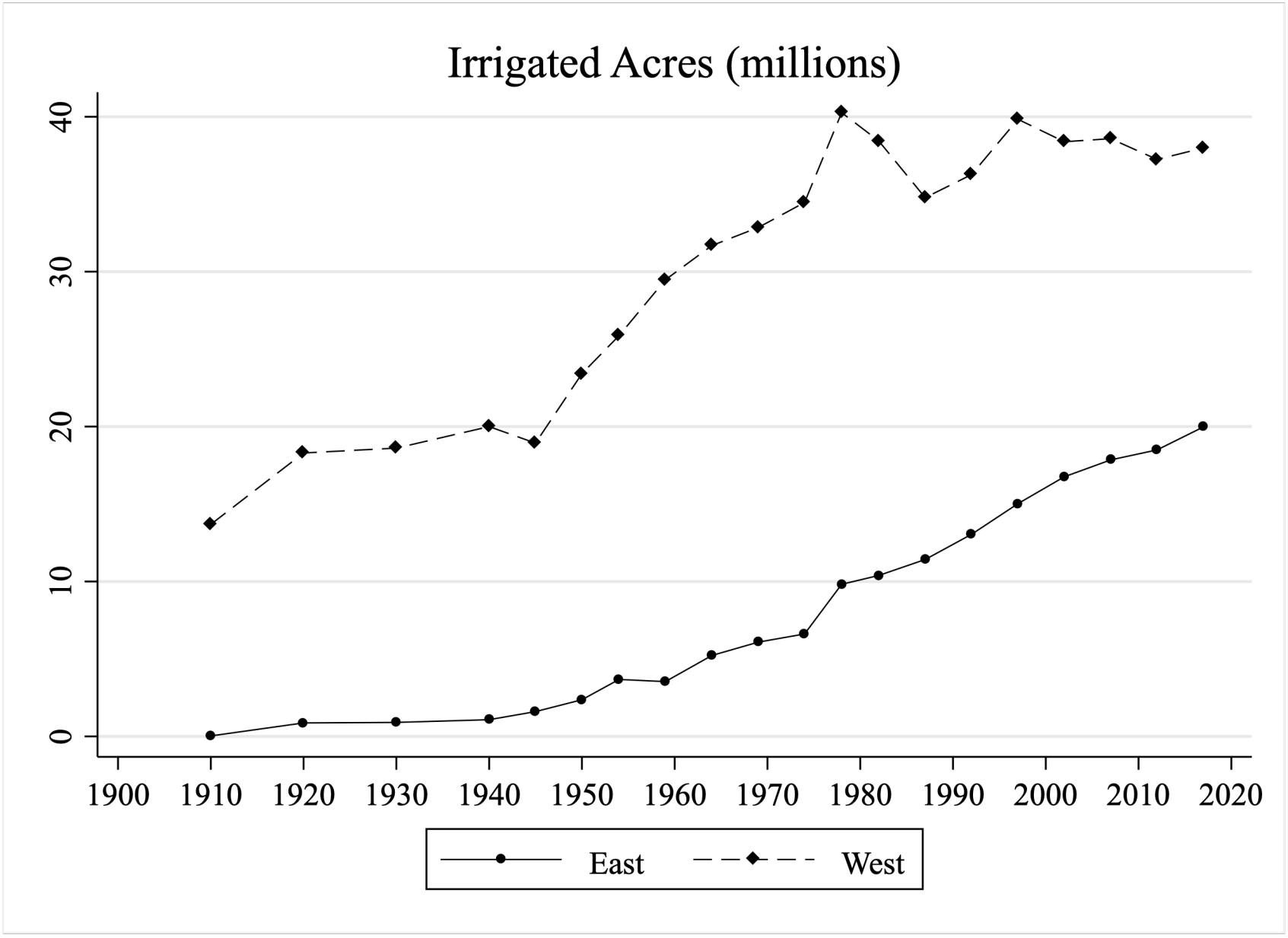
Technological Change and Climatic Resiliency: Evidence from Irrigation in the United States

Eric C. Edwards, North Carolina State University
Steven M. Smith, Colorado School of Mines

NBER DAE
Summer Institute
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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 increases level of ag production in arid western counties (Hornbeck and Keskin 2014; Edwards and Smith 2018)
- 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)



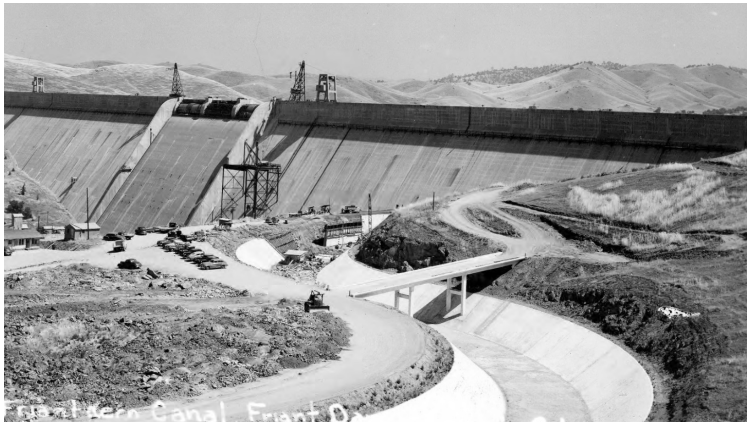


Lubbock/Dalhart (ca. 2010s)

