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Incentive-Based Groundwater Conservation Programs: Perverse Consequences?

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We consider two voluntary, incentive-based groundwater conservation programs and estimate their effects on groundwater extraction for irrigated agriculture. We find that the programs do not have the intended effect; the subsidization of more efficient irrigation technology induces the production of more water-intensive crops, thus increasing total extraction, and land retirement programs are generally not utilized on irrigated land, thus having little effect on groundwater extraction.

Also in this issue

Voluntary, incentive-based water conservation programs for irrigated agriculture are often billed as policies where everyone gains. They are politically feasible, farmers are able to install or upgrade their irrigation systems at a reduced cost, resulting in substantial increases in profits, less groundwater is "wasted" through runoff, evaporation, or drift, marginal lands can be profitably retired, and farmers can choose whether to participate. However, such policies can have unintended, even perverse, consequences. Here, we empirically evaluate two policies that have been used to decrease groundwater extraction.

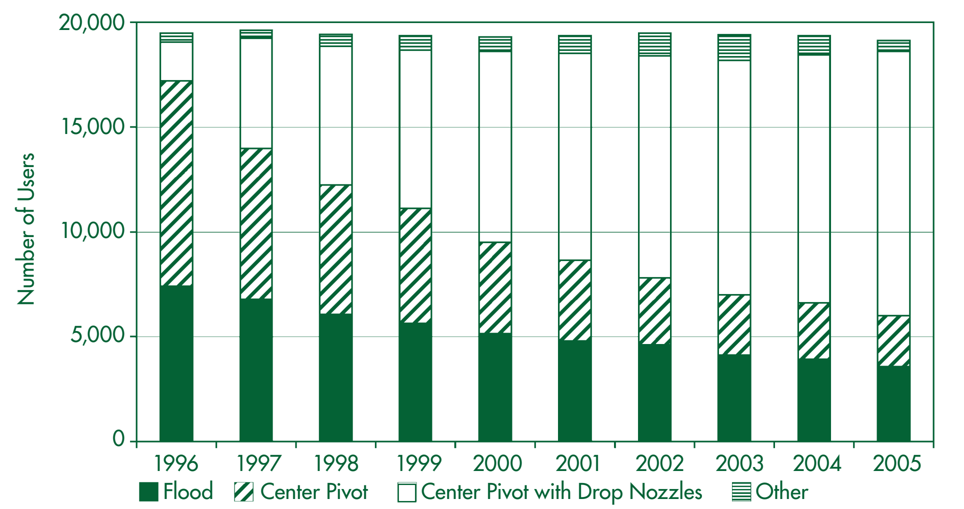
Agriculture accounts for 99% of groundwater withdrawals from the High Plains Aquifer of the midwestern United States, the largest freshwater aquifer system in the world. The region has experienced a decline in the level of the water table since intensive irrigation became widespread, starting in the 1970s. In parts of southwestern Kansas and in the Texas panhandle, the water table has declined by more than 150 feet. While declines in the water table are expected given rates of extraction that far exceed the recharge to the aquifer, concerns that the aquifer is being depleted too rapidly have become common in public policy and debate. Similar concerns have risen in many of the world's most productive agricultural basins, including California's agricultural regions. In many places, policymakers have attempted to decrease rates of extraction through incentive-based measures.

The state of Kansas was chosen for the analysis because of the availability of data; Kansas is a leader worldwide in the collection of data concerning groundwater extraction, water table levels, and policies affecting agriculture. The lessons from the analysis, however, are general and can be applied to agricultural groundwater basins anywhere. In fact, the same programs that are evaluated for Kansas also fund agricultural producers in California. Additionally, Pacific Gas and Electric is currently funding an Agricultural Pumping Efficiency Program that provides cash incentives for energy efficiency upgrades. Similar programs have been available in the past.

Incentive-Based Conservation Programs

The state has been subsidizing a shift toward more efficient irrigation systems. State and federal agencies have invested considerable resources in equipment cost sharing and technical assistance to farmers since about 1990. Between 1998 and 2005, more than $5.5 million was allocated to farmers through the Irrigation Water Conservation Fund and the Environmental Quality Incentives Program. Such programs pay up to 75% of

Figure 1. Irrigation Technology in Use in Western Kansas



the cost of purchasing and installing new or upgraded irrigation technology.

The irrigation technology employed by groundwater users in western Kansas has changed significantly since intensive irrigation development began. Land was converted from flood irrigation systems to center pivot systems. With flood irrigation, water is pumped to one edge of a field, then allowed to run down furrows through the fields between rows of crops and allowed to soak in. Flood irrigation necessitates flat land and quality soil with a high water holding capacity, and is relatively labor intensive. Center pivot systems, on the other hand, are generally self-propelled, can be used on sloped or rolling land, and the quantity of water delivered to the crop can be adjusted to soil and climatic conditions. Center pivots can be thought of as land-quality enhancing; they enhance the ability of lower quality soils to provide water and nutrients to crops, reducing the productivity differences between low and high quality land. Figure 1 shows the general trends in the change in irrigation technology use in western Kansas in the period 1996 to 2005. From figure 1, it can be seen that the conversion from flood to center pivot systems was well underway by 1996. Rather, most of the change comes in the conversion from center pivots to center pivots with dropped nozzle packages. Dropped nozzle packages (also called low-pressure nozzles) suspend the sprinkler heads just above the canopy of the crop. They increase the efficiency of water applied to the field by decreasing the amount lost to evaporation and drift, especially in hot and windy climates. More efficient irrigation systems decrease the amount of water that needs to be extracted for a given benefit to the crop, thus decreasing the cost to the irrigator. Thus, increased irrigation efficiency has been touted as an ideal way to decrease total water extraction.

