Resource Management, Risk, and Insurance: A Decomposition of Groundwater Management Impacts in the Ogallala Region

Calvin Bryan, Colorado State University, calvinRbryan@gmail.com

Christopher Goemans, Colorado State University, cgoemans@colostate.edu

Dale T. Manning, Colorado State University, dale.manning@colostate.edu

Matthew R. Sloggy, USDA Forest Service, Pacific Southwest Research Station, matthew.sloggy@usda.gov

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1. Introduction

As climate change and population growth both intensify at the global, national, and local level (Shobande & Shodipe; 2020), determining optimal allocations of natural resources within our global system is as important as ever (Ostrom; 2008). Policies targeting resource conservation have been passed at multiple levels of government, both in the United States (NREL 2009) and abroad (Lockwood et. al 2010). Prior research has shown that this can lead to interactive effects on resource use between policies at different levels of government (Goulder & Stavins; 2011). In this research, we seek to understand the extent to which federal risk management (i.e., crop insurance) policy influences observed responses to local conservation policies. Specifically, we ask how the insurance price that producers pay (i.e., premium paid per covered value) responds to the implementation of groundwater conservation policies (pumping restrictions). We then use the insurance price response to decompose observed policy impacts into a direct impact and an indirect impact that occurs through the insurance price adjustment.

Groundwater is an example of a “common pool resource” that has a high societal value because of its use for both domestic and agricultural consumption (de Frutos Cachorro et. al 2021). Combined with relatively low cost to access, it is often at high risk of depletion across the globe (Auschbach-Hertig & Gleeson; 2012). This has generated an urgency amongst policymakers, especially at the local level, to determine efficient conservation methods as groundwater availability is directly tied to important social issues like food security (Diwakara & Nagaraj; 2003). When evaluating the impacts of local groundwater conservation policies, accounting for the broader institutional context is crucial for determining the external validity of estimates.

Beyond its direct use as a production input in agriculture, groundwater is also important to agricultural production for risk management reasons. Irrigation capacity, which includes groundwater stocks, represents a form of self-insurance[1] for farmers (Foudi & Erdlenbruch; 2012) due to its ability to mitigate the negative financial effects of drought (Lewis & Nickerson; 1989). A policy which constrains farmers' ability to irrigate could theoretically impact the capacity to self-insure and increase production risk. This can in turn affect the price of insurance products, insurance demand, and the level of public subsidy available to a producer. These insurance market adjustments can lead to impacts on groundwater use (Deryuniga & Konar; 2017). Understanding how this alternative channel influences resource conservation is important for several reasons. First, if a local government is considering passing a conservation policy in a setting where there is overlapping federal regulation, the local mandate can be designed to account for the policy interaction. In some cases, it may be possible to coordinate federal and local policy to achieve desired conservation objectives. Also, a stronger grasp of policy mechanisms highlights the need for careful interpretation of impact estimates in an overlapping institutional environment. This is especially important for the external validity of estimates. Finally, our results contribute to our understanding of how resource consumption is impacted by restrictions on its use.

[1] Self-Insurance is the practice of an individual taking measures to reduce the financial burden of a "loss" event, conditional on the loss occurring (Briys & Schlesinger; 1990).

Prior research of conservation policy impacts on groundwater consumption has operated under an implicit assumption that the changes in behavior are driven by direct effects of conservation policy (Drysdale & Hendricks; 2018, Ifft, Bigelow, & Savage; 2018). In this research, we seek to understand whether groundwater conservation policies implemented at the local level can impact irrigation through the indirect channel of increased risk management costs. To do so, we take advantage of a natural experiment. Local governments[2] on the Ogallala Aquifer have enacted restrictions over the last few decades on the amount of groundwater a farmer can withdraw over a given time period. We merge information on the timing of conservation policy implementation with data from the USDA on policy rates for the Federal Crop Insurance Program at the county-level. We then estimate if groundwater policy implementation has any impact on the cost of traditional insurance. After finding that restrictions on irrigation lead to an increase in the unsubsidized crop insurance rate (i.e., risk is increased), we borrow other estimates from the literature (Drysdale & Hendricks; 2018, Sloggy et. al 2019) to find that a non-trivial portion of groundwater policy impacts on irrigation come through this increased cost of risk management. We then determine whether agricultural producers or the federal government bear the greater share of this cost increase, finding the financial burden is shared between the federal government through increased subsidy payment and agricultural producers through lower coverage levels. We also test mechanisms which

[2] These local governments are "natural resource districts" (NRDs) in Nebraska and subsets of "groundwater management districts" (GMDs) in Kansas. In Kansas, pumping restrictions have occurred through the use of "Local Enhanced Management Areas," or LEMAs. https://agriculture.ks.gov/divisions-programs/dwr/managing-kansas-water-resources/local-enhanced-management-areas

could be driving this insurance market response, with evidence pointing toward it being driven by an increased preference toward corn in irrigated crop production.

This work contributes to the literature on conservation policy impacts in several ways. First, we find robust estimates of irrigation restrictions leading to an increased cost of risk management. Second, we provide evidence that a significant portion of groundwater policy impacts on irrigation come through behavior changes due to the increased cost of risk management, contributing to knowledge on the mechanisms driving policy impacts. Third, previous studies on the interactive effects of federal and local conservation policies have mostly focused on quality regulations (Goulder & Stavins; 2011); we provide evidence of an interactive effect between quantity regulations. Finally, this work contributes to the vast literature on the drivers of demand for crop insurance (for example, Coble et al. 1996, O'Donoghue 2014, Sherrick et al. 2004).

The rest of the paper is organized as follows. Section 2 provides a background on groundwater conservation policies passed on the Ogallala Aquifer and provides a literature review on groundwater use, depletion, and management. In Section 3 we explain our conceptual model, data, and model parameterization. Section 4 presents the results that disentangle groundwater policy impacts into direct and indirect channels. Section 5 extends our analysis to determining the distribution of costs and mechanisms behind the insurance market response. In Section 6 we discuss our findings, including their policy implications, and conclude the paper.

2. Background

2.1 Groundwater depletion

Groundwater takes up a lion's share of the planet's precious freshwater supply; roughly 99% of liquid freshwater[3] is underground (Shiklomanov & Gleick 1993). Groundwater sources have become the primary reservoir of consumptive water for billions of people around the world (Jasechko & Perrone; 2021), or half of the world's population (Zektser & Everett; 2004). Groundwater is an essential input into global food production; roughly 38% of agricultural irrigation globally uses groundwater[4] (Siebert et. al 2010). Despite groundwater being an important resource for much of the world's population, its global value is difficult to price due to missing markets (Rad et al. 2020), a growing population globally, the advancement of climate change, and uncertainty with regard to groundwater depletion[5]. More problems have been created from groundwater depletion than just reduction in access for certain populations; it's also been linked to issues with sea level rise (Konikow 2011), deteriorating water quality (USGS 2018), and lower levels of non-groundwater aquatic resources such as lakes and streams (Tuluram & Krishna 2009, Brozović & Kuwayama; 2013).

Groundwater depletion is rarely desirable from society's perspective because groundwater stocks are a "common pool resource," (Shepler et al. 2019) where the private benefits of

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Commented [M6]: Cite Brozovic and Kuwayama here too—its in JEEM

Commented [M7]: Maybe cite a GW paper here.

