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Impact Analysis of the Walnut Creek Intensive Groundwater Use Control Area

Bill B. Golden and John C. Leatherman
Kansas State University – USA

Abstract: In 1992, an intensive groundwater-use control area (IGUCA) was established in the Walnut Creek Valley in central Kansas. Ex-post quasi-experimental control group analysis suggested that producers were able to mitigate the initial economic losses by maintaining/expanding the production of higher valued crops and by adopting efficient irrigation technologies and practices. It is hypothesized that the 'certainty' of water restrictions diminished the economic impacts. The foreknowledge that water use would be restricted into the foreseeable future allowed producers to develop long-run strategies to mitigate economic damages.

1. Introduction

For the majority of the 20th century, federal and state water policies in the western United States aimed to encourage settlement and develop surface water and groundwater natural resources for use by agriculture. Today, approximately 43 million acres of agricultural land are irrigated in the West. These lands produced 72 percent of crop sales on only 27 percent of the total harvested crop acreage. Irrigated agriculture currently consumes approximately 90 percent 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 are few case studies capable of providing guidance on the likely impacts.

In 1992, an Intensive Groundwater-Use Control Area (IGUCA) 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 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 an ex-post case study technique to the Walnut Creek situation. The quasi-experimental control group analysis used in this study can be characterized as a long-run dynamic analysis.

In the next section we briefly present background information on the establishment of the Wet Walnut Creek IGUCA. We then present a description of the ex-post quasi-experimental control group analysis technique employing the Mahalanobis distance function used for this research. We then present results comparing the economic performance of statistically-similar target and control regions and attempt to determine the effectiveness of the groundwater preservation policy. Finally, we discuss the policy implications of our findings.

2. The Wet Walnut IGUCA

The Cheyenne Bottoms Wildlife Area 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 (Great Bend Convention and Visitors Bureau, 2011). The 19,857-acre Cheyenne Bottoms Wildlife Area is part of a 41,000-acre natural land sink just northeast of Great Bend, Kansas (Figure 1). During the 1940s and 1950s, 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 (KDWP), 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. The 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.

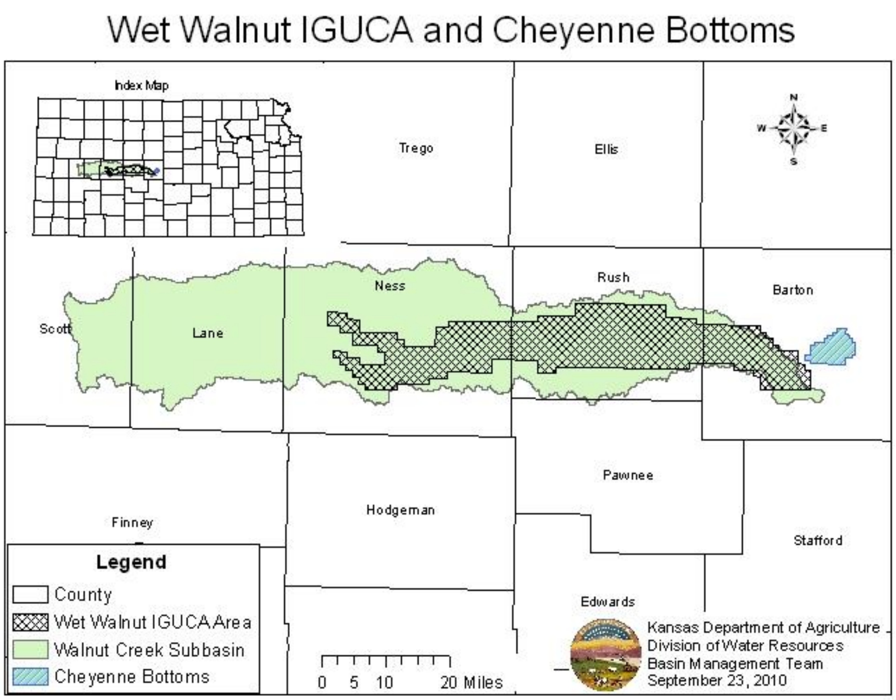

Figure 1. Map of the Wet Walnut Creek Area.

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 the 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 Department of Agriculture, 2010). 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.

