Measuring the Impact of the Environmental Quality Incentives Program (EQIP) on Irrigation Efficiency and Water Conservation

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Abstract

Since the passage of the 1996 Farm Act, the Environmental Quality Incentives Program (EQIP) has provided over $10 billion in technology adoption subsidies. One of the national conservation priorities in EQIP is water conservation, but it is not known how participation in EQIP by irrigators affects water application rates and decisions to expand or reduce a farm's irrigated acreage. Using a farm-level panel data set drawn from three national samples of irrigators taken in 1998, 2003, and 2008, this study provides the first national scale econometric estimates of the changes in water application rates and irrigated acreage that result when a farm receives EQIP payments. Due to a five-fold increase in EQIP funding following the 2002 farm bill, the change in EQIP participation between 2008 and earlier years is largely the result of an exogenous policy shock. A difference-in-differences estimator that exploits this change in EQIP funding and also controls for unobserved farm-specific variables, suggests that for the average farm participating in EQIP between 2004 and 2008, the EQIP payments may have reduced water application rates but also may have increased total water use and led to an expansion in irrigated acreage. However, since EQIP participation is voluntary, there may still be a need to correct for bias due to sample selection. A nearest neighbor matching estimator finds no evidence of any statistically significant effect of EQIP participation on technology adoption rates, water use, water application rates or acreages, which suggests that there is a high degree of self-selection into the program.

Introduction

U.S. farms now irrigate more cropland and pasture than ever before.[1] Irrigators collectively use more water than at any point since 1979.[2] However, as shown in table 1, the average water application rate (acre-feet per acre) has dropped about 10% over the past three decades. These dual trends – increases in water use and decreases in water application rate – raise questions about whether ongoing efforts to conserve water using aggressive technology subsidies are effective.

Since the passage of the 1996 Farm Bill, the Environmental Quality Incentives Program (EQIP) has provided about 10% of the total program, over $1 billion in subsidies, for the adoption of water-conservation-related practices. Most of these subsidies have gone toward technologies that could reduce water application rates (low-pressure sprinklers or drip irrigation systems) or improvements that reduce water losses (pipes, land leveling, and ditch lining). The challenge in evaluating EQIP is that is we do not directly observe what farmers who receive EQIP payments would have done without getting the payments.

In this study, we econometrically estimate the impact of EQIP on the average irrigator (or the average irrigated acre) for a variety of outcome variables – water use, application rates, share of operated acreage irrigated, and share of irrigated acreage in conserving technologies – by exploiting the large increase in EQIP funding that occurred following the 2002 Farm Act. We construct a panel data set by linking farm-level observations across multiple years of the Farm

[1] USDA Agricultural Census: 2007, table 1; 1978, chart 1.
[2] USDA Agricultural Census, FRIS: 2008, table 11; 1998, table 10; 1994, table 10; 1983, table 10.

and Ranch Irrigation Survey (FRIS). The panel structure of the data set allows us to control for omitted variables that influence a farm's average level of the dependent variables and for regional shocks that influence changes in application rates. We compare two methods – instrumental variables and matching – to control for the potential endogeneity of program participation.

Literature

Numerous economic studies using programming models have asked whether the adoption of lower-flow (higher-efficiency) irrigation technology will actually save water. The need for complicated programming models arises because on-farm water use depends on numerous factors and operator decisions that may be co-determined with irrigation technology choice. Adding voluntary participation in conservation programs to the analysis makes the problem more difficult. The literature on irrigation indicates several reasons that technology adoptions, and therefore technology subsidies, may not be an effective means to conserve water

The first concern over the effectiveness of voluntary cost-share programs such as EQIP is that the farms most likely to adopt practices in the absence of the program may also be the most likely to apply for the program. In the most extreme cases, cost-share programs may not induce any additional adoption of practices beyond what would happened in absence of the program. Unlike many of the wildlife conservation practices covered by EQIP, the irrigation practices have well documented private benefits. Farmers adopt water-saving practices and upgrade equipment even when no public incentive is offered, for example, in response to drought (Schuck et al., 2005; Quiggin et al., 2010) or high costs for water (Negri and Brooks, 1990; Moreno and Sunding, 2005). In some cases, differences in soil characteristics, climate, and cropping patterns may be the most important factors determining adoption (Green et al., 1996).

Even if technology subsidies successfully induce a change in technology adoption, irrigators may adjust to the new technology in a way that offsets the effects of the improvement. Most irrigation efficiency improvements conserve water by reducing the amount of applied water that is lost through evaporation, runoff or infiltration. Irrigators may keep application rates the same and allow crop uptake of water to increase (increasing consumptive use) or may apply more water (Ward and Pulido-Velazquez, 2008; Huffaker, 2008). Irrigators may also switch to more water intensive crops or expand irrigated acreage (Huffaker and Whittlesey, 2003; Scheierling et al., 2006; Pfeiffer and Lin, 2010.).

Research also suggests that not all farmers will respond in the same way to cost-sharing programs or to changes in technology. Potential water savings may depend on the types of technology a farm operator switches from and to, with the largest potential for conservation realized when switching from flood to subsurface drip systems (Peterson and Ding, 2005). But this study was limited to groundwater-irrigated corn farms in the High Plains, and the results may not apply to surface-water systems or other regions. Further, even models that predict increased water use note circumstances when cost-share programs for irrigation technology can improve water conservation (Huffaker and Whittlesey, 2003; Huffaker, 2008).

