Technological Change and Climatic Resiliency: Evidence from Irrigation in the United States

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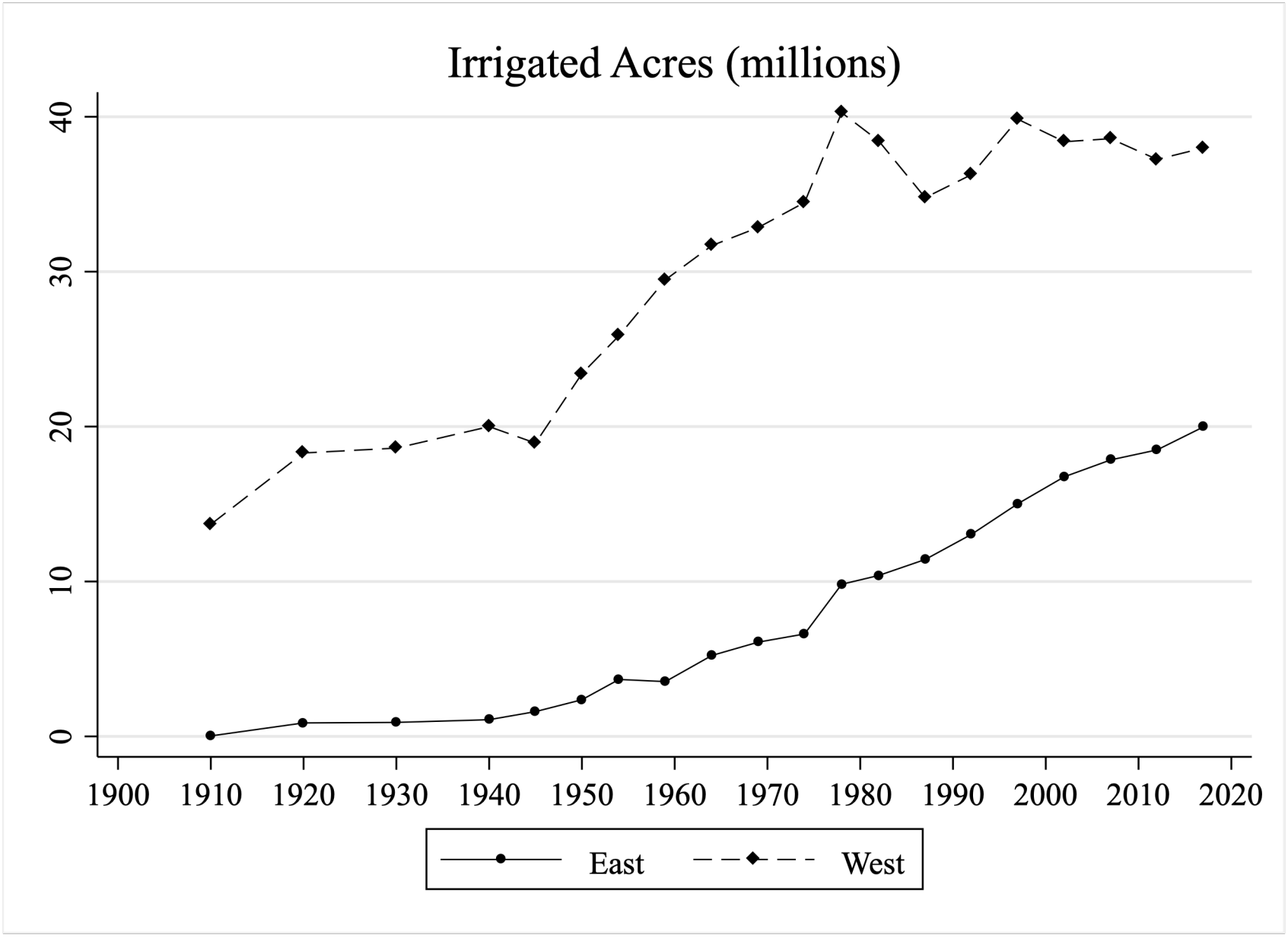
US Irrigated Agriculture



Background

- Droughts in the 1890s and 1930s had dramatic agricultural, social, and financial consequences (Hansen and Libecap 2004; Landon-Lane, Rockoff and Steckel 2009; Hornbeck 2012)
- Expanded irrigation and other technological advances increased level of ag production in arid western counties (Hornbeck and Keskin 2014; Edwards and Smith 2018; Olmstead and Rhode 2011)
- Growing literature on temperature shocks, but not drought and irrigation (e.g. Schlenker, Hannemann, and Fisher 2005; Deschenes and Greenstone 2007; Burke and Emerick 2016)
- Limited work on extent and mechanism by which irrigation mitigates shocks (Hornbeck and Keskin 2014; Hansen, Libecap and Lowe 2011)

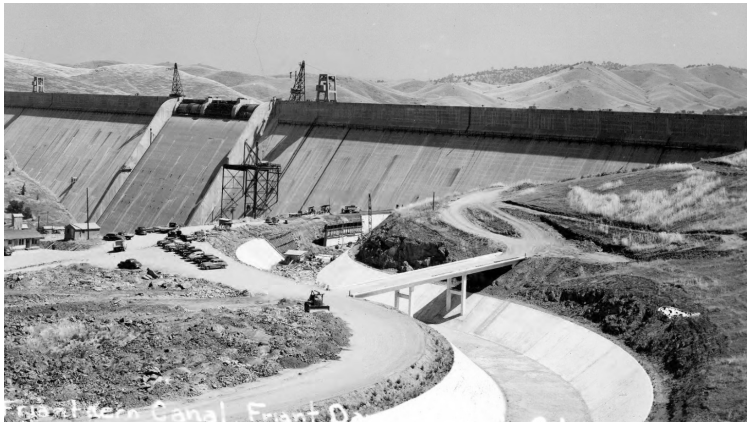
Motivation

Dalhart, TX (ca. 1938)

Lubbock/Dalhart (ca. 2010s)