Expansion of Irrigation Storage



Groundwater Pumping

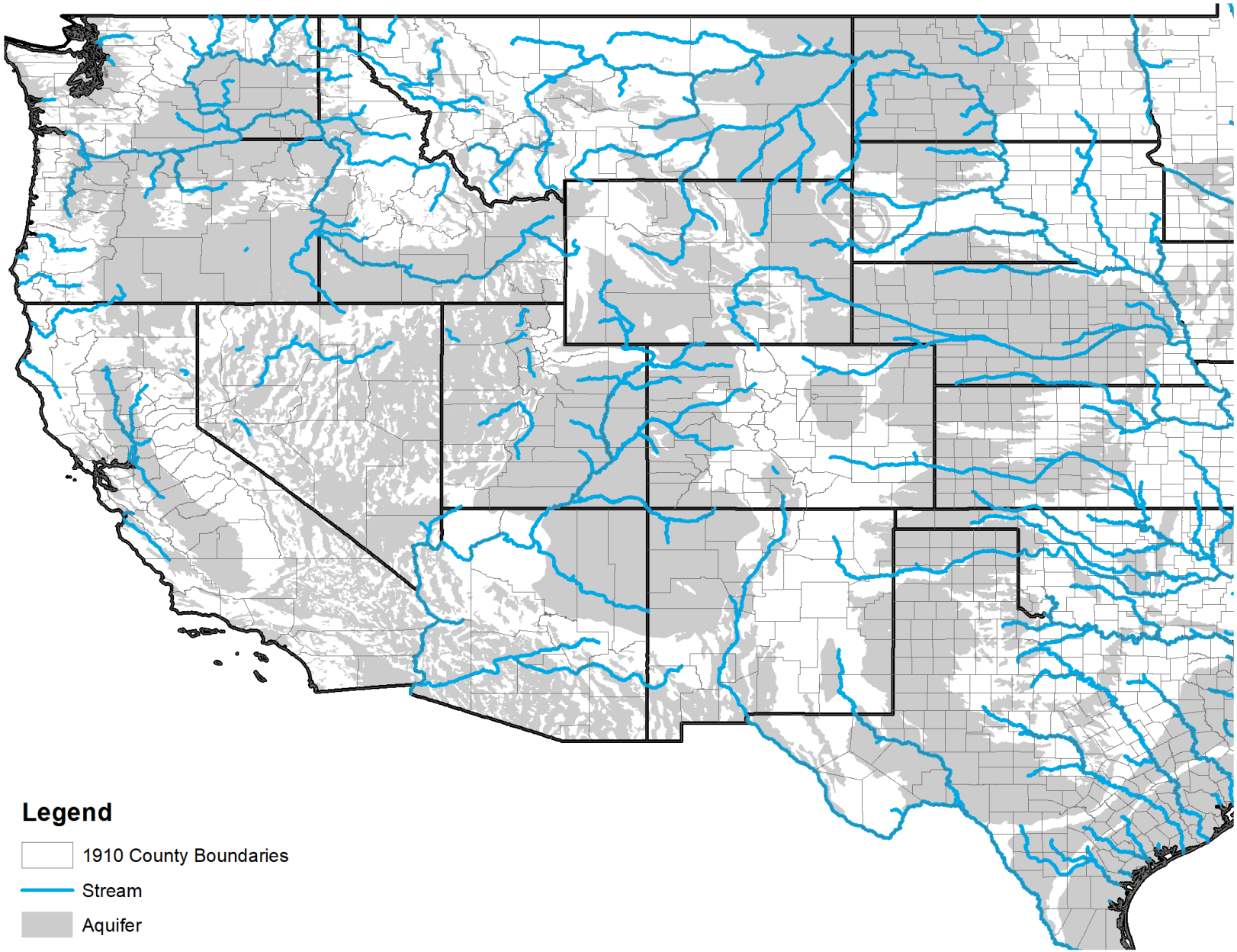


Federal Dams

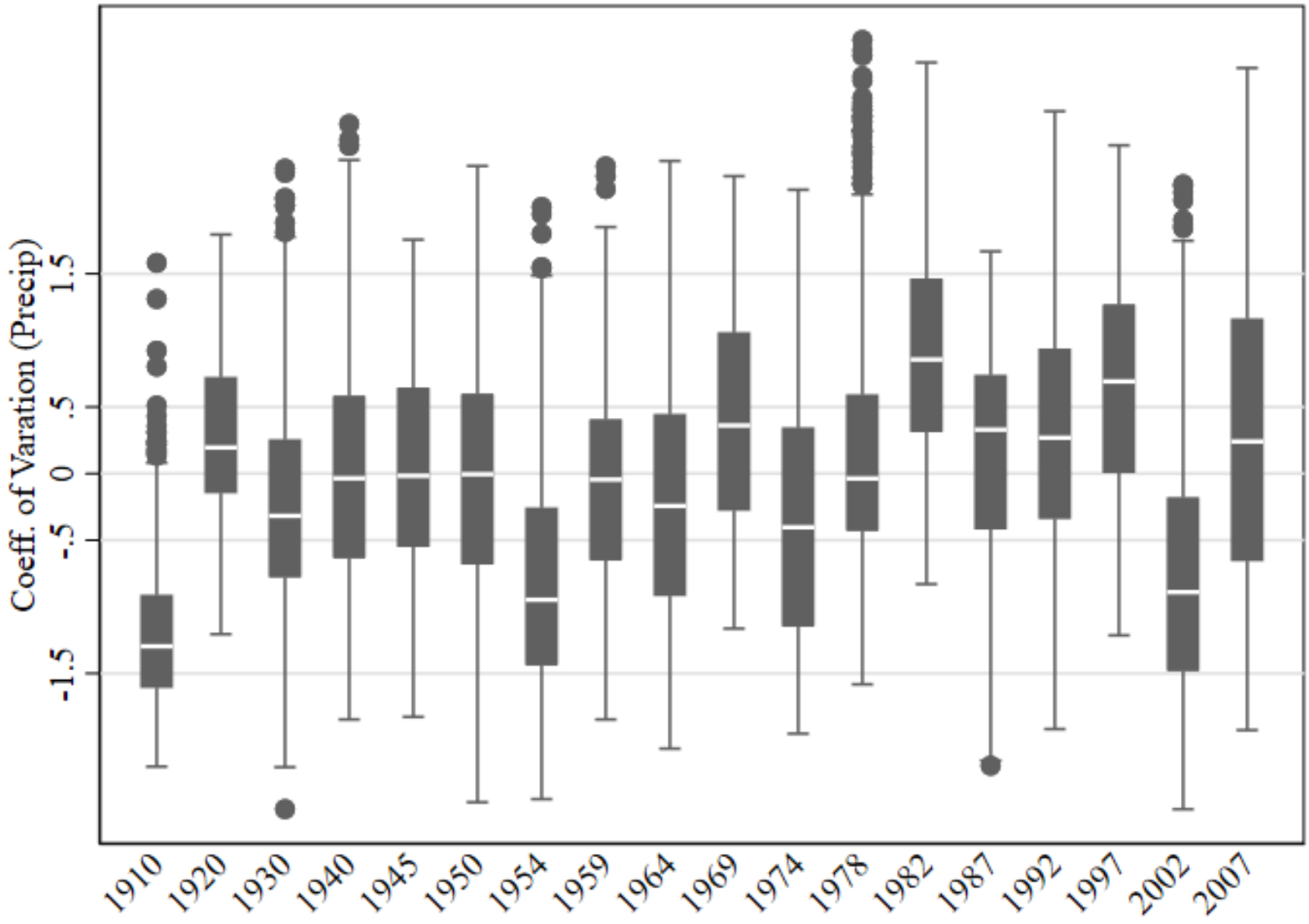
Research Design and Data

- 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 1910-2012
  - Crop value
  - Irrigated acres
  - Failed cropland