Background on EQIP

EQIP is the primary Federal conservation program aimed at working agricultural land. Created in the 1996 Farm Act to succeed several smaller working-lands conservation programs, EQIP has been reauthorized and expanded in the 2002 and 2008 Farm Acts.[3] EQIP works by distributing funds to States and U.S. territories, which then enter into contracts with farm operators to provide payments for developing conservation plans and then engaging in conservation farm management practices or installing conservation structures or equipment. The Natural Resources Conservation Service (NRCS), the agency responsible for administering EQIP, has developed guidelines for over 280 different conservation practices (and categories of equipment) that are eligible for inclusion in conservation plans.

The Farm Act specifies five national conservation priorities to be addressed by EQIP, and by law EQIP is required to devote 60% of funding for conservation issues related to livestock operations. One of the five national priorities that Congress established for EQIP is the conservation of ground and surface water resources (NRCS, 2009). To address this national priority, EQIP funds investments in equipment that can improve irrigation efficiency, structures and land leveling that can reduce water loss and runoff, and management practices to more precisely control the timing and rate of water application on irrigated fields.

EQIP is designed to reduce water use and conserve ground and surface water supplies. Program rules require that EQIP participants who receive payments for water conservation purposes actually reduce water use on the farm, rather than simply increasing efficiency and using the water savings elsewhere on the farm.[4] It is not clear to what extent this provision is monitored at state and local levels, or whether participation in EQIP among irrigated farms prompts farm-level changes along the intensive or extensive margin (e.g., by planting more water-intensive crops or expanding irrigated acreage).

Funding for irrigation practices is distributed throughout the country. Figure 1 shows county-level data on the number of water-conservation related contracts (as a share of total farms in a county) that were funded between 2005 and 2008.[5] Only counties with at least ten percent of harvested acreage under irrigation are included and only cropland areas are shown for those counties. The range in values illustrates significant regional differences in how water-conservation related EQIP funding is targeted.

Funding for Irrigation in EQIP

Until the 2002 Farm Act, total annual spending in EQIP averaged about $200 million per year. The 2002 Farm Act dramatically increased authorized funding for EQIP, with annual spending increasing to nearly $1 billion in the program by fiscal year 2007. The 2008 Farm Act expanded EQIP further, with authorized spending increased in the legislation to about $1.4 billion per year from 2008 to 2012. (Actual spending on EQIP during fiscal years 2008-2010 averaged about $1.1 billion per year.)

[3] 2002 Farm Bill: U.S. Public Law 107-171, May 13, 2002. 2008 Farm Bill: U.S. Public law 110-246, June 18, 2008.

[4] See section 7 Code of Federal Regulations part 1466.9. Available at: http://www.gpoaccess.gov/cfr/index.html.

[5] Source: ERS calculations of USDA, Natural Resources Conservation Service data.

To determine whether or not the expansion in EQIP also meant an expansion in funding for equipment and practices related to irrigated agriculture, we identified 32 practices that are potentially water-conservation related. Figure 2 shows the change in water-conservation related funding over time and the large increase in funding following the 2002 Farm Bill. Investments in irrigation equipment, such as sprinklers and micro-irrigation equipment, and water conveyance systems, such as pipelines, are the most significant components of EQIP funding for irrigation-related practices. These practices, which are capital intensive, also benefitted from a change in the 2002 Farm Act that increased the maximum size of EQIP contracts.

Federal funding for irrigation equipment has occurred amid a general trend of irrigation investments as irrigated farms switch to more water-efficient irrigation systems, and as irrigated acreage and water use expand in some regions. Estimates from the Farm and Ranchland Irrigation Survey, administered by the USDA National Agricultural Statistics Service, indicate that expenditures on irrigation equipment and machinery were about $816 million in 2003 and $1.5 billion in 2008.

Empirical Model

In this paper we use the treatment effects framework to evaluate the EQIP program. In this section we discuss our specification for EQIP participation, the use of differencing to control for unobserved farm-specific, time-constant variables, and controls for any remaining bias due to endogeneity of participation.

EQIP Participation

On the simplest level, irrigators either participate in EQIP or they do not. In evaluating the effectiveness of EQIP, modeling participation as a binary treatment is a useful approach. It allows us to examine the average treatment effect for the treated, the change in outcome for the average farm that has participated in the program. In this way, we examine the effectiveness of the national program while implicitly conditioning on the average suite of practices that farmers have voluntarily selected. Due to this approach, our findings are only applicable to this particular program over this particular time period.

Average Treatment Effect on the Treated, Controlling for Unobservables

Let the following model represent an outcome for an irrigated farm (i) at time (t) conditional on a farm-level fixed effect (a(i)), a time trend, and an indicator of EQIP participation.

$$Y(i,t) = \alpha(i) + \beta \cdot D(i,t) + \delta \cdot t + \varepsilon(i,t)$$

The outcome for the farm is differenced to remove the farm-level fixed effect. The remaining error is composed of a regional outcome shock (m(j) and an idiosyncratic farm-level shock (u(i)).

$$\begin{aligned} &Y(i,1) - Y(i,0) = \delta + \beta \cdot D(i,1) + \mu(j) + u(i) \\ &where: e(i,1) - e(i,0) = \mu(j) + u(i) \end{aligned}$$

For this model to be consistently estimated in this form, the critical identification assumption is that the farm's participation decision is exogenous with respect to the farm's idiosyncratic shock. Our estimation primarily relies upon the large increase in funding after 2003 to ensure this identification. Farms were simply not able to participate to the same extent prior to this period, particularly for capital-intensive conservation projects such as irrigation efficiency improvements.