Expansion of Irrigation Storage

Groundwater Pumping

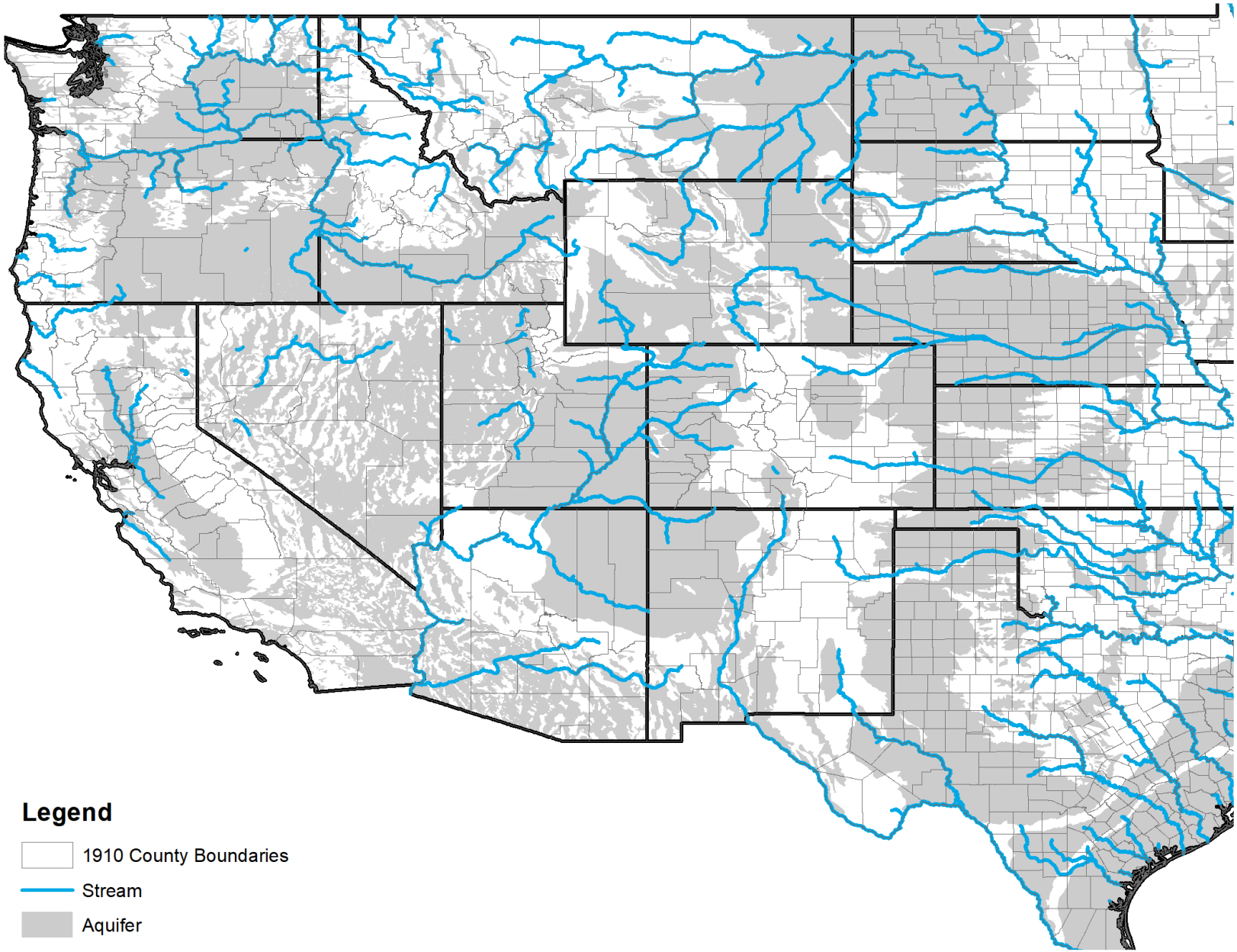


Federal Dams

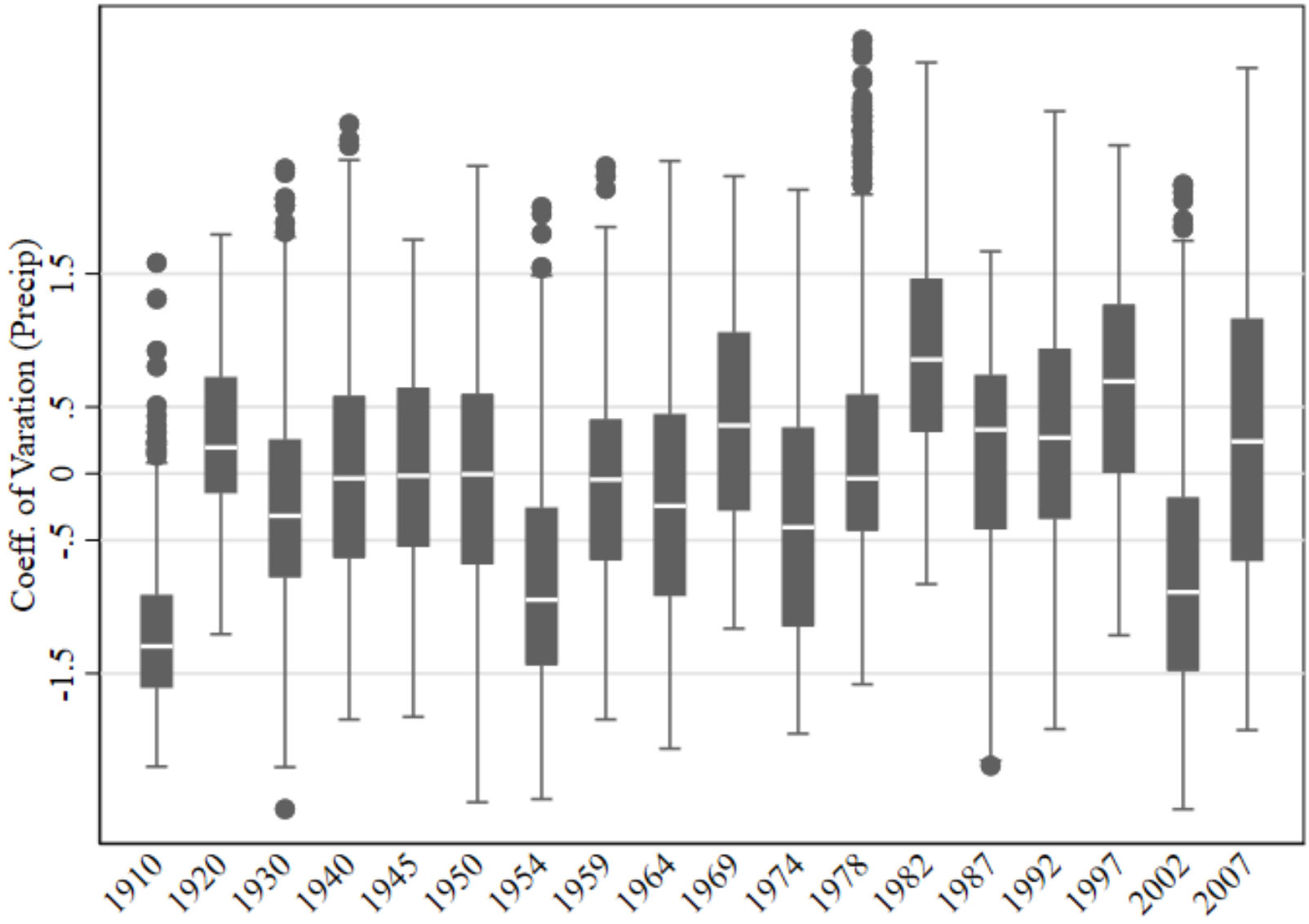
Research Design and Data

- How do counties with potential storage react to drought before/after 1945 relative to those without?
- Create individual county measures of precipitation shock
  - Relative changes versus levels
- Does this change based on type of storage?
  1. Small stream (irrigation but no storage)
  2. **Large river** (surface storage)
  3. **Aquifer**
  4. **Joint** (Large river and aquifer)
- Ag census data 1910-2007 (digitized by Haines, 2010)
  - Crop value
  - Irrigated acres
  - Failed cropland

