The Economic Value of Secure Water: Landowner Returns to Defining Groundwater Property Rights

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UC SANTA BARBARA economics

EDF ENVIRONMENTAL DEFENSE FUND
Finding the ways that work

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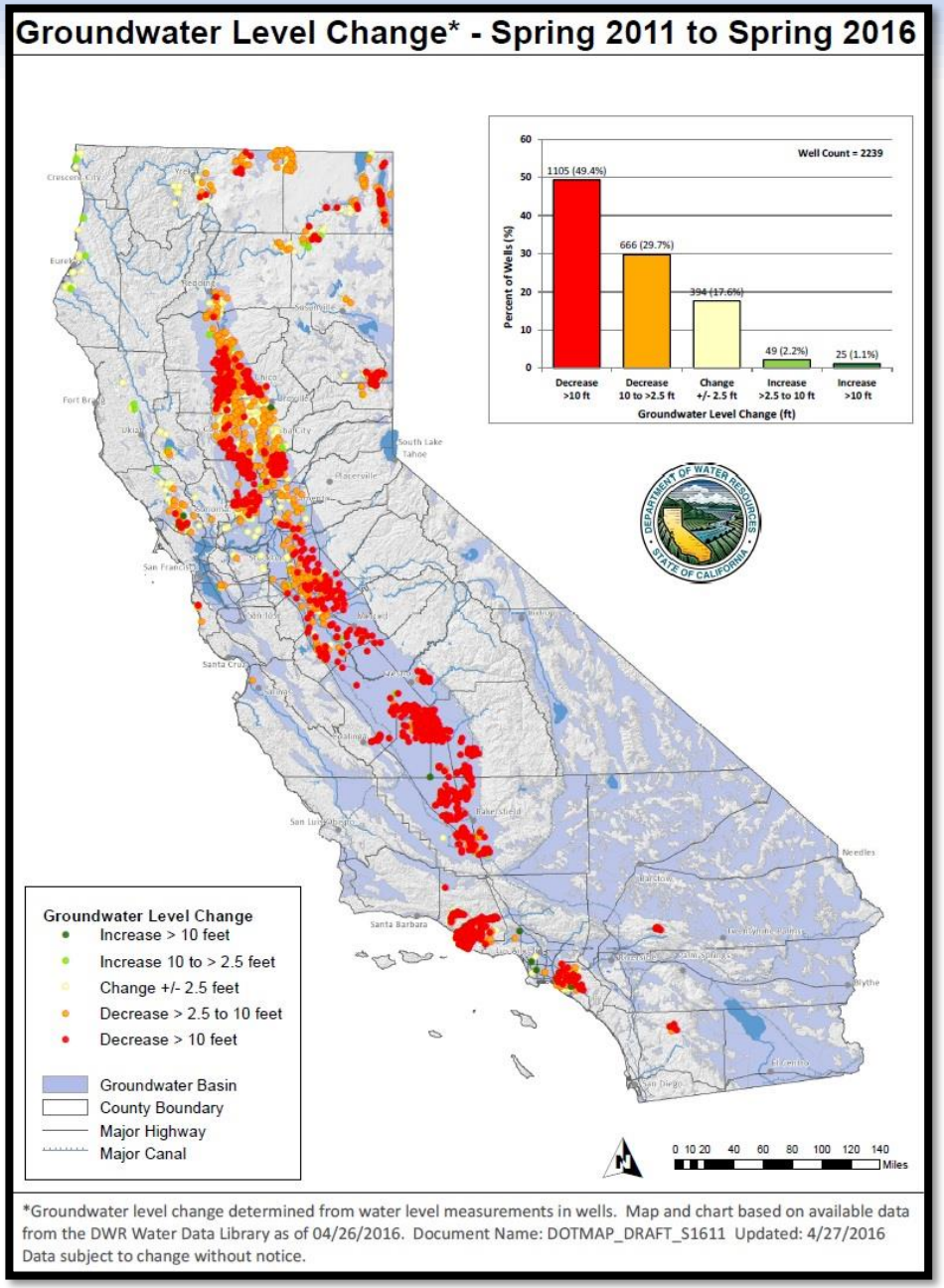
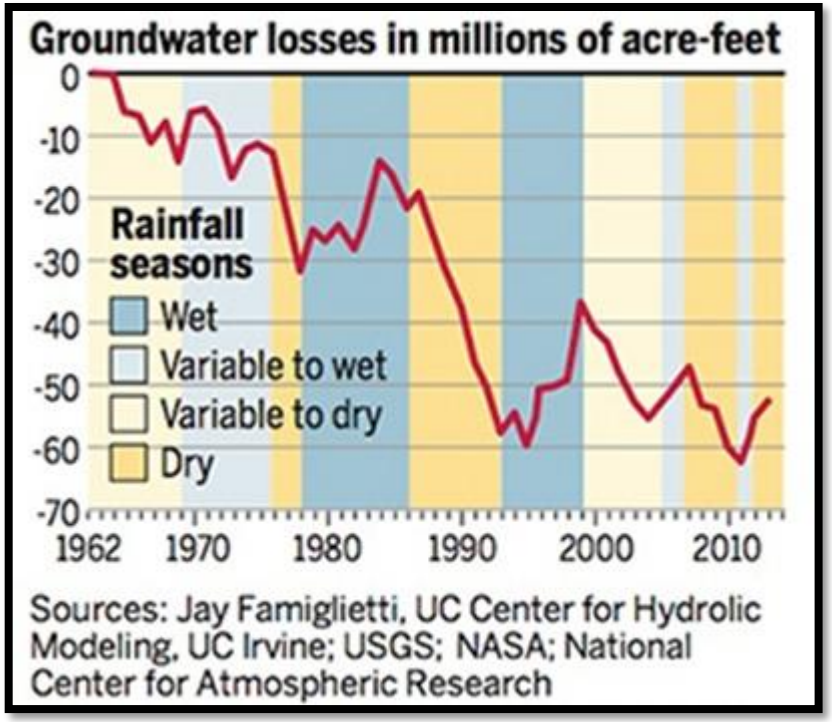
Economic Problem Statement

Common-pool Problem under Open Access

- Groundwater subject to drawdown, collateral impacts


Groundwater Level Change* - Spring 2011 to Spring 2016
Well Count = 2239
1105 (49.4%)
666 (29.7%)
394 (17.6%)
49 (2.2%)
25 (1.1%)
Percent of Wells (%)
Decrease >10 ft
Decrease 10 to >2.5 ft
Change +/- 2.5 ft
Increase >2.5 to 10 ft
Increase >10 ft
Groundwater Level Change (ft)
Groundwater Level Change
Increase > 10 feet
Increase 10 to > 2.5 feet
Change +/- 2.5 feet
Decrease > 2.5 to 10 feet
Decrease > 10 feet
Groundwater Basin
County Boundary
Major Highway
Major Canal
0 10 20 40 60 80 100 120 140
Miles
*Groundwater level change determined from water level measurements in wells. Map and chart based on available data from the DWR Water Data Library as of 04/26/2016. Document Name: DOTMAP_DRAFT_S1611 Updated: 4/27/2016
Data subject to change without notice.


Groundwater losses in millions of acre-feet
0
-10
-20
-30
-40
-50
-60
-70
Rainfall seasons
Wet
Variable to wet
Variable to dry
Dry
1962
1970
1980
1990
2000
2010
Sources: Jay Famiglietti, UC Center for Hydrolic Modeling, UC Irvine; USGS; NASA; National Center for Atmospheric Research

Economic Problem Statement

Common-pool Problem under Open Access

- Groundwater subject to drawdown, collateral impacts

Resource Value Depends on Institutions

- Definition of economic property is key (Coase, 1960; Barzel, 1989)
- Value of water: difficult measurement w/ inefficient pricing
- Bargaining over property rights: Do landowners gain?

What is the effect of defining groundwater property rights on land value?

