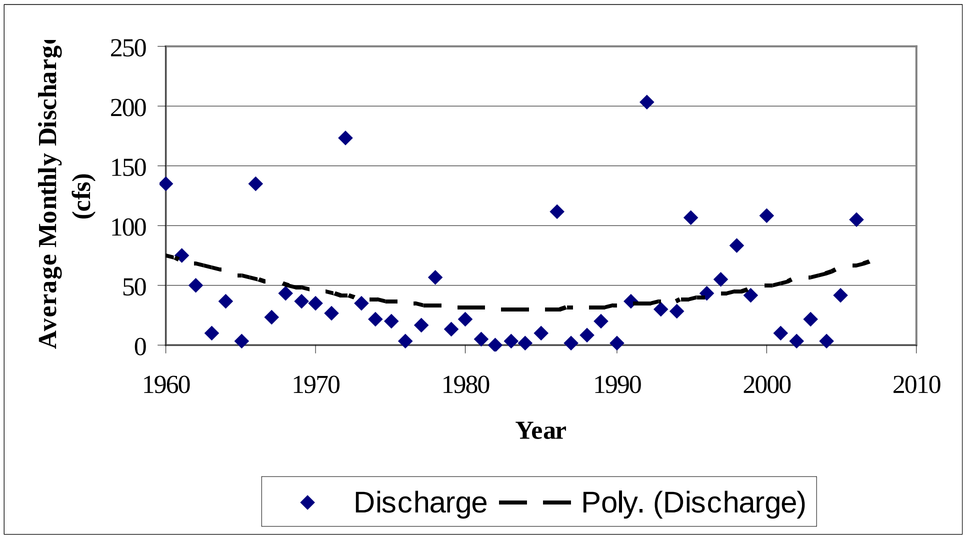


Figure 13. Time Series of Annual Streamflows in the Wet Walnut Creek at the Albert Gauging Station



Annual monthly discharge is defined as the average of the monthly mean discharge reported by the USGS