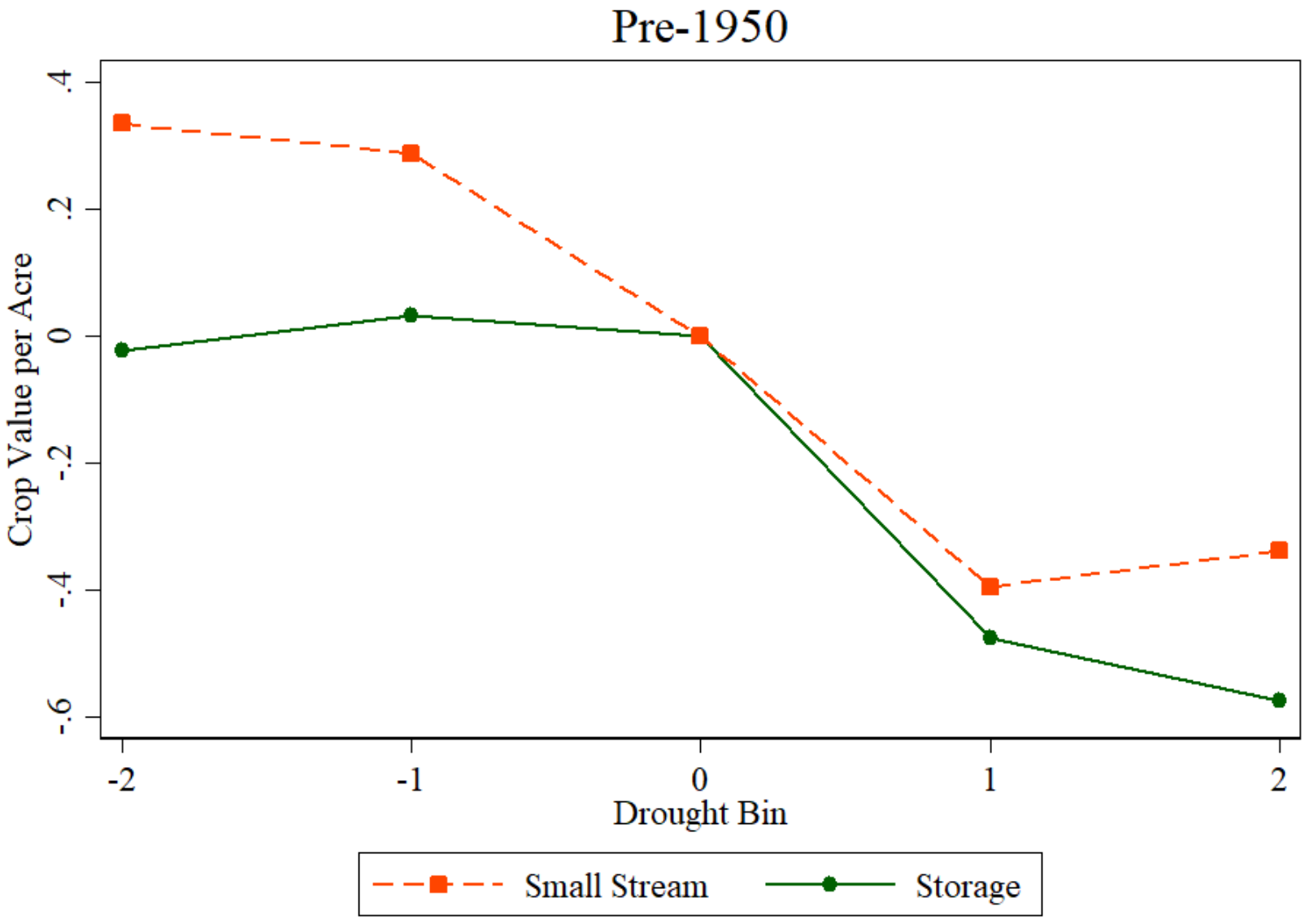
Measuring Storage Potential



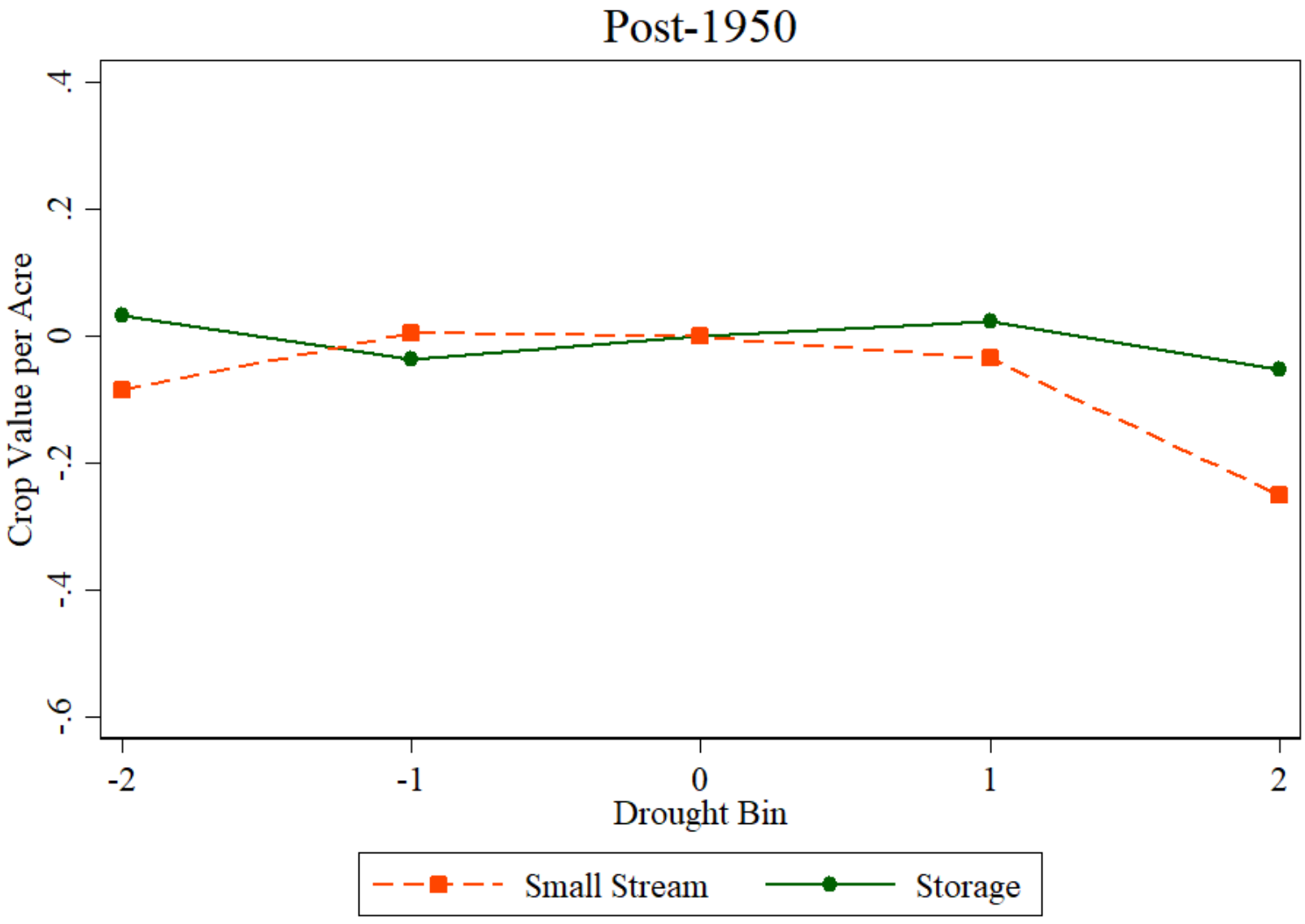
Western Precipitation



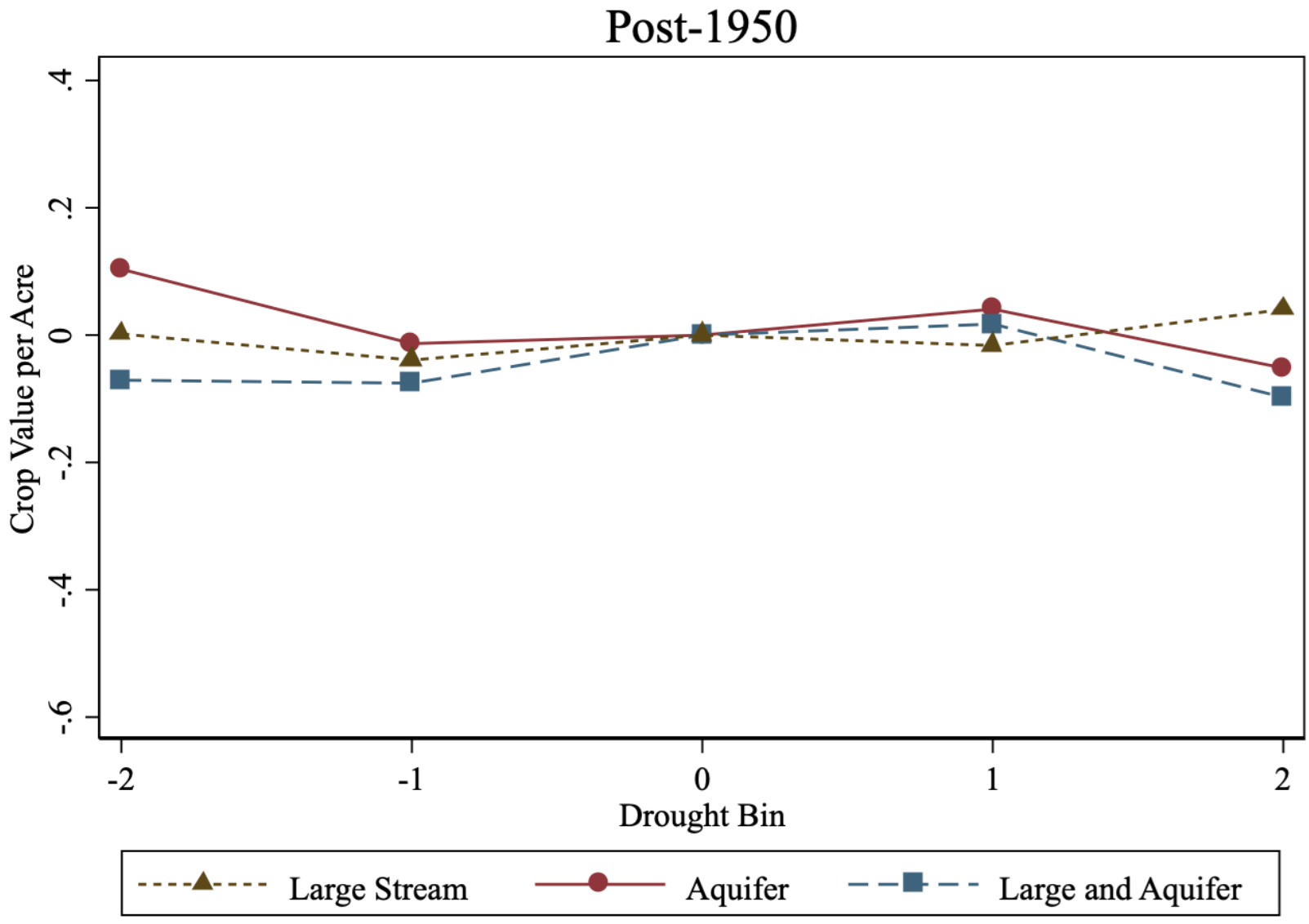
Crop Value Pre-1950



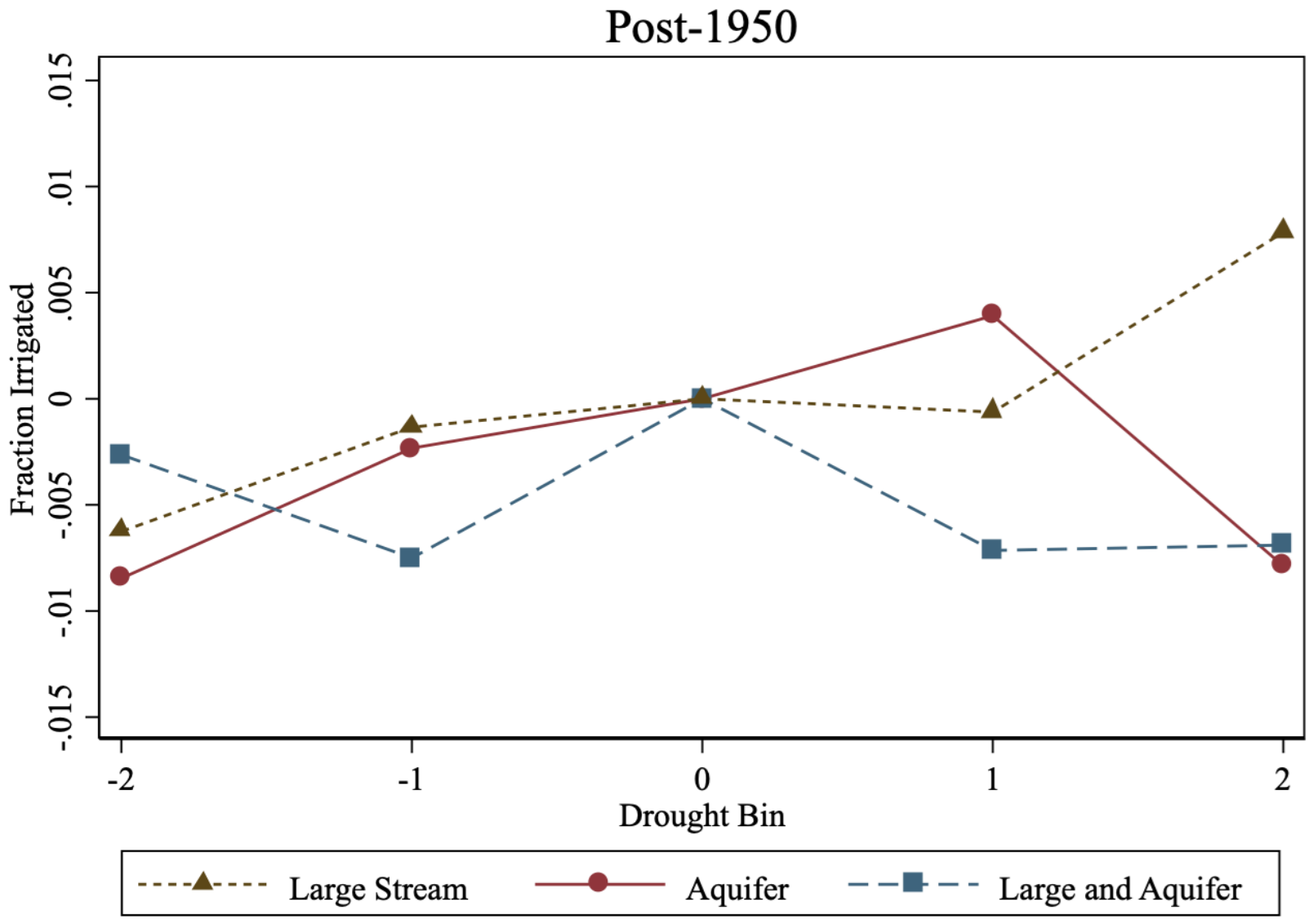
Crop Value Post-1950



Crop Value by Storage Type Post-1950



Fraction Irrigated by Storage Type Post-1950



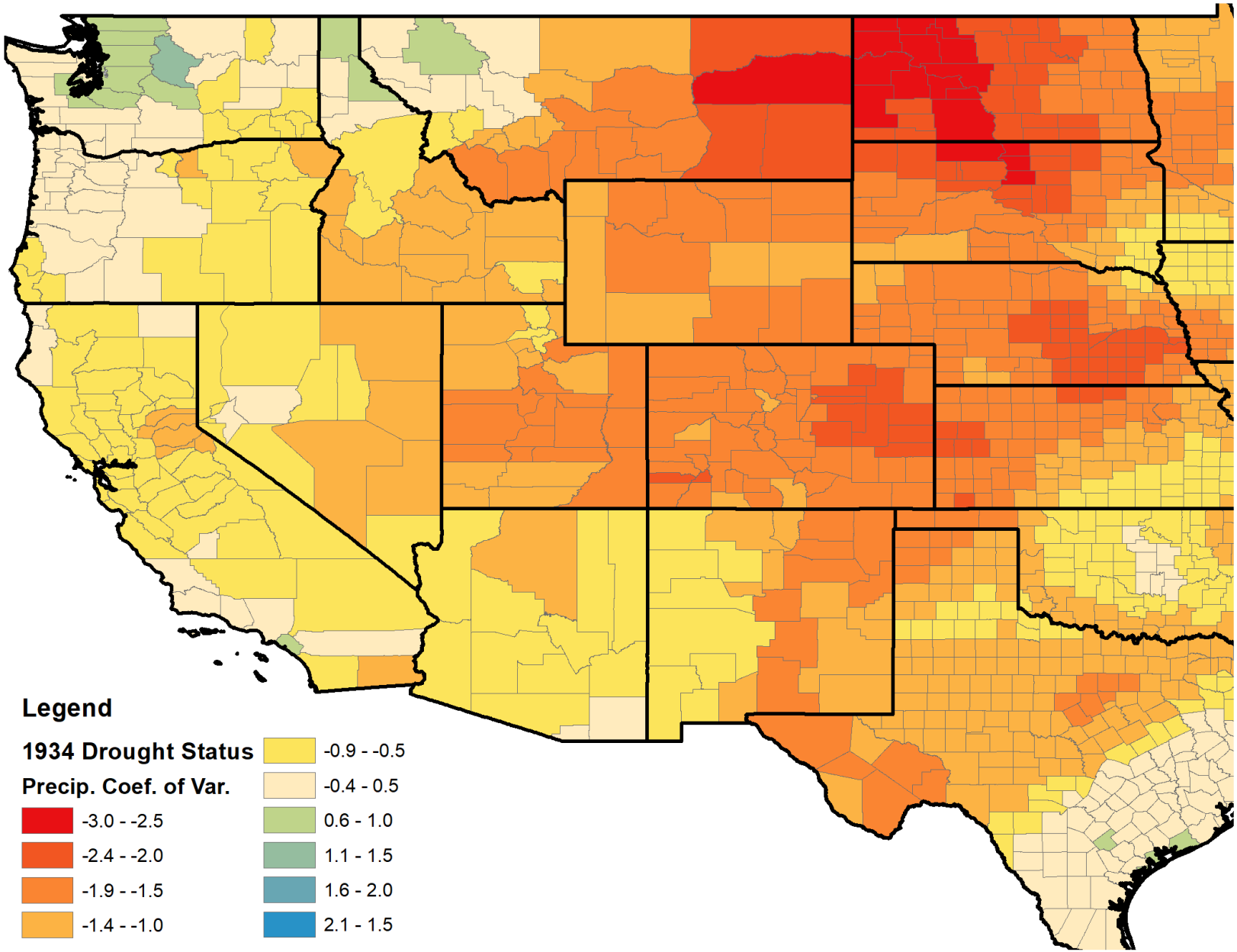
Summary and Next Steps

- **US agriculture has become more resilient to drought, but only partially as a result of adding large dams and groundwater**
- The type of irrigation technology affects how the production process changes: **resiliency is interaction between technological and behavior changes**