Challenge: Few, endogenous treatments and many margins

Approach: Historical management boundary in Mojave enables hedonic regression discontinuity method

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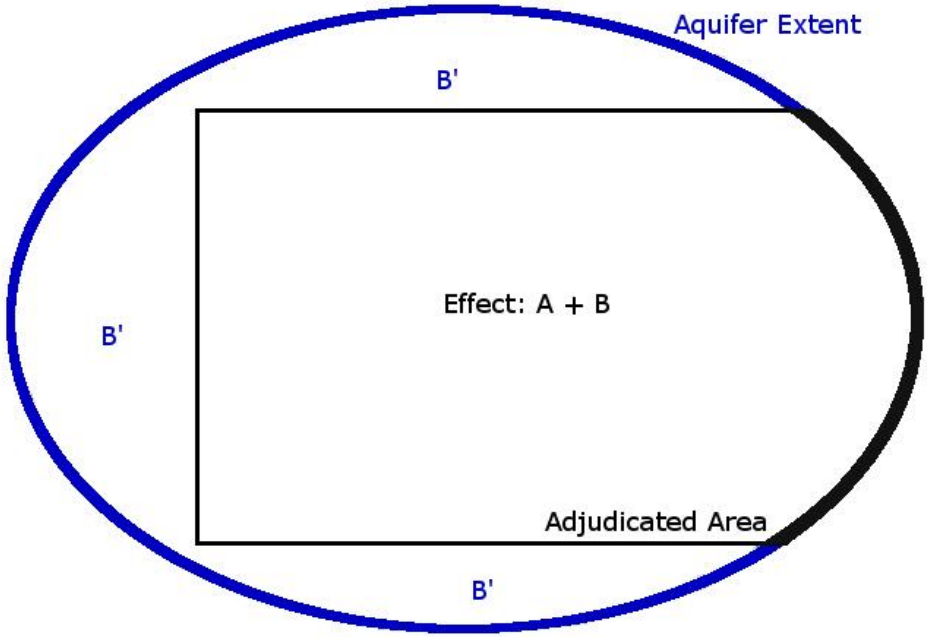
Approach: Historical management boundary in Mojave enables hedonic regression discontinuity method

Effect A
Effect of holding right: pumping rights quantified, wealth effect, and potentially gains from trade.

Effects B and B'
Resource endowment effect: resource stock improvement translated to agricultural land rents.



$$A + B > A + B - B'$$

Outline

- Background
  - Adjudicated Pumping Rights and Empirical Setting
- Conceptual Model: Intuition
- Empirics
  - Regression Discontinuity Results and Robustness
- Discussion and Conclusion

Literature & Contribution

Estimates of Water Value, not Returns to Rights

- Hornbeck and Keskin (2014), Yoo et al. (2013), Buck et al. (2014)

Groundwater Management Literature Focused on Irrigation

- *Groundwater*: Edwards (2015), Smith et al. (2017)
- *Fish*: Grafton et al. (2000)

Behavioral Margins Matter

- *Technology vs. Incentives*: Reimer, Abbott, and Haynie (2017)
- *Hedonic Advantage*: Grout et al. (2011), Turner et al. (2014)

We provide first plausible estimate of (causal) returns to PR for groundwater, use parcel-level data, and apply hedonic methods to account for all behavioral margins.

What is an Adjudicated Water Right?

Volumetric Entitlement in Perpetuity

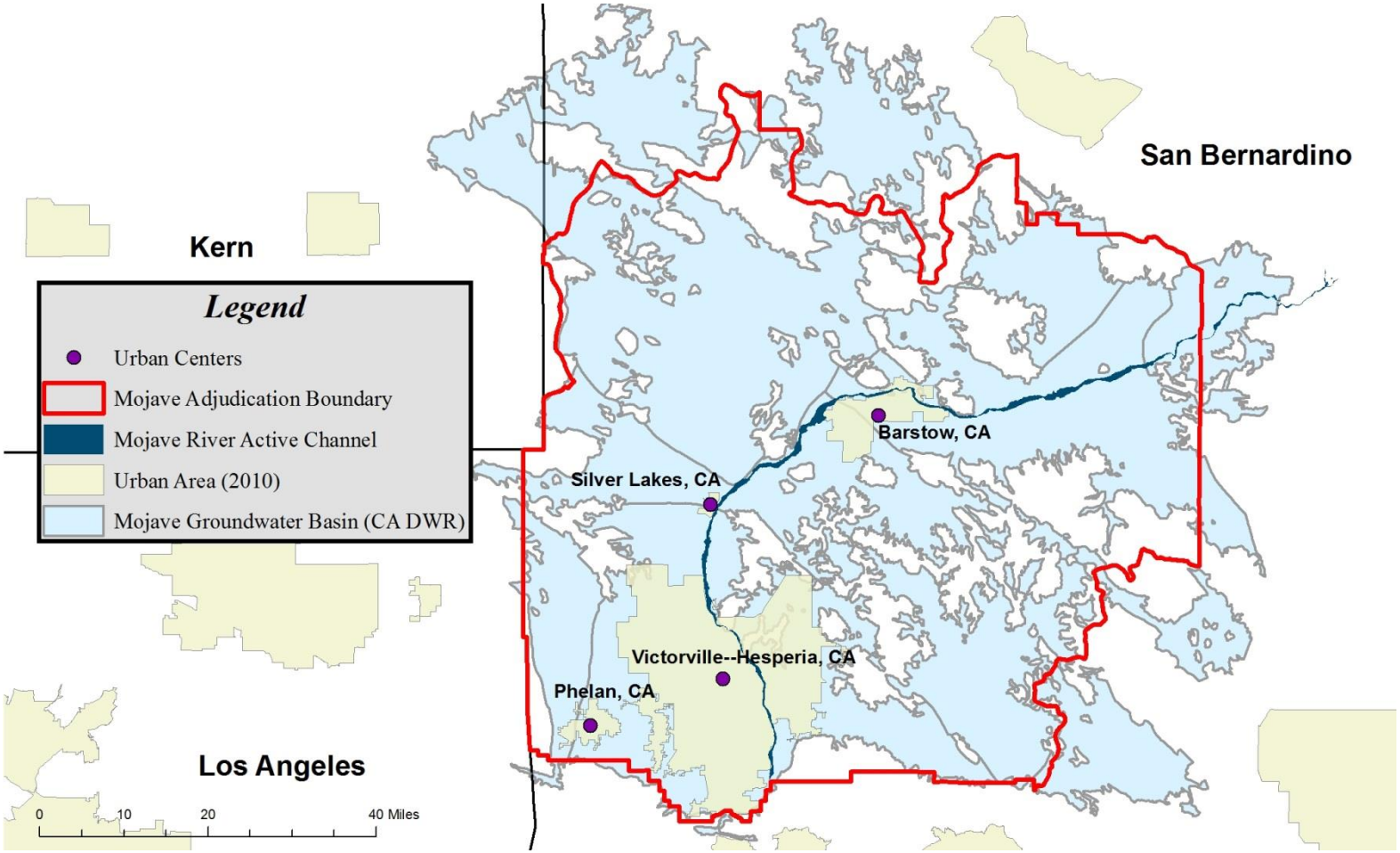
- Legal property
- Aggregate withdrawals = aggregate recharge
- Grandfathered: recent historical use

Trading does not Require Proximity

- “Paper water”

Enforced by Third-party Watermaster

Study Area


San Bernardino
Kern
Legend
Urban Centers
Mojave Adjudication Boundary
Mojave River Active Channel
Urban Area (2010)
Mojave Groundwater Basin (CA DWR)
Barstow, CA
Silver Lakes, CA
Victorville--Hesperia, CA
Phelan, CA
Los Angeles
0
10
20
40 Miles


Source: USGS

Conceptual Model

Land Price = PV(Ag Rents + Property Assets)

Effect of adjudication: $A + B$

- Implicit water rights and resource health
- Insufficient for optimal path, but improvement

Identification Confounded in Standard Setting

- Spatial discontinuity: counterfactual
- Complication: drainage spillover
- Solution: Model expectation at boundary

Model Intuition

Stabilize Water Table → Resource Benefits

- Free riders benefit without costs

However, Cooperating Users Receive Asset

- Can be traded and is capitalized into land value
- Asset value tied to growth rate in permit price

RD Sign Depends on Relative Magnitude

Model Predictions

Under standard assumptions, we estimate $\widehat{\boldsymbol{\beta}}_{\boldsymbol{RD}}$:

$$V_i^{AD} - V_i^{FR} = (A + B) - B' = A + (B - B')$$

1. $\hat{\beta}_{RD} > 0$ if $A > (B - B')$
2. $\hat{\beta}_{RD}$ increases w/growth rate of permit price
3. $\hat{\beta}_{RD}$ is lower bound