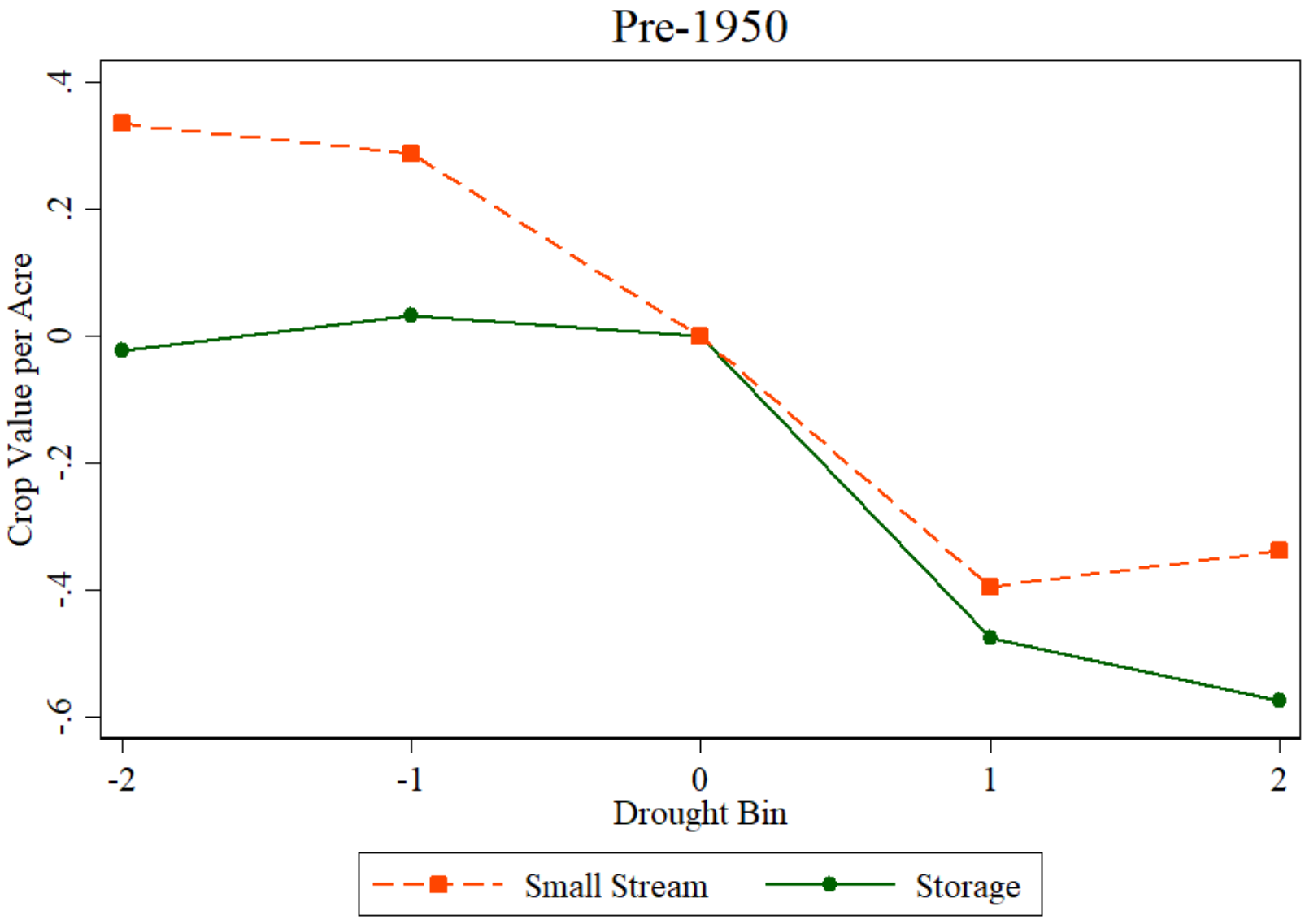
Measuring Storage Potential



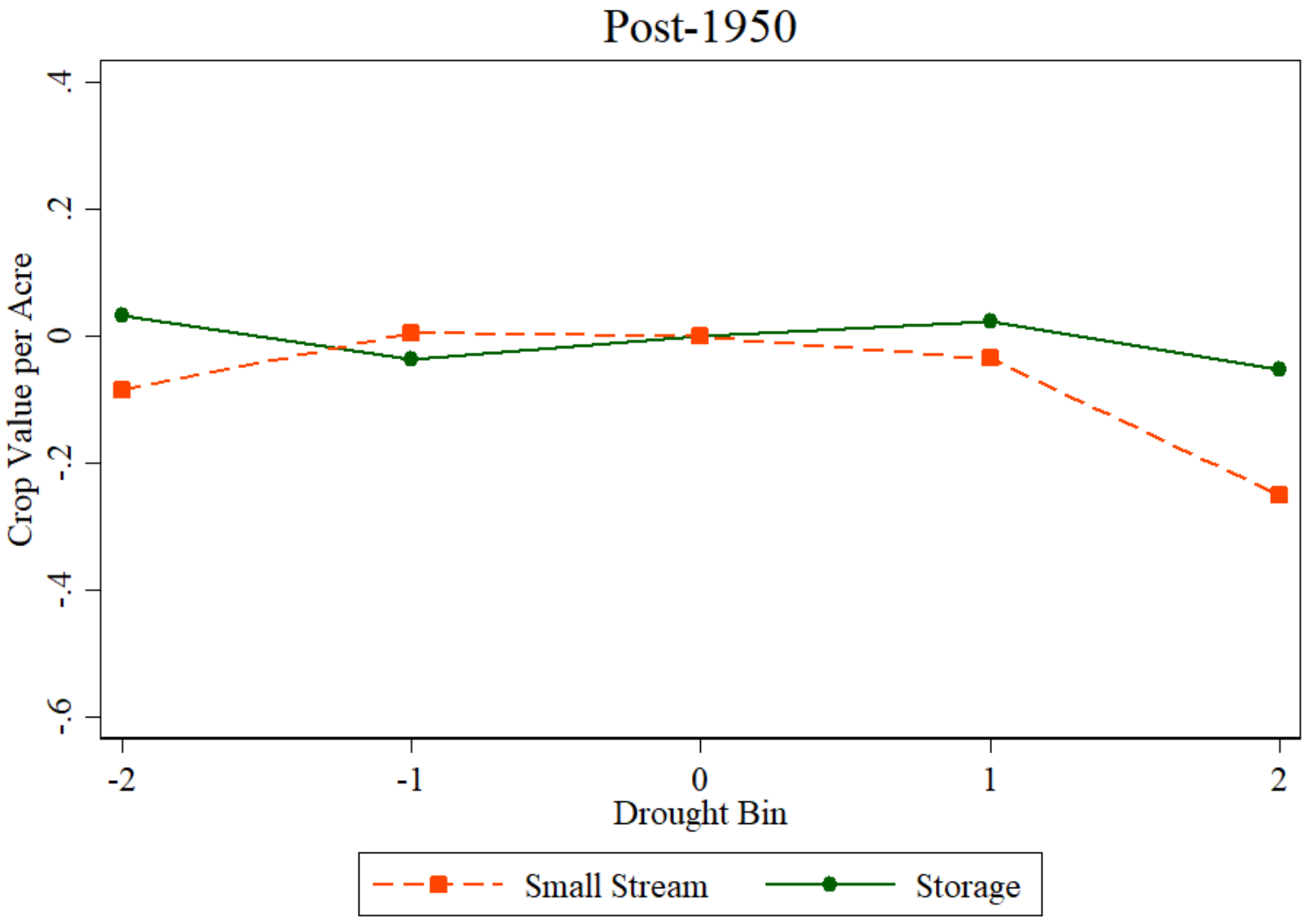
Western Precipitation



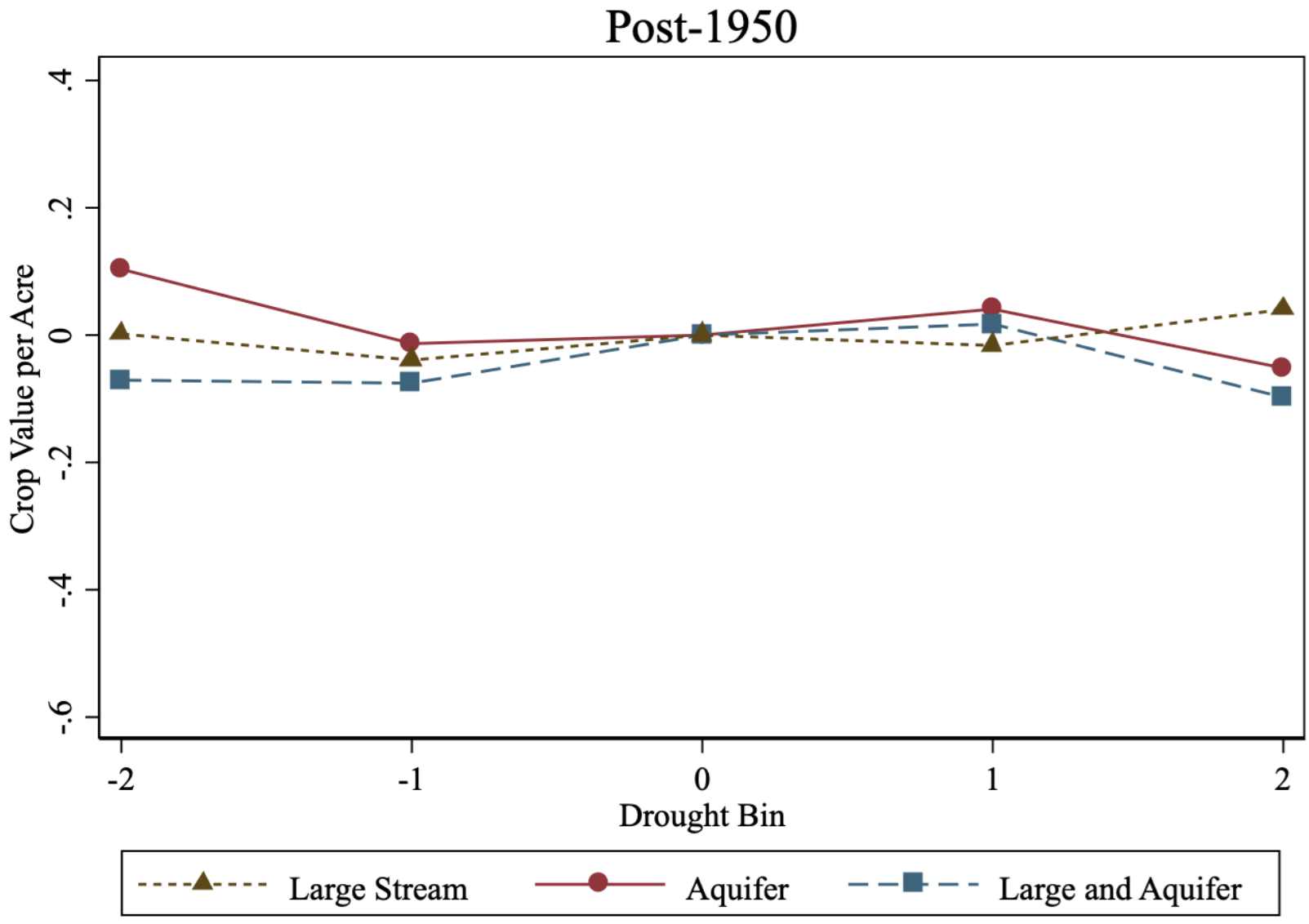
Crop Value Pre-1950



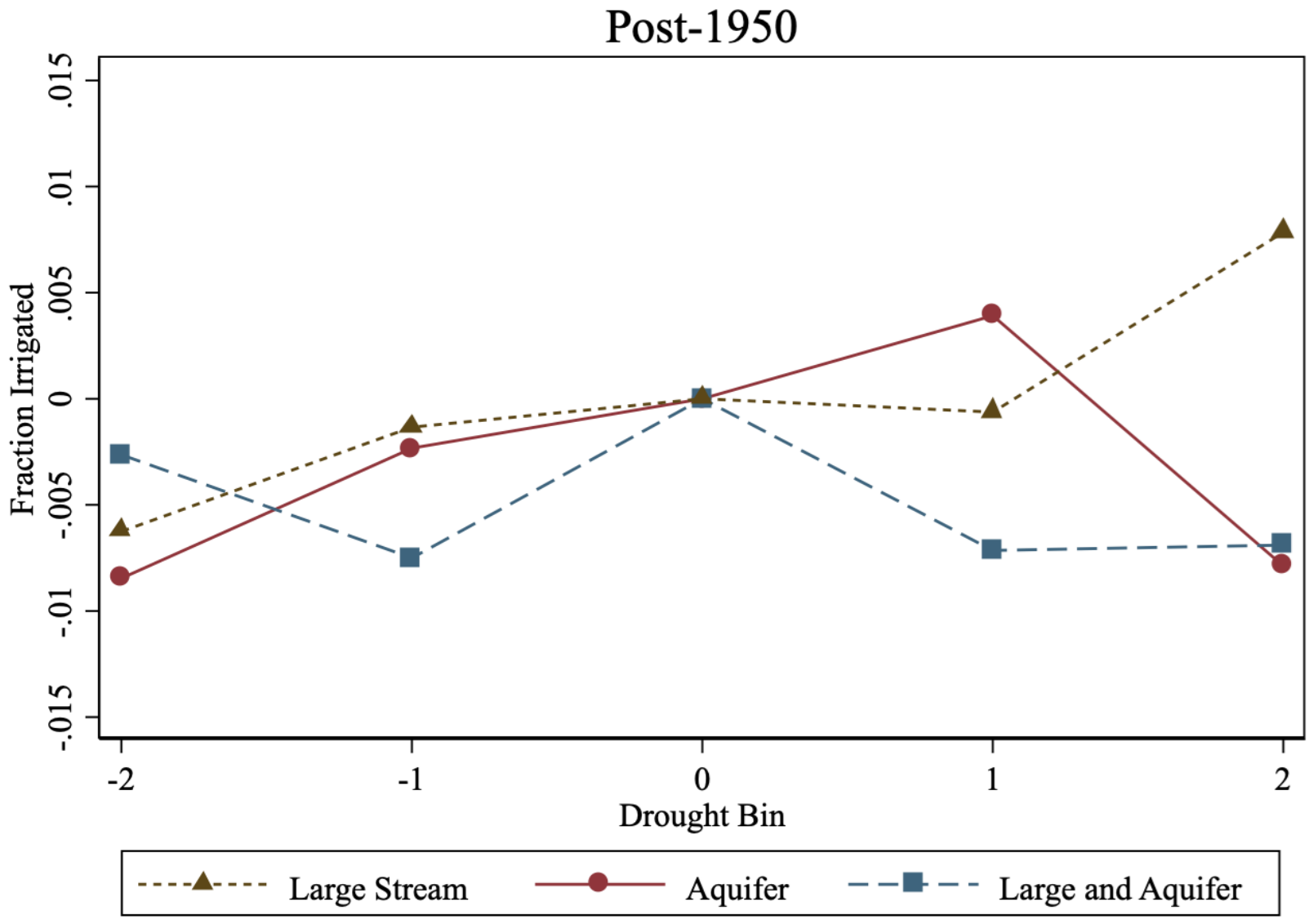
Crop Value Post-1950



Crop Value by Storage Type Post-1950



Fraction Irrigated by Storage Type Post-1950



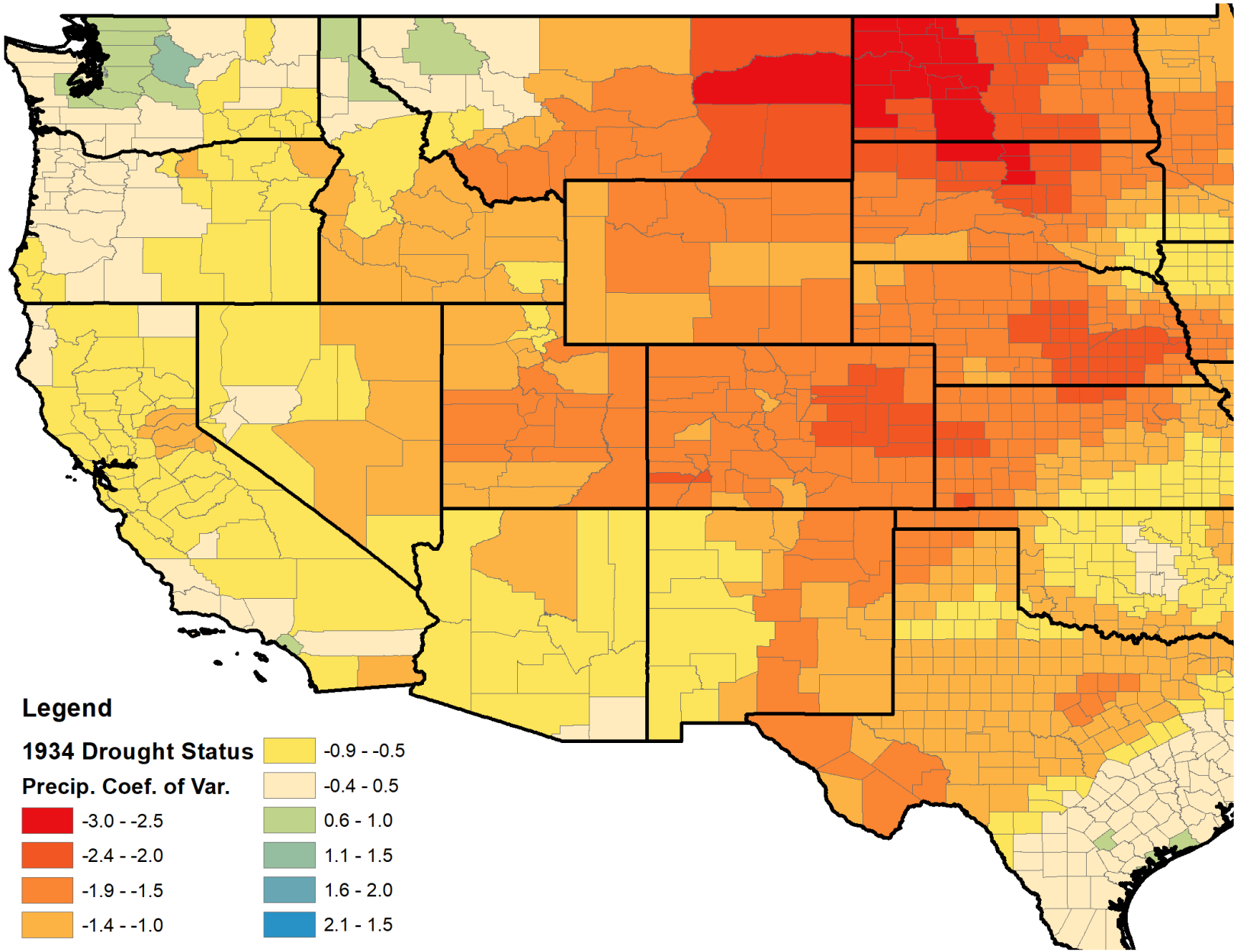