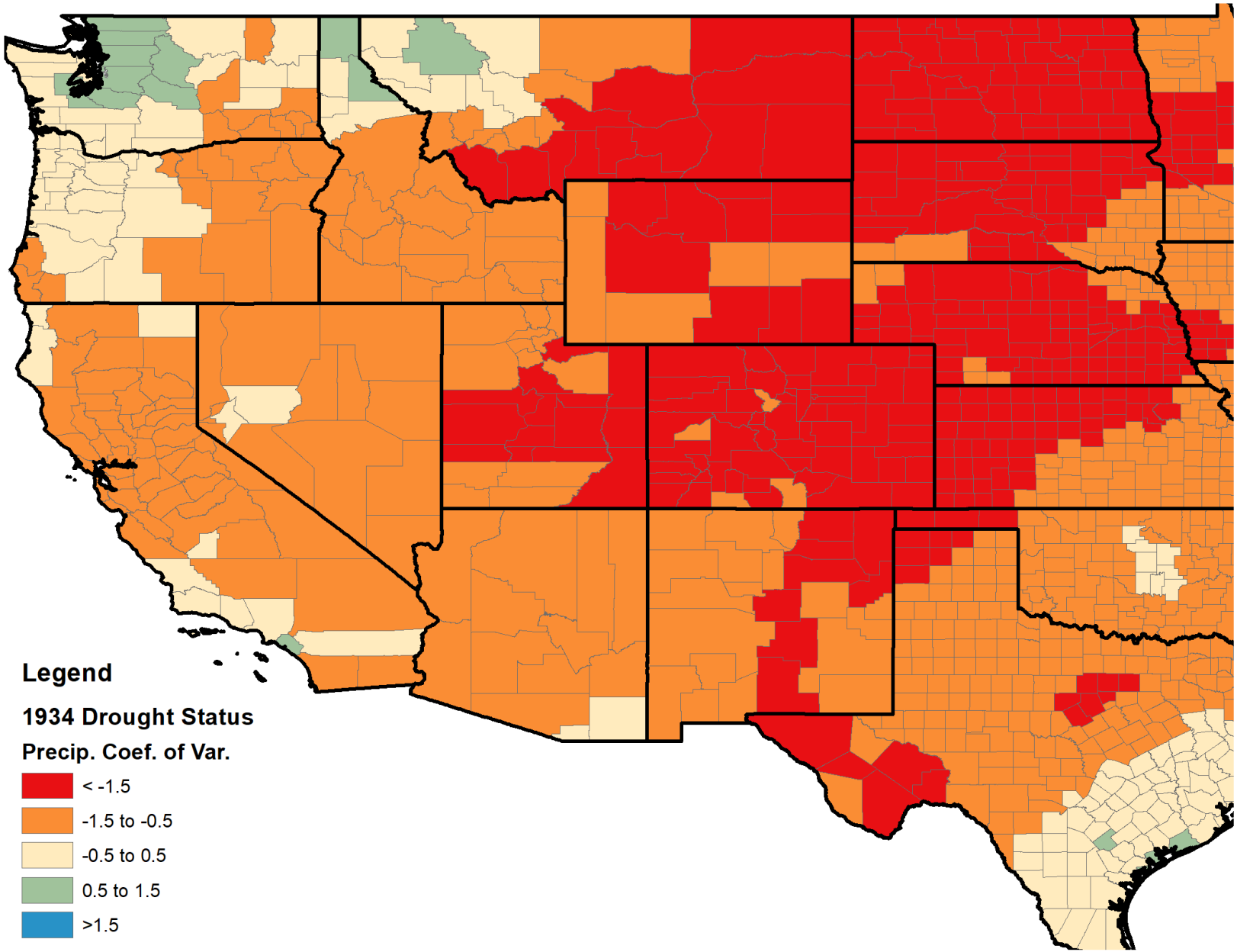
- Refine and test robustness of measures of drought/temperature
  - Palmer Drought Severity Index
  - Heat shocks
- Ag census data (1850-1900)
- Data by specific crops (1850-2012)
- Irrigation expansion in the East

- Thank you!