Data

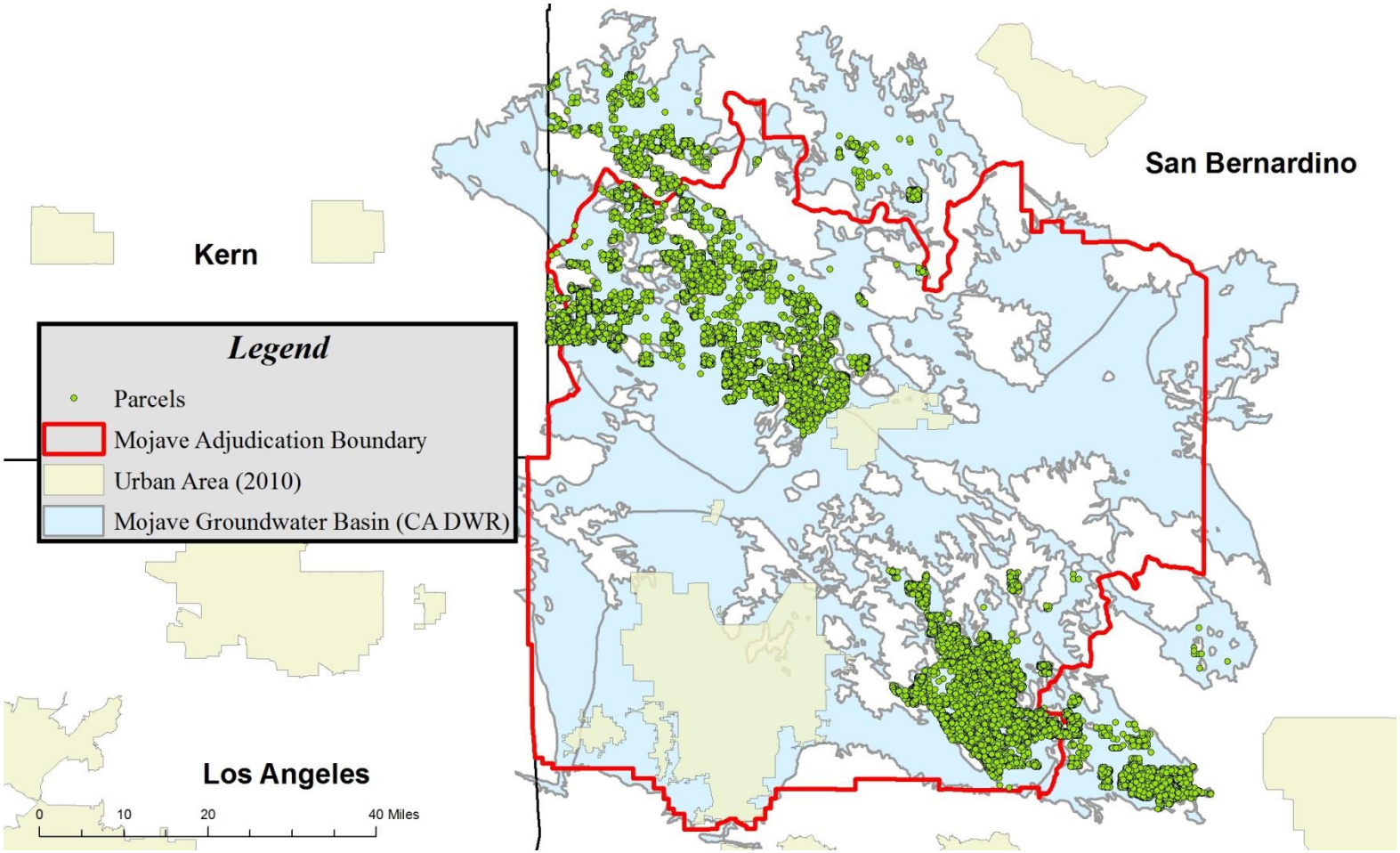
Assessed Land Values

- Reflect groundwater access rights (County Assessor, 2016)
- Capture determinants of agricultural productivity (Ma and Swinton, 2012)

San Bernardino County

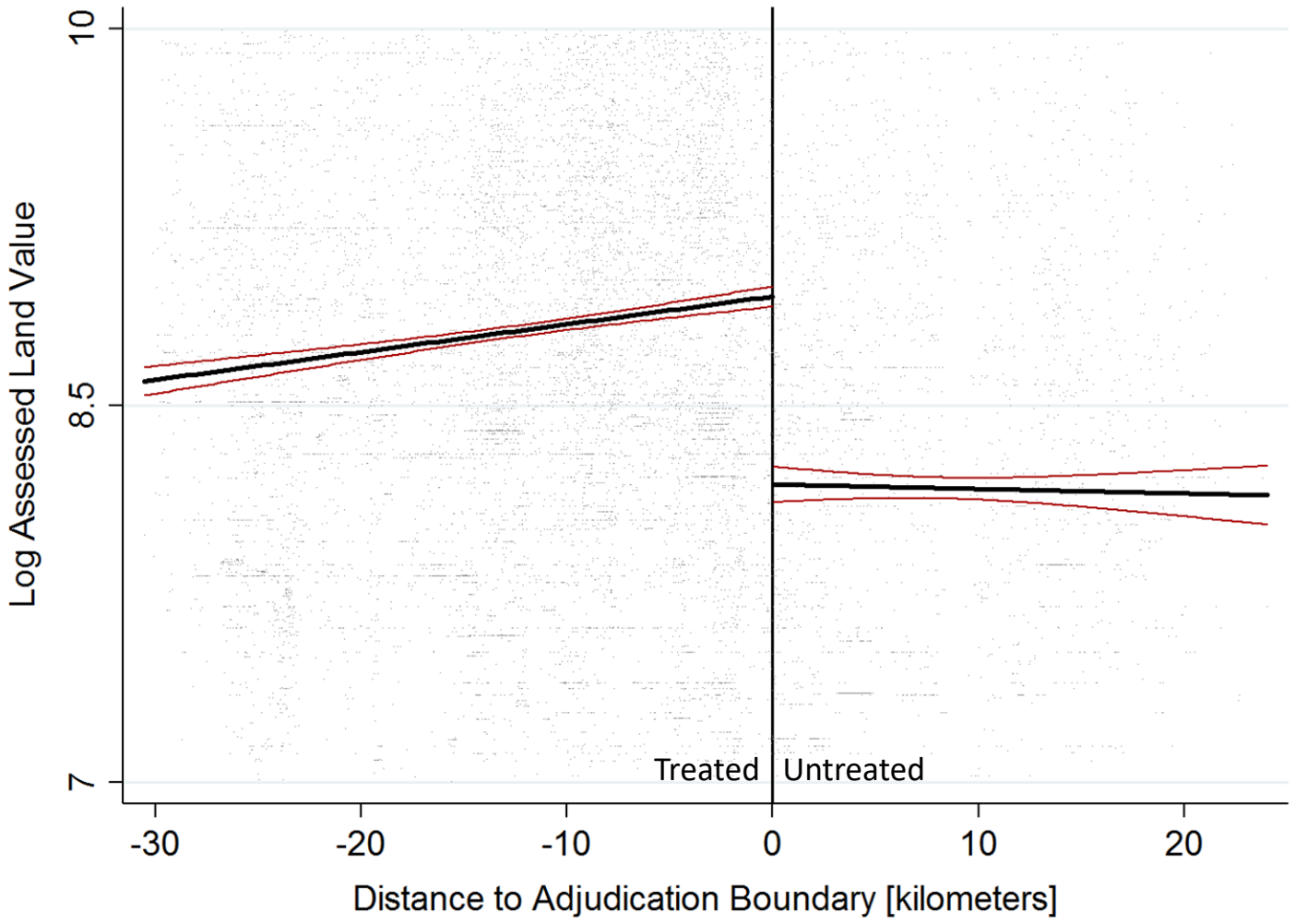
- Controls:
  - Base year of appraisal (Assessor)
  - Parcel area (SB County)
  - Distance to urban center (Authors)
  - Aggregate recharge effect (MWA/Authors)
  - Parcel slope (USGS/Authors)

Study Sample



[McCrary Test (NE)]

Raw Data - Linear Fit



[Typical Bandwidth]

$$Ln(Value_i) = \beta_0 + \beta_1 Distance_i + \beta_2 Distance_i * Adj_i + \beta_3 Adj_i + [\beta_4 X_i] + \varepsilon_i$$

$$Ln(Value_i) = \beta_0 + \beta_1 Distance_i + \beta_2 Distance_i * Adj_i + \beta_3 Adj_i + [\beta_4 X_i] + \varepsilon_i$$

	Dependent Variable: Ln(Land Value)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Adjudication Dummy		0.479**						
		(0.196)						
Observations		4,005						
Polynomial		Linear						
Bandwidth Choice		CCT						
Kernel		Uniform						
Covariates		Yes						

Standard errors in parentheses and corrected for heteroscedasticity and spatial autocorrelation, and significance as follows: *** p<0.01, ** p<0.05, * p<0.1.

[All Coefficients] [Covariates RD] [McCrary Test] [Bin Estimate] [Falsification]

$$Ln(Value_i) = \beta_0 + \beta_1 Distance_i + \beta_2 Distance_i * Adj_i + \beta_3 Adj_i + [\beta_4 X_i] + \varepsilon_i$$

	Dependent Variable: Ln(Land Value)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Adjudication Dummy		0.479**		0.423**				
		(0.196)		(0.202)				
Observations		4,005		3,028				
Polynomial		Linear		Linear				
Bandwidth Choice		CCT		IK				
Kernel		Uniform		Uniform				
Covariates		Yes		Yes				

Standard errors in parentheses and corrected for heteroscedasticity and spatial autocorrelation, and significance as follows: *** p<0.01, ** p<0.05, * p<0.1.

[All Coefficients] [Covariates RD] [McCrary Test] [Bin Estimate] [Falsification]

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	Dependent Variable: Ln(Land Value)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Adjudication Dummy		0.479**		0.423**		0.570**		0.577**
		(0.196)		(0.202)		(0.239)		(0.240)
Observations		4,005		3,028		4,537		4,429
Polynomial		Linear		Linear		Quadratic		Quadratic
Bandwidth Choice		CCT		IK		CCT		IK
Kernel		Uniform		Uniform		Uniform		Uniform
Covariates		Yes		Yes		Yes		Yes

Standard errors in parentheses and corrected for heteroscedasticity and spatial autocorrelation, and significance as follows: *** p<0.01, ** p<0.05, * p<0.1.