Summary and Next Steps

- **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**

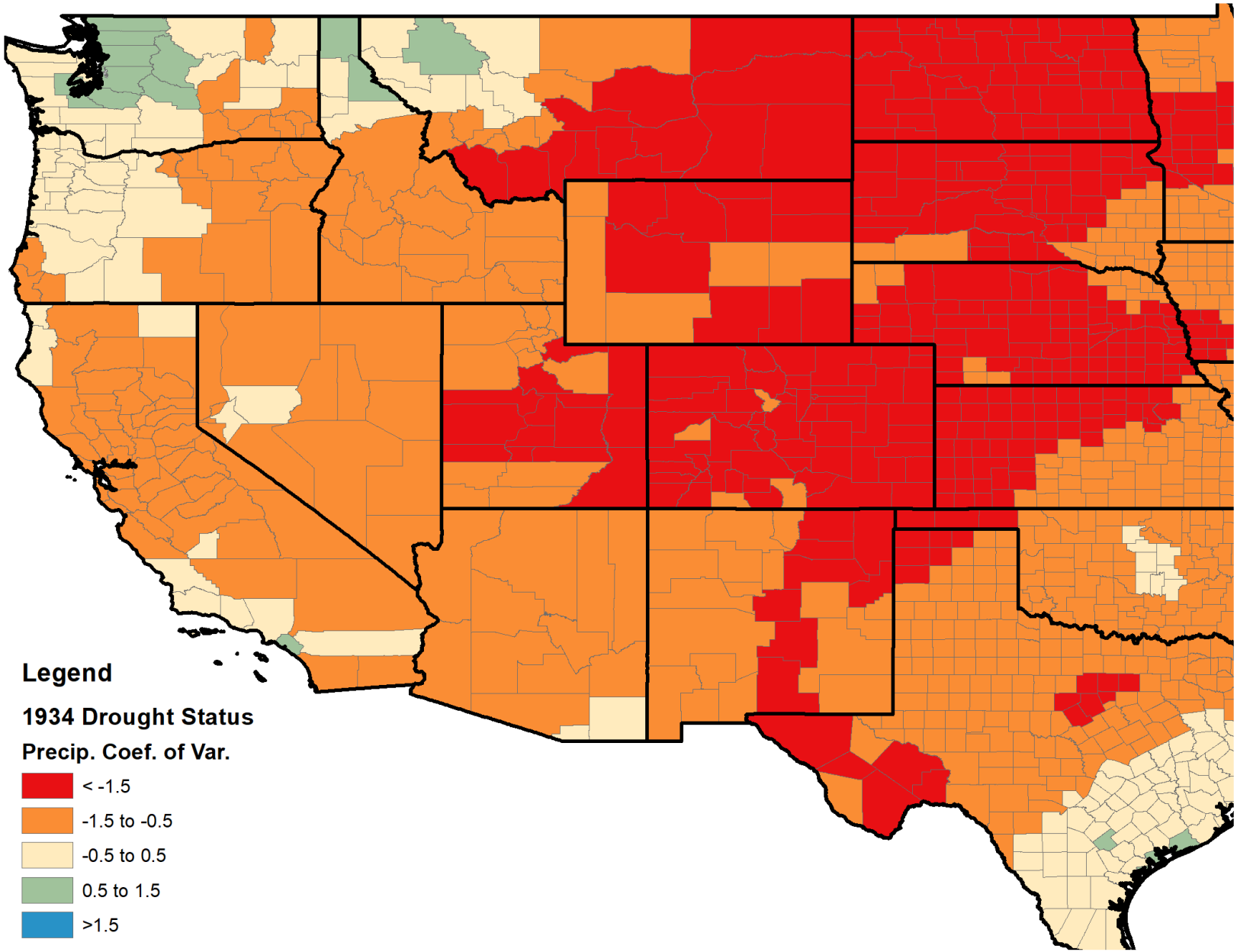
- Refine and test robustness of measures of drought/temperature
  - Palmer Drought Severity Index
  - Heat shocks
- Ag census data (1850-1900)
- Data by specific crops (1850-2012)
- Irrigation expansion in the East

- Thank you!