Identifying a Causal Effect when Participation is Endogenous

The identification assumption may not hold because participation is voluntary and contracts are not randomly assigned. Even after the increase in EQIP funding that followed the 2002, more than 85% of investment in irrigation technology is funded directly by farmers. Farms that did participate in EQIP may have made the irrigation investments in absence of program funding, and it's possible that irrigation outcomes (such as technology choices or acreage expansion) are driving the decision to participate in EQIP. We explore two alternative specifications to control for the endogeneity this would induce.

An instrumental variables model uses a set of variables that are excluded from the regression but are able to predict the probability that a farm participates in EQIP. As a two-stage-least-squares estimator, this implicitly uses a linear probability model to predict participation. The exclusion restrictions are assumed to hold for several variables: EQIP participation in the previous period, a proxy for EQIP competitiveness that takes into account the number of farms in a given county and the number of EQIP contracts that go toward addressing other conservation concerns, and the sources of information a farm relies on to learn about conservation program improvements.

Matching methods present an alternative approach based on an assumption that observations can be matched based on observation covariates to a sufficient extent so that the treatment is "ignorable" in the sense that, conditional on the matching, the treatment is independent of the potential outcomes for a treated farms (Heckman *et al.* 1997, Abadie 2005, Heckman and Vylacil 2007). Ideal matching covariates are those variables that impact both the outcome and the likelihood of treatment but are not themselves influenced by the treatment. Given the desire to ensure that the treatment group is match to controls with similar climate and water resources, we use a nearest-neighbor matching method and incorporate latitude and longitude among the matching covariates. We also include a number of variables taken from the first year in each panel (either 1998 or 2003).

Data

Panel data provides a means to control for unobserved producer heterogeneity that is central to irrigation technology demand and a significant endogeneity concern for cross-sectional studies on irrigation. Unfortunately, true panel data on irrigators is exceedingly rare (e.g.: Schoengold *et al.*, 2006). A few studies have created cross-sectional, time series data sets by pooling multiple years of USDA's Farm and Ranch Irrigation Survey (FRIS) (Moore *et al*. 1994, Mullen *et al*. 2009). To our knowledge, this paper is the first study to construct a true panel dataset by linking farm-level observations across years.

The FRIS is conducted every five years following the U.S. Census of Agriculture, and collects information from irrigators on water application, expenditures on irrigation equipment, acreage irrigated and technologies used, water sources, and other farm-level data. The three most recent surveys were conducted in 1998, 2003, and 2008. The population of irrigated farms is identified using the previous year's Census responses, and a stratified sample of farms is selected in each state.

The final FRIS sample totals about 10% of all irrigated farms in the United States. Due to the highly skewed distribution of farm sizes, larger farms are sampled with a higher probability than other farms to ensure that they are adequately represented in the sample. (The largest irrigators are in a "certainty stratum" and are sampled with a probability of one.) This sampling design provides a significant advantage for constructing panels across multiple survey years. As shown in the summary statistics table, the 2003/2008 panel has about 4,000 observations and the 1998/2008 panel has about 2,000 observations. While the stratified sampling makes these larger sample sizes possible, it also makes inference about national-level program effects more difficult. To preserve the ability to make inference about EQIP's impacts at the population level, we use frequency weights that are the product of NASS sampling weights across the years in each panel.[6]

Summary statistics are presented in table 2, which is organized by type of variable (treatment, outcome, or covariate) and by panel.

FRIS allows us to identify each respondent's EQIP participation history. The survey asks respondents if they currently or have in the last five years participated in any government payment or technical assistance program. If yes, the respondent indicates whether they participated in EQIP or other programs. These responses are used to identify the treated group of the sample, i.e., those who participate in EQIP. The binary nature of this question corresponds to the binary specification of program participation in the empirical model. As indicated in the first row of table 2, about 9.5 percent of 2008 irrigators participated in EQIP between 2004 and 2008. About 4.9 percent of 2008 irrigators participated between 1999 and 2003. Only 2.1 percent participated in both periods. (In the 1998/2008 panel, the participation rate is about 8.2 percent in the initial period of 1996-1998. The rate of participation in both periods remains low at 2.7 percent.)

FRIS also collects a great deal of data on outcome variables. We use seven different outcome variables to measure rates of technology adoption, water use, water application rates, and land use.

For technology adoption, we use two different variables. The variable *improveYEAR* is a binary variable that equal 1 if a farm indicated having made a capital or technical improvement over the

[6] NASS sampling weights are the inverse of the probability that a farm is selected. Since the surveys are independent draws, the probability that a 2008 irrigator was selected in both 2008 and 2003 (for example) is the product of the inverse of the farm's 2008 weight and the inverse of the farm's 2003 weight. Therefore, since smaller farms are much less likely to be captured in the panel dataset, they receive more weight in light of their lower probability of selection.

past five years for the expressed purpose of conserving water and/or reducing energy use. About 39.1 percent of irrigators made a water- or energy-conserving investment between 2004 and 2008, roughly four times as many as participated in EQIP. The variable *shr_cons_YEAR* is the share of acres that are in a potentially water conserving technology (of the type typically funded by EQIP). This variable is constructed from the data collected on acres irrigated by different technologies and relies on the definitions used in Schaible et al. (2009). The average farm's share of acreage in conserving technologies is 36.3 percent in 2008, only minimally higher that the average of 35.7 percent in 2003. (For the 1998/2008 panel, this share actually went down between periods.)