[All Coefficients] [Covariates RD] [McCrary Test] [Bin Estimate] [Falsification]

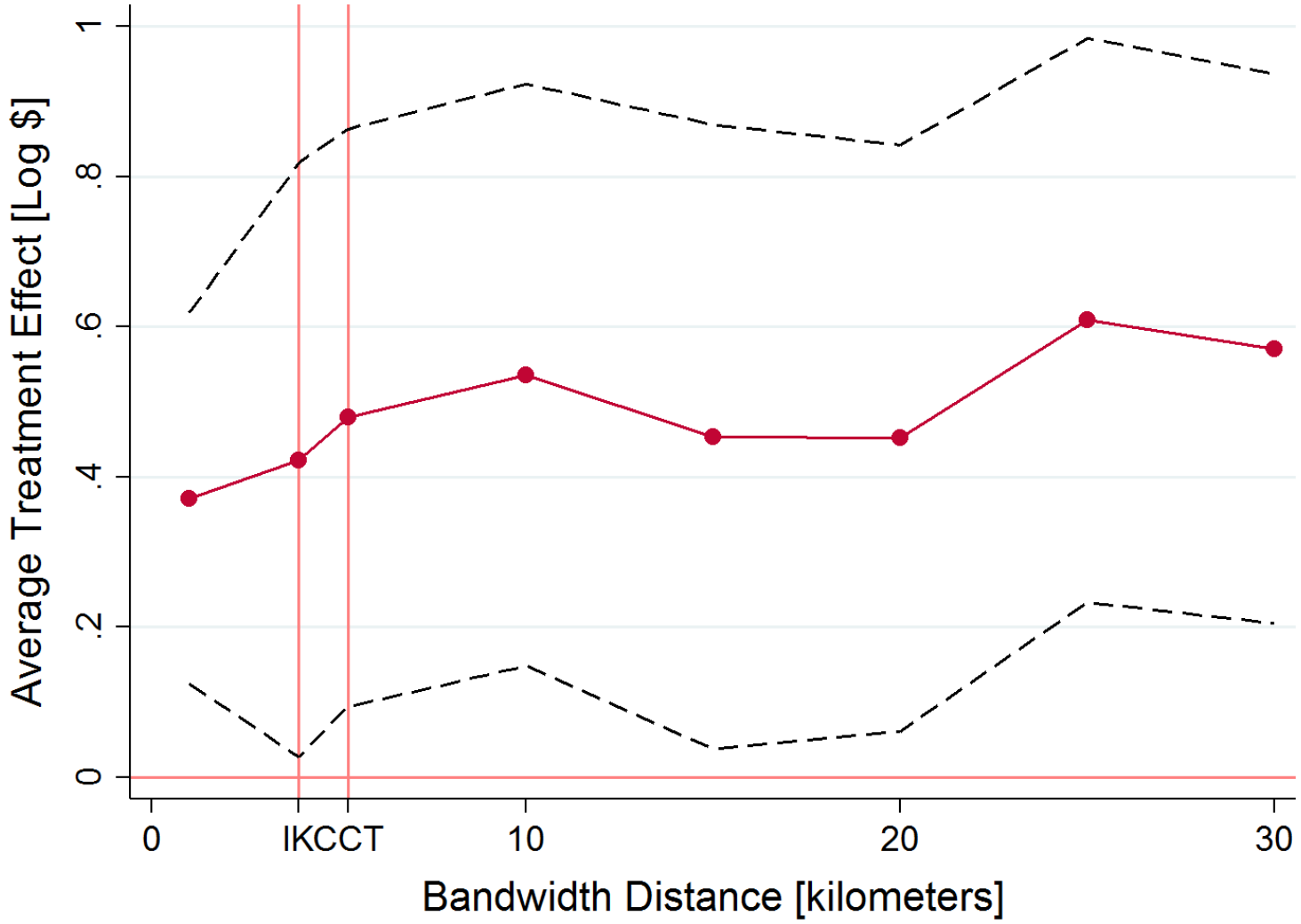
$$Ln(Value_i) = \beta_0 + \beta_1 Distance_i + \beta_2 Distance_i * Adj_i + \beta_3 Adj_i + [\beta_4 X_i] + \varepsilon_i$$

	Dependent Variable: Ln(Land Value)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Adjudication Dummy	0.372	0.479**	0.376	0.423**	0.439	0.570**	0.465	0.577**
	(0.276)	(0.196)	(0.297)	(0.202)	(0.308)	(0.239)	(0.306)	(0.240)
Observations	4,005	4,005	3,028	3,028	4,537	4,537	4,429	4,429
Polynomial	Linear	Linear	Linear	Linear	Quadratic	Quadratic	Quadratic	Quadratic
Bandwidth Choice	CCT	CCT	IK	IK	CCT	CCT	IK	IK
Kernel	Uniform	Uniform	Uniform	Uniform	Uniform	Uniform	Uniform	Uniform
Covariates	None	Yes	None	Yes	None	Yes	None	Yes

Standard errors in parentheses and corrected for heteroscedasticity and spatial autocorrelation, and significance as follows: *** p<0.01, ** p<0.05, * p<0.1.

[All Coefficients] [Covariates RD] [McCrary Test] [Bin Estimate] [Falsification]

ATE vs. Bandwidth



Conclusions

Strong, Positive Effect

- First estimate of economic returns to GW property rights
- Scarcity: overdraft was 2/5 of total by 1980

Robustness: Supports Inference

- Systematic sorting not a concern
- Falsification in space returns no result

Incentive for Landowners

- Nonetheless, very costly negotiations
- Sustainable Groundwater Management Act


Thank You!
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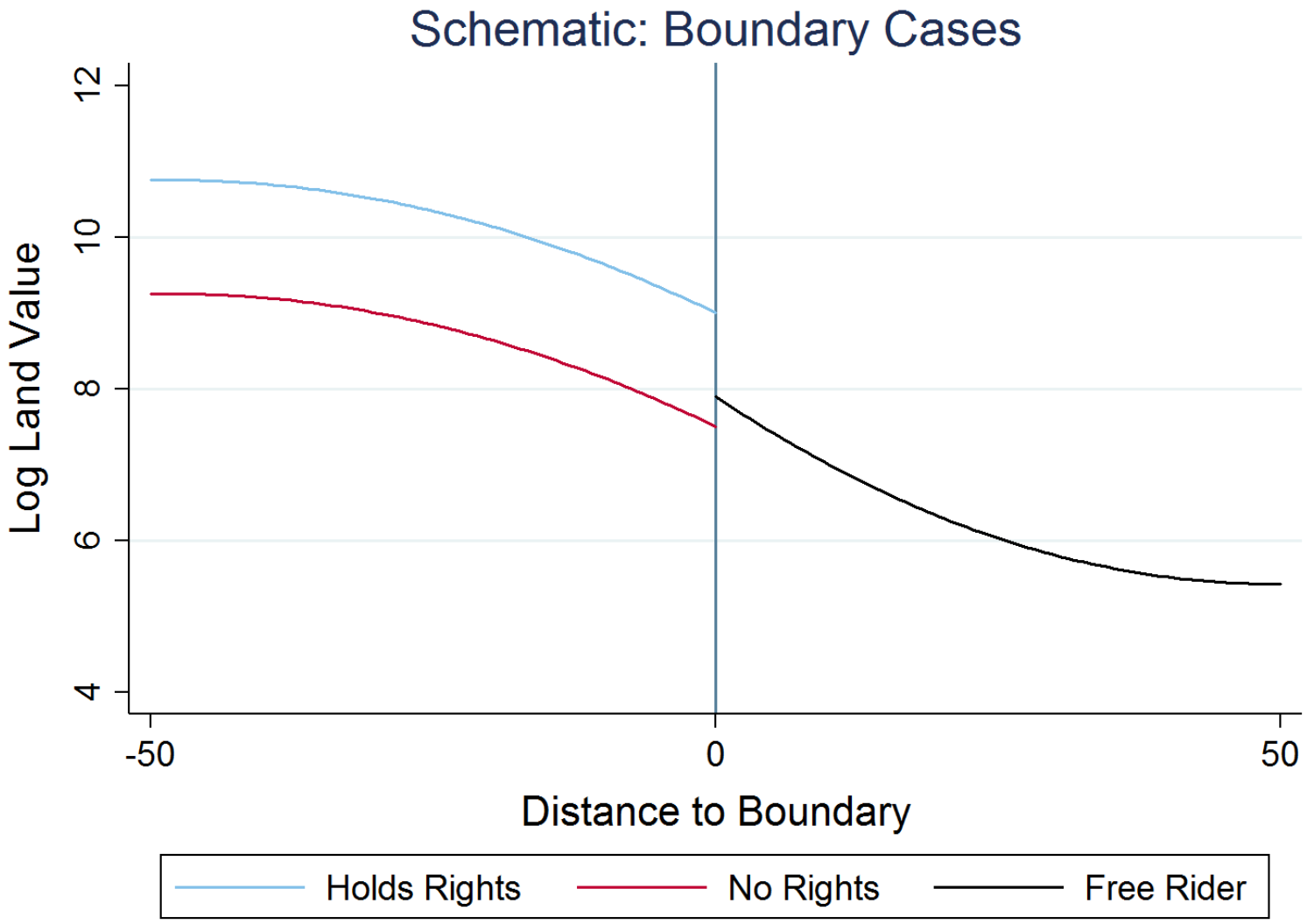
APPENDIX SLIDES


