Do Environmental Markets Improve on Open Access?

Evidence from California Groundwater Rights

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Mojave Desert

RESEARCH QUESTION

Do environmental markets improve on open access regimes for natural resources?

- Comparing to the open access regime, does the water right market generate net benefits?

GROUNDWATER LEVEL

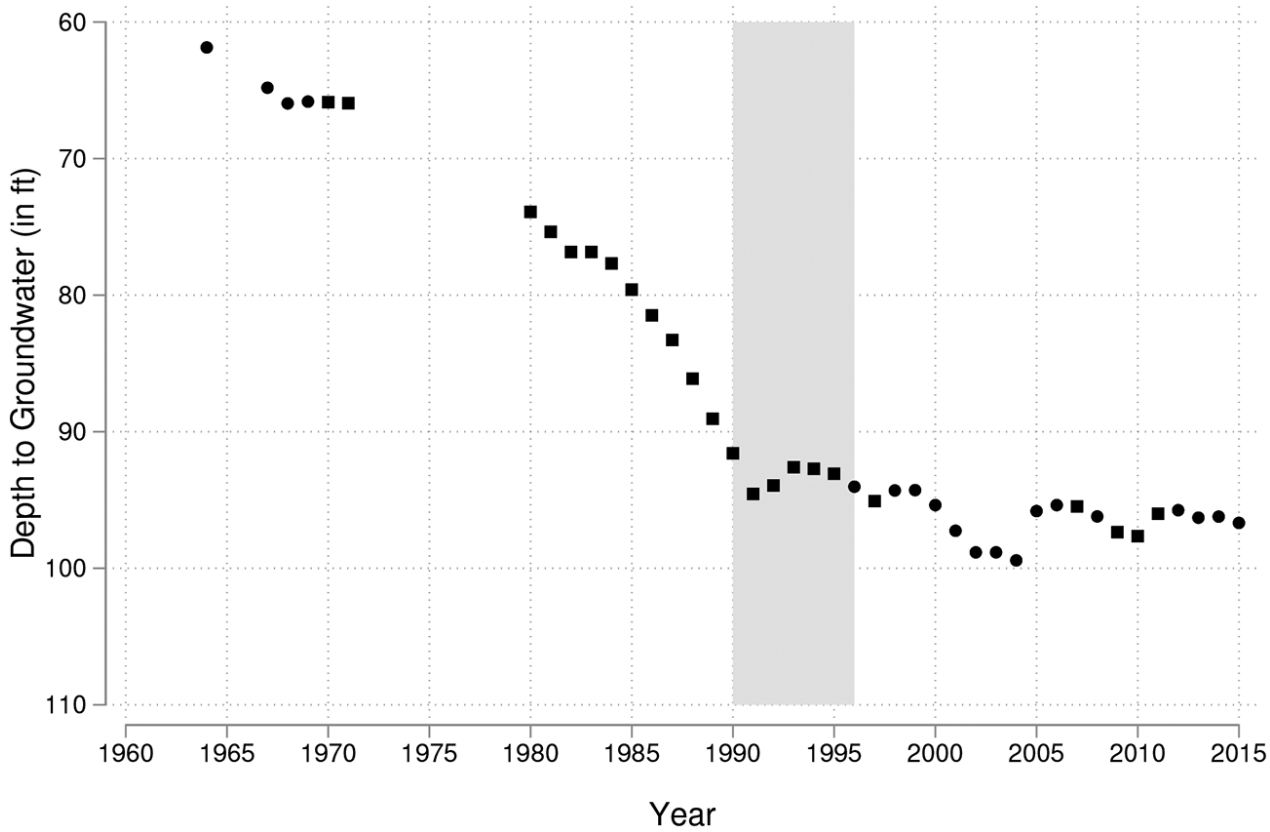


Figure: Depth to groundwater before and after adjudication.

Theory

Setup

- N landowners, each has $1/N$ of the area of the aquifer
- Instantaneous profits: $\pi(w, h)$.
  - Assume $\pi(w, h)$ is concave and singled peaked in w, increasing in h, and $\pi_{wh} > 0$.

THEORY

OPEN ACCESS REGIME

A profit-maximizing landowners solves:

$$\max_{w} \pi(w, h)$$

- $\partial\pi/\partial w = 0$ defines $w^a(h)$
- Using Cramer's rule, $dw^a/dh = -(\pi_{wh}/\pi_{ww}) > 0$, which means pumping rates under open access increase with the height of the water table.

Theory

Open assess regime

All pumps have the same rate, water level change rate is then

$$\dot{h}^a(t) = R - Nw^a(h(t))$$

The steady state is defined as $\bar{h}^a$ such that $\dot{h}^a = R - N\bar{w}^a = 0$, where $\bar{w}^a = w^a\left(\bar{h}^a\right) = R/N$.