The Conservation Reserve Program (CRP) was created by the federal government in 1985 to "provide technical and financial assistance to eligible farmers and ranchers to address soil, water, and related natural resource concerns on their lands in an environmentally beneficial and cost-effective manner." These programs include payments to landowners to retire, leave fallow, or plant non-irrigated crops on their land. Kansas has used the CRP and other more recent programs to retire (at least temporarily) land in areas of the state where the water table has been falling most rapidly. An average of 2.7 million acres of land has been under the CRP in Kansas each year since 1996, and an additional 600,000 acres have been placed under other land conservation programs since 2003. The largest recent increases in the number of acres under conservation programs have been concentrated in counties with the largest changes in the depth of the water table. These programs are an effort by the state to reduce water extraction in areas that may have been over-appropriated.

The state of Kansas has spent nearly \$6 million on incentive programs (cost-sharing or subsidizing the purchase) to fund the adoption of more efficient irrigation systems. An additional amount of farm and environmental program money goes toward land fallowing and land and water rights retirement programs each year. About \$8 million per year is spent on Conservation Reserve Program acres, and an additional \$3 million in 2004 and \$5 million in 2005 was used for other programs in western Kansas alone, including the Conservation Security Program, the Grasslands Security Program, and the Environmental Quality Incentives Program (EQIP) Ground and Surface Water program. These policies are implemented under the auspices that they will decrease

Table 1. Estimated Effects of Irrigation Systems and Conservation Programs on Crop Choice

	Acres of alfalfa	Acres of corn	Acres of soybeans	Acres of wheat	Acres of sorghum	Acres non-irrigated
Flood irrigation system	Control group					
Center pivot system	33.59***	26.27***	27.99***	16.03**	20.77**	
Center pivot w/ dropped nozzles	30.90***	27.01***	26.80***	15.64***	18.02***	
Acres in CRP and env conservation programs in the county (thousands)	0.03**	-0.01*	0.10***	0.05***	0.06***	0.24***

** significant at 5%, ** significant at 1%, *** significant at 0.1%*

the total consumptive use of groundwater, a key goal of state water managers, and are in response to declining aquifer levels that are occurring in some portions of the state due to extensive groundwater pumping for irrigation.

Definition of Irrigation Efficiency

Gross irrigation is the quantity of water diverted (extracted, in the case of groundwater), and net irrigation is the quantity of water consumed by the crop. Efficiency, therefore, is the share of gross irrigation that is used by the crop. More efficient irrigation systems reduce the amount of water that must be extracted for a given benefit to the crop. Center pivot systems with dropped nozzles use about 8% less water than traditional center pivot systems by reducing drift and evaporation, and standard center pivot systems use up to 30% less water than flood irrigation systems through reduced runoff, improved timing, and more uniform application.

Economics of Incentive-Based Water Conservation Programs

Recent work has suggested that policies of encouraging the adoption of more efficient irrigation technology may not have the intended effect. Irrigation is said to be "productivity enhancing"; it allows the production of higher value crops on previously marginal land. Thus, a policy of subsidizing more efficient irrigation technology can induce a shift away from dry-land crops to irrigated crops. They may also induce the planting of more water-intensive crops on already irrigated land, as by definition, more efficient irrigation increases the amount of water the crop receives per unit extracted.

A similar story emerges when one considers land retirement programs. Such programs operate on an offer-based contract between the landowner and the coordinating government agency. The contractual relationship is subject to asymmetric information, and adverse selection may arise because the landowner has better information about the opportunity cost of supplying the environmental amenity than does the conservation agent. There is substantial evidence that farmers enroll their least productive, least intensively farmed lands in the programs while receiving payments higher than their opportunity costs, thus accruing rents. It is quite unlikely that an irrigated parcel, which requires considerable investment in a system of irrigation (which, in turn, enhances the productivity of the parcel), will be among a farmer's plots with the lowest opportunity cost and thus enrolled in the program. Enrolling a non-irrigated plot in the CRP program will not have any effect on the amount of irrigation water extracted.

Table 2. Estimated Effects of Irrigation Systems and Conservation Programs on Water Pumping

	Estimated coefficient from water pumping regression (given crop choice)	Total marginal effect
Flood irrigation system	Control group	
Center pivot system	-15.20***	30.683
Center pivot with dropped nozzles	-14.42***	29.727
Acres in CRP and environmental conservation programs in the county (thousands)	0.15***	0.209

** significant at 5%, ** significant at 1%, *** significant at 0.1%*

An Empirical Economic Model to Estimate the Effects of the Programs

A large dataset of more than 20,000 agricultural groundwater wells from western Kansas, over the years 1996 to 2005, is used to investigate the effectiveness of voluntary land retirement and subsidized irrigation technology adoption on groundwater extraction. The well locations are geo-referenced, and we match them to soil quality characteristics, precipitation, and hydrological information about the aquifer from which they are drawing, such as the depth to groundwater.