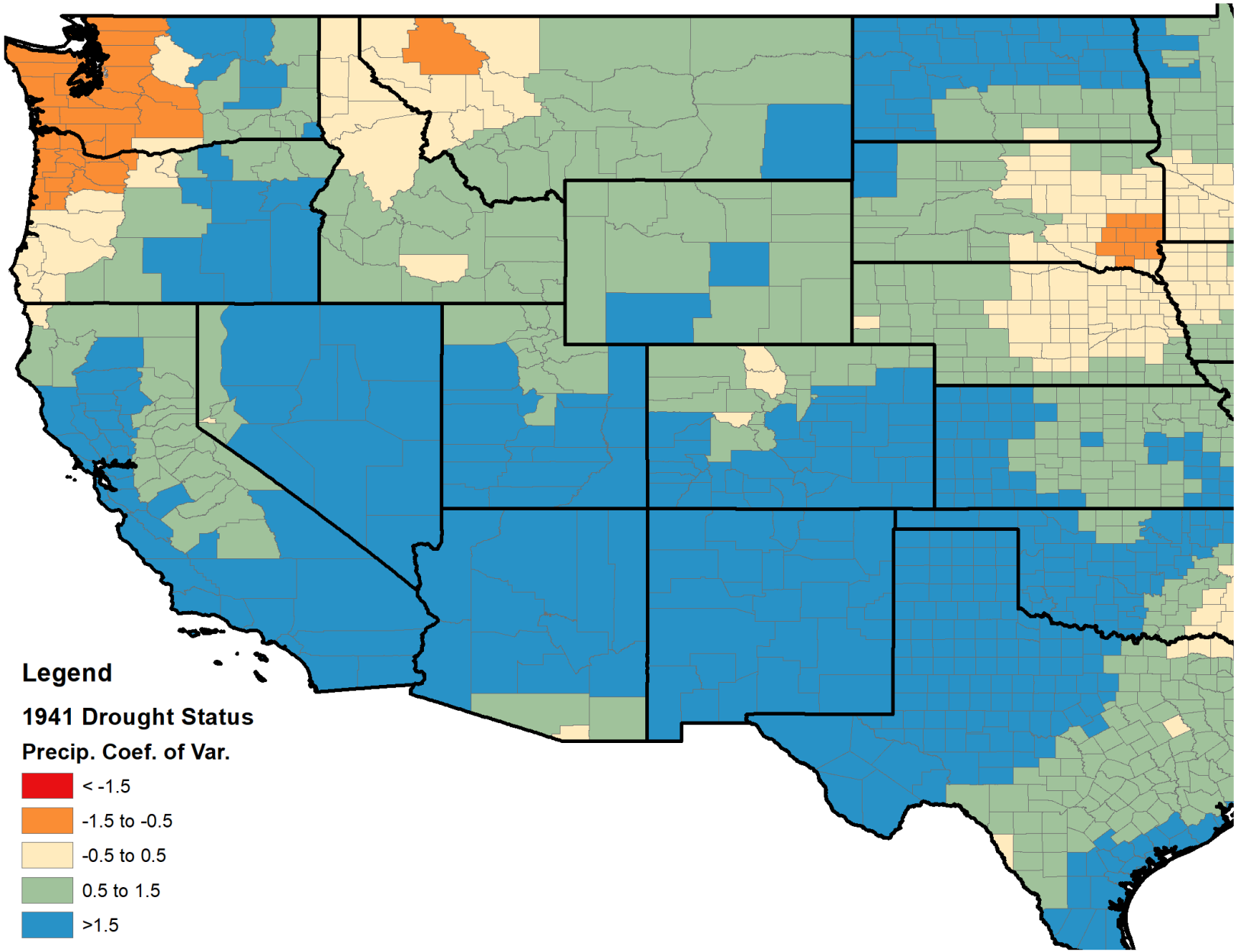
Drought Status in 1934



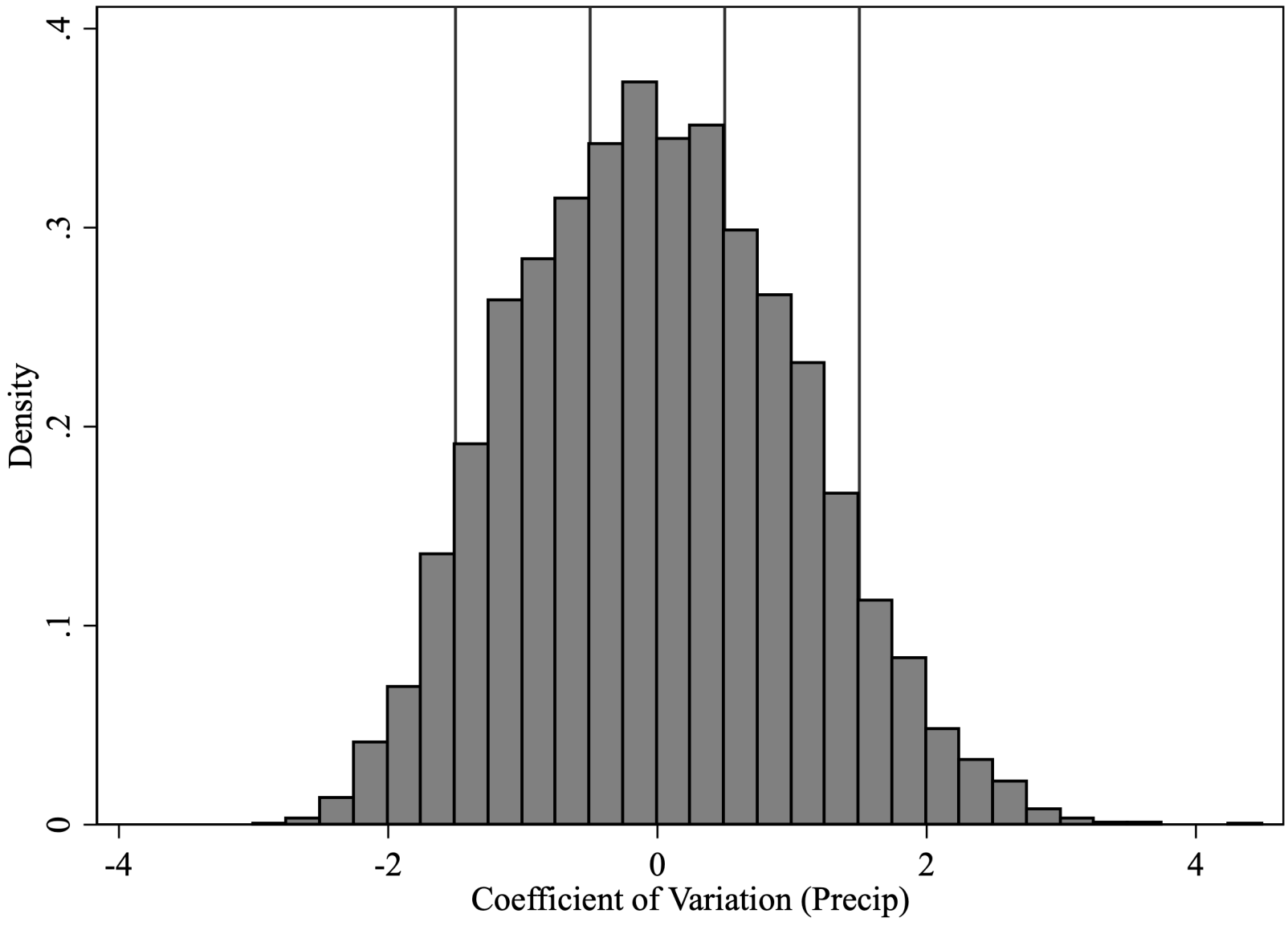
1934 Binned Drought Status



Wettest Year: 1941



Precipitation Bins



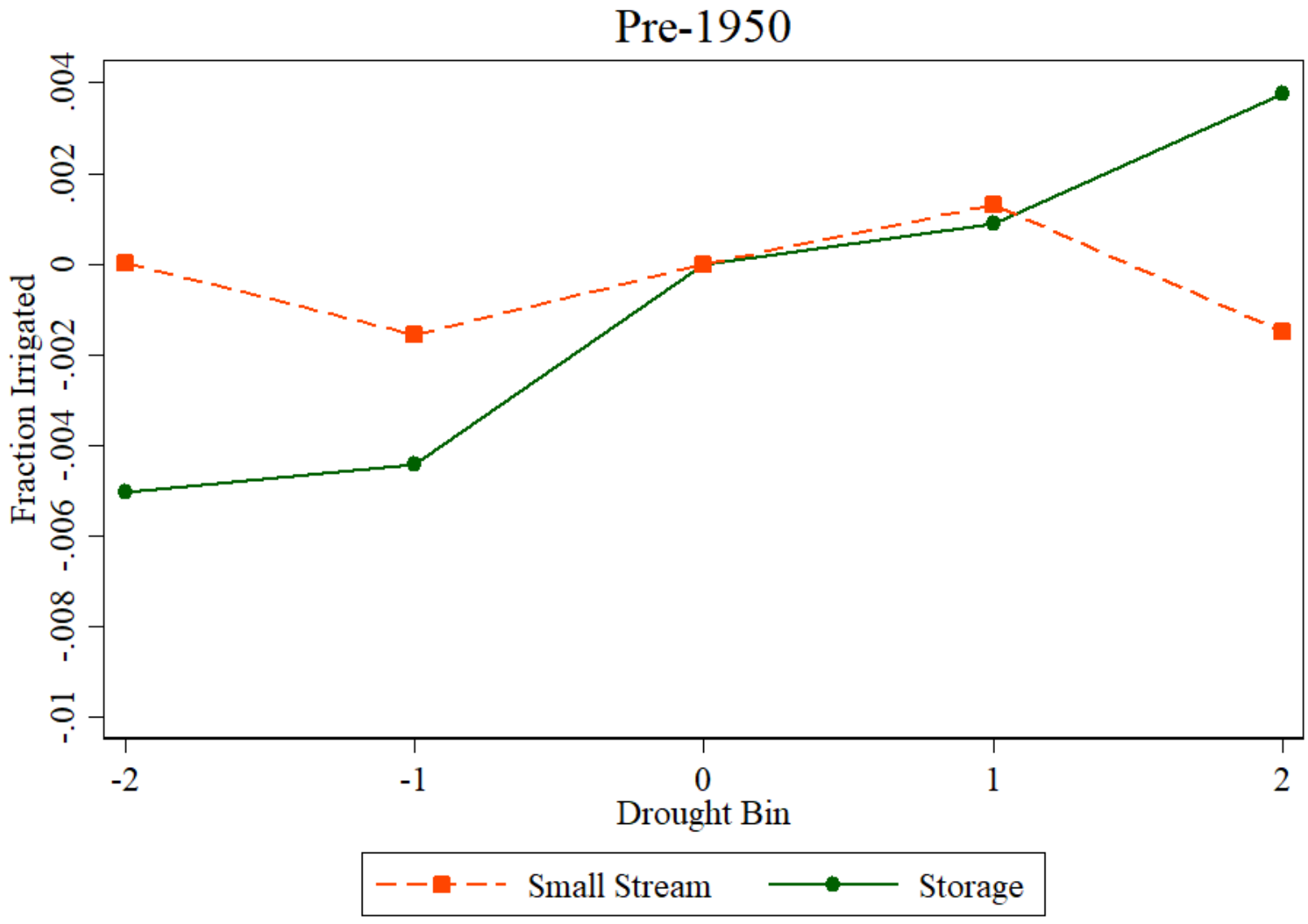
Regression Results: Storage

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