For water use, the variable *acreft_YEAR* measures the total amount of water used on irrigated acreage by taking the sum of the water used across all crops and pasture. The average water use per farm is 611.3 acre-feet in 2008 and 536.8 acre-feet in 2003. There is an alternative way of constructing total water use from FRIS, namely by summing total water used across water sources, which we do not use in this paper.

For water application rates, we use two different variables. The primary measure, *avg_app_YEAR*, is the acre-weighted average of the application rate for each crop harvested by a farm, including pasture. The average application rate was 1.875 acre-feet per acre in 2008 and 1.191 acre-feet per acre in 2003. (In the 1998/2008 panel, the average application rate was 1.302 acre-feet per acre in 2008 and 1.563 acre-feet per acre in 1998.) The sensitivity in these averages to the sample is highly suggestive of the need for panel data methods. The secondary measure is an effort to control for double cropping, it divides the sum of water use across all crops (excluding pasture) by the total harvested acreage. In almost all cases this alternative application rate has a higher average than its counterpart; the one exception is the 2003 application rates.

For land use, the variable *ac_irr_YEAR* captures the total number of acres irrigated in a survey year, and the variable *shr_irr_YEAR* captures the share of operated acres that are irrigated.

Covariates used include a number of variables constructed directly from FRIS: the average marginal price of water, per acre maintenance cost, per acre labor costs, share of acres irrigated using groundwater as a source, a set of dummy variables for the sources of information used to obtain information about water conservation practices, and a set of dummy variables for sources of off-farm water.[7] In addition, we use each observation's county to incorporate the following county-level variables: latitude, longitude, July Palmer drought index in each survey year, share of harvested acreage in a county that is irrigated, crop reporting district identifiers, and a proxy for EQIP competitiveness, which we describe in more detail below.

Description of Protracts data

[7] The average marginal price of water paid by a farm is the sum of the average price per acre-foot paid for any off farm water and the average per-acre pumping costs. Per-acre pumping cost is the sum of all pumping costs (across different energy sources) divided by the total amount of water applied. While this could potentially understate the marginal cost for farms that use both pumped and unpumped water, assuming that only qroundwater is pumped leads to unrealistically high marginal cost estimates. Scarcity rent for groundwater is not included directly in the estimate of the marginal price of water, but both depth to groundwater and a set of dummy variables indicating whether the aquifer is declining or rising are used in the analysis.

In addition to farm-level data drawn from FRIS, we construct a measure of county-level competition for EQIP contracts. The competition measure is used as an instrument to predict which irrigated farms have a high probability of participating in EQIP, but which is plausibly unrelated to irrigation outcomes at the farm level.

County-level competition for EQIP contracts is drawn from administrative data. State and local jurisdictions enter individual EQIP contract information into the Protracts database, maintained by the USDA Natural Resources Conservation Service. Protracts provides a detailed description of conservation practices adopted through EQIP and payments that operators receive for each practice. Each contract can be located within a county where the contract was initiated. However, detailed information about farms and operators is not available to link contracts directly with other data sets (such as FRIS).

Each contract in the database is classified based on whether it includes any water-conserving practices. The competition measure is defined as the ratio of the total number of these contracts during fiscal years 2005-2008 to the total number of farms in the county (from the 2007 Census of Agriculture). The analysis is restricted to counties where at least 10% of the cropland is irrigated.

Table A1 describes the practices funded in EQIP that could be used for irrigation water conservation. Practices are further distinguished by whether they likely can be used only for irrigation-related water conservation, or if they may be used to address multiple environmental concerns in addition to water conservation. For a contract to be included in the numerator of the competition ratio, it must include one of the practices from the top panel of table A1.[8] Figure 1 shows counties included in the analysis and the distribution of the competition measure.

Results

Table 3 presents the results of the analysis. Values in the table present the estimated of EQIP participation between 2004 and 2008 on the outcome variables. Each row represents a different outcome variable. The first seven rows of the table show the results for the 2003/2008 panel, which uses first-differencing between 2003 and 2008 to control for unobserved farm-level variables. The bottom seven rows of the table show the results for the 1998/2008 panel, which uses first-differencing between 1998 and 2008 to control for unobserved farm-level variables.

Each column represents a different model. Each model makes different assumptions about how to appropriately define the control group of farms that did not participate in EQIP.

The first model (DnD-1) is a difference-in-differences model that does not control for other time-varying covariates (weather and price) or for region-specific shocks. For this model, all non-

[8] Identifying practices with multiple conservation uses is more important when measuring competition in EQIP participation by a dollar-based ratio (e.g., the ratio of EQIP payments for irrigation-related water conservation to total EQIP funding in the county). In that case, spending on multiple-use practices would be included if the contract also contained practices from the top panel of table A1; i.e., the multiple-use practices would be judged to be part of a conserving irrigation project.

participating farms are assumed to be the appropriate control group. In general, the effects of this model cannot be taken as the causal effects of EQIP participation. This model is presented to provide an indication of the extent of the selection bias.