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[3] Groundwater makes up 30% of total freshwater stocks, liquid and solid, where 69% of freshwater is frozen in glaciers and ice caps.
[4] One-third of industrial water use relies upon groundwater as well (Lall et al. 2020), showing that the agricultural sector is not the only consumptive commercial user of this resource.
[5] *Groundwater depletion* has been defined as the multi-year withdrawal of groundwater from an aquifer at a rate faster than its replenishment, often causing groundwater level declines and volume reductions (Margat et al. 2006).

groundwater extraction greatly exceed their private costs. This problem is further worsened by the fact that many local (and federal) governments around the world have failed to legislate groundwater in a timely manner prior to its scarcity approaching critical levels[6] (Nayak 2009, Reddy 2005). Evidence points toward local management of groundwater resources being preferred to national or global policy solutions (Foster et al. 2013), both for geographic and hydrogeologic reasons. A variety of policies have been implemented at the local-level around the world to curb groundwater depletion (Endo 2015), including direct regulation, market-based approaches, and community management (Ifft, Bigelow, & Savage; 2018, Drysdale & Hendricks; 2018, Kataoka 2006).

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2.2 Groundwater Management on the Ogallala Aquifer

Beyond its importance globally, groundwater is also an essential resource in the United States, making up 26% of the freshwater withdrawn every day (USGS 2009). The most important source of agricultural groundwater is the Ogallala Aquifer, which is the largest aquifer in the country and the source of 30% of all groundwater used for irrigation (USDA 2011). The Ogallala Aquifer is situated in the High Plains region, providing water to residents of 215 counties in Texas, Oklahoma, Kansas, Nebraska, South Dakota, Wyoming, Colorado, and New Mexico (Gollehon & Winston; 2013). Previous estimates of the Ogallala Aquifer's value have exceeded $20 billion (Little 2009), mostly due to its importance to the agricultural sector.

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[6] In some cases, policies can contribute directly to depletion. For example, in India, many agricultural groundwater users receive free electricity for pumping (Kondepati 2013).

The 112 million acres of land the aquifer is situated upon produces over 1/5th of the US's corn, wheat, and cotton supply (Houston et al. 2013). Outside of agriculture, the Ogallala Aquifer also provides drinking water to over 2.3 million people (Houston et al. 2013).

Since numerous industries and communities rely on access to this groundwater reservoir, a broad set of values exist which must be considered in its management (Lauer 2018). The Ogallala Aquifer has traditionally been thought of as a common pool resource from a management perspective due to producers often failing to internalize all its values, only those which come through their profits and utility (Lauer et al. 2018). With the vast amount of agricultural production occurring in the High Plains region, this would suggest that the Ogallala is at high risk of depletion in the absence of any conservation policies. Previous depletion estimates of the Ogallala have determined that the aquifer, containing 3,608 km^3 of groundwater, loses 410 km^3 annually (USGS 2005). This problem has grown more dire as of late, with 32% of the total depletion that has occurred since the beginning of the 20th century happened from 2001 to 2008 (Konikow 2013).

Groundwater depletion on the Ogallala Aquifer is worsened by heterogenous management by the eight different states its located within. For example, in Kansas and Colorado, groundwater rights are managed through prior appropriation, where senior water rights holders are granted preference to junior holders (White & Krom 1995), while Texas governs groundwater under "rule of capture", where landowners can withdraw as much groundwater as they're capable. Over the last few decades there has been a transition toward local management of groundwater resources for efficiency reasons. These local governments have included “Groundwater Management Areas” in northern Texas, which mostly focus on monitoring use and identifying technology-based conservation solutions for their region (HPWD 2022). Nebraska has taken a different approach; the state has been split into “natural resource districts”, which manage groundwater (among other resources) through a variety of quantity and quality regulations. These policies include tradable groundwater permits, restrictions on expanding the number of acres you can irrigate on your property, moratoriums on drilling any new wells, or groundwater pumping restrictions.

Of the policies mentioned, pumping restrictions (called “allocation schemes” in Nebraska) have received the most attention from researchers on effective conservation management[7] (Drysdale & Hendricks, 2018; Ifft, Bigelow, & Savage; 2018, Deines et al. 2019). These policies typically restrict the amount of groundwater an agricultural producer can access within a set time period, ranging from one year to five, creating a binding constraint on their ability to access groundwater (Schoengold & Brozovic; 2018). In total, nine resource districts in Nebraska and one groundwater management districts in Kansas have adopted a pumping restriction as a means of conserving groundwater stocks.

One particular example of one of these pumping restrictions comes from the Sheridan 6 Local Enhanced Management Area (LEMA) in Kansas, which states that-

> *“Each irrigation water right within the Sheridan 6 LEMA shall be limited to a total maximum quantity of 55 inches per irrigated acre for the Sheridan 6 LEMA Period. This five-year quantity of 55 inches shall be known as the ‘initial irrigation allocation’, …”*

[7] Pumping restrictions were implemented at the local level in both Nebraska and Kansas.

In the Sheridan 6 LEMA, the pumping restriction was initially instituted from January 2013 through December 2017, with a goal of diverting no more than 114,000 acre-feet of water during the five-year period (Sheridan 6 LEMA, 2012). On January 1, 2018, the pumping restriction in the LEMA was renewed until December 31, 2022.

Using a difference-in-differences econometric framework, Ifft, Bigelow, and Savage (2018) find that pumping restrictions generally had no impact on farmland values in Nebraska from 1999 to 2012. However, they do find a heterogenous impact in parts of the state which rely more heavily upon irrigated crop production. Prior research focused on the pumping restriction implemented at the Sheridan 6 LEMA, a groundwater management district in Kansas, found that the policy induced a 26% decline in irrigation across the district (Drysdale & Hendricks, 2018). That finding is supported by Deines et al. (2019), who find that the reduction in irrigation mostly came through improvements in pumping efficiency and switching to crops that are less water intensive. While these findings match economic intuition, they also implicitly assume that all the impacts of a pumping restriction come directly from the policy, rather than through an indirect channel. In this next section I will briefly discuss the literature on the linkages between crop insurance and groundwater.

2.3 Crop Insurance and Groundwater

Crop insurance and irrigation, commonly viewed as a form of self-insurance, are two of the most utilized risk management tools in agricultural production (Ghosh, Miao, & Malikov; 2021). Crop insurance has been shown to drive irrigation decisions through a few different mechanisms; insurance participation has been shown to shift production toward more water-intensive crops (O'Donoghue et al. 2009) and expanded production on to marginal land (Miao et al. 2016, Claasen et al. 2017). Evidence also points toward moral hazard as an important behavioral channel present in farmers' irrigation decisions during adverse weather events (Deryuniga & Konar; 2017), leading them to underwater their crops in the expectation of an insurance payment for their loss.

Several recent studies have estimated the relationship between groundwater use and crop insurance prices, with evidence suggesting them to be complements. Deryuniga et al. (2021) find that a 1% increase in insured acreage corresponds to a 0.22% increase in irrigation withdrawals. Ghosh, Miao, and Malikov (2021) estimate the elasticity of premium subsidies on water use[8], finding a 1% increase in the subsidy payment resulted in a 0.446% increase in irrigation. Sloggy et al. (2019) focuses on the impact of the irrigated crop insurance rate, finding that a 1% increase in the price resulted in a 0.55% decline in groundwater withdrawals. While we have an idea how insurance may be affecting groundwater use, little is known about how restricted access to groundwater could be impacting perceptions regarding the risk of production, and in turn, the cost of risk management. In the next section, we will discuss our conceptual framework for estimating the effect of a groundwater pumping restriction on crop insurance rates.