Manix
Harvard
Newberry Springs
Barstow-Daggett Airport
Minneola
Yermo
Google
Imagery ©2018 Google, Map data ©2018 Google
United States


Schematic: Boundary Cases
Log Land Value
12
10
8
6
4
-50
0
50
Distance to Boundary
Holds Rights
No Rights
Free Rider

[Back]

Covariate Smoothness

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Parcel Area	Base Year	Urban Dist	Agg Recharge	Avg Slope	Parcel Area	Base Year	Urban Dist	Agg Recharge	Avg Slope
Adjudication Dummy	3.988	-64.20	4.610	-0.00808	-0.240	7.683*	-31.04	3.422	-0.00319	-0.119
	(3.918)	(71.80)	(3.044)	(0.00601)	(0.289)	(4.456)	(77.30)	(3.307)	(0.00622)	(0.307)
Constant	6.323**	1,576***	33.43***	0.174***	1.693***	5.785*	1,617***	33.10***	0.174***	1.670***
	(2.920)	(51.31)	(2.366)	(0.00352)	(0.221)	(2.969)	(59.42)	(2.632)	(0.00396)	(0.241)
Observations	4,005	4,005	4,005	4,005	4,005	3,028	3,028	3,028	3,028	3,028
Bandwidth	CCT	CCT	CCT	CCT	CCT	IK	IK	IK	IK	IK
Kernel	Uniform	Uniform	Uniform	Uniform	Uniform	Uniform	Uniform	Uniform	Uniform	Uniform

Standard errors in parentheses and corrected for heteroscedasticity and spatial autocorrelation, and significance as follows: *** p<0.01, ** p<0.05, * p<0.1. Columns (1)-(5) present covariate results for CCT bandwidth, (6)-(10) for IK.

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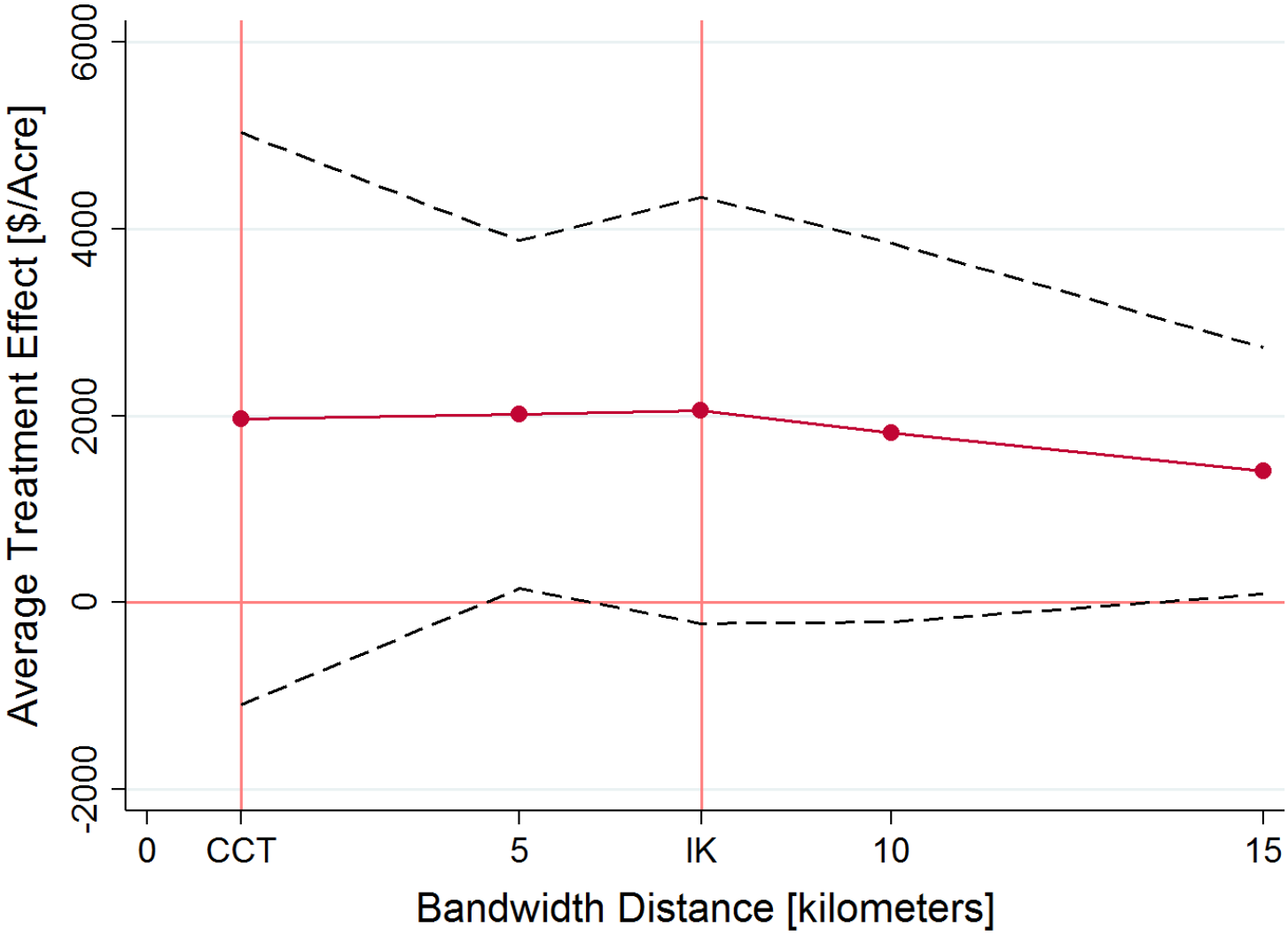
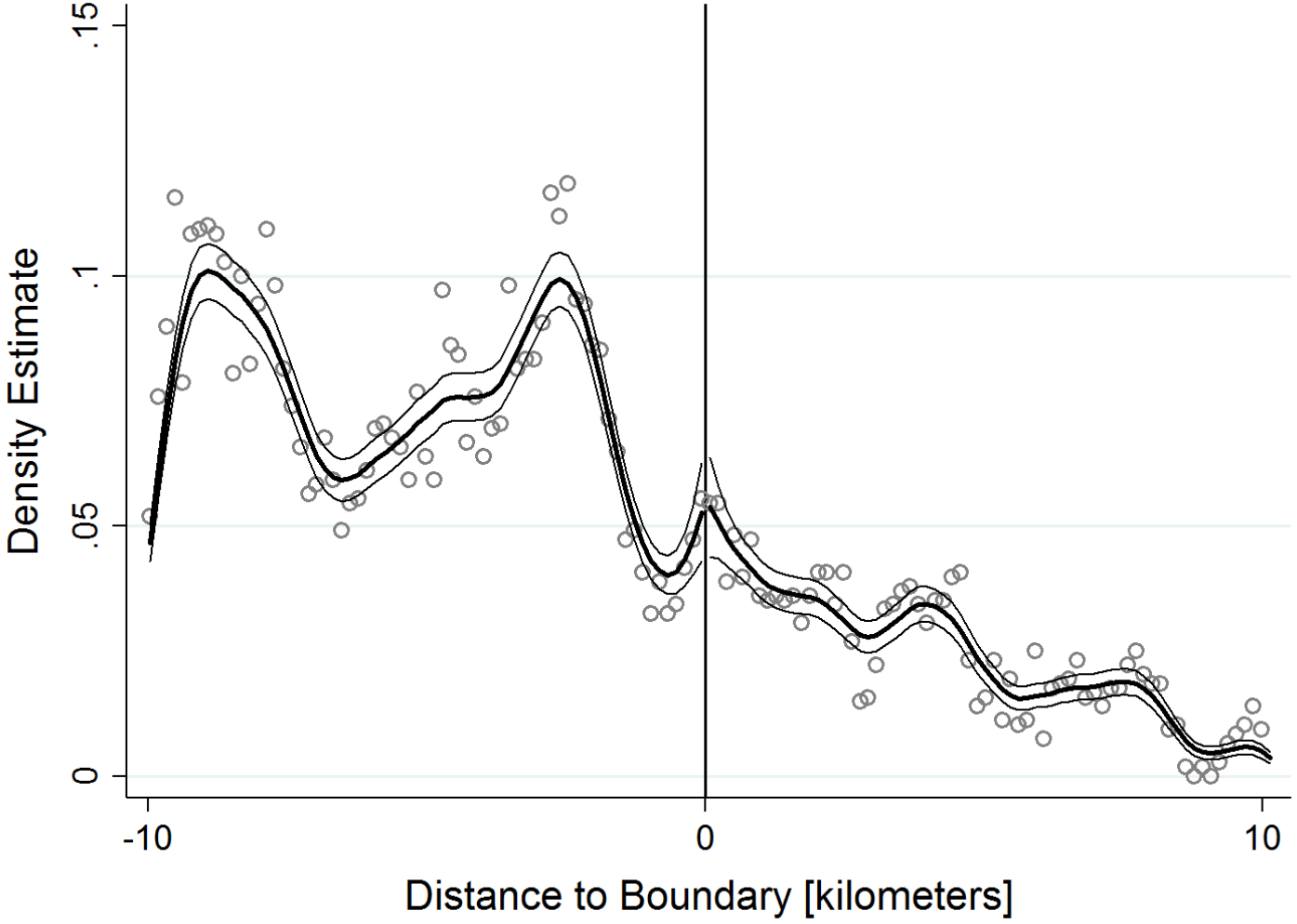
Value/Acre Results