The second model (DnD-2) adds time-varying covariates and crop-reporting district dummy variables to the first model. For the second model, the control group for EQIP participators includes farms within the same crop reporting district with similar changes in drought indicies and marginal water prices. As expected, the effects are smaller for all of the outcome variables. The main explanation for this is geographic variation in EQIP funding. Regions that are experiencing greater water scarcity are more likely to have investments in water-conserving technology and more likely to have average reductions in water application rates, which would bias the previous model away from zero in its estimates of the effects of EQIP participation.

The DnD-2 model suggests that in terms of technology adoption, irrigators participating in EQIP were more likely to adopt a water or energy saving technology and had a larger average change in the share of potentially water-conserving technologies. This holds true for both the 2003 and the 2008 panels. However, relative to all other farms in both panels, irrigators participating in EQIP increased their water use, increased their irrigated acreage, and increased the share of operated acres that are irrigated. In terms of application rates, farms participating in EQIP had relative declines in application rates (by either measure). In summary, the DnD-2 model suggests that EQIP may lead to technology changes and reductions in application rates, but actually leads to an increase in water use by facilitating an expansion of irrigated acreage.

As noted in the empirical methodology section, the DnD-2 model may suffer from biased estimates of the effect of EQIP participation. For most of our outcome variables, subsequent analysis suggests that this is likely to be the case. Application rates provide a useful example.

In evaluation of job training programs, difference in marginal effects based this difference in baseline conditions has become known as "Ashenfelter's dip." With respect to flow-rates, a similar bias could occur if farm's participating in EQIP tended to have above average application rates in the baseline periods. To test the DnD-2 model for potential bias due to this effect, the fifth column of the table (DnD-2 check) shows the results of regressing the baseline level of each outcome variable (in either 2003 or 1998) on the regional dummies and the differenced drought indicies and marginal prices. In most cases, this check reveals a statistically significant difference in baseline conditions between the treatment and control groups. For the 2003/2008 panel, the DnD-2 model suggests that EQIP participation lowered water application rates by 0.222 acre-feet acre, but the test of Ashenfelter's dip reveals that these participators also began in 2003 with an average application rate that was 0.241 acre-feet per acre higher than the control groups.

The other results in the fifth column indicate other, perhaps unexpected, systematic difference between the treatment and control groups in the DnD-2 model. Farms participating in EQIP tended to be more likely have higher levels of potentially conserving technologies in the baseline period. Farms participating in EQIP also tended to use more water in the baseline, the opposite of what we would expect in terms of "Ashenfelter's dip." For the 1998/2008 panel, farms that participated in EQIP also tended to have more irrigated acreage in the baseline period. This could be a case of large farms getting larger and also being more likely to participate in EQIP.

The third model (NN) is the nearest neighbor matching estimator and is shown in the third column of the table. In all but one case, the estimated marginal effect of EQIP participation is not statistically different from zero. One reason for this is that the point estimates of the effects are generally smaller, as expected based on the Ashenfelter dip tests. Another reason is the loss of efficiency due to the effort to control for bias.

If we interpret the statistically insignificant coefficients in the matching estimators as true zeros, then our analysis indicates that EQIP participation has not had a significant effect on technology adoption, water application rates, or overall water use. This result suggests that irrigators self-select into the program and rely on the program to pay for irrigation improvements that they would be likely to make anyway. If we were to accept the bias of the DnD-2 model in exchange for the efficient improvements, we would still conclude that EQIP does not reduce water use at the farm level.

The fourth model (IV) is presented in the fourth column of the table. The IV model generally suffers from weak instruments, as evidenced by the large changes in coefficient estimates, some of which switch signs.

Conclusion

The dramatic increase in EQIP funding following the 2002 Farm Act provided an opportunity to evaluate the impact of EQIP on irrigation efficiency and water conservation. Using a unique farm-level panel dataset that spans this increase in funding, we are able to compare the changes in several different outcomes between farms that participated in EQIP and appropriately defined control groups. Based on a nearest-neighbor matching estimator, we find no evidence that EQIP has resulted in any measurable water conservation at the farm-level.