We develop an empirical model that assumes that farmers optimize their cropping decisions to maximize profits. They choose between the five most common irrigated crops grown in western Kansas (corn, alfalfa, soybeans, sorghum, and wheat) or decide not to irrigate a parcel. Then, given their crop choice, they decide how much water to pump. Both stages of the estimation are important because irrigators can adjust their water use in two ways: along the "extensive" margin by shifting their cropping patterns, and along the "intensive" margin by adjusting groundwater extraction. The full effect (the "total marginal effect") is a combination of the two.

Results

In our empirical models of irrigators' crop choice and water pumping decisions, we include indicators of the type of irrigation system that is installed in the field. Efficient irrigation systems have the desired negative impact on water extraction along the intensive margin in the pumping model, as indicated in table 2. For example, given crop and acreage choice, users with center pivot systems use 15.2 fewer acre-feet of water than those with flood irrigation systems, and those with dropped nozzles extract 14.4 fewer acre-feet of water than those with flood irrigation (see table 2). However, center pivot systems allow the production of water-intensive crops and are installed where those crops can be produced. Thus, the impact of efficient irrigation technology on crop

Center pivots with dropped nozzle packages (low-pressure nozzles) suspend the sprinkler heads just above the canopy of the crop. They increase the efficiency of water applied to the field by decreasing the amount lost to evaporation and drift, especially in hot and windy climates.

Photo courtesy of Gene Alexander, USDA Natural Resources Conservation Service

choice must be considered. As reported in table 1, center pivot and dropped-nozzle center pivots increase the number of acres planted to all the irrigated crops as compared to flood irrigation. For example, an irrigator with a center pivot system will plant 26.2 more acres of corn, at the margin, than if he had a flood irrigation system, and 27 more acres of corn if he had a dropped nozzle system. Additionally, the effects are the largest effect on corn, alfalfa, and soybeans, the most water-intensive crops.

The total marginal effects (a combination of the effects on crop choice and water pumping) reported in table 2 are also positive, indicating that when crop choices are considered, efficient irrigation technology does not reduce overall water use. It is unlikely that the shift in irrigation technology has resulted in real water savings. In fact, it has significantly increased water use relative to flood irrigation systems.

From table 1, conservation programs have a small negative effect on the number of acres in thousands planted to corn in a county (-0.01), and a positive effect on the amount of acres not irrigated (0.24). Program acres have a small positive effect, however, on the planting of alfalfa, soybeans, wheat, and sorghum. While sorghum and wheat are relatively low water-use crops, alfalfa and soybeans are not. The total marginal effect is also very small, but positive (0.15). This may indicate a substitution *toward* irrigated cropland; if a user retires a low opportunity cost plot elsewhere on his land, he may be more likely to plant a higher profit (and possibly more water intensive) crop on his irrigated land.

Conclusion

The depletion of the High Plains Aquifer has become an important topic of policy in western Kansas, as it has in agricultural basins all over the world. Crop and livestock systems form the base of the economy and depend almost exclusively on water extracted from the High Plains Aquifer. As high volumes of water are extracted, the water table drops and extraction becomes more expensive. In some areas, the economic systems that depend on the water are not sustainable because recharge to the aquifer is very small. In order to make the water last longer, policy has focused on reducing rates of extraction.

Policy makers must consider the legal ramifications of policies designed to reduce groundwater extraction; reductions in allowed extractions can amount to a taking of property, depending on the state's groundwater laws. Third party effects are also a concern; seed and farm implement dealers, restaurants and other services, and even schools may be adversely affected by policies that reduce groundwater extraction. Therefore, voluntary, incentive-based measures are generally the most politically feasible types of policies to enact. An additional incentive is that the full costs of such programs are rarely borne by the beneficiaries. Two such policies, the subsidization of efficiency-enhancing irrigation technologies and conservation land retirement programs, are analyzed here for their effect on groundwater extraction. A myriad of other states, regions, and countries have experimented with similar measures, often funded by state and national governments, and often with the help of international organizations in the case of developing countries.

The measures taken by the state of Kansas to reduce groundwater extraction have not been effective in reducing groundwater extraction. The subsidized shift toward more efficient irrigation systems has in fact increased extraction through a shift in cropping patterns. Better irrigation systems allow more water-intensive crops to be produced at a higher marginal profit. The farmer has an incentive to both increase irrigated acreage and produce more water-intensive crops. Similarly, land and water conservation and retirement programs have done little to reduce groundwater extraction, although billed as such. Theoretically, we know that because the programs are offer-based, farmers will enroll their least productive land. Our empirical results support this conclusion; we find essentially no effect of land conservation programs on groundwater pumping, which occurs, by definition, on irrigated, and thus, very productive land.

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