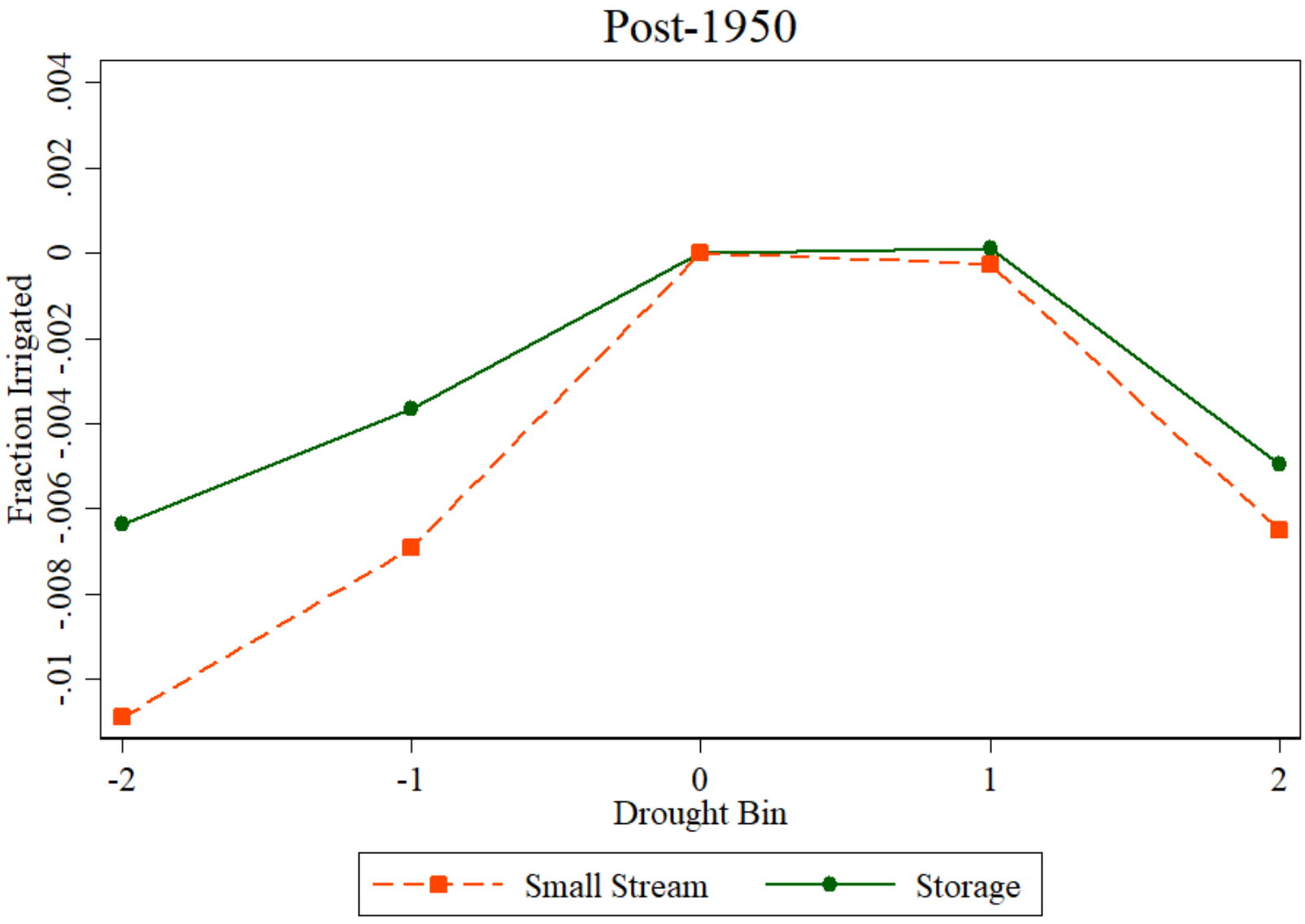
Robust standard errors in parentheses

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

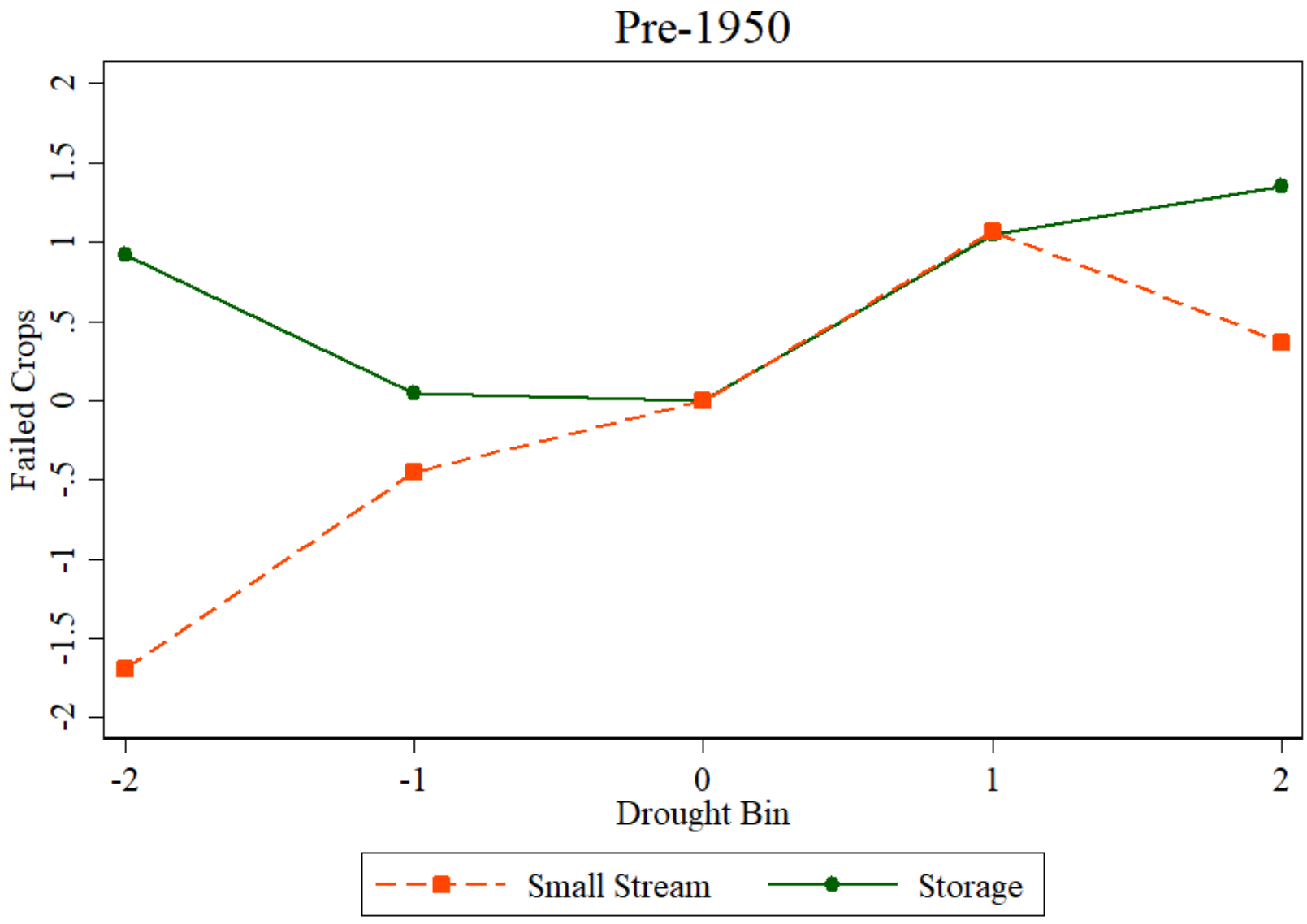
Irrigated Acreage Pre-1950



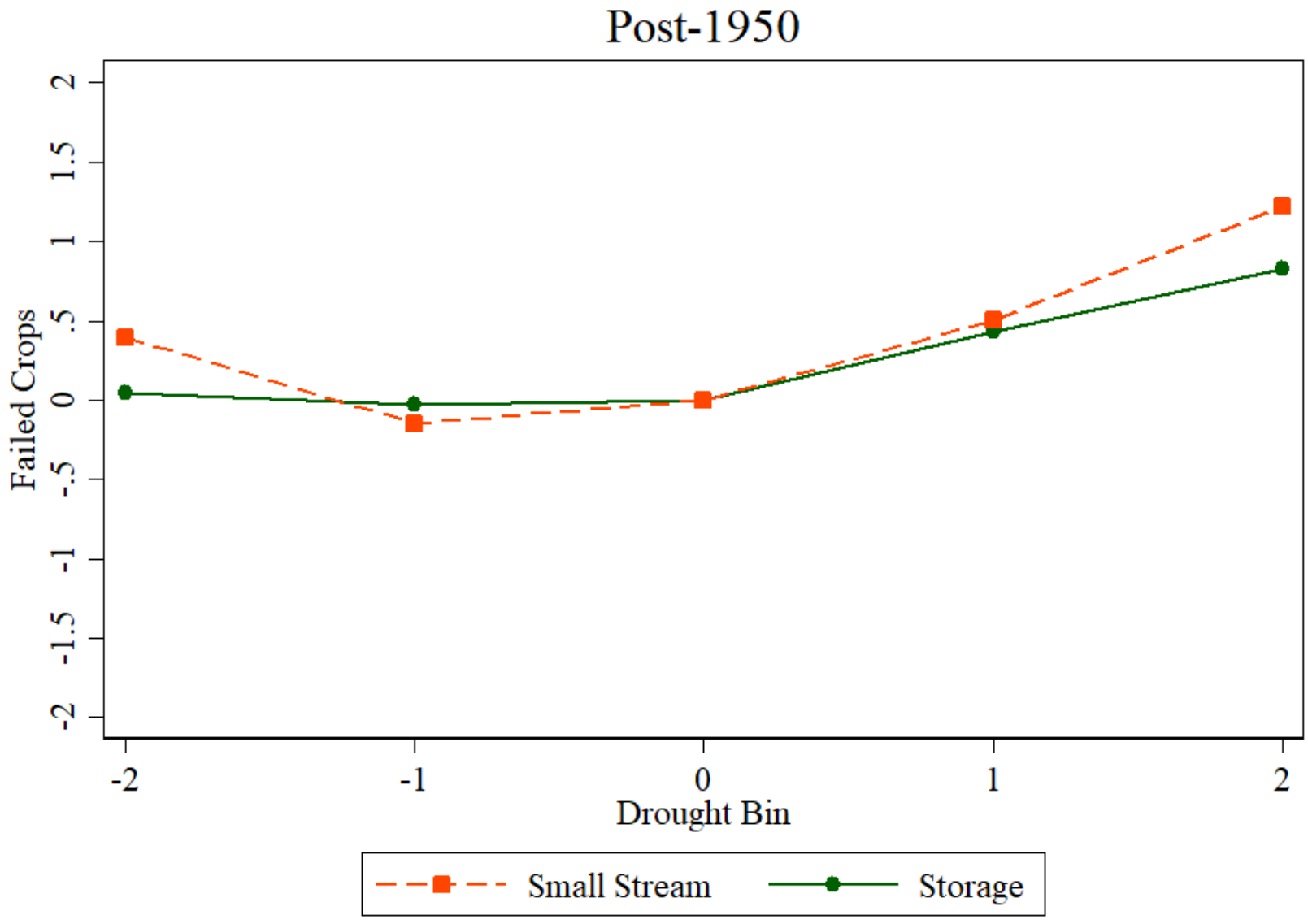
Irrigated Acreage Post-1950



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)