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.[1] Users with senior water rights for irrigation 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. Users with junior rights for irrigation had their appropriated quantity curtailed by 64 percent to 71 percent, again depending on location.

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. 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).

3. Ex-post quasi-experimental control group analysis

A major difficulty in measuring the impact of regional policy is the identification of what would have happened in the absence of the policy. Ona et al. (2007) suggests that the quasi-experimental control group analysis method enables the measurement of what would have happened in the absence of a policy. Hicks (2007) indicates that the quasi-experimental methods are typically applied to specific events where broader regional analysis is inappropriate. 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. 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 (Bucholtz et al., 2004).

The quasi-experimental control group analysis has been used extensively in economic/impact analysis (Bucholtz et al., 2004; Bohm and Lind, 1993; Reed and Rogers, 2003; Eklund et al., 1999; Huff et al. 1985; Ona et al., 2007). Similar to quasi-experimental control group analysis, Supalla et al. (2006) suggested 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.

3.1. The control group

Developing an appropriate control group is at the heart of quasi-experimental control group analysis (Bucholtz et al., 2004). The use of control group analysis relies on two major assumptions: first, that there

[1] 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.

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 (Bucholtz et al., 2004). While no two areas are exactly the same, the Mahalanobis distance metric is often used in control group analysis (Isserman and Rephann, 1995; Ona et al., 2007; and Bucholtz et al., 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 irrigated, 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 $\bar{T}$ 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

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

The smaller the Mahalanobis distance metric is, the more similar vector C is to vector T. Given the vector $\bar{T}$, 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 ensures 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 ensures 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 Patterns, the United States Department of Agriculture's National Agricultural Statistics 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.

3.2. The conceptual quasi-experimental model

Broder et al. (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:

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

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, and $D1$ and $D2$ are binary variables that take 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:

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

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:

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

where Δ designates the difference in the variable's value between the control and target area.[2]

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 et al., 2006; Leatherman et al., 2006). To capture both the short-run and long-run effects, the model incorporates two binary variables. $D1$ takes a value of zero for t greater than 1991 and less than 1996 and a value of one otherwise. This specification captures the short-run impacts (the 3 years following the implementation of the IGUCA). $D2$ takes a value of zero for t less than or equal to 1995 and a value of one otherwise. This specification captures the long-run impacts. If the parameter estimate for either λ_1 or λ_2 is positive and statistically significant, then the interpretation is that the implementation of the IGUCA caused a reduction in the socio-economic variable in the target area for the time period considered.

4. Results

In the following sections, models for each socio-economic variable of interest will be developed and the results reported and discussed. Making direct comparisons of socio-economic variables across the target and control areas is problematic. While the data are statistically similar, the magnitude will not be identical, so indexed values will be used 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 the starting value that occurs in each year.

4.1. Impacts on irrigated acreage and water use

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.[3] These data are collected and made available to the public by the Kansas Division of Water Resources.

Data from the WRIS for the years 1985 through 2005 were used in this analysis. Each irrigator is required to report 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 through 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 were short-run and long-run declines 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.

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

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

The model results for water use and all other agriculture variables are reported in Table 1. The results suggest that the IGUCA resulted in statistically significant short-run and long-run reductions in total

[2] 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.

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

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.

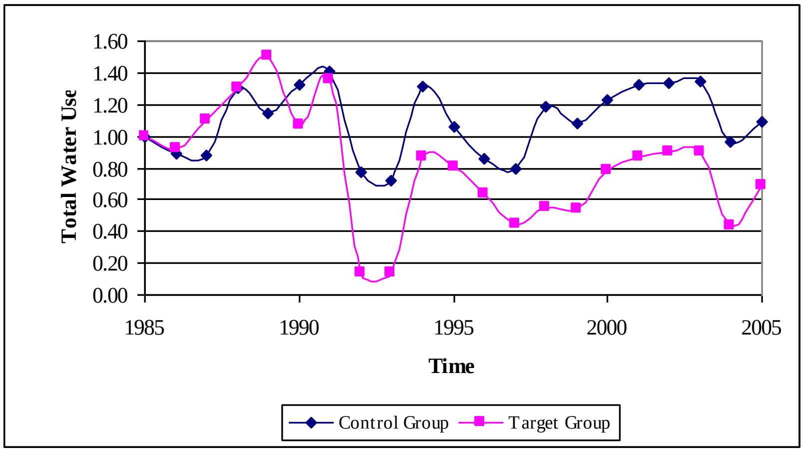

Figure 2. Time series comparison of the indexed values of total groundwater use.