THEORY

LAND PRICE UNDER THE OPEN ACCESS REGIME

The full open access land price is given by

$$V^a = \int_0^\infty \pi\left(w^a(s), h^a(s)\right) e^{-\delta s} ds,$$

where δ is the discount rate.

THEORY

INCOMPLETE RIGHTS

Define $\alpha \in [0, 1]$ as the share of open access landowners.

The right holders solve:

$$\max_{w} \pi(w, h) \text{ subject to } w \leq w^e.$$

THEORY

INCOMPLETE RIGHTS

The dynamics of the water table under imcomplete rights:

$$\dot{h}^{ma} = \alpha R + \theta \left(h^{mr} - h^{ma}\right) - \alpha N w^{a} \left(h^{ma}\right)$$

$$\dot{h}^{mr} = (1-\alpha) R + \theta \left(h^{ma} - h^{mr}\right) - (1-\alpha) N w^{mr}$$

THEORY

STABILIZATION AND TRANSITION

Assume the target of property right is to stablize the aquifer within the adjudication area at $\bar{h}^{mr} = h_0$ by imposing the pumping limit $w^{mr}(t)$.

$$\dot{h}^{mr} = (1-\alpha)R + \theta\left(h^{ma}(t) - \bar{h}^{mr}\right) - (1-\alpha)Nw^{mr}(t) = 0$$

Although the water table is stabilized in the adjudication area, it continues to be drawn down in the open access area. Consider $\dot{h}^{ma}$ at $t = 0$:

$$\dot{h}^{ma} = \alpha R + \theta\left(\bar{h}^{mr} - h^{ma}\right) - \alpha N w^{a}\left(h^{ma}\right) = \alpha R - \alpha N w^{a}\left(h_0\right),$$

THEORY

LAND VALUE AND WATER TRADING

Under incomplete property rights, the land price for a given owner in the adjudication area is:

$$V^{nr} = \int_0^{\infty} \left[\pi\left(w^{mr}(s), \bar{h}^{mr}\right) - p^{w}(s)\left(w^{mr}(s) - w^{e}(s)\right)\right] e^{-\delta s} ds$$

The land price for landowners in the open access area is:

$$V^{ma} = \int_0^{\infty} \pi\left(w^{ma}(s), h^{ma}(s)\right) e^{-\delta s} ds$$