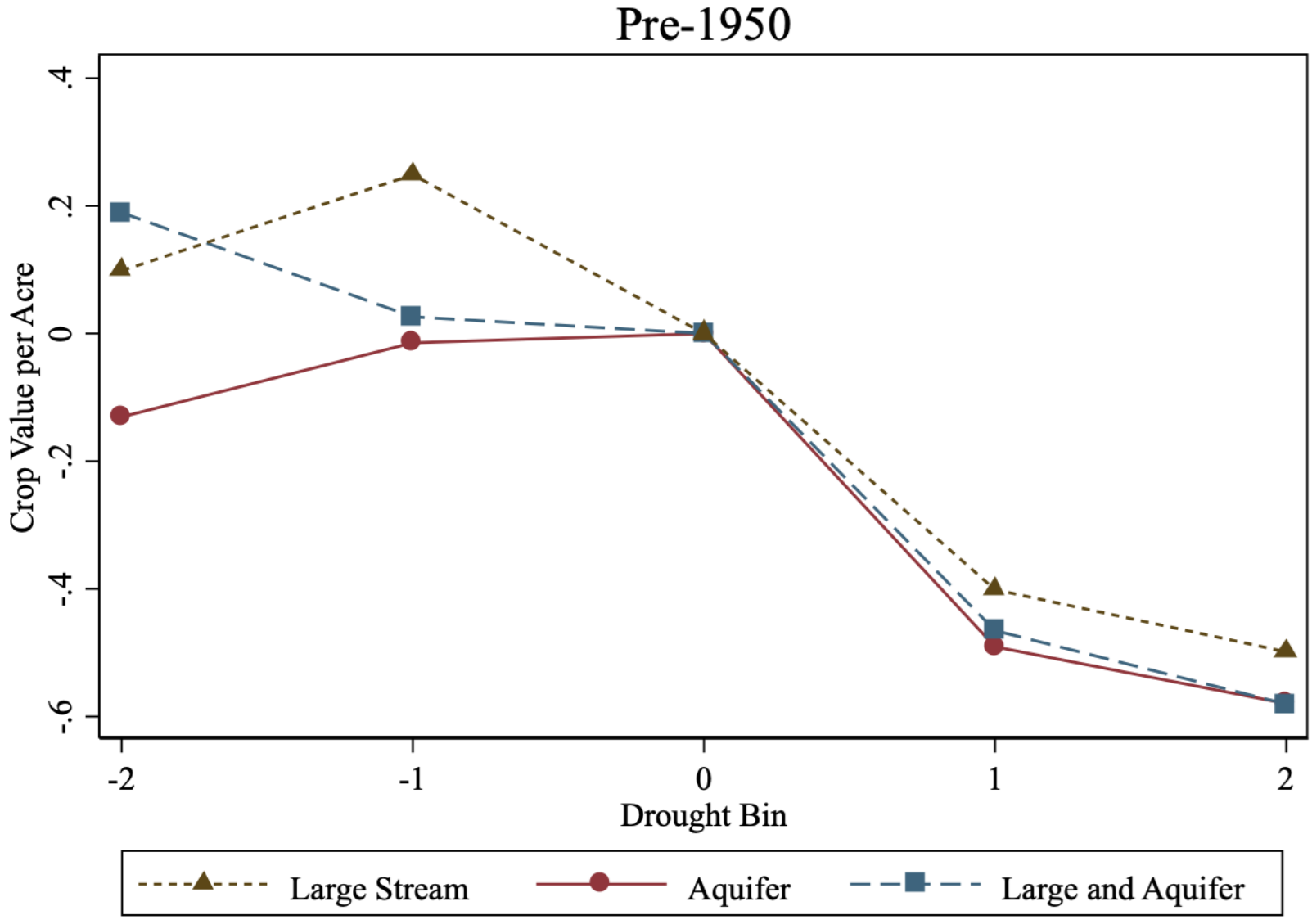
Regression Results: Storage Types

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

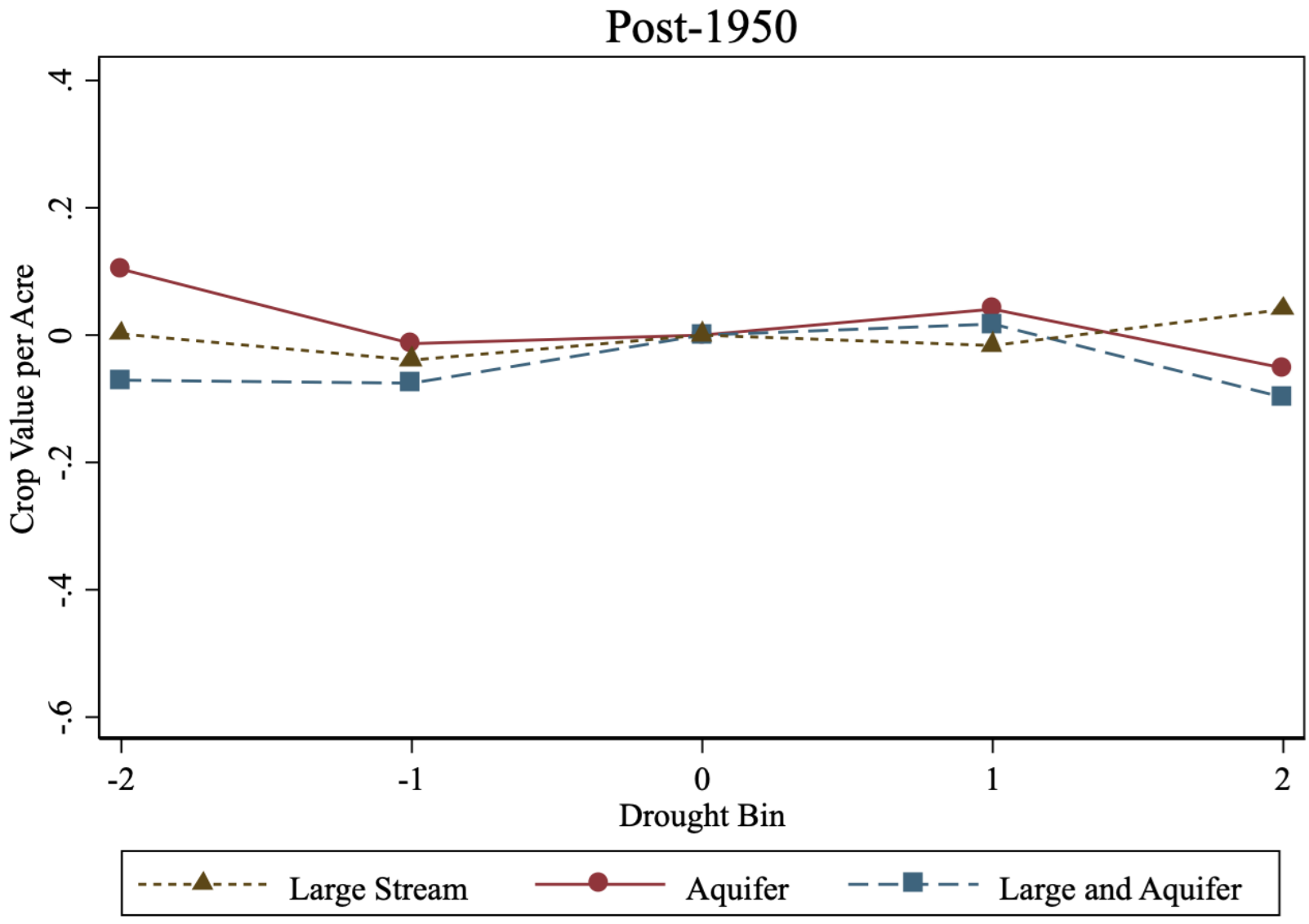
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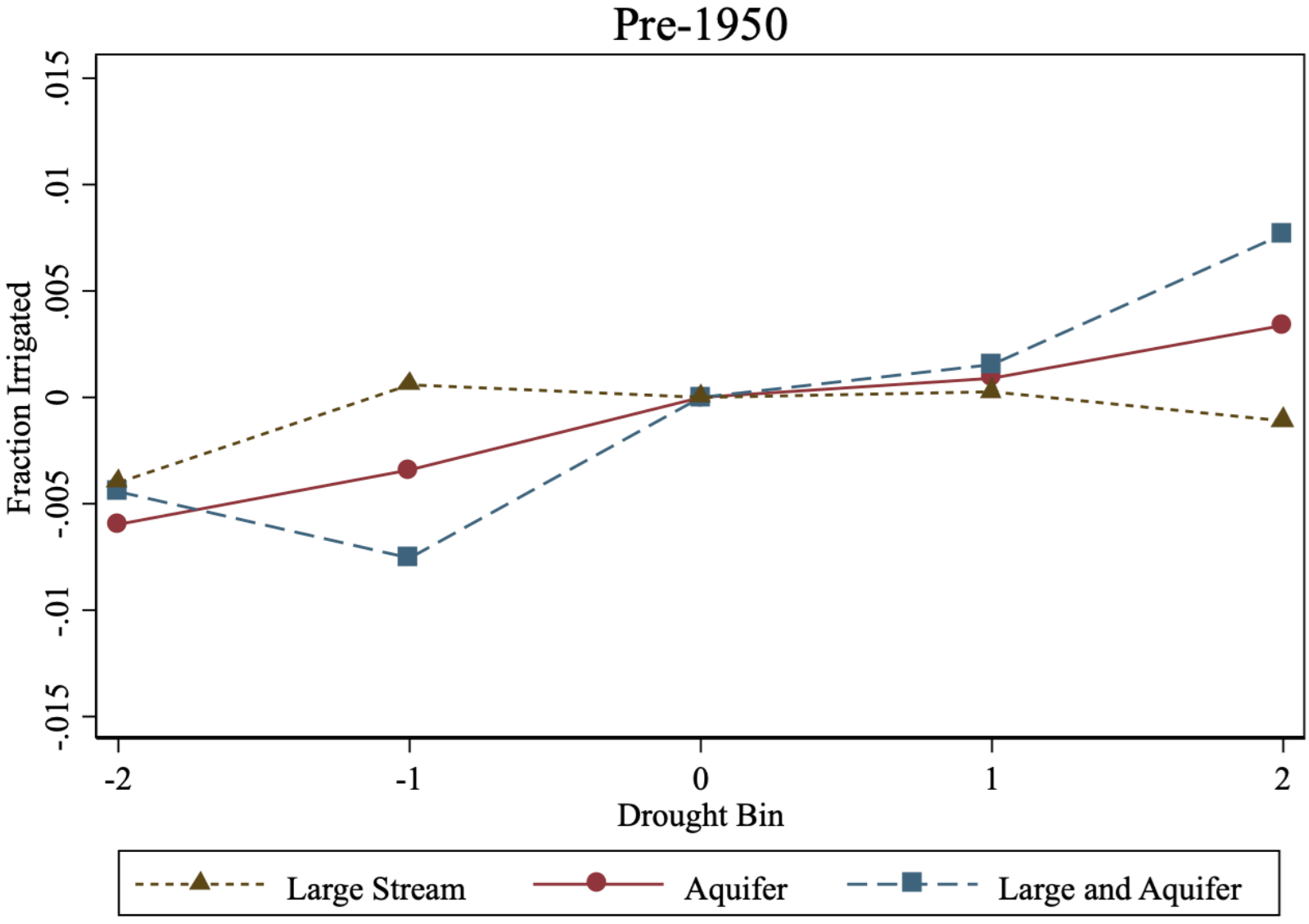
Crop Value by Storage Type Pre-1950