[8] They're research focuses on the impact of "total fresh-water withdrawals", which contains both groundwater and surface water.

3. Conceptual Framework & Methods

In this section, we describe the conceptual model of how a conservation policy could affect natural resource use through multiple channels. After discussing our model, we then explain its parameterization. We then describe the sources and structure of the data we used for the parameterization. Section 3 concludes with a brief discussion of the impact of the conservation policy on risk management.

3.1 Conceptual Model

An irrigation restriction can affect the amount of groundwater a farmer withdraws to irrigate their crops for direct reasons, due to being faced with a more binding resource constraint. They also could indirectly affect groundwater use through interactions with other policies (Goulder & Stavins, 2011), especially in a multi-layered policy environment. If the passage of groundwater policy increases the riskiness of crop production in the US, then they also have implications for the federally managed crop insurance program. If there are changes in crop insurance policies, such as rate increases, this could affect farmers' irrigation decisions by further changing the amount that they irrigate (Sloggy et al. 2019, Deryuniga et al. 2021).

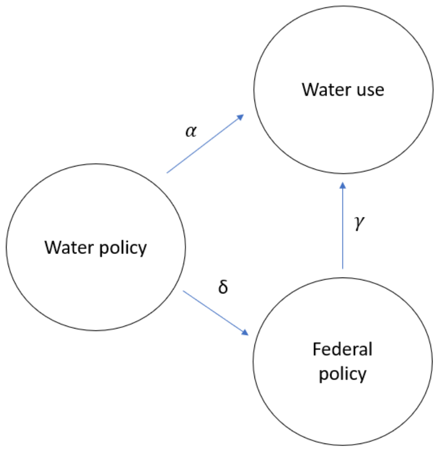

Figure 1 Potential direct and indirect effects of groundwater policy on irrigation

Figure 1 depicts our hypothesized relationship between groundwater withdrawal restrictions, irrigation, and crop insurance. Policy can impact water use directly (α) or indirectly though impacts to the federal crop insurance policy (γ) and (δ). Mathematically, groundwater use can be described as:

$$W = C + \beta\, A \tag{1}$$

W is the amount of groundwater an agricultural producer extracts. A is the presence of a pumping restriction (we also refer to this as an allocation scheme), making β the total impact of a groundwater policy on extraction. In this framework, $\hat{\beta}$ then becomes the observed total effect of the policy on groundwater use. It is common to implicitly assume that the observed impact of groundwater conservation policy is through the channel α in Figure 1.

In order to study additional channels, we modify the conventional approach by allowing an indirect channel by which a pumping restriction could impact irrigation decisions through updates to crop insurance policies.

$$W = C + \alpha A + \gamma(p(A)) \tag{2}$$

p is defined as the crop insurance rate, where $p(A)$ depicts that price (or price schedule) as a function of a pumping restriction in place $(A = 1)$. γ is the impact of crop insurance rates on groundwater use. When we take the derivative of this function with respect to A, we can then derive our hypothesized function for the total impact of groundwater withdrawal restrictions on irrigation, made up of both direct and indirect effects-

$$\frac{\partial W}{\partial A} = \alpha + \gamma \frac{\partial p}{\partial A} \tag{3}$$

When we substitute $\hat{\beta}$ back in for the total effect of a pumping restriction on groundwater use and depict the impact of a pumping restriction on crop insurance rates as δ, our equation becomes[9]-

[9] In our empirical estimates, we log groundwater use and explore relationships in terms of proportional impacts. i.e., $\hat{\beta} = \frac{dW}{W}$.

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$$\underbrace{\widehat{\beta}}_{Total\,Effects} = \underbrace{\alpha}_{Direct\,Effects} + \underbrace{\gamma\delta}_{Indirect\,Effects} \tag{4}$$

In Section 3.2 we will discuss how we parameterize the model above using a combination of previous estimates borrowed from the literature on the economics of groundwater conservation and parameters we econometrically estimated on our own.

3.2 Methods

3.2.1 Model Parameterization

To parameterize the model, we focus on the groundwater management policy implemented in the Kansas LEMA. Drysdale & Hendricks (2018) estimate this policy decreased groundwater use by 26%. Therefore, $\hat{\beta} = 0.26$. Next, Sloggy et al. (2019) find that a one percent increase in the price of irrigated insurance leads to a 0.55 percent decrease in water use. This implies $\gamma = 0.55$.

Finally, we econometrically estimate the value of δ using county-level panel data (which we will discuss more in the following sub-section). Equation (5) shows the econometric specification we use.

$$Y_{ct} = \delta A_{ct} + \beta_1 L_{ct} + \beta_2 W_{ct} + \beta_3 G_{ct} + \delta_c + \Theta_t + \epsilon_{ct} \tag{5}$$

Where Y_{ct} is the outcome variable of our model; since we are interested in the impact of a conservation policy on the costs of risk management, Y_{ct} for our main specification is the *un*subsidized crop insurance rate, P_{ct}, in county *c* and year t. A_{ct} is the presence of a pumping restriction constraining agricultural producer access to groundwater reserves. L_{ct} is a vector of controls for other conservation policies in a county. G_{ct} is the county-level saturated thickness, a measure of aquifer depth. W_{ct} is a vector of controls for weather. δ_c is a county-level fixed effect, accounting for any time-invariant heterogeneity in county *c*. θ_t is a state-year fixed effect, which will account for any statewide shocks felt in year *t*. The error term is ϵ_{ct}, with standard errors clustered at the county-level.

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While Drysdale & Hendricks (2018) focus only on the impact of the pumping restriction in Sheridan 6 LEMA, we estimate the effect of pumping restrictions in both Kansas and Nebraska to observe how stable the impacts are across the Ogallala Aquifer[10]. To allow our estimates more representative of the LEMA, and therefore Drysdale & Hendricks (2018), we use a similar sample as them with multiple crops. First, we estimate the impact of a pumping restriction on the irrigated insurance rate for each crop in our sample individually; corn, soybean, and wheat. Then, we find the share of production devoted to each crop in the Kansas Sheridan 6 LEMA based on acreage, weighting those impacts we observed for each crop individually by their acreage share to define δ in our model. We then estimate the value of $\delta * \Upsilon$, the indirect effect of a pumping restriction on irrigation, using the "nlcom" command in Stata (version 17), which allows us to back out the direct effect, α, as well.

[10] An added benefit is we obtain more statistical power using a wider geographic range, as we only have county-level data while Drysdale & Hendricks use well-level.

3.2.2 Data

To estimate the impact of groundwater management policies on crop insurance rates, we construct a panel dataset of all counties with agricultural production above the Ogallala Aquifer from 2002 to 2016, a time period which saw multiple resource districts implement pumping restrictions. Table 1 below provides a snapshot of select variables in our analysis.