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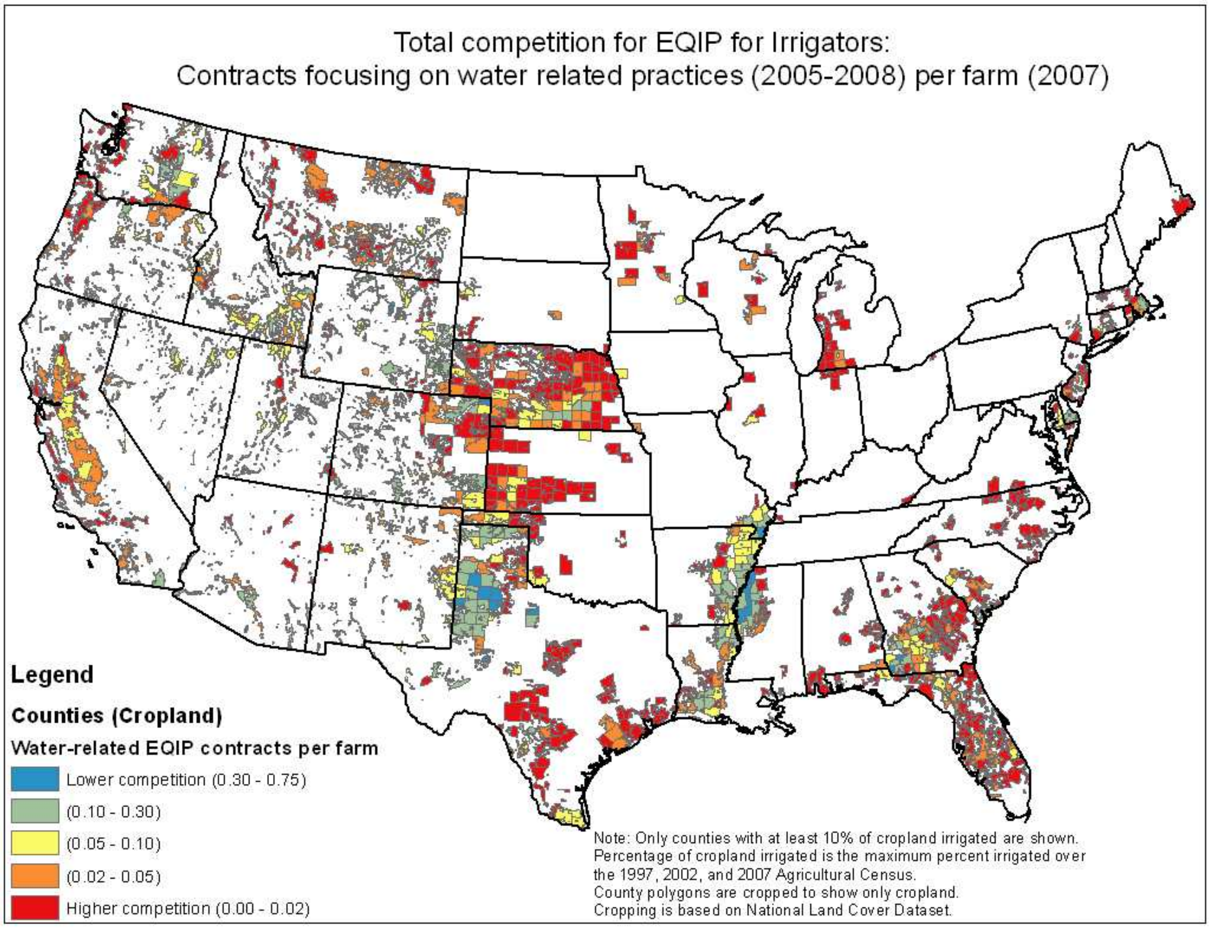
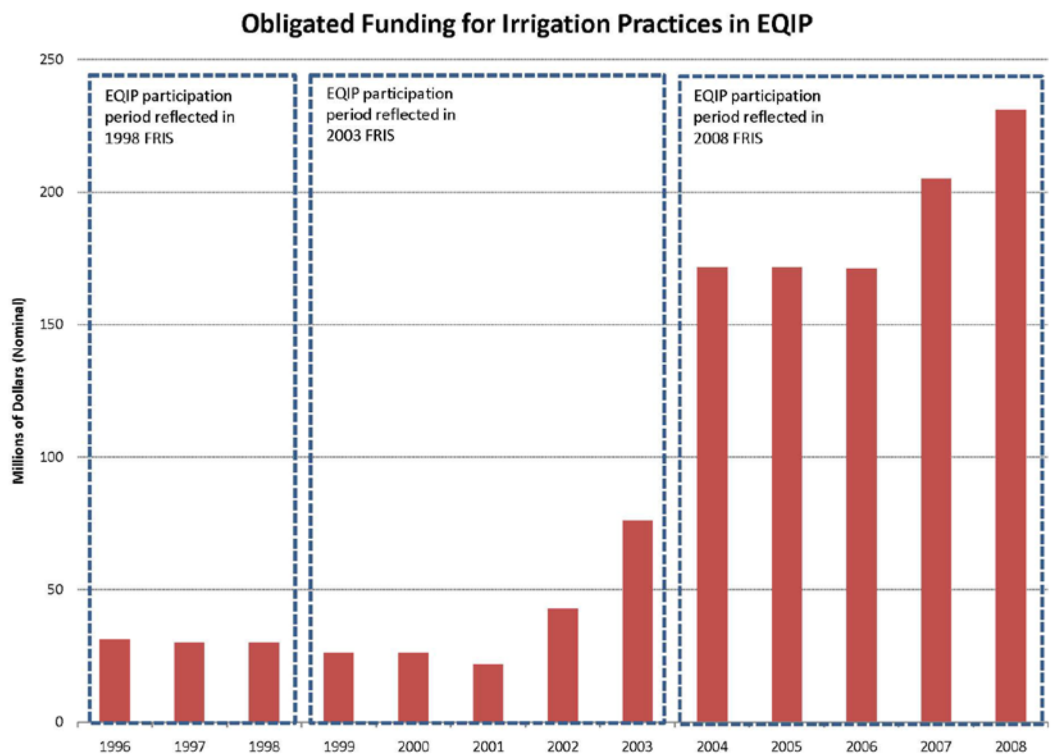
Figure 1: Location of and competition for EQIP funding



Source: Acreage of cropland irrigated and number of farms per county obtained from USDA Agricultural Census. Number of water-related contracts per county obtained from authors' analysis of USDA PROTRACTS database.