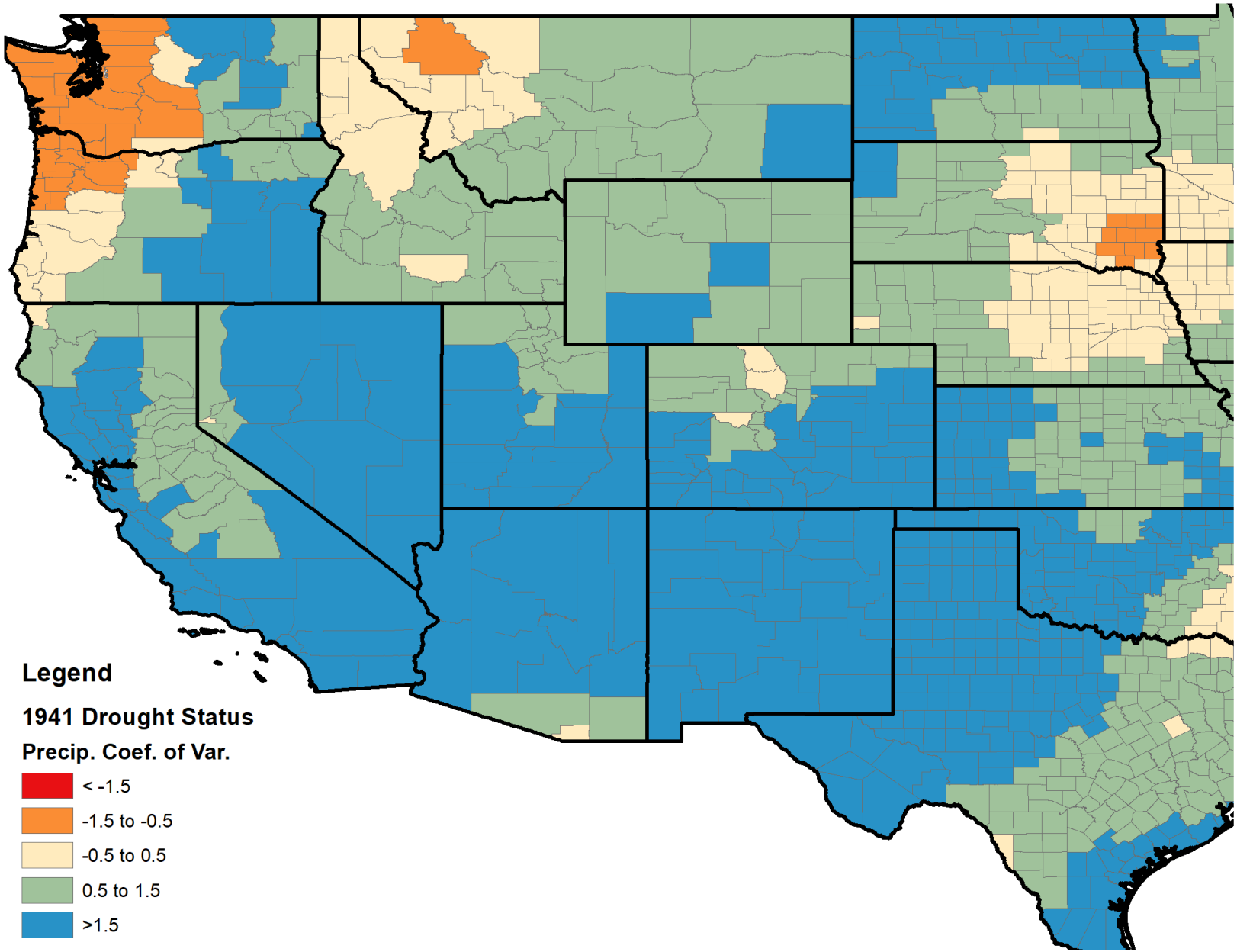
Drought Status in 1934



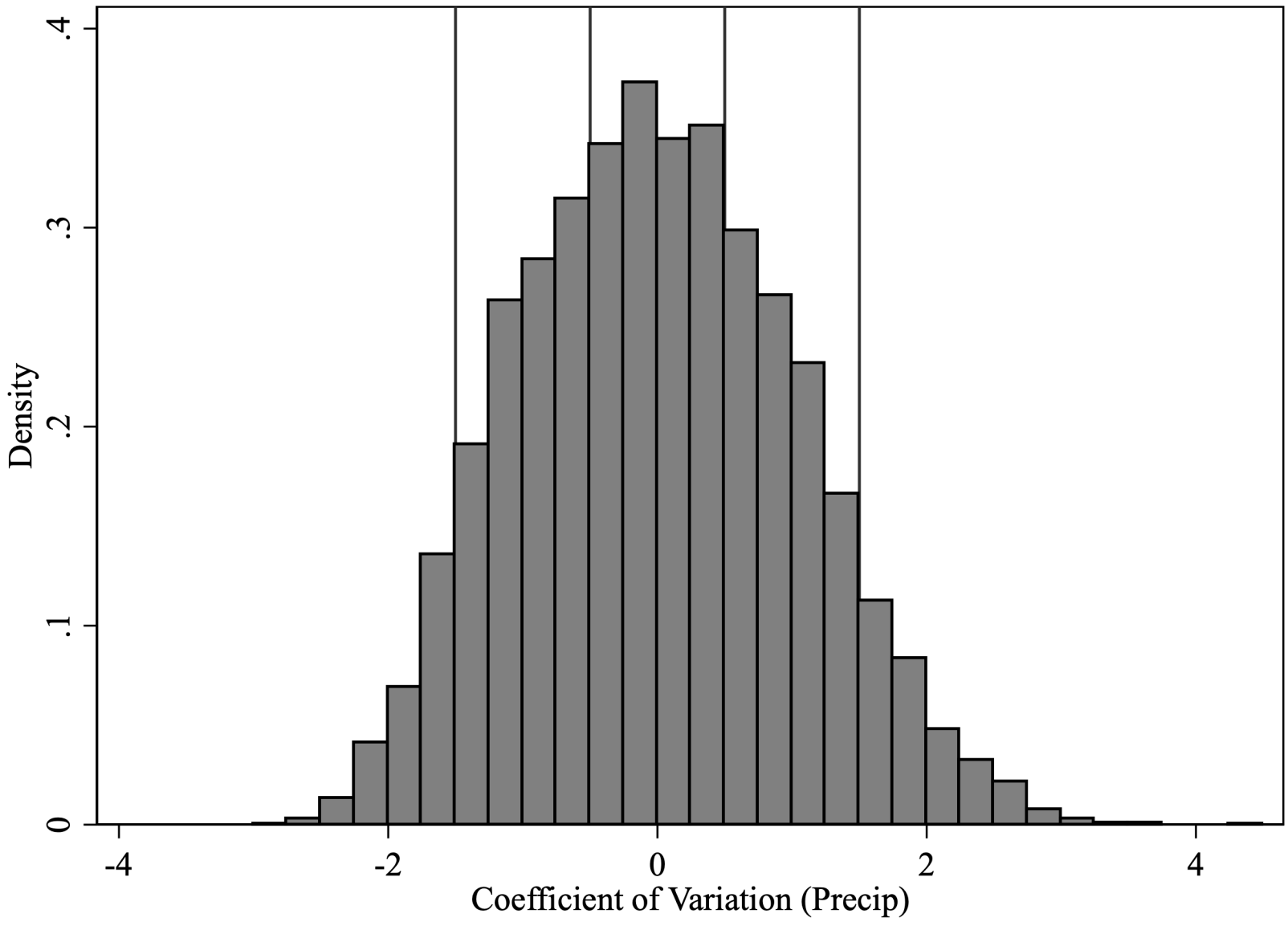
1934 Binned Drought Status



Wettest Year: 1941



Precipitation Bins



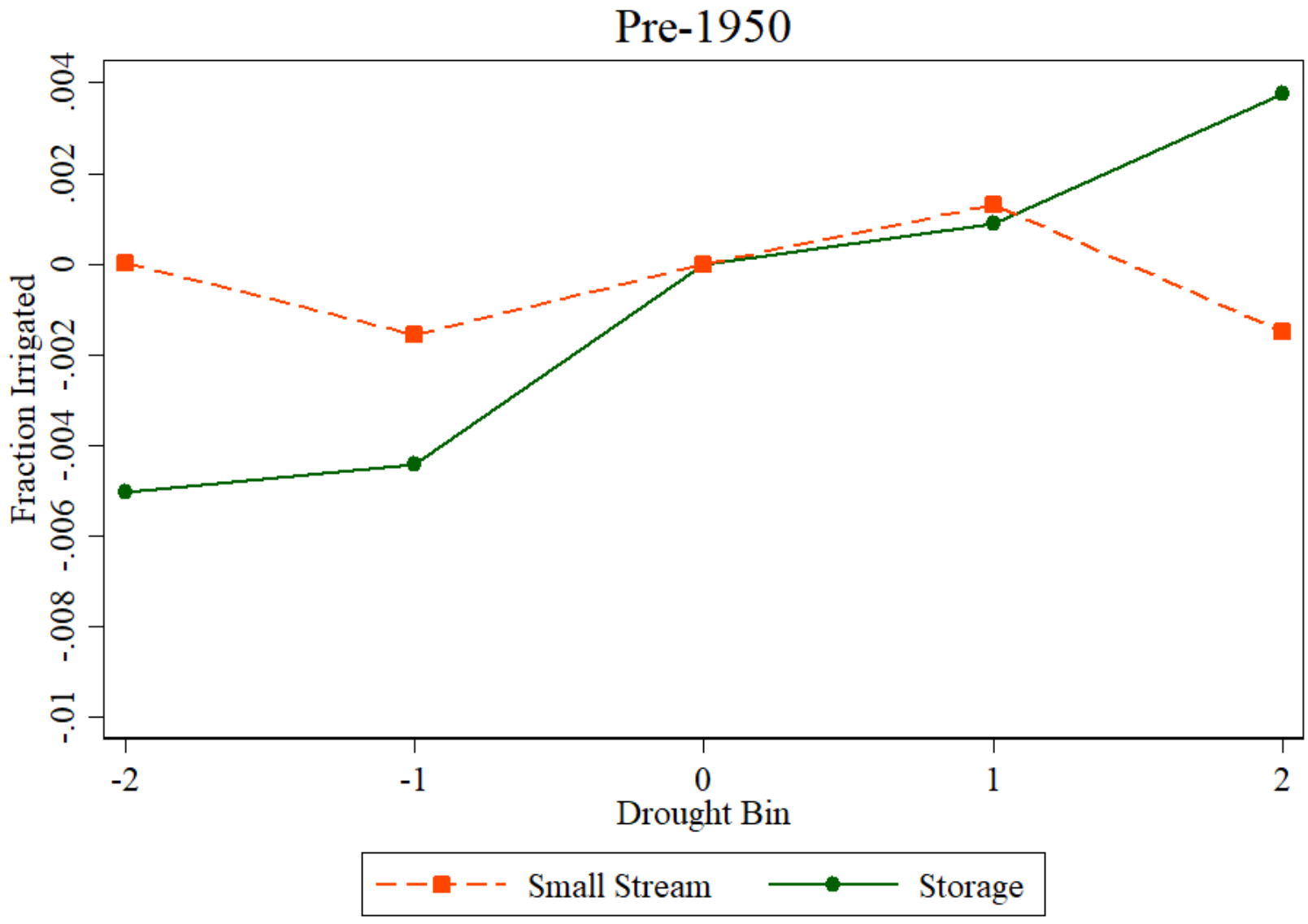
Regression Results: Storage

VARIABLES	(1) Pre-1950 Ln(Crop Value)	(2) Post-1950 Ln(Crop Value)	(3) Pre-1950 Pctg Irr.	(4) Post-1950 Pctg Irr.	(5) Pre-1950 Ln(Failure)	(6) Post-1950 Ln(Failure)
Bin 1	0.336***	-0.0841	3.94E-05	-0.0109***	-1.692***	0.398**
	(0.102)	(0.059)	(0.002)	(0.002)	(0.082)	(0.187)
Bin 2	0.289***	0.00597	-0.00156	-0.00692***	-0.451	-0.146
	(0.092)	(0.037)	(0.003)	(0.002)	(0.322)	(0.142)
Bin 4	-0.394***	-0.0344	0.00131	-0.000265	1.067***	0.504***
	(0.090)	(0.045)	(0.001)	(0.001)	(0.253)	(0.126)
Bin 5	-0.338***	-0.250***	-0.00149	-0.00649**	0.371	1.220***
	(0.078)	(0.094)	(0.003)	(0.003)	(0.255)	(0.137)
Storage x Bin 1	-0.358***	0.118*	-0.00508*	0.00454	2.612***	-0.351*
	(0.126)	(0.069)	(0.003)	(0.004)	(0.254)	(0.204)
Storage x Bin 2	-0.256**	-0.0419	-0.00285	0.00327	0.496	0.122
	(0.103)	(0.041)	(0.004)	(0.002)	(0.374)	(0.154)
Storage x Bin 4	-0.0811	0.0582	-0.000416	0.000362	-0.02	-0.0695
	(0.106)	(0.050)	(0.001)	(0.002)	(0.266)	(0.143)
Storage x Bin 5	-0.236**	0.197**	0.00526*	0.00153	0.976***	-0.394**
	(0.092)	(0.100)	(0.003)	(0.004)	(0.288)	(0.163)
Observations	1,914	6,617	1,914	6,688	954	3,285
R-squared	0.335	0.355	0.094	0.151	0.315	0.719
Number of stcounty	479	479	479	479	478	474