Table (1) Summary statistics for irrigated corn

Variable	Mean	Std. Dev.	Min.	Median	Max.	Obs.
Dependent Variables						
Unsubsidized Rate Parameter	0.05	0.03	0.01	0.04	0.28	2404
Subsidized Rate Parameter	0.03	0.02	0.00	0.03	0.15	2289
Subsidy per Liability	0.05	0.02	0.01	0.05	0.22	2289
Independent Variables						
Share of county covered 'Allocation Scheme'	0.01	0.11	0.00	0.00	1.00	2404
Share of county covered by 'Stay on Irrigated Acre'	0.07	0.24	0.00	0.00	1.00	2404
Share of county covered by 'Drilling Moratorium'	0.08	0.26	0.00	0.00	1.00	2404
Total Precipitation (mm)	552.30	173.43	119.82	537.82	1214.26	2404
Average Daily Max. Temperature (C)	19.98	2.59	11.85	20.02	26.95	2404
PDSI	0.65	2.78	-5.08	0.51	8.03	2404
Saturated Thickness	121.54	134.24	0.00	76.57	704.75	2404

This dataset contains the share of a county covered by a policy of three types (pumping restriction, stay on irrigated acres, and moratorium on drilling wells); we focus our analysis on the impact of pumping restrictions. Data on groundwater management policies, including implementation dates and policy specifics, were collected from a combination of information reported on natural resource district websites, email correspondence with the district office, and phone conversations with employees. Identifying variation in this research not only comes from the policies being passed at different points in time in our sample period, but also from the share of the county covered by a pumping restriction. Groundwater management policies in

Nebraska are implemented at the resource district level, whose boundaries are not congruent to county lines, evidenced by the map in Figure 2, resulting in pumping restrictions covering varying shares of a county.

Data on insurance and production decisions at the county-level for corn, soybean, and wheat producers; and controls for climate and Ogallala Aquifer depths. Insurance variables, including indemnity payments, liability values, and coverage levels, were obtained from the USDA's Summary of Business (SOB) Reports (USDA 2022). Insurance rate parameters, which are separated by crop and irrigation practice type, are obtained from RMA (RMA 2021). We obtain data from NASS on the number of acres planted and yield for each crop, aggregated and broken up by irrigation status. We include several types of subsidies in our analysis. Crop insurance subsidies are included in the variables obtained from the Summary of Business reports. Other sources of farm subsidies are obtained from the Environmental Working Group (EWG)[11], aggregated at the county level.

Controls in our analysis include environmental and weather variables (PDSI, temperature, and precipitation) and county-level saturated thickness values of the Ogallala Aquifer. PDSI, obtained from the NOAA (Dai et al. 2004) is measured specifically for agriculture land[12]. Daily average temperature and total precipitation by year were acquired from Gridmet (Abatzoglou 2013). Saturated thickness, a measure of the distance between a water table and bedrock surface (USGS 2012), is obtained from Haacker, Kendall, and Hyndman (2016).

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Risk Management Agency, 2021, “title of webpage” , [Link], Accessed 2021

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Haacker, E.M., Kendall, A.D. and Hyndman, D.W., 2016. Water level declines in the High Plains Aquifer: Predevelopment to resource senescence. *Groundwater*, *54*(2), pp.231-242.

[11] Available at ewg.org
[12] Land deemed as "agricultural land" was determined by the USGS's National Land Cover Database

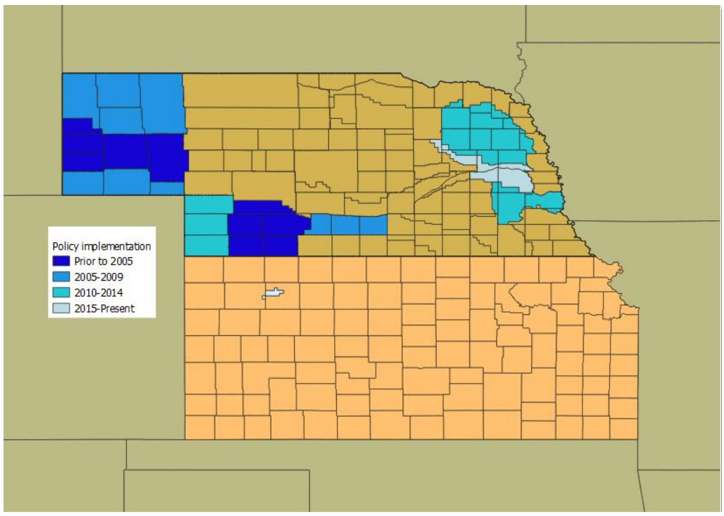

Figure 2 Map of pumping restriction coverage in Kansas in Nebraska from 2002 to 2016

<u>3.2.3 Impacts on Crop Insurance Rates</u>

When estimating the impact of a conservation policy on crop insurance rates, we focus on the rate available for irrigated corn producers on the Ogallala Aquifer. Economic intuition could suggest a positive or negative effect on the irrigated insurance rate. Restricted groundwater access may increase risk per acre and lead to higher insurance prices. Alternatively, producers may adjust to higher risk by planting fewer acres and concentrating irrigated production on higher quality land. This could decrease the cost of insuring.

In Table 2, we present the results of our estimation of δ in Equation (5) in Section 3.2.i using three different sets of controls in our model. Our first specification includes the full set of controls and fixed effects. The results reported in the second column lack any controls, only containing the state-year and county fixed effect. The third specification excludes controls for groundwater levels, due to potential endogeneity concerns if changing insurance rates could also be influencing groundwater levels over time.

Table (2) Dependent Variable: Unsubsidized Rate Parameter

	(1) Mean unsubsidized rate parameter	(2) Mean unsubsidized rate parameter	(3) Mean unsubsidized rate parameter
Share of county covered by 'Allocation Scheme' policy	0.017^{***}	0.017^{***}	0.017^{***}
	(0.004)	(0.005)	(0.004)
Share of county covered by 'Well Drilling Moratorium'	0.009^{*}		0.008^{*}
	(0.005)		(0.005)
Share of county covered by 'Irrigated Acre Stay' policy	0.001		0.002
	(0.007)		(0.006)
Lagged Precip. (mm)	-0.000		-0.000
	(0.000)		(0.000)
Lagged Max. Temp. (C)	-0.008^{***}		-0.009^{***}
	(0.003)		(0.003)
PDSI	0.000		0.000
	(0.001)		(0.001)
Saturated Thickness	0.000		
	(0.000)		
Saturated Thickness^2	0.000^{*}		
	(0.000)		
County Fixed Effects	Yes	Yes	Yes
State-Year Fixed Effects	Yes	Yes	Yes
Observations	2,342	2,342	2,342
R-Squared	0.541	0.533	0.537
Counties	188	188	188

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Standard errors clustered at the county level in parentheses.
Includes Year fixed effects.

The first row of Table 1 presents our estimates of δ. We find that restricting access to groundwater results in a statistically significant increase in the available crop insurance rate to insure irrigated corn. The magnitude of our estimate, 0.017, is robust across all three of the models we specify and suggests that, on net, restricting groundwater access increases risk per acre planted.

Finally, we use equation (6) to calculate the direct effect of the pumping restriction as:

$$\hat{\alpha} = \beta - \gamma\delta \tag{6}$$

4. Results

In Table 4, we present the estimated parameters of equation 4, which describes the decomposed estimate of groundwater policy impacts.

Table (4) Share of indirect impacts on water consumption from an NRD-level irrigation policy

Policy Impact	Impact on RP (%)	Decomposition of D&H coefficient	St. Error	z	$p > \|z\|$	CI (Lower)	CI(Higher)
Indirect Effects ($\gamma * \delta$)	39.274	0.102	17.44	2.25	0.024	5.09	73.45
Direct Effects (α)	60.726	.158	17.44	3.4	0.000	26.55	94.9
Total Effect	100	0.26					

Estimates suggest that the indirect channel occupies a non-trivial share of the impacts of a pumping restriction on total irrigation. We find that the adjustment of crop insurance rates to a pumping restriction makes up 39.3% of the total effect of this policy on irrigation, a result which we find to be statistically significant. While we do find that most of the impact of a pumping restriction on irrigation comes from the direct channel—roughly 60.7% of the total impact—ignoring the indirect channel would lead to significant overestimation of this effect. Our results imply that the pumping restriction directly reduced irrigation by 15.8% (coefficient of 0.158), while the increased cost of risk management include a 10.2% decline in irrigation. All standard errors reported in Table (4) are bootstrapped.