McCrary Test



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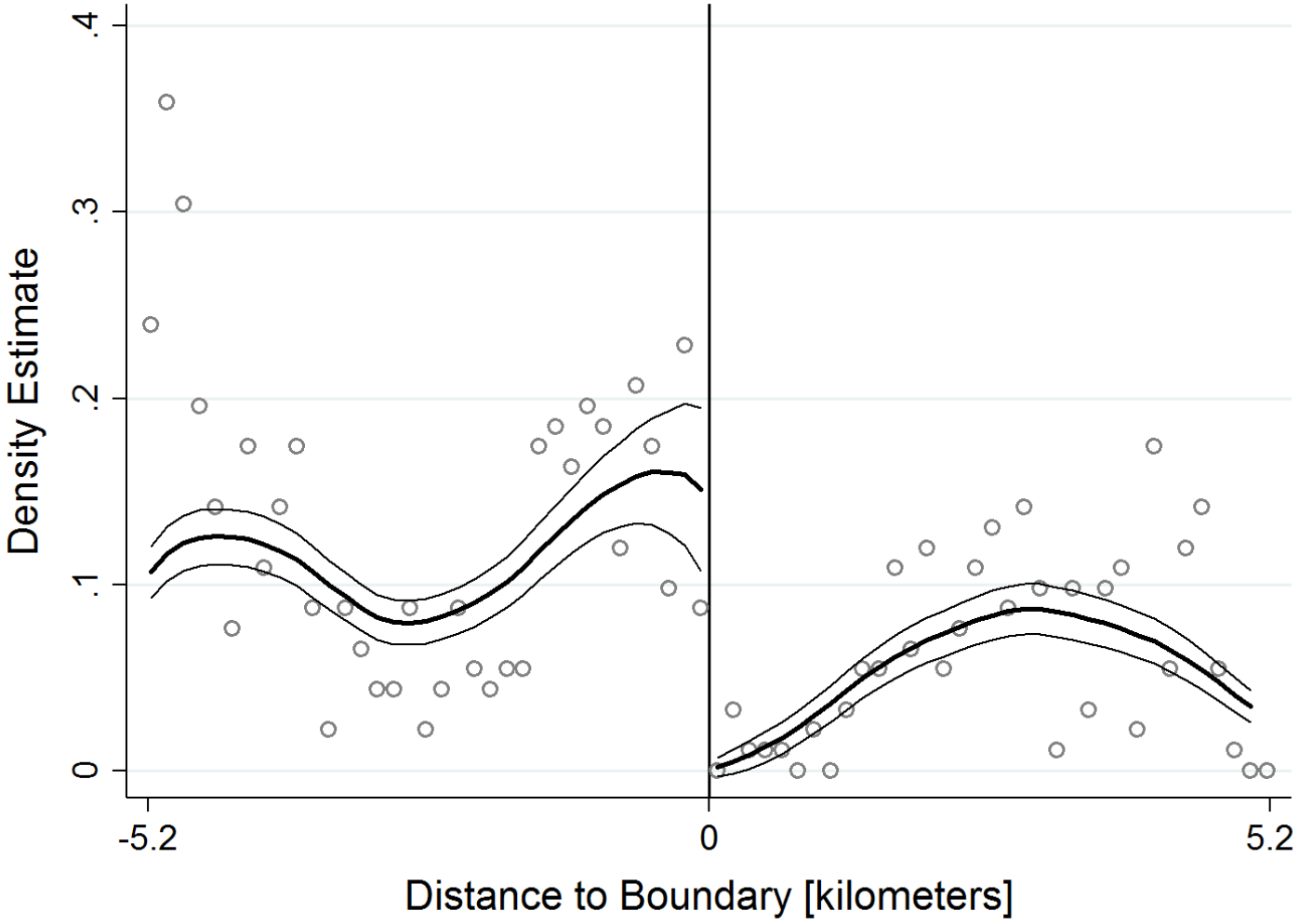
McCrary Test (NE)



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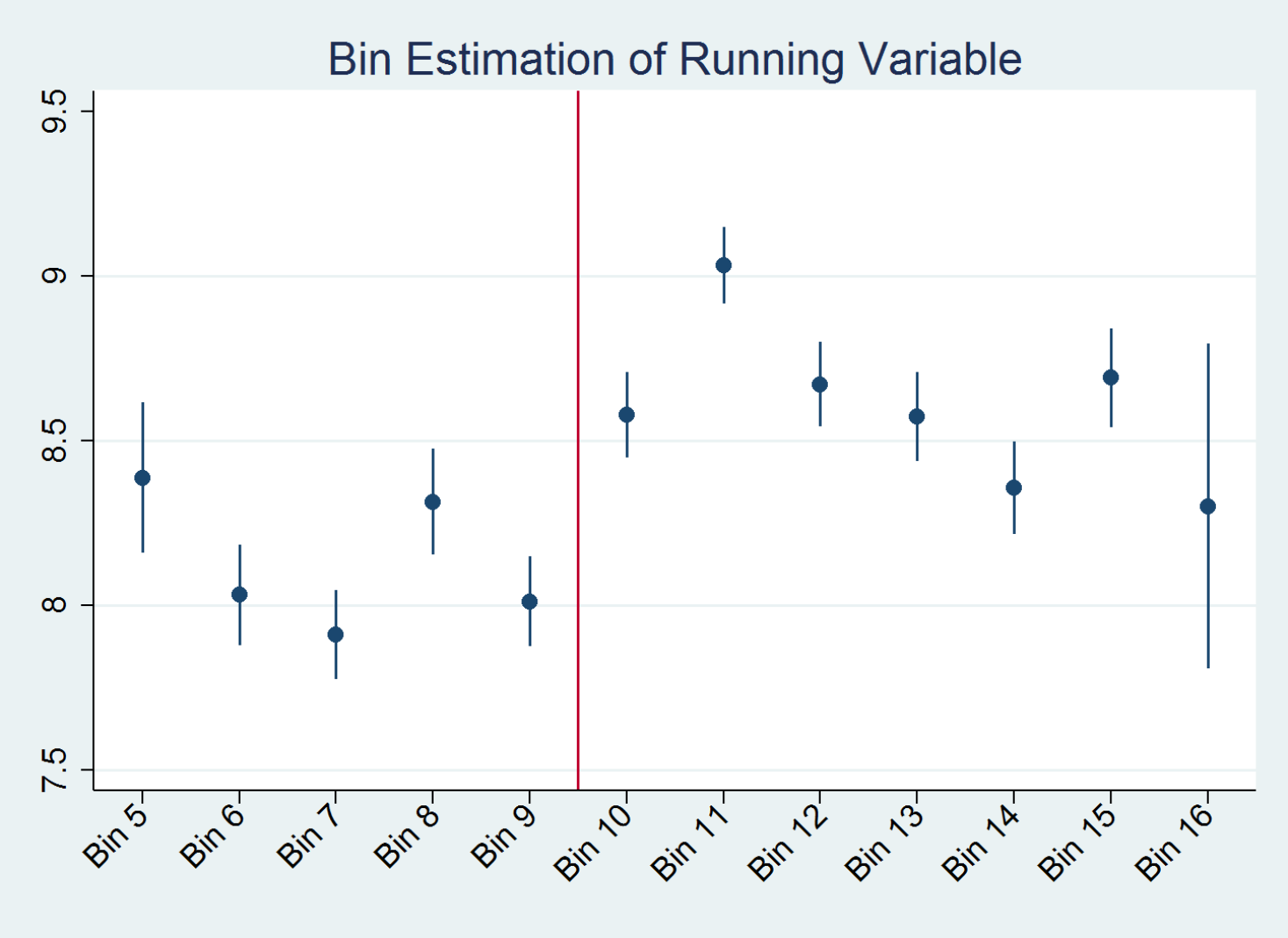
Bin Estimation