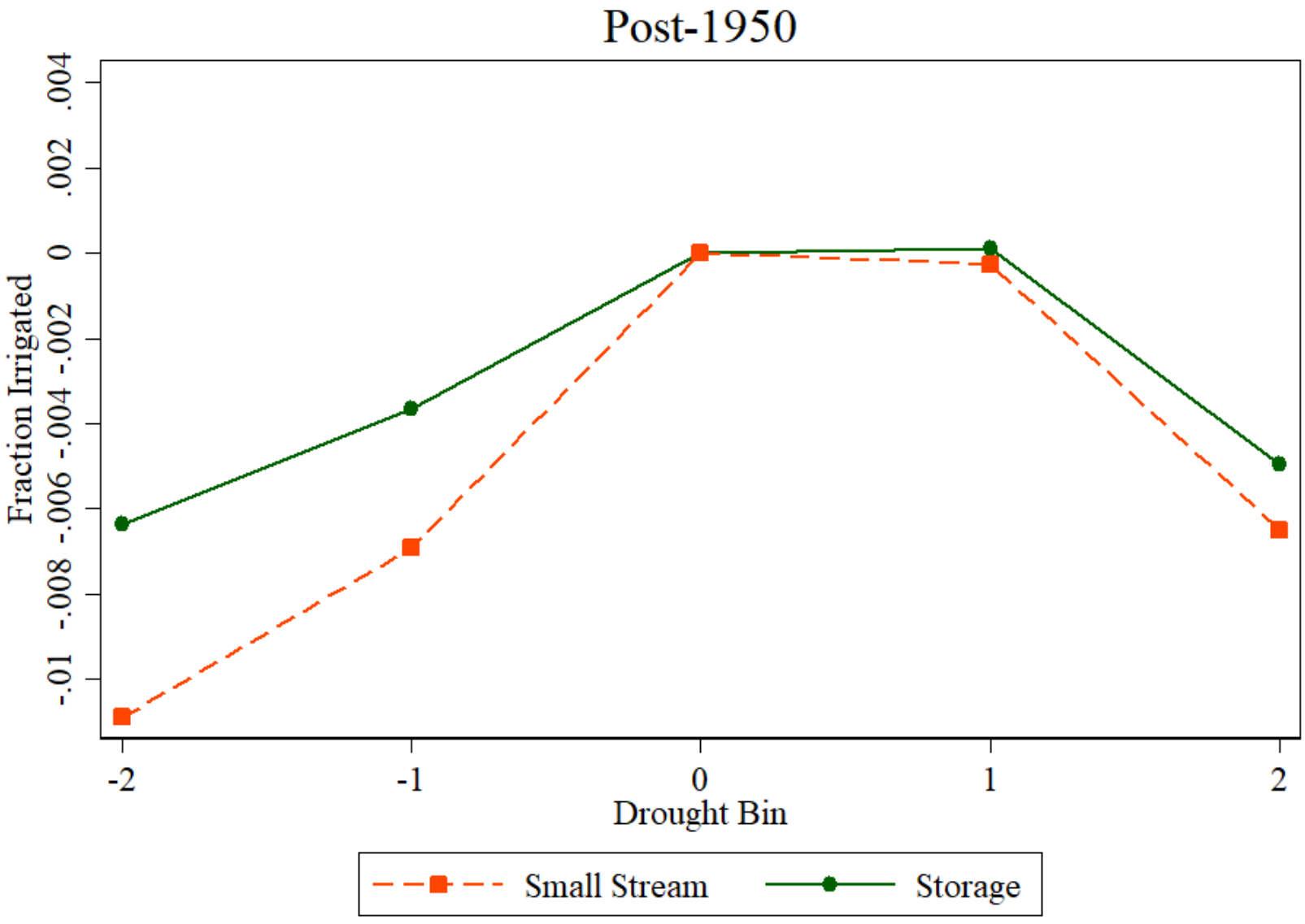
Robust standard errors in parentheses

$***p < 0.01, **p < 0.05, *p < 0.1$

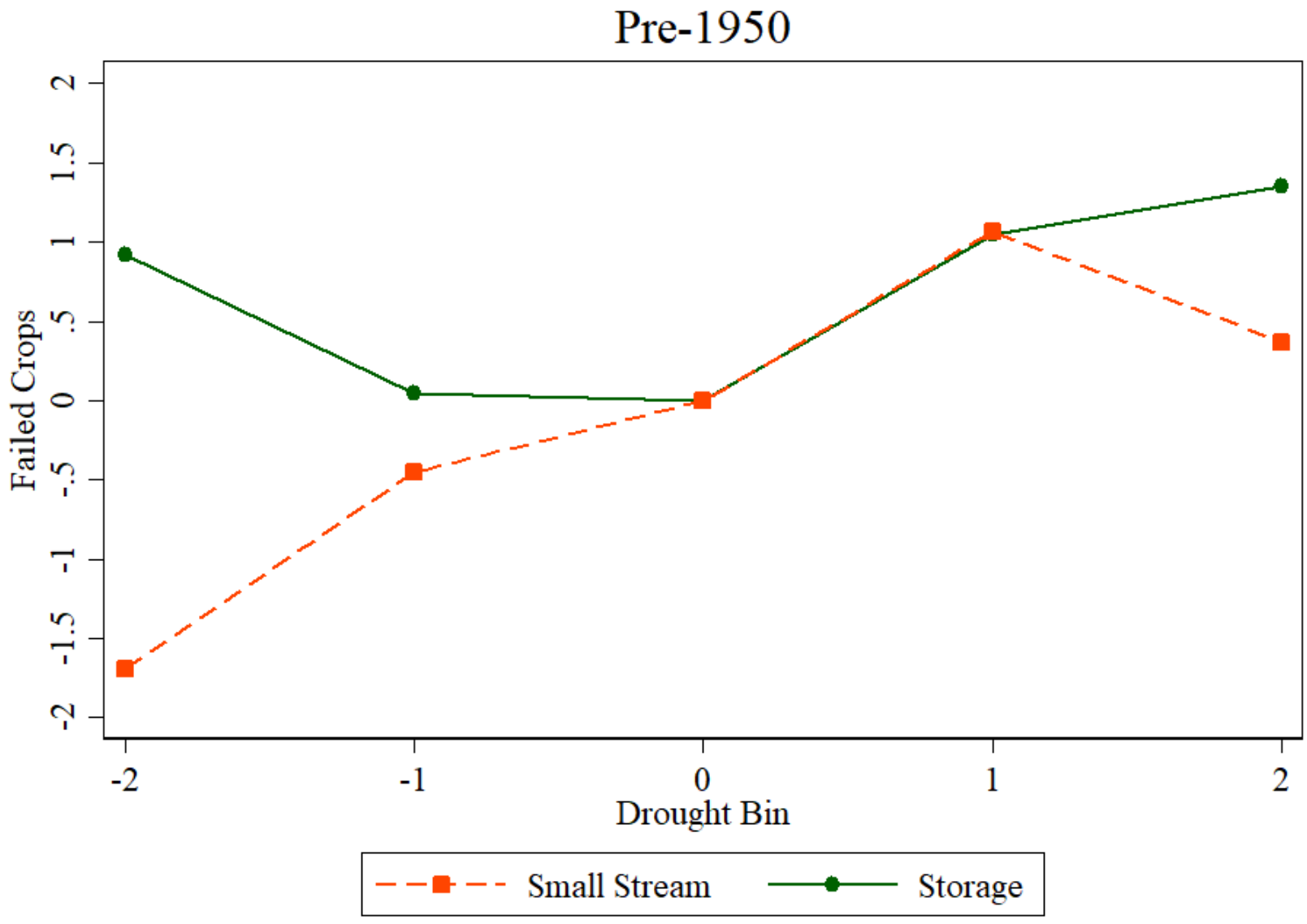
Irrigated Acreage Pre-1950



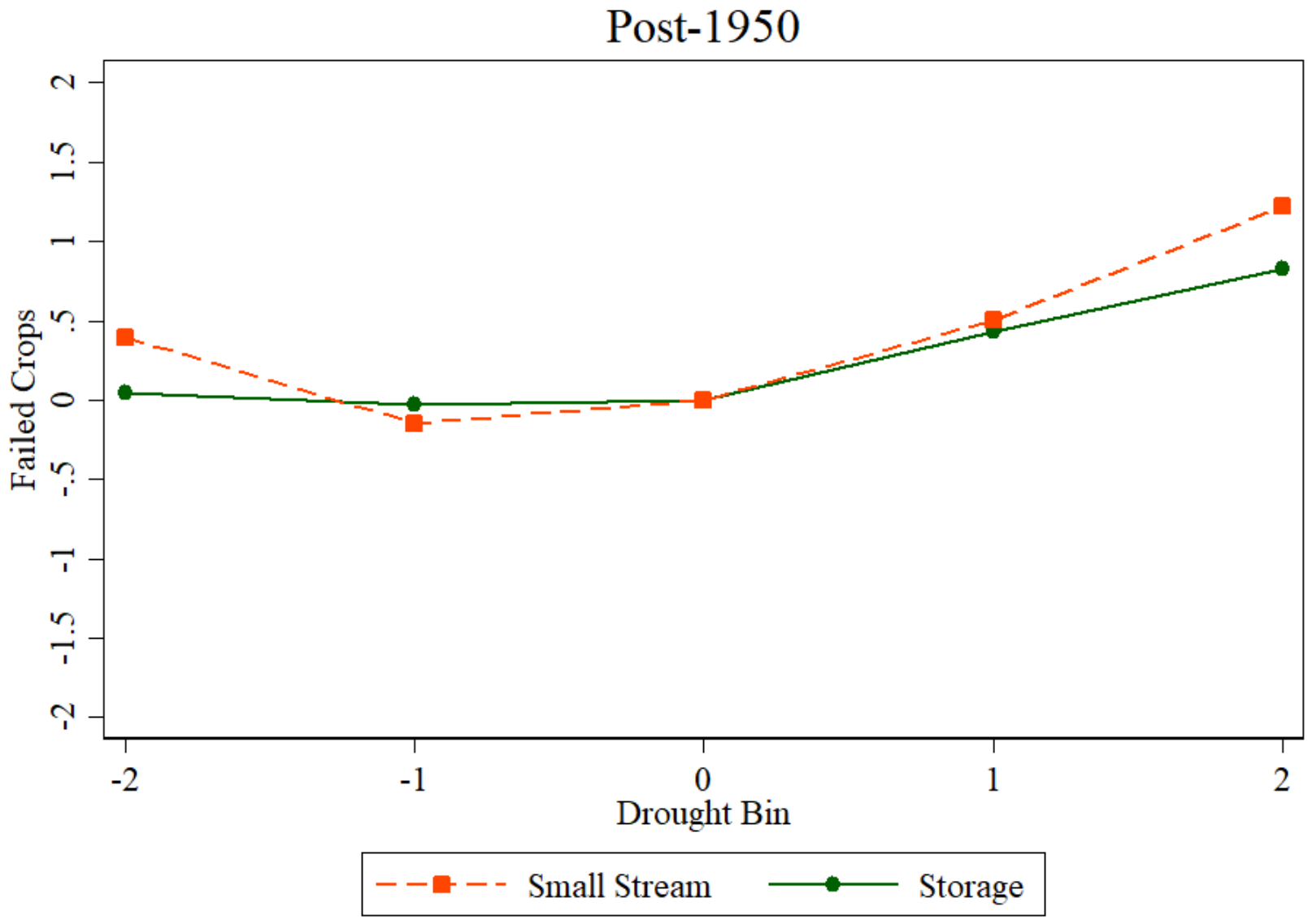
Irrigated Acreage Post-1950



Crop Failure Pre-1950



Crop Failure Post-1950



Regression Results: Storage Types

VARIABLES	(1) Pre-1950 Ln(Crop Value)	(2) Post-1950 Ln(Crop Value)	(3) Pre-1950 Pctg Irr.	(4) Post-1950 Pctg Irr.	(5) Pre-1950 Ln(Failure)	(6) Post-1950 Ln(Failure)
Bin 1	0.337***	-0.084	5.03E-05	-0.0109***	-1.714***	0.399**
	(0.102)	(0.059)	(0.002)	(0.002)	(0.083)	(0.188)
Bin 2	0.291***	0.00595	-0.00154	-0.00691***	-0.456	-0.145
	(0.092)	(0.037)	(0.003)	(0.002)	(0.324)	(0.142)
Bin 4	-0.393***	-0.0346	0.00137	-0.000284	1.081***	0.504***
	(0.090)	(0.045)	(0.001)	(0.001)	(0.254)	(0.127)
Bin 5	-0.337***	-0.250***	-0.00138	-0.00657**	0.386	1.219***
	(0.078)	(0.094)	(0.003)	(0.003)	(0.256)	(0.137)
Aquifer x Bin 1	-0.467***	0.188**	-0.00602*	0.00245	2.831***	-0.323
	(0.152)	(0.077)	(0.003)	(0.006)	(0.266)	(0.221)
Aquifer x Bin 2	-0.305***	-0.0193	-0.00187	0.00459*	0.791*	0.126
	(0.117)	(0.045)	(0.004)	(0.003)	(0.414)	(0.166)
Aquifer x Bin 4	-0.0973	0.0754	-0.000474	0.0042	0.141	0.0128
	(0.127)	(0.053)	(0.001)	(0.003)	(0.276)	(0.152)
Aquifer x Bin 5	-0.243**	0.198*	0.00476	-0.00131	1.186***	-0.440**
	(0.114)	(0.106)	(0.004)	(0.005)	(0.322)	(0.190)