While our analysis reveals that there exists this alternative channel for a groundwater conservation policy to affect irrigation, we still know very little about the mechanism(s) driving this effect. In the next section, we test several mechanisms which could be driving the impact of pumping restrictions on resource use through the crop insurance market.

5. Extensions

We have now seen that (i) restrictions on groundwater access increase the irrigated crop insurance rate and (ii) that rate increase induces an indirect channel for agricultural producers to curb their irrigation. At this point, however, we lack knowledge on what behavioral or production changes could be driving this rate increase. Since crop insurance is also a heavily subsidized market (Coble & Barnett 2013), we lack knowledge on the incidence of this increased risk of irrigated production. In this section, we will explore several mechanisms which could explain our result in Table (2). We will then determine who shoulders the burden of this increased risk: agricultural producers or the federal government?

5.1 Mechanisms

While we have evidence that pumping restrictions increase the unsubsidized crop insurance rate, we do not know what behavioral or production changes could be driving this effect. To test potential mechanisms, we re-estimate our econometric models in Section 3.2.1 using different dependent variables: (i) county-level average coverage level for irrigated corn,

(ii) indemnity payment (per acre) for irrigated corn, (iii) logged irrigated corn yields, (iv) logged irrigated corn acres planted, (v) total irrigated acres planted to corn, wheat, and soybean, and (vi) the share of irrigated acres dedicated to corn. Table (5) shows the results of these estimations, using our model which includes all sets of controls and fixed effects.

Column 1 shows the impact that a pumping restriction has on the county-level average coverage level for irrigated corn production; a measure of insurance coverage on the intensive margin. Our estimation shows that the greater share of a county covered by a pumping restriction, the lower the average coverage level, with a coefficient of -0.015. This result indicates that agricultural producers who rely on irrigation respond to restrictions on groundwater access by reducing their coverage. In the second column we test whether another insurance mechanism could be driving this rate increase; we use the county-level measurement of total indemnity[13] per insured acre. Risk perceptions regarding irrigated corn production could be increasing, particularly for insurers, if producers receive higher indemnity payments in counties whose groundwater supply is governed under a pumping restriction. Column 2 shows a negative impact of the groundwater restriction on the loss payment received by irrigated corn producers, but that result is not statistically significant.

Columns 3 and 4 estimate the impact of groundwater conservation policies on logged yields and planted acres, both for irrigated corn production. We find that there is no observable impact of pumping restrictions on yields, matching the intuition in Column 2 that there is no change in the county-level indemnity payment. Column 4 shows that a pumping restriction's

[13] Indemnities are payments made to producers who observe a crop loss event.

implementation does not result in a statistically significant change in the total acres planted to irrigated corn at the county-level.

Table (5) Potential Mechanisms: Models with Full Controls

	(1) Coverage Level	(2) Indemnity per Acre	(3) Ln(Irr. Yield)	(4) Ln(Planted Acres)	(5) Total Irrigated Acres Planted	(6) Share of irrigated acres to corn
Share of county covered by 'Allocation Scheme' policy	-0.015***	-1.643	-0.040	-0.051	-2294.305	0.138***
	(0.006)	(4.617)	(0.050)	(0.032)	(15521.425)	(0.049)
Share of county covered by 'Well Drilling Moratorium'	0.003	-2.205	0.024	-0.040	-46109.895	-0.090
	(0.014)	(5.572)	(0.056)	(0.039)	(47938.312)	(0.149)
Share of county covered by 'Irrigated Acre Stay' policy	-0.025	-1.431	-0.019	0.009	56579.422	0.146
	(0.016)	(8.721)	(0.069)	(0.042)	(46473.787)	(0.159)
Lagged Precipitation (mm)	0.000	-0.034	0.000*	0.000**	12.250	0.000
	(0.000)	(0.029)	(0.000)	(0.000)	(7.627)	(0.000)
Lagged Max. Temp. (C)	0.002	-2.360	-0.015	0.032	4301.022**	0.056*
	(0.005)	(4.817)	(0.031)	(0.025)	(1861.333)	(0.029)
PDSI	-0.002**	0.906	-0.008*	-0.004	1115.954**	0.009
	(0.001)	(1.652)	(0.005)	(0.005)	(471.414)	(0.007)
Saturated Thickness	-0.003***	0.774	0.003	-0.005	812.664**	-0.002
	(0.001)	(0.880)	(0.005)	(0.006)	(377.901)	(0.003)
Saturated Thickness^2	0.000**	-0.001	0.000	0.000	0.732	0.000
	(0.000)	(0.002)	(0.000)	(0.000)	(0.794)	(0.000)
County Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
State-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,239	1,079	2,239	1,082	2,342	2,342
R-Squared	0.800	0.709	0.976	0.984	0.869	0.568
Counties	181	136	182	182	182	182

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Standard errors clustered at the county level in parentheses.

Includes Year fixed effects.

In Column 5 we use the total irrigated acres planted to corn, wheat, and soybean as our dependent variable. We find a negative coefficient, but it is statistically insignificant. In Column 6, we estimate how the policy may affect the share of total irrigated acres (Column 5's dependent variable) are planted to corn. We find that there is statistically significant and positive impact on the share of irrigated production dedicated to corn, with a coefficient of 0.138. These estimates reveal that here is no observable impact of groundwater restrictions on the amount of irrigated crop production, but those irrigated acres are being re-allocated for corn production.

Our evidence up to this point would suggest that implementing a groundwater withdrawal restriction will increase the unsubsidized insurance rate, which will in turn create an indirect channel to curb irrigation levels. Analysis of potential mechanisms revealed that this increased crop insurance rate could be driven by an increased demand for irrigated corn policies, evidenced by our finding that the share of irrigated acres allocated to corn increases following the implementation of a pumping restriction. The groundwater policy also is likely to induce a lower insurance coverage on the intensive margin for irrigated corn producers, evidenced by a lower county-wide coverage level. While this finding is interesting, we are still unable to show how a declining insurance coverage could be contributing to irrigation impacts until we know who is actually bearing the financial burden of increased risk. In a multi-layered policy environment where the federal government subsidizes risk management tools, it's possible that this burden could fall onto the government through increased subsidy payments, it could fall onto corn producers through increased cost of risk management post-subsidy (or lower coverage levels), or it could be split between the two. In Section 5.2 we will investigate who shoulders the burden of additional risk from groundwater restrictions.

5.2 The Incidence of Increased Risk

Our results in Table (2) show that the *unsubsidized* price of irrigated crop insurance increases following the implementation of a pumping restriction. At first blush, it may appear that this increases the cost of risk management for irrigated corn producers. However, it is entirely plausible that the insurance rate corn producers face when making risk management decisions is actually unaffected if they decrease coverage levels to levels that are more heavily subsidized by the federal government. Similar to the specifications we use in Table (5), the original difference-in-differences econometric model is re-estimated using a different set of dependent variables, including the subsidized crop insurance rate parameter for irrigated corn and the county-level total subsidies paid.