Theory

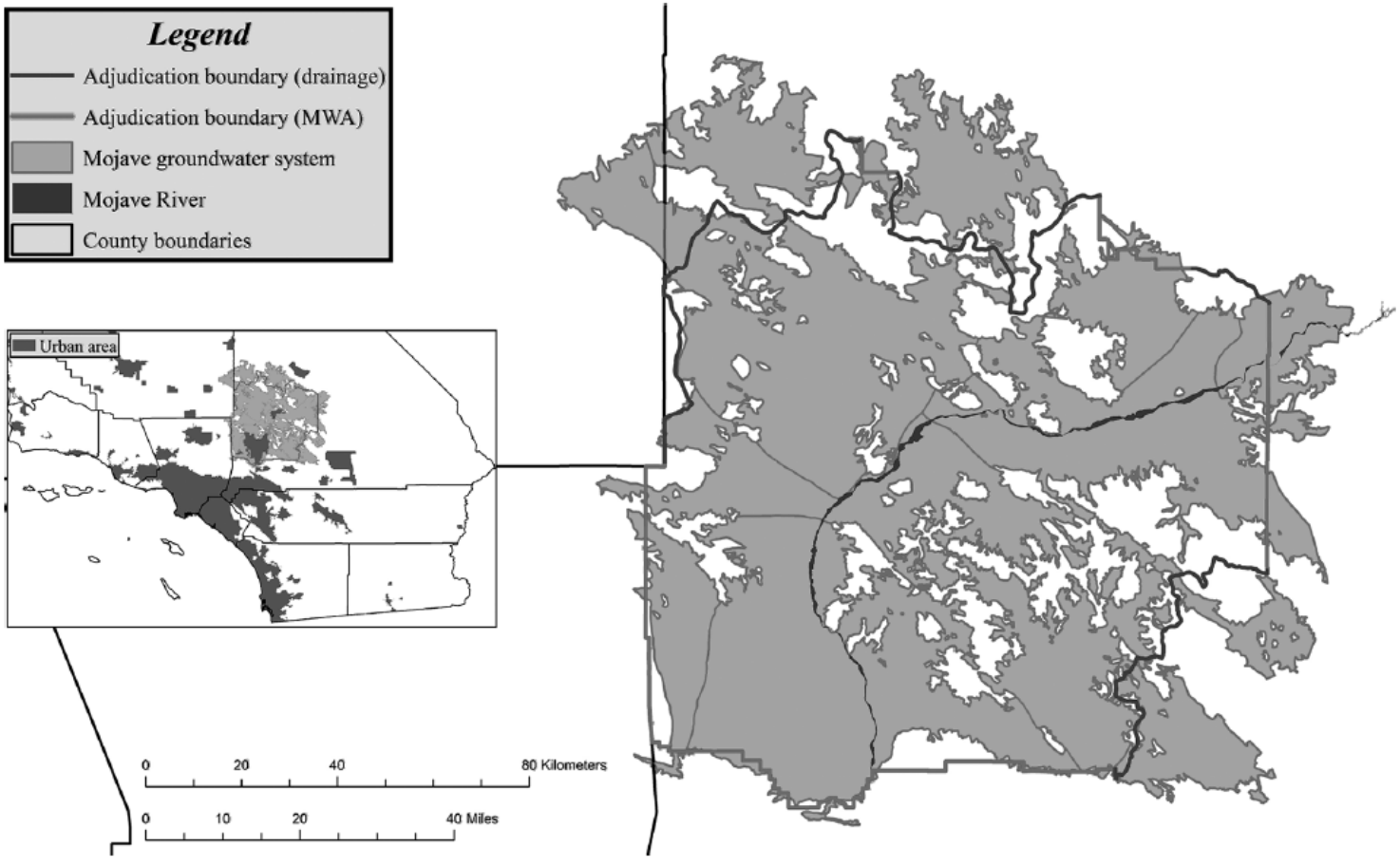
Comparing across regimes

- $V^{mr} - V^{a} \gtreqless 0$ (treatment effect has ambiguous sign);
- $V^{mr} - V^{ma} \gtreqless 0$ (estimated effect has ambiguous sign);
- $\left(V^{mr}\left(h^{b}\right) - V^{a}\right) - \left(V^{mr}\left(h^{b}\right) - V^{ma}\left(h^{b}\right)\right) \geq 0$ (estimated effect at the boundary is a lower bound for treatment effect at the boundary);
- $\left(V^{mr} - V^{a}\right) - \left(V^{mr}\left(h^{b}\right) - V^{a}\right) \geq 0$ (treatment effect at the boundary is a lower bound for treatment effect in the interior); and
- $(d/dt)\left(V^{mr}\left(h^{b}\right) - V^{ma}\left(h^{b}\right)\right) \gtreqless 0$ (the change over time in the estimated effect at the boundary has ambiguous sign).

EMPIRICAL STRATEGY

The RD estimator:

$$\begin{aligned}\hat{\beta}^{RD} &= \mathop{\mathbb{E}}_{d_i \downarrow 0}[V_i^{mr}] - \mathop{\mathbb{E}}_{d_i \uparrow 0}[V_i^{ma}] \\ &= \underbrace{\mathop{\mathbb{E}}_{i:d_i=0}[V_i^{mr} - V_i^{ma}]}_{\geqq 0}\end{aligned}$$


Legend
Adjudication boundary (drainage)
Adjudication boundary (MWA)
Mojave groundwater system
Mojave River
County boundaries
Urban area
0 20 40 80 Kilometers
0 10 20 40 Miles

Figure

EMPIRICAL STRATEGY

The RD estimator serves as a weak lower bound for the treatment effect at the boundary.

Average treatment effect:

$$\beta = \underbrace{\mathbb{E}\left[V_i^{mr} - V_i^{a}\right]}_{\geqq 0},$$

And, from the theory,

$$\beta_{i:d_1=0} - \hat{\beta}^{RD} = \underbrace{\mathop{\mathbb{E}}_{i:d_i=0}\left[(V_i^{mr} - V_i^{a}) - (V_i^{mr} - V_i^{ma})\right]}_{\geq 0},$$