Figure 2: Time-line for EQIP data



Source: Authors' analysis of USDA PROTRACTS database.

Table 1: Thirty years of U.S. irrigation

Year	Total acres irrigated	Total water use (acre-feet)	Average application rate (ac.ft./ac.)	Change in application rate since 1979
1979	50,154,249	93,071,345	1.856	
1984	45,821,428	82,182,177	1.794	-3.4%
1988	47,753,727	84,182,177	1.763	-5.0%
1993	46,418,380	79,627,392	1.715	-7.6%
1998	50,028,439	90,563,665	1.810	-2.4%
2003	52,492,687	86,757,665	1.653	-10.9%
2008	54,929,915	91,235,036	1.661	-10.5%

Source: USDA Agricultural Census, FRIS: 2008, table 11; 1998, table 10; 1994, table 10; 1983, table 10.

Table 2: Selected summary statistics

2003/2008 Panel					
Variable	**Description**	**Median**	**Mean**	**Std. dev.**	**N**
PARTICIPATION VARIABLES					
eqip2008	Participated '04-'08		0.095	0.294	3,781
eqip2003	Participated '99-'03		0.049	0.215	3,781
eqip0308	Participated both		0.021	0.142	3,781
OUTCOME VARIABLES					
improve2008	Improved '04-'08		0.391	0.488	3,781
shr_con_2008	Share conserving '08	0.000	36.366	45.472	3,781
shr_con_2003	Share conserving '03	0.000	35.727	44.524	3,781
acreft_2008	Water use '08	56.000	611.301	2718.683	3,781
acreft_2003	Water use '03	24.200	536.828	2202.950	3,781
avg_app_2008	Application rate '08	1.400	1.875	1.719	3,780
avg_app_2003	Application rate '03	1.100	1.191	0.816	3,717
alt_app_2008	Alternative rate '08	1.400	1.937	1.764	3,747
alt_app_2003	Alternative rate '03	1.100	1.164	0.802	3,743
ac_irr_2008	Acres irrigated '08	62.000	413.143	1016.387	3,781
ac_irr_2003	Acres irrigated '03	63.000	369.999	1020.962	3,781
shr_irr_2008	Share irrigated '08	58.333	50.552	28.291	3,781
shr_irr_2003	Share irrigated '03	61.111	49.134	28.816	3,781
INDEPENDENT VARIABLES					
waterprice2008	Water price '08	9.259	36.205	100.074	3,781
waterpr~2003	Water price '03	5.068	102.882	1664.070	3,781
rising2008	Rising aquifer '08		0.344	0.475	2,860
rising2003	Rising aquifer '03		0.073	0.261	2,794
decline_2008	Declining aquifer '08		0.104	0.305	2,860
decline_2003	Declining aquifer '03		0.382	0.486	2,794
shr_gw_2008	Share groundwater '08	30.120	47.423	48.316	3,781
shr_off_2008	Share off-farm '08	0.000	21.226	40.546	1,748
info_ea_2003	Extension agent (0/1)		0.231	0.422	3,781
info_cn_2003	Consultant (0/1)		0.203	0.402	3,781
info_gt_2003	Government (0/1)		0.105	0.306	3,781
avgdepth2008	Depth to water '08	105.000	123.516	101.527	2,860
avgdepth2003	Depth to water '03	87.500	93.495	78.118	2,794
scarcity2008	Scarce water (0/1)		0.025	0.155	3,781
julyPDSI2008	Drought index '08	1.940	0.809	2.462	3,747
julyPDSI2003	Drought index '03	1.320	0.410	2.248	3,747
shr_w_con	Water contracts/farm	0.065	0.090	0.076	3,745

Table 2 (continued)