Following others in the literature, we define the "subsidized" crop insurance rate as the county-level total premium divided by the total liability (Goodwin 1993). For the sake of consistent interpretation of our results, we also divide the county-level total subsidies paid by the total liability in our analysis. Table (6) reveals the results of our econometric estimation of the impact of a pumping restriction on the subsidized rate parameter. Table (7) shows the same for total subsidies (per liability). Both tables follow the format of Table (2) in Section 3.2.3, where the first column reports results with all controls and fixed effects, the second column reports only fixed effects, and the third column includes all controls except for the measure of county-level Ogallala Aquifer depths.

Table (6) shows that there is not a statistically significant effect of the pumping restriction on the subsidized crop insurance rate parameter, the rate producers actually face when making insurance decisions. This effect remains positive, but in-significant, no matter which set of controls we include. When this result is taken into context with the lower coverage levels, it appears that agricultural producers bear a portion of this increased risk; farmers who live on land covered by a pumping restriction end up having lower coverage level, yet pay similar insurance rates (statistically).

Table (6) Dependent Variable: Subsidized Rate Parameter

	(1) Mean subsidized rate parameter	(2) Mean subsidized rate parameter	(3) Mean subsidized rate parameter
Share of county covered by 'Allocation Scheme' policy	0.002 (0.002)	0.002 (0.002)	0.003 (0.002)
Share of county covered by 'Well Drilling Moratorium'	0.001 (0.002)		0.001 (0.002)
Share of county covered by 'Irrigated Acre Stay' policy	-0.003** (0.001)		-0.002* (0.001)
Lagged Precip. (mm)	0.000 (0.000)		0.000 (0.000)
Lagged Max. Temp. (C)	-0.001 (0.001)		-0.001 (0.001)
PDSI	-0.000 (0.000)		-0.000 (0.000)
Saturated Thickness	-0.000* (0.000)		
Saturated Thickness^2	0.000*** (0.000)		
County Fixed Effects	Yes	Yes	Yes
State-Year Fixed Effects	Yes	Yes	Yes
Observations	2,239	2,239	2,239
R-Squared	0.803	0.801	0.801
Counties	181	181	181

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Standard errors clustered at the county level in parentheses.
Includes Year fixed effects.

Table (7) Dependent Variable: Subsidy per Liability

	(1) Subsidy per Liability	(2) Subsidy per Liability	(3) Subsidy per Liability
Share of county covered by 'Allocation Scheme' policy	0.004** (0.002)	0.004** (0.002)	0.004** (0.002)
Share of county covered by 'Well Drilling Moratorium'	0.000 (0.002)		0.000 (0.002)
Share of county covered by 'Irrigated Acre Stay' policy	0.001 (0.002)		0.001 (0.002)
Lagged Precipitation (mm)	0.000* (0.000)		0.000* (0.000)
Lagged Max. Temp. (C)	-0.001 (0.001)		-0.001 (0.001)
PDSI	-0.000 (0.000)		-0.000 (0.000)
Saturated Thickness	-0.000 (0.000)		
Saturated Thickness^2	0.000** (0.000)		
County Fixed Effects	Yes	Yes	Yes
State-Year Fixed Effects	Yes	Yes	Yes
Observations	2,239	2,239	2,239
R-Squared	0.835	0.834	0.834
Counties	181	181	181

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Standard errors clustered at the county level in parentheses.
Includes Year fixed effects.

While we are observing producers lower their coverage levels, it is possible that the federal government could be sharing that cost through increased subsidy payments. Table (7) reports the regression results with the county-level total subsidies (per liability) to irrigated corn producers as the dependent variable; we find that the counties with a greater share of their land covered by a pumping restriction receive higher subsidies from the federal government for the crop insurance program. We obtain a robust coefficient estimate of 0.004, which remains statistically significant no matter which set of controls is utilized. This represents an 8% increase at the average subsidy payment. The results of Table (4) already suggested that there is an interactive effect occurring between local- and federal-level conservation policies. Our results for the impacts on subsidies further contextualize that interaction, showing that the incidence of increased risk is passed in part onto society, through the federal government.

While it is interesting that the magnitude of our results in Tables (6) and (7) (subsidized insurance rate and total subsidies) are much lower than the magnitude on our estimate in Table (2) (unsubsidized insurance rate), we think this finding makes sense given our coverage level results in Table (5). Figure (3) depicts the market for insurance coverage before and after the increased risk of a groundwater pumping restriction.

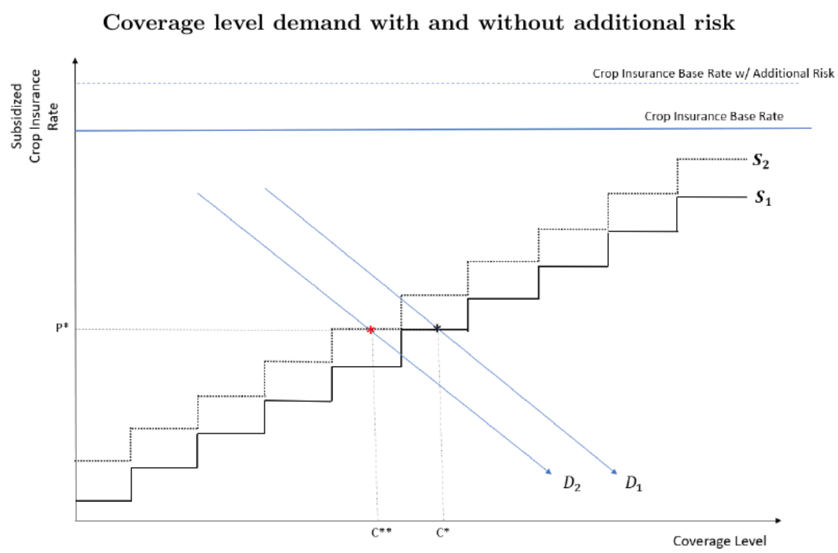

Figure 3 *Graph depicts supply and demand for crop insurance coverage with and without the increased risk of a pumping restriction*

The blue lines at the top of the graph in Figure (3) represent the base crop insurance rate, with the dashed line depicting the increased rate in the presence of a pumping restriction (see Table 2). This shifts the supply curve for coverage to left, going from S_1 to S_2, by increasing the insurance rate at each coverage level. Curve D_1 represents the coverage level demand in the absence of a pumping restriction, while D_2 shows the same relationship following the implementation of one. This depiction of the graph shows how there could be a decline in the coverage level; going from C* to C**; after the implementation of a pumping restriction (see Table 5), despite no change in the subsidized insurance price (see Table 6).

6. Conclusion

With groundwater depletion accelerating in severity around the world (Auschbach-Hertig & Gleeson; 2012) and on the Ogallala Aquifer (Konikow 2013), it's vital that we understand the optimal conservation method of this resource. A wide range of policies have been implemented around the world for purposes of long-term conservation of groundwater (Elshal et al. 2020, Kataoka 2006), most being passed at the local government level. In this research, we seek to understand if there are interactions between local and federal level conservation policies which create an indirect channel for resource use to be controlled.

Over the last several decades, local governments situated upon the Ogallala Aquifer have passed policies intended to curb the rate of groundwater depletion, one policy of note being restrictions on pumping. This phenomenon is used as a natural experiment to determine if an indirect channel exists which further reduces groundwater withdrawals through interactions with the Federal Crop Insurance Program. We devise a conceptual model for breaking the total effect of a pumping restriction on irrigation into measurable direct and indirect effects; with the indirect effect being farmers adapting their irrigation to a changing cost of risk management.