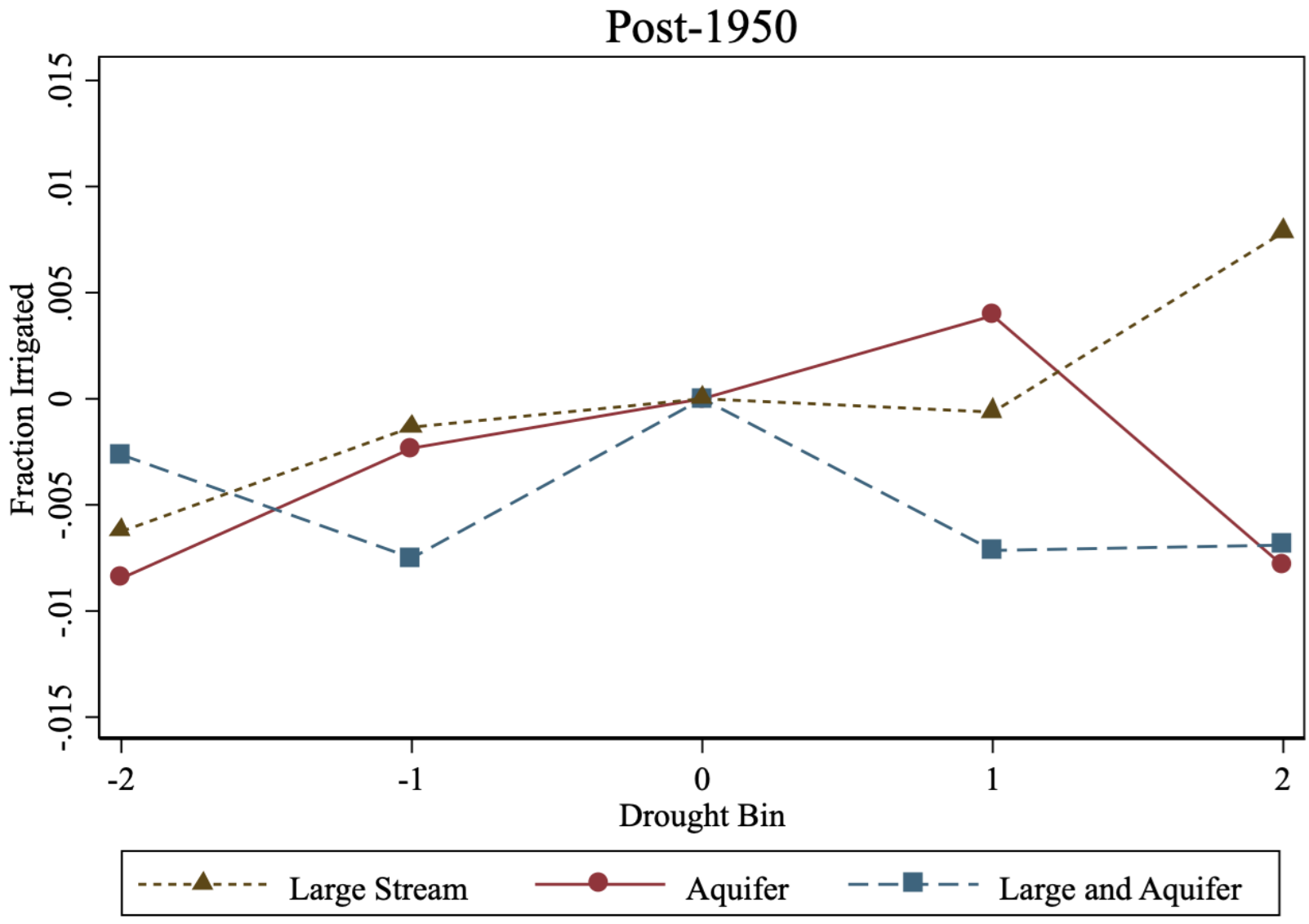
Crop Value by Storage Type Post-1950



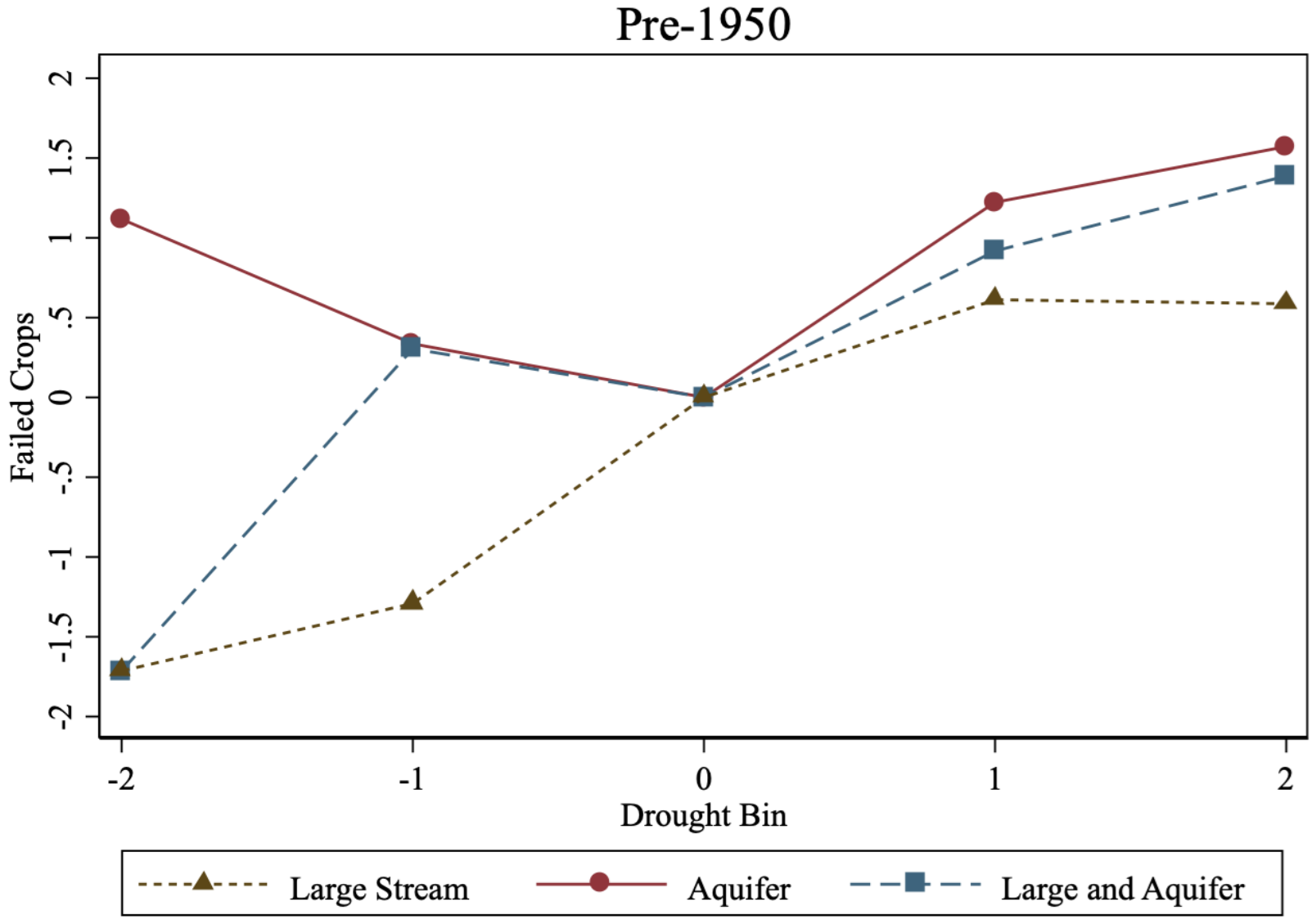
Fraction Irrigated by Storage Type Pre-1950



Fraction Irrigated by Storage Type Post-1950



Crop Failure by Storage Type Pre-1950



Crop Failure by Storage Type Post-1950