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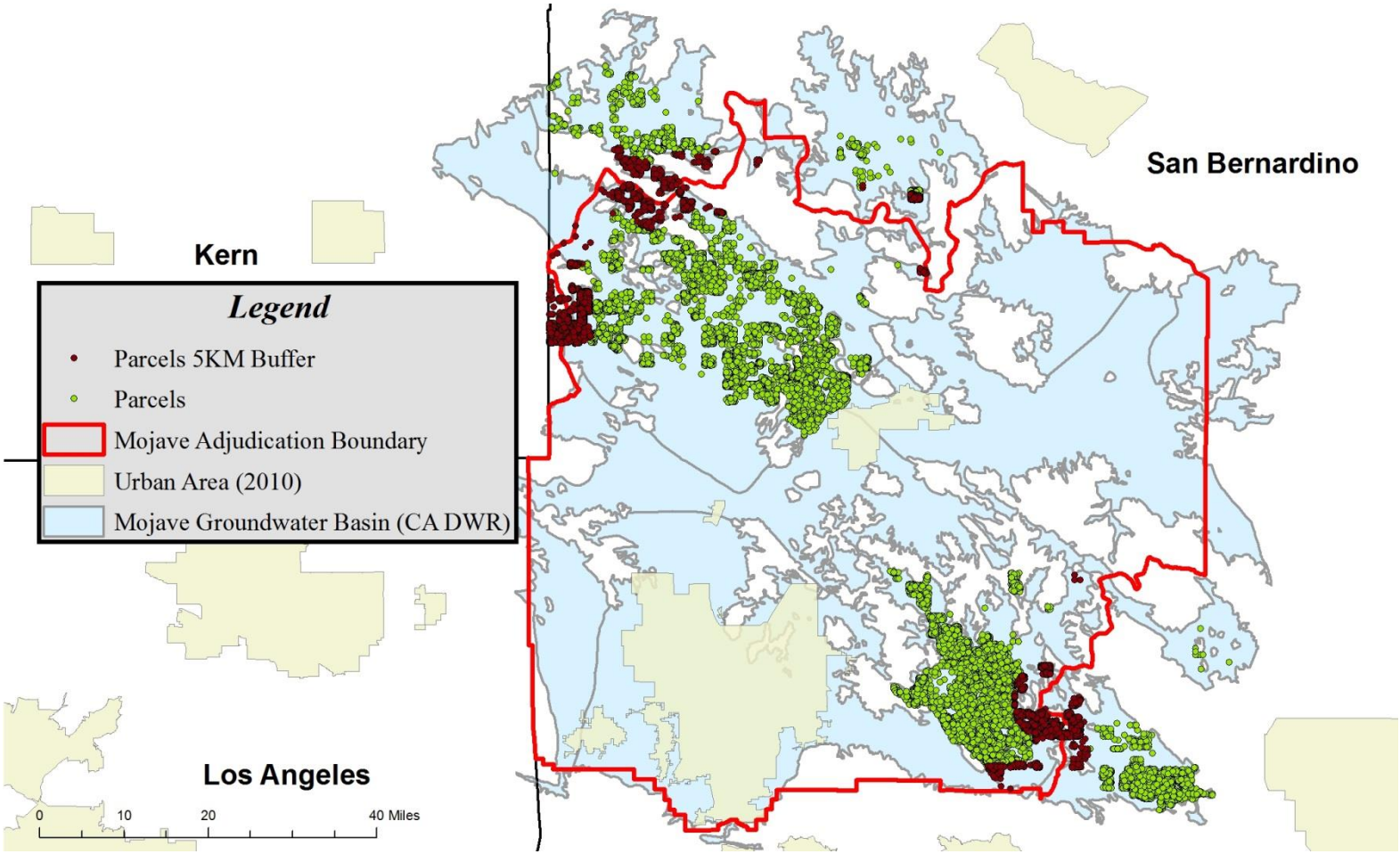
	(1) Log LV	(2) Log LV	(3) Log LV	(4) Log LV	(5) Log LV	(6) Log LV	(7) Log LV	(8) Log LV
Adjudication Dummy	0.372	0.479**	0.376	0.423**	0.439	0.570**	0.465	0.577**
	(0.276)	(0.196)	(0.297)	(0.202)	(0.308)	(0.239)	(0.306)	(0.240)
Boundary Distance	-0.115	-0.228***	-0.182	-0.276**	-0.118	-0.305	-0.122	-0.298
	(0.0816)	(0.0728)	(0.118)	(0.124)	(0.210)	(0.240)	(0.215)	(0.246)
Distance*Adjudicated	0.274***	0.419***	0.386**	0.507***	0.00434	-0.0127	0.00347	-0.0116
	(0.104)	(0.0881)	(0.154)	(0.141)	(0.0320)	(0.0363)	(0.0339)	(0.0382)
Distance^2					0.228	0.461	0.205	0.437
					(0.294)	(0.293)	(0.302)	(0.302)
Distance^2*Adjudicated					0.00564	0.0197	0.0120	0.0220
					(0.0347)	(0.0382)	(0.0367)	(0.0404)
Covariate Controls								
Parcel Area		0.0130***		0.0130***		0.0136***		0.0134***
		(0.00166)		(0.00186)		(0.00169)		(0.00167)
Base Year		-1.31e-05		1.50e-05		-1.87e-05		-1.98e-05
		(2.92e-05)		(3.38e-05)		(2.77e-05)		(2.82e-05)
Distance to Urban Center		-0.0183**		-0.00506		-0.0203***		-0.0184**
		(0.00882)		(0.0116)		(0.00750)		(0.00777)
Recharge Distance		-5.670		0.348		-5.358		-5.106
		(6.213)		(7.376)		(5.438)		(5.606)
Average Slope		0.0131		0.0145		0.0164		0.0118
		(0.0108)		(0.0113)		(0.0110)		(0.0106)
Latitude		-0.979**		-0.700		-1.091***		-1.092***
		(0.436)		(0.633)		(0.412)		(0.408)
Longitude		-1.363***		-1.298**		-1.428***		-1.401***
		(0.453)		(0.553)		(0.449)		(0.447)
Constant	7.865***	-116.5***	7.783***	-120.2**	7.841***	-120.3***	7.839***	-117.2***
	(0.242)	(44.65)	(0.266)	(49.53)	(0.284)	(44.69)	(0.284)	(44.69)
Observations	4,005	4,005	3,028	3,028	4,537	4,537	4,429	4,429
Bandwidth	CCT	CCT	IK	IK	CCT	CCT	IK	IK
Kernel	Uniform	Uniform	Uniform	Uniform	Uniform	Uniform	Uniform	Uniform
Covariates	None	Yes	None	Yes	None	Yes	None	Yes

[Back]

Typical Selection



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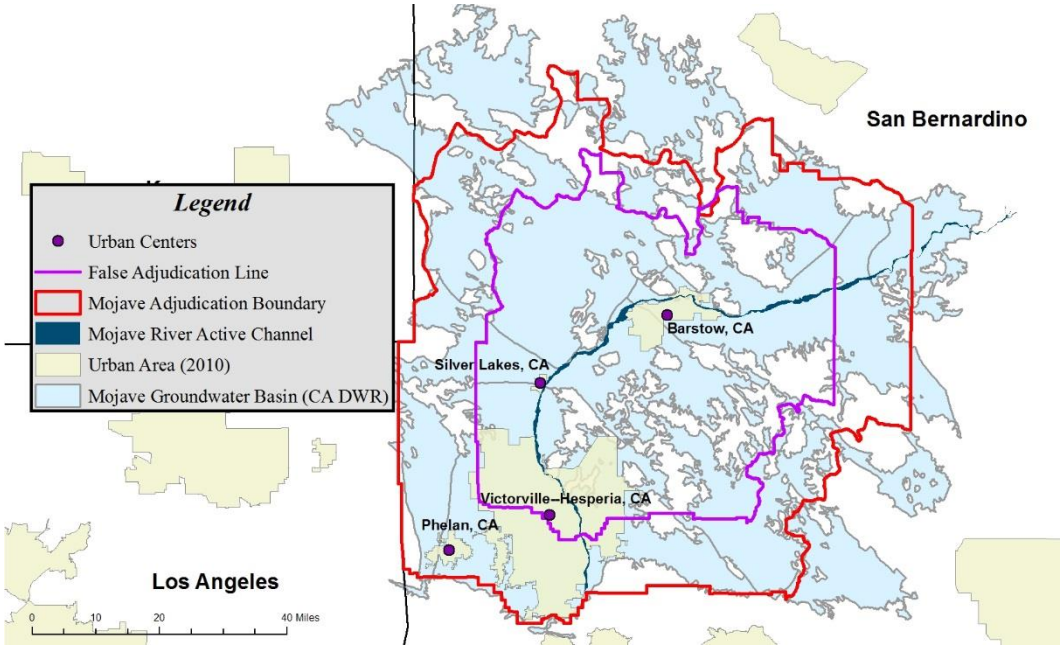
Falsification Test