1998/2008 Panel					
Variable	**Description**	**Median**	**Mean**	**Std. dev.**	**N**
PARTICIPATION VARIABLES					
eqip2008	Participated '04-'08		0.099	0.298	2,076
eqip1998	Participated '99-'03		0.082	0.275	2,076
eqip9808	Participated both		0.027	0.163	2,076
OUTCOME VARIABLES					
improve2008	Improved '04-'08	1.000	0.655	0.475	2,076
shr_con_2008	Share conserving '08	0.000	25.158	39.945	2,076
shr_con_1998	Share conserving '03	27.273	39.127	35.622	2,076
acreft_2008	Water use '08	102.000	637.496	2514.618	2,076
acreft_1998	Water use '03	305.250	606.311	1548.363	2,076
avg_app_2008	Application rate '08	0.853	1.302	1.058	2,076
avg_app_1998	Application rate '03	0.974	1.563	1.251	2,046
alt_cro~2008	Alternative rate '08	0.950	1.348	1.120	2,064
alt_cro~1998	Alternative rate '03	1.000	1.578	1.260	2,068
ac_irr_2008	Acres irrigated '08	196.000	410.865	972.968	2,076
ac_irr_1998	Acres irrigated '03	407.000	438.812	715.111	2,076
shr_irr_2008	Share irrigated '08	61.250	55.482	27.863	2,076
shr_irr_1998	Share irrigated '03	56.528	59.244	24.331	2,076
INDEPENDENT VARIABLES					
waterpr~2008	Water price '08	79.116	99.810	105.052	2,076
waterpr~1998	Water price '03	13.566	18.545	48.279	2,076
rising2008	Rising aquifer '08	0.000	0.493	0.500	1,582
rising1998	Rising aquifer '03	1.000	0.761	0.426	1,568
declini~2008	Declining aquifer '08	0.000	0.054	0.226	1,582
declini~1998	Declining aquifer '03	0.000	0.183	0.387	1,568
shr_gw_2008	Share groundwater '08	100.000	60.710	46.293	2,076
shr_sw_~2008	Share off-farm '08	100.000	60.071	48.277	972
info_ea_1998	Extension agent (0/1)	1.000	0.585	0.493	2,076
info_cn_1998	Consultant (0/1)	0.000	0.216	0.411	2,076
info_gt_1998	Government (0/1)	0.000	0.335	0.472	2,076
avgdepth2008	Depth to water '08	45.000	54.492	52.127	1,582
avgdepth1998	Depth to water '03	28.000	30.561	26.792	1,568
scarcity2008	Scarce water (0/1)	0.000	0.073	0.260	2,076
julyPDSI2008	Drought index '08	0.870	1.560	2.999	2,049
julyPDSI1998	Drought index '03	3.470	3.396	3.036	2,049
shr_f_w_wa~n	Water contracts/farm	0.034	0.068	0.075	2,048

Table 3: Marginal Effects of EQIP Participation

2003/2008 Panel	Model				
OUTCOME	DND-1	DnD-2	NN	IV	DnD-2 Check
Technology improvement (0/1)	0.2814***	0.2613***	0.1089	0.8274***	0.1416***
Share of conserving	3.3612***	0.6647	5.9682	-7.4453	1.9494***
Water Use (acre-ft)	205.0744***	80.1353**	24.5318	1014.0318***	82.5347**
Application rate (ac.ft./ac.)	-0.8378***	-0.2227***	-0.0787	-0.5892***	0.2410***
Alternative app. rate	-0.7458***	-0.2633***	-0.0417	-0.8693***	0.3636***
Acres irrigated	109.6832***	85.7923***	-46.5130	360.2370***	17.9994
Share of acres irrigated	3.3097***	-1.2544***	-0.2591	-16.4541***	-0.24

1998/2008 Panel	Model				
OUTCOME	DND-1	DnD-2	NN	IV	DnD-2 Check
Technology improvement (0/1)	0.0114*	0.1957***	0.1020	-0.0339**	0.3069***
Share of conserving	37.1074***	18.8031***	17.7322	82.7562***	6.2847***
Water Use (acre-ft)	598.5524***	121.8216**	1021.0570	435.9363***	227.1722**
Application rate (ac.ft./ac.)	0.1595***	-0.2844***	-0.0759	1.0725***	0.0223
Alternative app. rate	0.3600***	-0.2019***	-0.1054	1.0805***	-0.0129
Acres irrigated	224.8989***	147.3422***	514.0017*	447.4918***	235.1802***
Share of acres irrigated	6.7054***	-0.6228	2.9534	16.3844***	-11.5901***

Model notes:

DnD-1: First-differences in outcome regressed on EQIP participation dummy variable.

DnD-2: DnD-1 with weather and price differences as well as crop reporting district fixed-effects

NN: Nearest-neighbor matching estimator of average treatment effect for the treated with three matches. Matching covariates are latitude, longitude, difference in weather and water price, and baseline values for acres operated, acres rented, acres in pasture, application rate, share of acres in groundwater, water supplier and EQIP participation.

IV: DnD-2 with following exogenous instruments for EQIP participation: EQIP participation in the baseline period, a water scarcity indicator, a proxy for competitiveness of EQIP for irrigators in a given county and a set of dummy variables on where a farm gets information about water conservation.

Table A1. EQIP practices used to address water conservation issues on irrigated farmland

NRCS Practice Code	Practice Name
a. Irrigation-related practices	
320	Irrigation canal or lateral
388	Irrigation field ditch
428A, B, C	Irrigation water conveyance, ditch and canal lining
430AA, CC, DD, EE, FF	Irrigation water conveyance, pipeline
436	Irrigation storage reservoir
441	Microirrigation system
442	Sprinkler system
443	Surface and subsurface irrigation system
447	Tailwater recovery system
449	Irrigation water management
464	Land leveling for irrigation
552A, B	Irrigation pit or regulating reservoir
b. Irrigation-related practices with multiple uses	
348	Dam, diversion
349	Dam, multiple purpose
351	Well decommissioning
355	Well water testing
362	Diversion
402	Dam
431	Multi-outlet pipeline, above ground
450	Anionic polyacrylamide application
521	Pond sealing or lining
533	Pumping plant for water control
587	Structure for water control
607	Surface drainage field ditch
608	Surface drainage main or lateral
610	Toxic salt reduction
636	Water harvesting catchment
640	Water spreading
642	Water well
738	Soil salinity control
740	Pond sealing or lining, soil cement
743	Improved water application

Note: Detailed practice descriptions are available on the USDA, NRCS website: http://www.nrcs.usda.gov/technical/Standards/nhcp.html