In order to parameterize this model, we must first determine exactly how pumping restrictions affect insurance prices, so we collect data for every county on the Ogallala Aquifer on dates of implementation for groundwater conservation policies and crop insurance rates. We find that the passage of a pumping restriction results in an increase in the unsubsidized crop insurance rate for irrigated corn. The point estimate of this impact is about 0.017, representing a 34% increase at the mean irrigated corn insurance rate.

Finding that pumping restrictions increase the cost of risk management, we hypothesize that this could create an alternative channel for restrictions on groundwater access to lower irrigation levels. We examine the role of indirect policy interactions in driving the total effect of pumping restrictions on irrigation estimated by Drysdale & Hendricks (2018). We find that a non-trivial share of irrigation reductions are coming from the increased risk of irrigated production, occupying just under 40%. Using the mean applied inches from Drysdale & Hendricks, a back of the envelope calculation shows that the LEMA reduced irrigation by 164 applied inches through this indirect channel.

Finally, we test for potential mechanisms driving this indirect channel and evaluate the incidence of risk impacts. We find that the passage of a pumping restriction leads to more of irrigation production shifting to corn and reductions in the county-level average coverage level. When determining who bears the burden of the increased risk we observed, our estimation showed that pumping restrictions had no observable impact on the subsidized crop insurance rate. We did find that the government pays higher levels of subsidies to counties with greater coverage by a pumping restriction. The increased subsidy payments along with lower coverage levels (and unchanged prices) suggests that the costs of this increased risk are shared by both agricultural producers and the federal government.

Future work on our end will involve estimating whether there is any heterogeneity in this impact based on the specifics of the pumping restriction (i.e. exactly how much water they can withdraw within a set time frame). It would also be helpful to understand if the groundwater policy's *implementation* that drove the changes we observed, or the policy's *announcement*. We also want to test if there is an impact on crop-related subsidies unrelated to crop insurance in the areas covered by pumping restrictions.

This work makes several contributions to the field natural resource economics and policy. First, we provide evidence of conservation policy interactions occurring between local and federal quantity regulations; previous work has mostly focused on resource quality regulations (Goulder & Stavins 2011). Second, our findings underscore the need to take the broader institutional climate into consideration when determining the optimal policy solution. Third, we provide a template for breaking down policy impacts, not just conservation policies, into direct and indirect effects. Finally, to our knowledge we are the first to estimate the impact of groundwater pumping restrictions on crop insurance rates. We contribute even more to this thread of literature by estimating that part of the financial burden of increased risk is passed on to society through the federal government.

There are several policy insights which come from this work, beyond providing more information about the broad impacts of pumping restrictions. We observed in this work that pumping restrictions had no observable impact on the subsidized price of crop insurance, possibly clouding producer decision-making with regard to their personal resource use. This seems to be an area where efficiency gains could be achieved if the federal government were to re-think how, or to what degree, they subsidized crop insurance for irrigated production in areas with restricted groundwater access. Crop insurance is one of many goods/services that the federal government will subsidize; this work can inform future local-level policy discussions regarding their interaction with a federal policy, especially one involving a subsidy. Our research also has the potential to contribute to conversations regarding the merits of conservation *technology* versus conservation *policy*, both for groundwater and other natural resources. Finally, as issues with climate change and food insecurity both intensify, we believe this research could be an important part of discussions about collaborative, inter-governmental management of the Ogallala Aquifer, as well as any other natural resource stock managed by several different bodies of government.

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Appendix

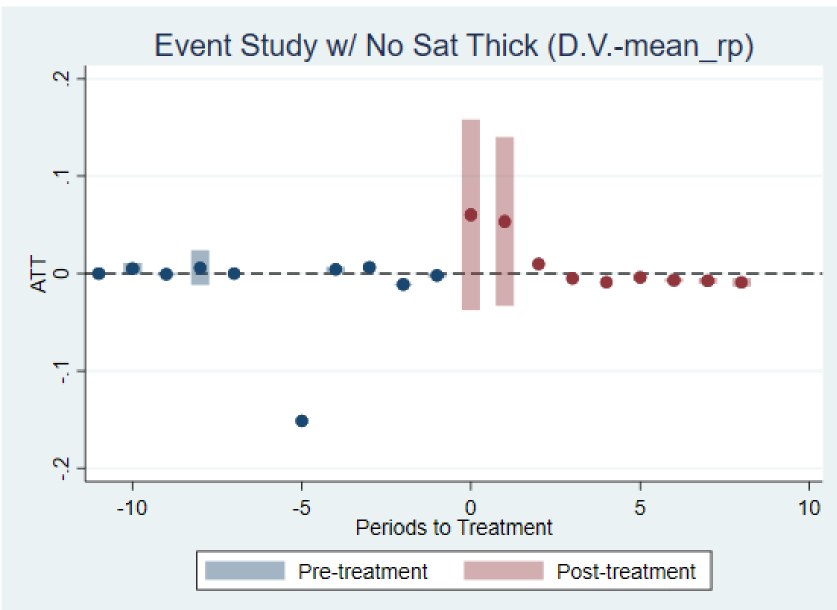

Figure A1: Santana-Callaway Difference-in-Difference estimates with unsubsidized rate parameter as dependent variable. Treatment variable is a binary indicator if a county has more than 25% of its land covered by a pumping restriction.