	Dependent Variable: Ln(Land Value)			
	(1)	(2)	(3)	(4)
False Adjudication Dummy	-0.169 (0.182)	-0.0108 (0.143)	-0.0799 (0.226)	0.0513 (0.174)
Observations	3,809	3,809	4,650	4,650
Polynomial	Linear	Linear	Quadratic	Quadratic
Bandwidth Choice	IK	IK	IK	IK
Kernel	Uniform	Uniform	Uniform	Uniform
Covariates	None	Yes	None	Yes

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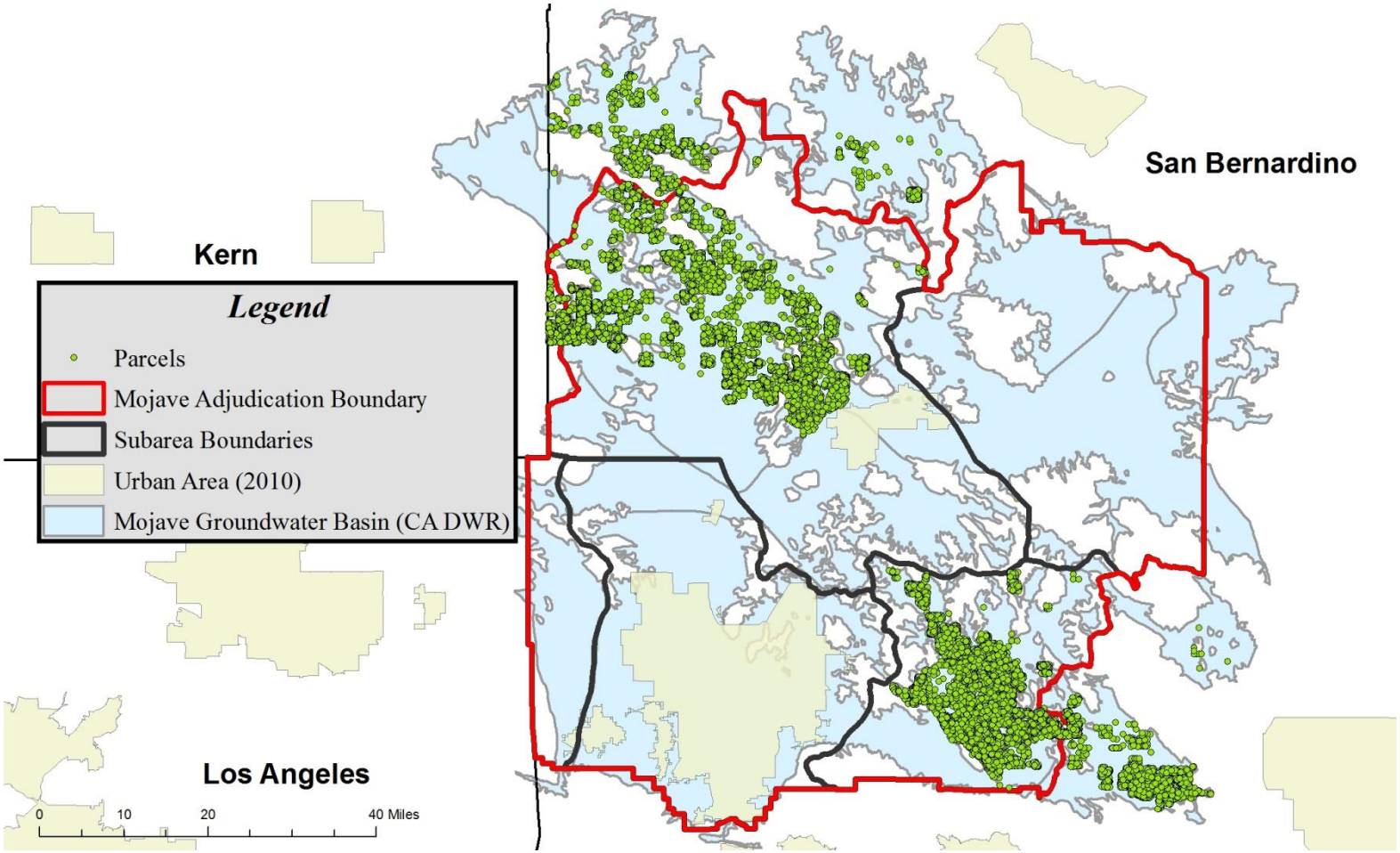
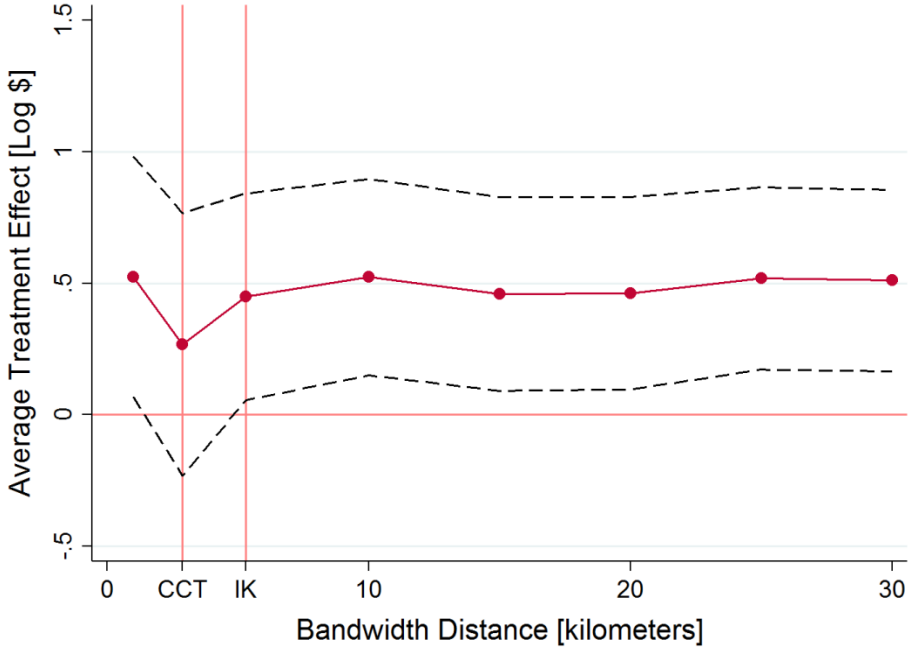
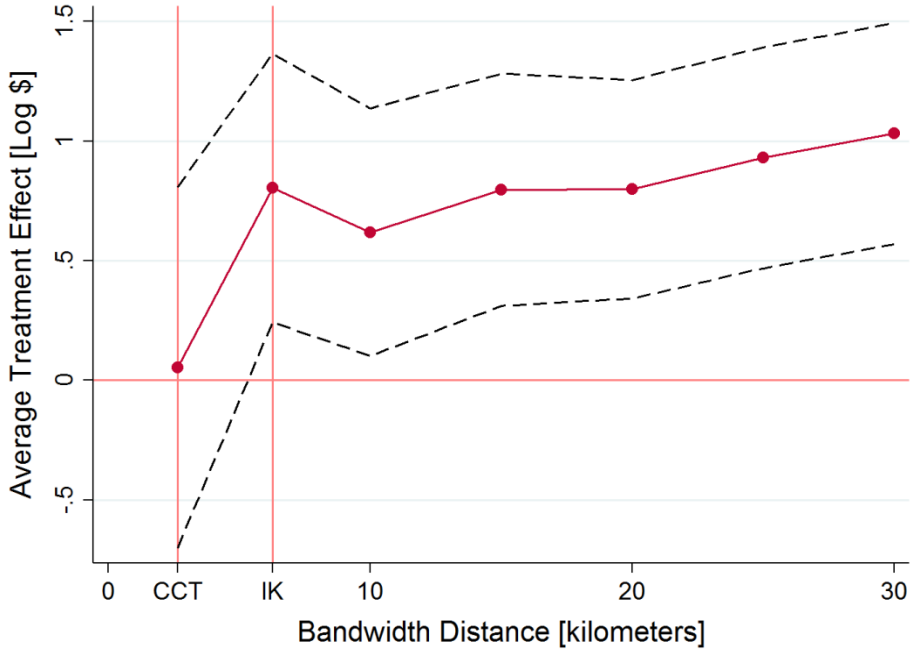
Mojave Basin Subareas



Northwest (Centro)



Southeast (Este)



Groundwater

Groundwater: a Literal Common Pool

- Commonality controlled by conductivity, faults
- California: Open access for Ag users

Returns to Management

- Losses sensitive to productivity, proximity, collateral impacts (Koundouri, 2004; Brozovic et al., 2010)
- Instrument of interest: pumping rights