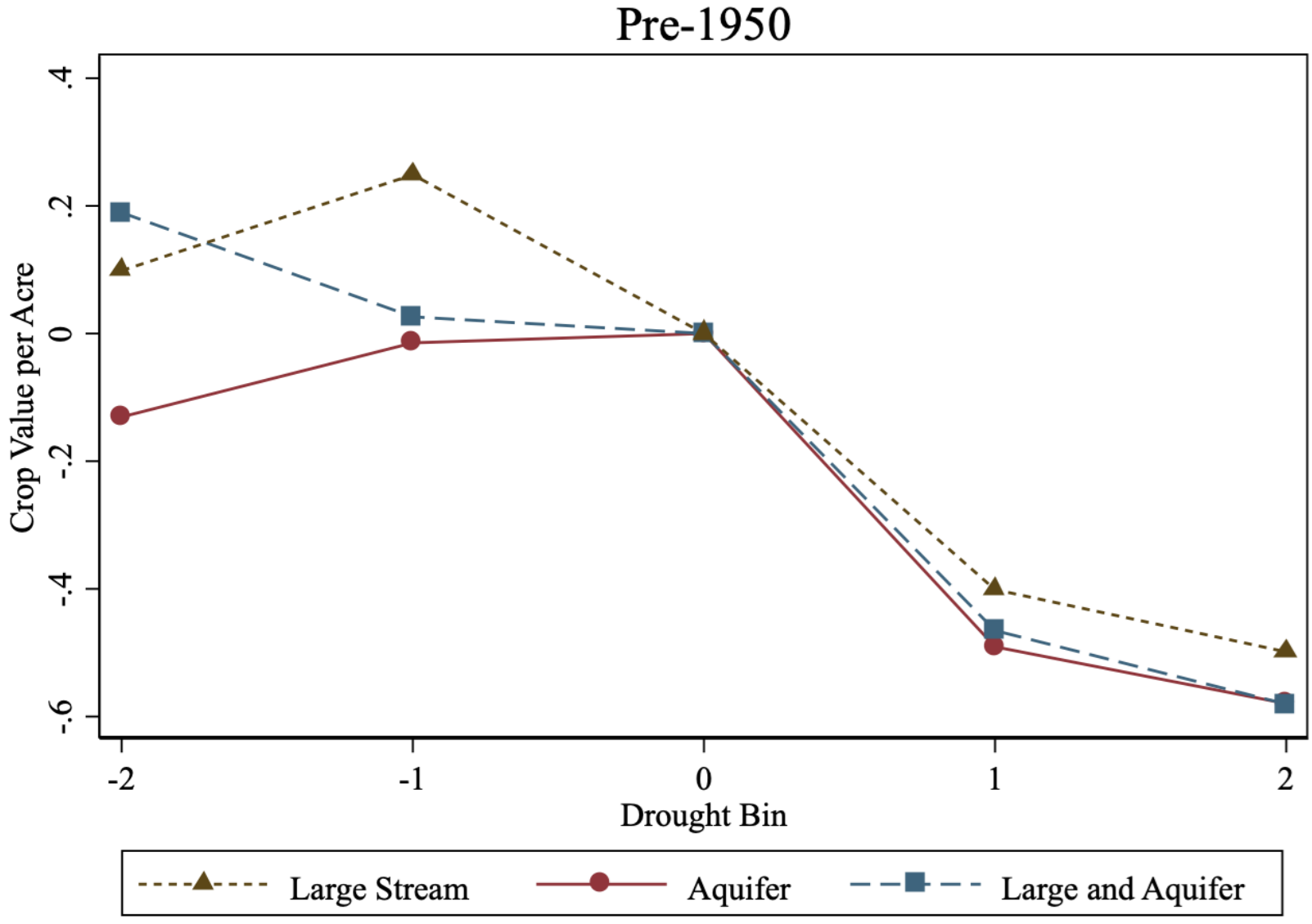
Regression Results: Storage Types

Joint x Bin 1	-0.147	0.0132	-0.00448	0.00827		-0.406*
	(0.120)	(0.088)	(0.004)	(0.009)		(0.237)
Joint x Bin 2	-0.264**	-0.0814*	-0.00601	-0.000584	0.760*	0.15
	(0.121)	(0.049)	(0.006)	(0.004)	(0.455)	(0.184)
Joint x Bin 4	-0.0719	0.052	0.000169	-0.00686*	-0.164	-0.135
	(0.114)	(0.055)	(0.002)	(0.004)	(0.311)	(0.185)
Joint x Bin 5	-0.244**	0.152	0.00905*	-0.000326	1.002***	-0.289
	(0.113)	(0.108)	(0.005)	(0.006)	(0.354)	(0.210)
Large Stream x Bin 1	-0.238	0.0858	-0.00405	0.00465		-0.346
	(0.182)	(0.106)	(0.004)	(0.003)		(0.263)
Large Stream x Bin 2	-0.0418	-0.0452	0.00213	0.00558***	-0.835	0.0515
	(0.140)	(0.055)	(0.004)	(0.002)	(0.528)	(0.207)
Large Stream x Bin 4	-0.00778	0.0182	-0.00111	-0.000345	-0.469	-0.227
	(0.135)	(0.063)	(0.001)	(0.002)	(0.378)	(0.191)
Large Stream x Bin 5	-0.162	0.290**	0.000272	0.0144***	0.201	-0.442*
	(0.117)	(0.116)	(0.003)	(0.004)	(0.423)	(0.251)
Observations	1,914	6,617	1,914	6,688	954	3,285
R-squared	0.338	0.356	0.101	0.153	0.331	0.719
Number of stcounty	479	479	479	479	478	474
Fixed Effects	Year, Cty	Year, Cty	Year, Cty	Year, Cty	Year, Cty	Year, Cty