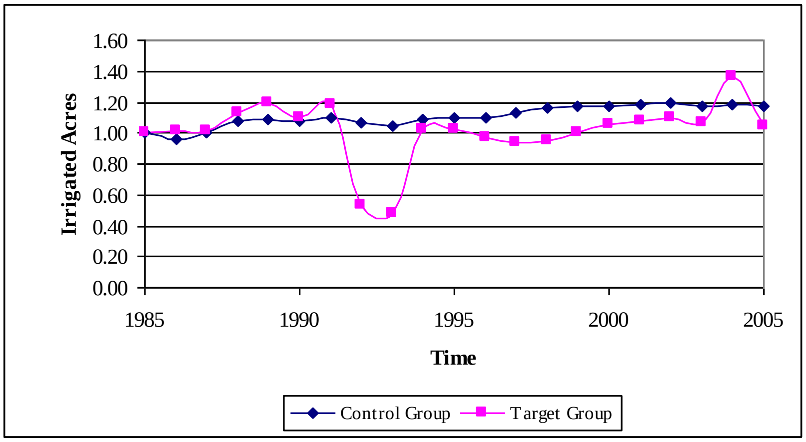

Figure 3. Time series comparison of the indexed values of irrigated acreage.

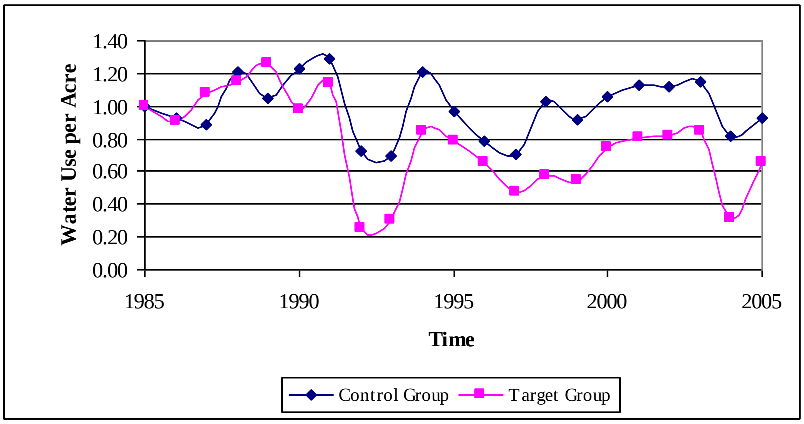

Figure 4. Time series comparison of the indexed values of water use per acre.

Table 1. Regression results of short- and long-run impacts to target and control areas.

Variable	Intercept	Short-run Impact	Long-Run Impact	Model R^2	Change in Annual Precipitation
Total Water Use	-0.045	0.600*	0.476*	0.757	N.A.
Annual Water Use per Acre	-0.013	0.412*	0.339*	0.712	-0.019
Irrigated Acres	-0.050	0.434*	0.152*	0.594	N.A.
Irrigated Crop Revenue	-0.055	0.490*	0.094	0.571	N.A.
Irrigated Alfalfa Acreage	-0.123	0.256	-1.971*	0.648	N.A.
Irrigated Corn Acreage	0.107	-0.493	-0.119	0.045	N.A.
Center Pivot Irrigated Acreage	-0.050	0.247	-1.794*	0.531	N.A.
Regression Binary Variables	-0.055	-0.004	0.066	0.165	N.A.
Total Ag. Assessed Valuations	-0.055	0.020		0.118	N.A.

**Statistically significant at the 10% level.*

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

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

Golden and Peterson (2006) suggest that annual precipitation (AP) has a significant impact on water use per acre, so ΔAP and has been included as an explanatory variable in this model. The model results suggest that the IGUCA resulted in statistically significant short-run and long-run reductions 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 due to the inclusion of annual precipitation as one of the variables in the Mahalanobis distance metric which defined similar regions.

The econometric model for the difference in the indexed values of total irrigated acreage, ΔTIA_t, follows the same general form as Equation (5), substituting the change in total irrigated acreage for total water use. The model results suggest that the IGUCA resulted in statistically significant short-run and long-run reductions in annual irrigated acreage. The short-run impact was greater than the long-run reduction in total irrigated acreage. As with water use, 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 acres 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.