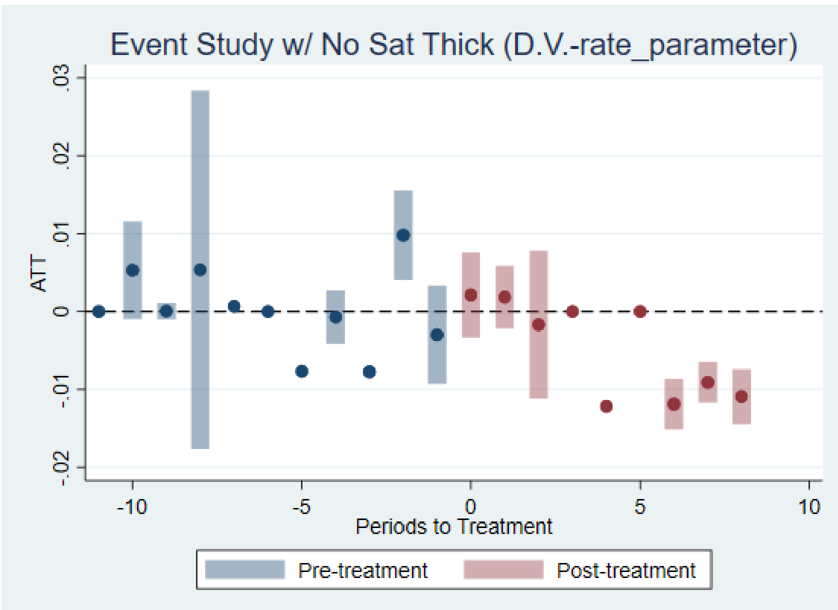

Figure A2: See Figure A1. Dependent variable - Subsidized insurance rate

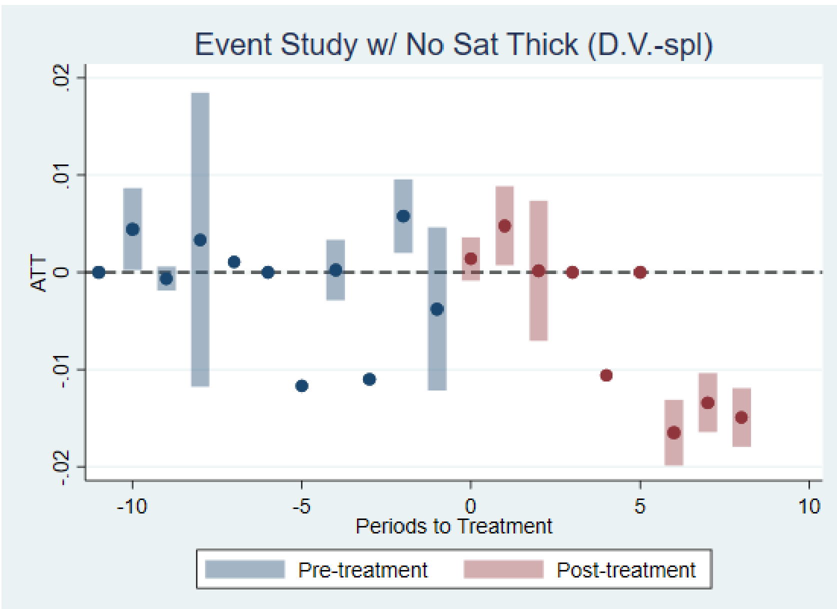

Figure A3: See Figure A1, Dependent Variable - Subsidies per Liability

Table (A1) Summary statistics for other dependent variables

Irrigated Crop	Variable	Mean	Std. Dev.	Min.	Median	Max.	Obs.
Primary Dependent Variables (soybean and wheat)							
Irrigated Soybean	Unsubsidized Rate Parameter	0.08	0.04	0.01	0.07	0.34	1856
	Subsidized Rate Parameter	0.05	0.03	0.00	0.05	0.53	1690
	Subsidy per Liability	0.07	0.04	0.02	0.07	0.68	1690
Irrigated Wheat	Unsubsidized Rate Parameter	0.10	0.05	0.02	0.08	0.37	2331
	Subsidized Rate Parameter	0.07	0.02	0.00	0.07	0.23	2266
	Subsidy per Liability	0.11	0.04	0.02	0.10	0.41	2266
Dependent Variables for other potential mechanisms							
Irrigated Corn	Coverage Level	0.68	0.10	0.00	0.70	1.00	2289
	Indemnity per Acre	21.03	60.08	-2.19	6.75	1047.35	1115
	Yield	88.39	91.42	0.00	0.00	232.50	2226
	Acres Planted	25707.95	44866.76	0.00	0.00	238000.00	2404
	Ln(Acres Planted)	10.35	1.25	5.99	10.59	12.38	1117
	Share of Total Irrigated Acres	0.36	0.40	0.00	0.00	1.00	2404

Table (A2) Dependent Variable: Unsubsidized Rate Parameter (irrigated soybean)

	(1) Mean unsubsidized rate parameter	(2) Mean unsubsidized rate parameter	(3) Mean unsubsidized rate parameter
Share of county covered by 'Allocation Scheme' policy	0.002	0.003	0.002
	(0.005)	(0.005)	(0.005)
Share of county covered by 'Well Drilling Moratorium'	0.004		0.004
	(0.003)		(0.003)
Share of county covered by 'Irrigated Acre Stay' policy	-0.005		-0.004
	(0.004)		(0.003)
Lagged Precip. (mm)	0.000		0.000
	(0.000)		(0.000)
Lagged Max. Temp. (C)	-0.006***		-0.005***
	(0.002)		(0.002)
PDSI	0.001		0.001
	(0.001)		(0.001)
Saturated Thickness	-0.001		
	(0.000)		
Saturated Thickness^2	0.000		
	(0.000)		
County Fixed Effects	Yes	Yes	Yes
State-Year Fixed Effects	Yes	Yes	Yes
Observations	1,836	1,836	1,836
R-Squared	0.802	0.798	0.801
Counties	147	147	147

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Standard errors clustered at the county level in parentheses.

Includes Year fixed effects.

Table (A3) Dependent Variable: Subsidized Rate Parameter (irrigated soybean)

	(1) Mean Subsidized rate parameter	(2) Mean Subsidized rate parameter	(3) Mean Subsidized rate parameter
Share of county covered by 'Allocation Scheme' policy	0.002	0.002	0.002
	(0.003)	(0.002)	(0.003)
Share of county covered by 'Well Drilling Moratorium'	0.003		0.003
	(0.002)		(0.002)
Share of county covered by 'Irrigated Acre Stay' policy	-0.005*		-0.004*
	(0.003)		(0.002)
Lagged Precip. (mm)	-0.000*		-0.000*
	(0.000)		(0.000)
Lagged Max. Temp. (C)	-0.002		-0.002
	(0.003)		(0.003)
PDSI	0.001		0.000
	(0.000)		(0.000)
Saturated Thickness	-0.000		
	(0.000)		
Saturated Thickness^2	0.000		
	(0.000)		
County Fixed Effects	Yes	Yes	Yes
State-Year Fixed Effects	Yes	Yes	Yes
Observations	1,665	1,665	1,665
R-Squared	0.647	0.646	0.647
Counties	147	147	147

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Standard errors clustered at the county level in parentheses.

Includes Year fixed effects.

Table (A4) Dependent Variable: Unsubsidized Rate Parameter (irrigated wheat)

	(1) Mean unsubsidized rate parameter	(2) Mean unsubsidized rate parameter	(3) Mean unsubsidized rate parameter
Share of county covered by 'Allocation Scheme' policy	-0.017	-0.018	-0.017
	(0.012)	(0.012)	(0.012)
Share of county covered by 'Well Drilling Moratorium'	-0.013		-0.013
	(0.014)		(0.014)
Share of county covered by 'Irrigated Acre Stay' policy	-0.013		-0.012
	(0.013)		(0.013)
Lagged Precip. (mm)	-0.000**		-0.000**
	(0.000)		(0.000)
Lagged Max. Temp. (C)	-0.003**		-0.003*
	(0.002)		(0.002)
PDSI	0.002***		0.002***
	(0.001)		(0.001)
Saturated Thickness	-0.001***		
	(0.000)		
Saturated Thickness^2	0.000		
	(0.000)		
County Fixed Effects	Yes	Yes	Yes
State-Year Fixed Effects	Yes	Yes	Yes
Observations	2,284	2,284	2,284
R-Squared	0.905	0.897	0.901
Counties	172	172	172

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Standard errors clustered at the county level in parentheses.

Includes Year fixed effects.

Table (A5) Dependent Variable: Subsidized Rate Parameter (irrigated wheat)

	(1) Mean Subsidized rate parameter	(2) Mean Subsidized rate parameter	(3) Mean Subsidized rate parameter
Share of county covered by 'Allocation Scheme' policy	0.002 (0.004)	0.001 (0.004)	0.002 (0.004)
Share of county covered by 'Well Drilling Moratorium'	-0.005 (0.008)		-0.005 (0.008)
Share of county covered by 'Irrigated Acre Stay' policy	-0.011 (0.007)		-0.011 (0.007)
Lagged Precip. (mm)	-0.000 (0.000)		-0.000 (0.000)
Lagged Max. Temp. (C)	-0.001 (0.001)		-0.001 (0.001)
PDSI	0.001*** (0.000)		0.001*** (0.000)
Saturated Thickness	-0.001*** (0.000)		
Saturated Thickness^2	0.000 (0.000)		
County Fixed Effects	Yes	Yes	Yes
State-Year Fixed Effects	Yes	Yes	Yes
Observations	2,221	2,221	2,221
R-Squared	0.761	0.745	0.752
Counties	170	170	170

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Standard errors clustered at the county level in parentheses.

Includes Year fixed effects.