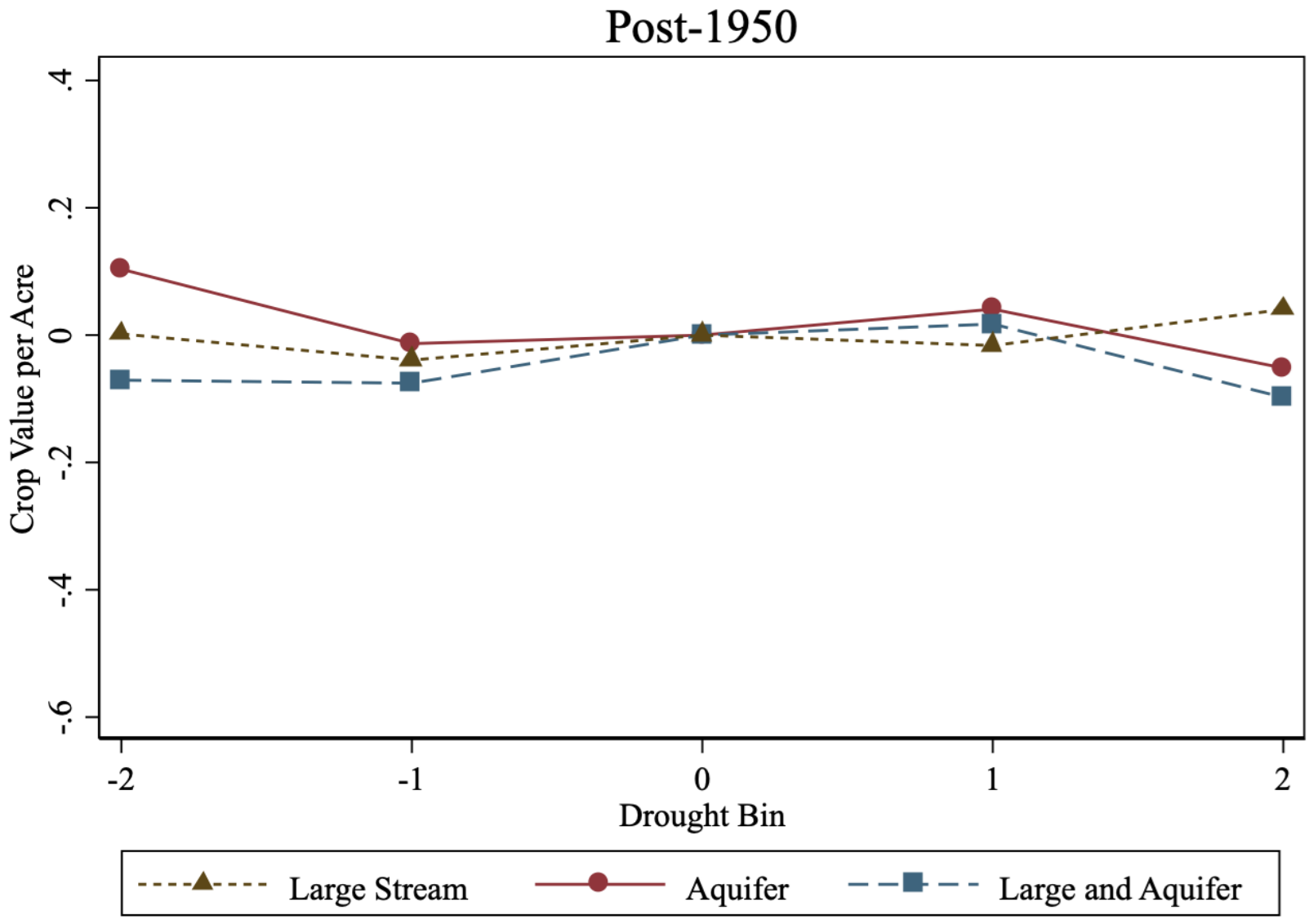
Robust standard errors in parentheses

$***p < 0.01, **p < 0.05, *p < 0.1$

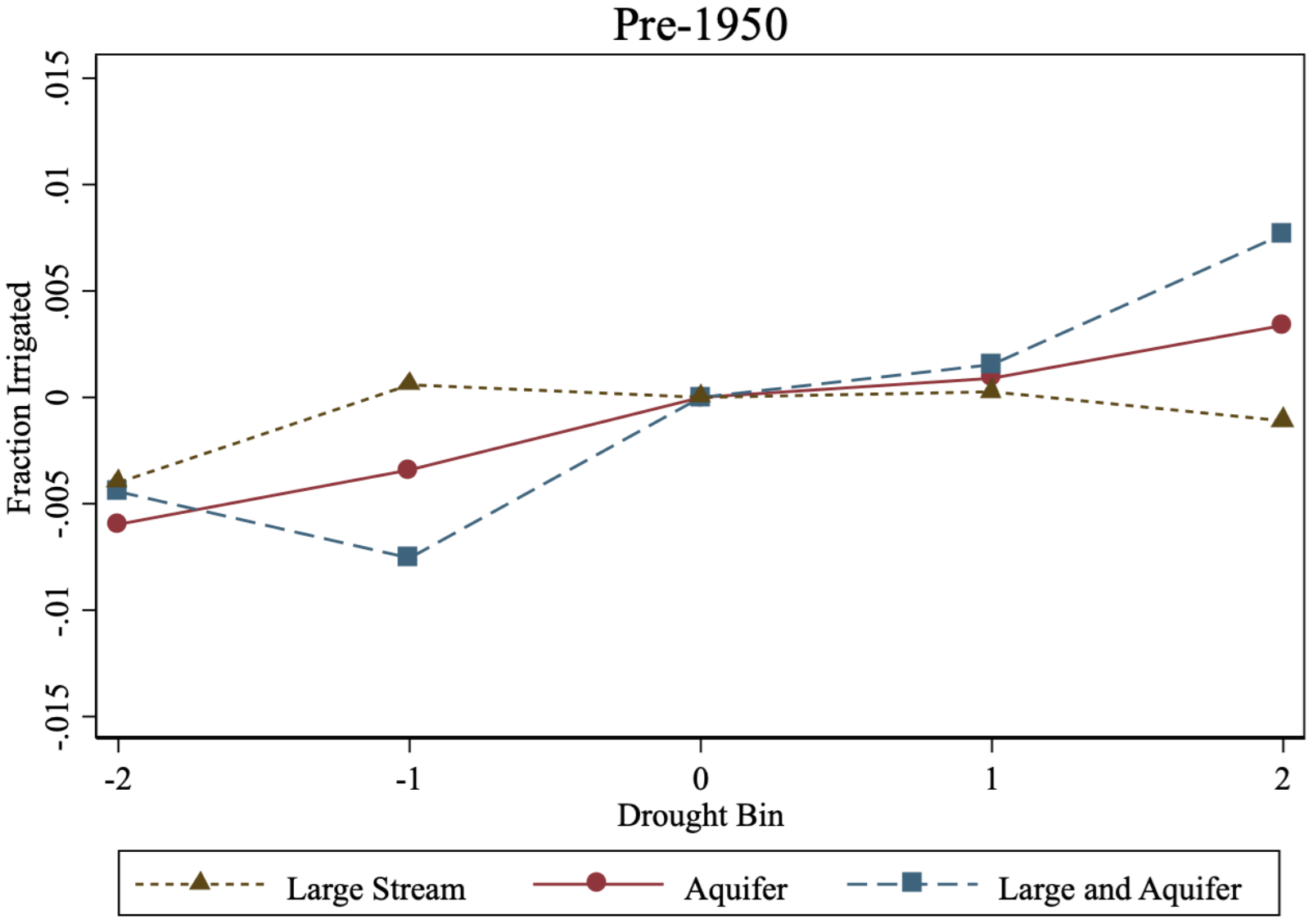
Crop Value by Storage Type Pre-1950



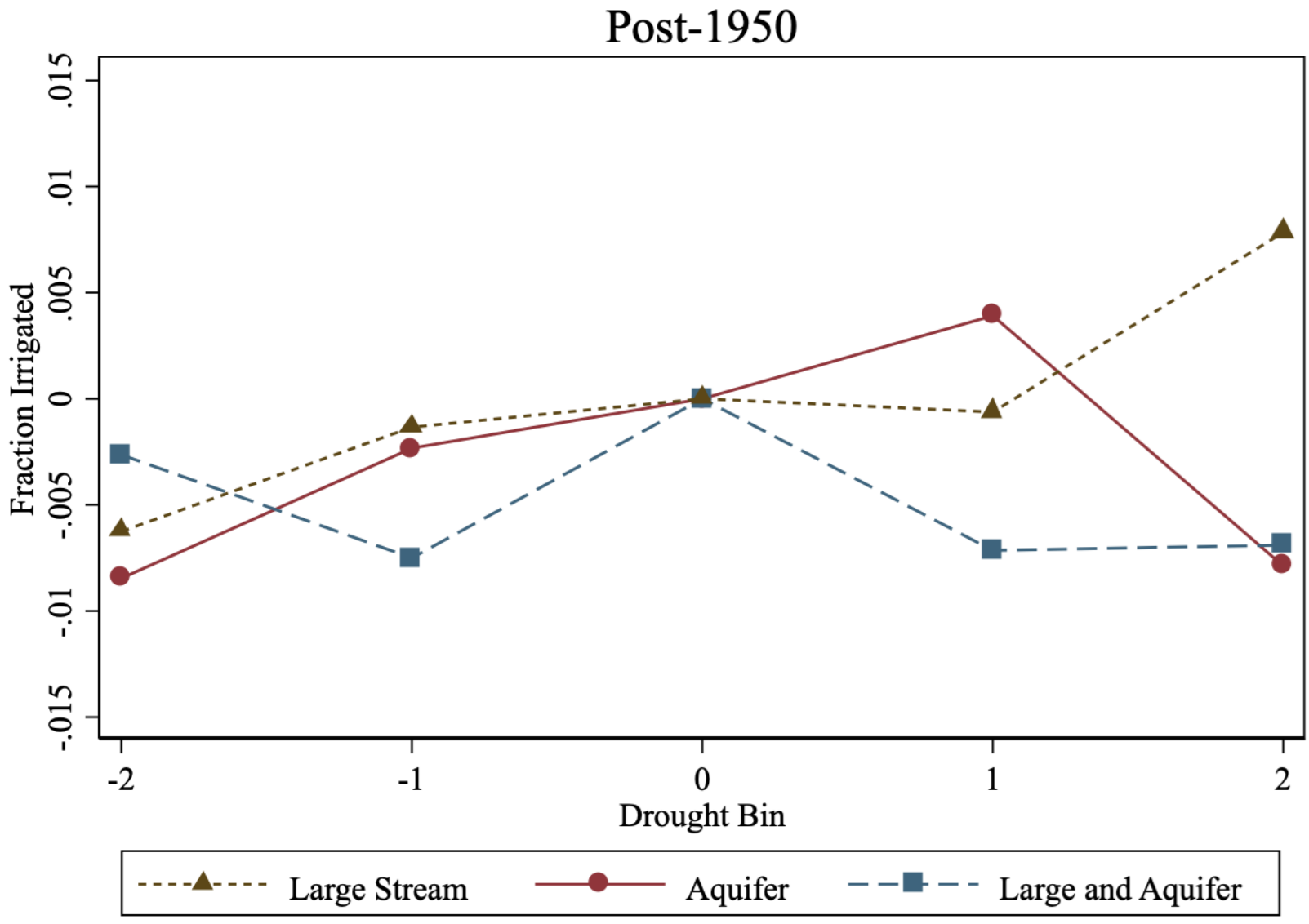
Crop Value by Storage Type Post-1950



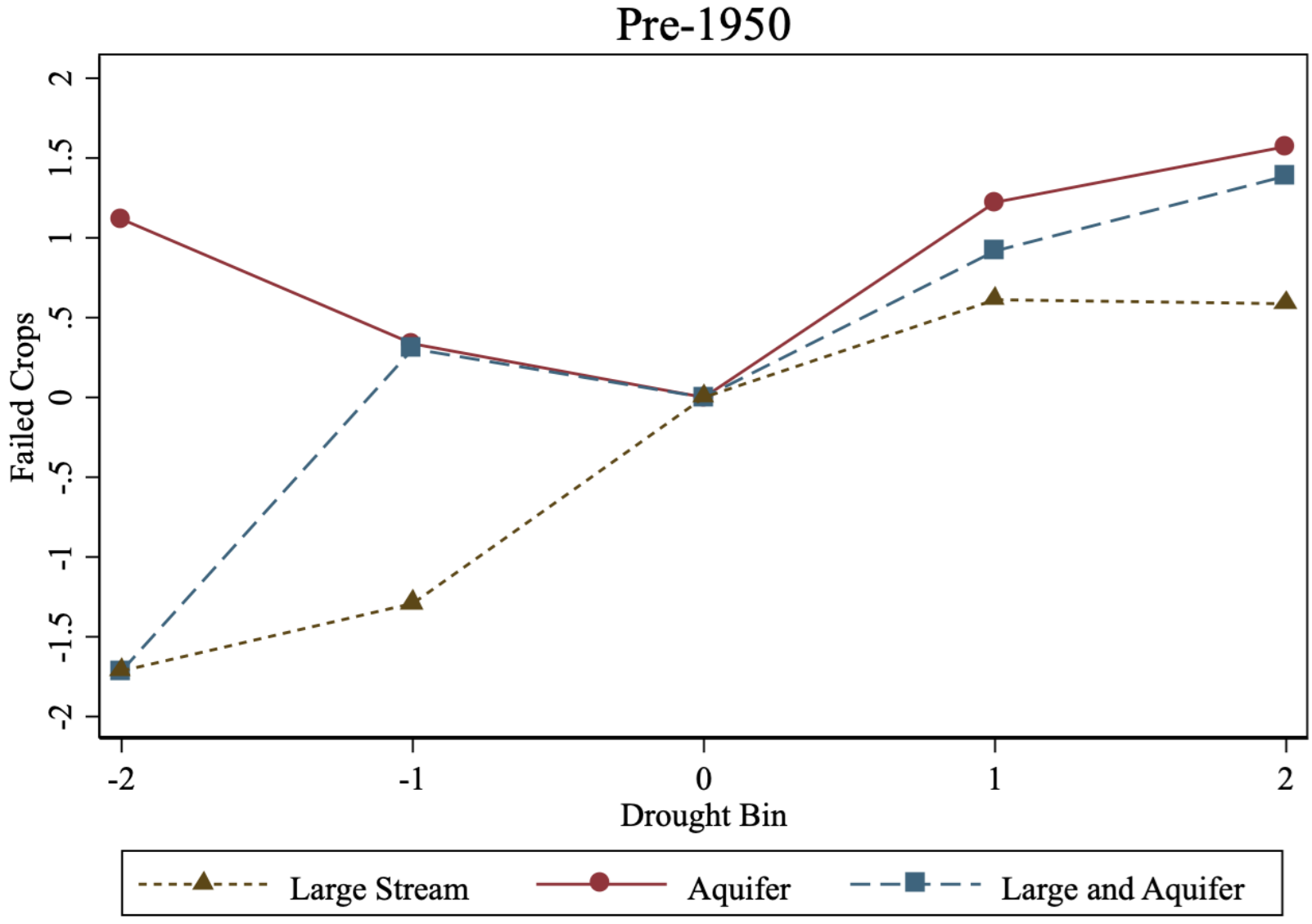
Fraction Irrigated by Storage Type Pre-1950



Fraction Irrigated by Storage Type Post-1950



Crop Failure by Storage Type Pre-1950



Crop Failure by Storage Type Post-1950