4.2. 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 on 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.

The econometric model for the difference in the indexed values of total irrigated crop revenue, ΔTIR_t, follows the same general form as Equation (5), substituting the change in total irrigated crop revenue for total water use. The model results (Table 1) 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 for 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 of approximately $2.5 million in revenues generated from irrigated cropland. As reflected in Figure 3 and Table 1, the IGUCA resulted in statistically significant short-run and long-run reductions in annual irrigated acreage. It is possible that idled irrigated acres generated non-irrigated 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.

4.3. 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 et al. (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) and 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 et al. (2004) suggest that computer-aided technologies and improved irrigation scheduling might provide a solution. Schlegel et al. (2005) report significant water savings with the adoption of a 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. The econometric models for the difference in the indexed values of irrigated crop acreage, ΔIA_t, follow the same general form as Equation (5), substituting the change in indexed values of irrigated crop acreage for total water use. The model 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).

Data on the indexed time trends for acres irrigated with center pivot technology from WRIS were obtained. The econometric models for the difference in the indexed values of acres irrigated with center pivot technology, ΔCPT_t, follows the same general form as Equation (5), substituting the change in indexed values of acres irrigated with center pivot technology for total water use. The model 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 1, statistically significant short-run and long-run reductions in water use per acre were 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 et al. (2005). It is unclear whether computer-aided technologies and improved irrigation scheduling, as suggested by Harris and Mapp (1986) and Klocke et al. (2004), enabled producers to reduce water consumption, as data on these practices are unavailable.

4.4. 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 et al. (2006). This hedonic appraisal technique allows for the unbiased estimation of the value of irrigated cropland based 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:

$$P = \beta_0 + \sum_{i=1}^{n} \beta_i EV_i + \sum_{i=n+1}^{j} \beta_i BV_i \qquad (7)$$

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.

Given Equation 4 and Equation 7, the econometric models for the difference in binary variables, ΔBV_t, can be specified as in Equation (5), substituting the change in the binary variable for total water use. The model results (Table 1) 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. In 1997, those irrigated parcels within the IGUCA boundaries that were classified as having 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. The econometric models for the difference in the indexed values of total agricultural assessed valuations, $\Delta TAAV_t$, can be specified as:

$$\Delta TAAV_t = \lambda_0 + \lambda_1 D1_t. \tag{8}$$

This model specification includes only one binary variable which takes the value of one for the period 1997 through 2005. The regression 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.

4.5. 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 whether the IGUCA met 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 are 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. From 1993 to 2008, on average, the groundwater elevation has increased during the observation period (conversely the depth to water has decreased).

The econometric model for depth to groundwater (DTG) can be specified as:

$$DTG_t = \lambda_0 + \lambda_1 P_t + \lambda_2 P_t^2 + \lambda_3 D1_t, \tag{9}$$

where P is the annual precipitation and $D1$ is a binary variable that takes the value of one for all years after 1992. The regression results are reported in Table 2. 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.

Table 2. Regression results for the change in depth to groundwater.

USGS Well Number	County	Intercept	Annual Precip.	Annual Precip.^{2}	Post-1992	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	0.000	-2.874*	27	0.506
382749099352001	Ness	30.452*	-0.017	-0.002	-2.639*	27	0.659

**Statistically significant at the 10% level.*

It is important to note that there was a rapid decrease in the depth to water during the 1992-1994 period. We note higher than normal precipitation and a large reduction in total groundwater use during this period. These rapid changes in variables that impact depth to water may have influenced our 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.

Several factors can impact streamflow, including groundwater elevation, precipitation quantity and intensity, soil conservation structures within the watershed, land use, and vegetation. However, a rather simplistic model can be defined as:

$$SF_t = \lambda_0 + \lambda_1 P_t + \lambda_2 D1_t, \qquad (10)$$

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. Assuming that all other factors that impact streamflow were similar for the pre- and post-1992 period, the 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. This research suggests a statistically significant improvement in groundwater elevations and streamflow associated with the IGUCA.

5. Discussion

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.

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.

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 they 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 percent of the reduction in year 1 and the remaining 50 percent 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 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 foreknowledge 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 generate diminishing economic impacts 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 could ensure 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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