Results

Regression specification

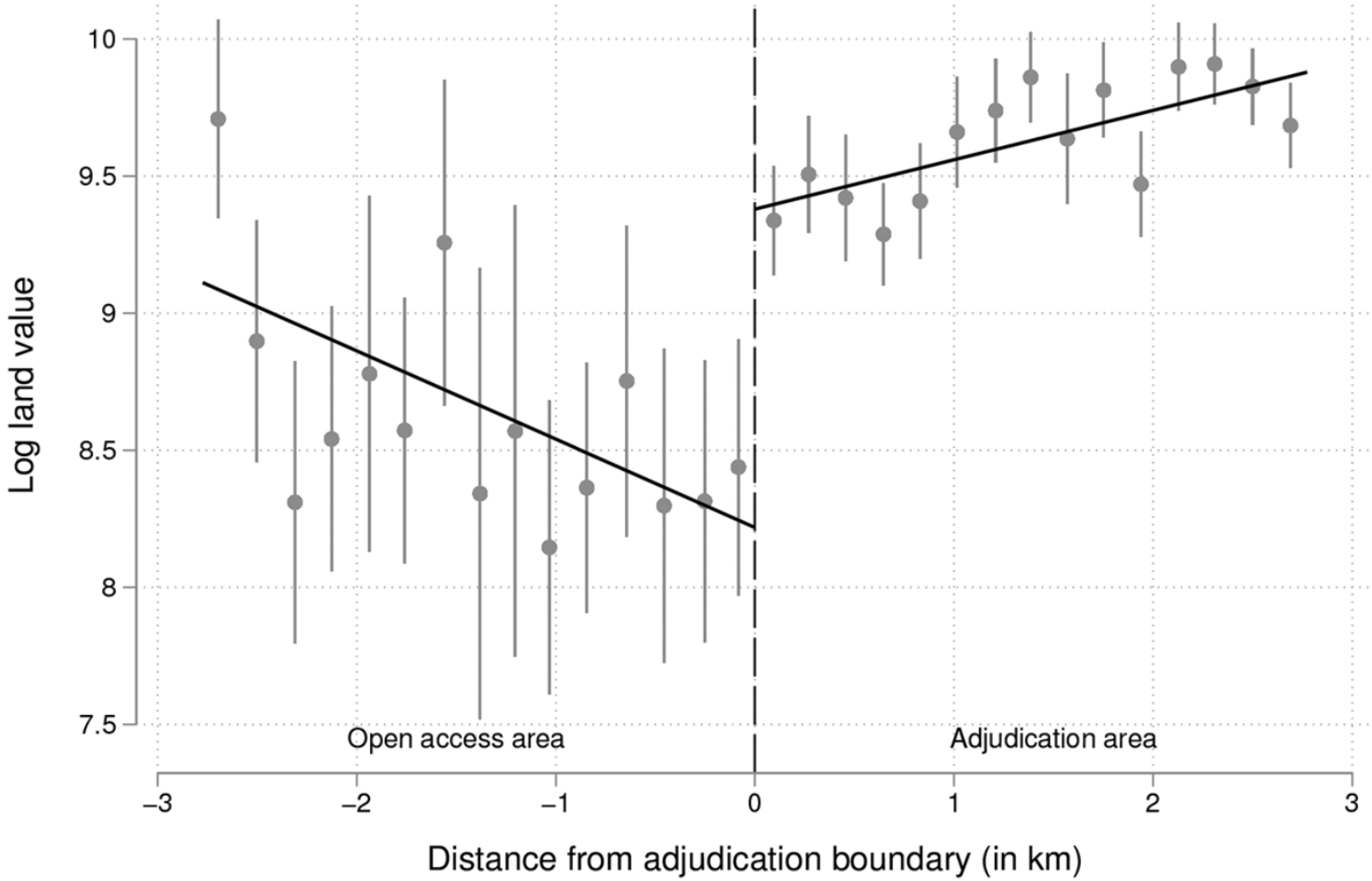
$$\ln V_i = \beta^{RD} R_i + f(d_i) + \theta' \mathbb{X}_i + \epsilon_i$$

TABLE 1
EXAMINING COVARIATE SMOOTHNESS

	Slope (1)	Aspect (2)	Near Well (3)	Last Sales Year (4)	Percent Change since Last Sale (5)	Size (6)
$\hat{\beta}^{RD}$	3.027	−21.510	.007	−1.034	25.587	3.383
p	.188	.929	.721	.184	.635	.181
95% confidence interval	−.833 to 4.23	−53.249 to 48.632	−.234 to .162	−2.91 to .559	−118.806 to 194.822	−4.675 to 24.823
Average open access value	1.858	150.759	.827	1,992.363	274.929	11.818
Observations	3,060	3,060	3,060	3,060	3,047	3,060
Zip codes	27	27	27	27	27	27

TABLE 2
MAIN RD RESULTS (Outcome: Log Land Value)

	(1)	(2)	(3)	(4)
$\hat{\beta}^{RD}$	1.161	1.344	1.216	1.345
p	.019	.031	.008	.032
95% confidence interval	.207–2.32	.123–2.644	.322–2.196	.125–2.724
Percentage effect (%)	219	284	237	284
95% confidence interval	23–918	13–1,307	38–799	13–1,423
Polynomial order	1	2	1	1
Covariates	No	No	Yes	No
Last sales year	1997–2015	1997–2015	1997–2015	2015
Bandwidth	2.774	4.715	3.126	3.073
Observations	3,060	5,341	3,535	206
Zip codes	28	30	28	24


Log land value
10
9.5
9
8.5
8
7.5
Open access area
Adjudication area
−3
−2
−1
0
1
2
3
Distance from adjudication boundary (in km)