Consequences of the Clean Water Act and the Demand for Water Quality

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Any opinions and conclusions expressed herein are those of the authors and do not necessarily represent the views of the U.S. Census Bureau. All results have been reviewed to ensure that no confidential information is disclosed.

Overview

- **Research Questions**
  - How has water pollution changed since before 1972?
  - Did Clean Water Act cause changes?
  - How do residents value changes?
- **1972 US Clean Water Act**
  - Costly, controversial, understudied
  - *SWANCC, Rapanos,* Clean Water Rule, Apr 2017 Supreme Court
  - Benefits $<$ costs? (Lyon and Farrow 1995, Freeman 2000, EPA 2000)
- **Approach**
  - Analyze $680 billion in Clean Water Act expenditures
  - Many datasets new to economic research

Overview: Results

1. **Pollution has declined substantially**

2. **Clean Water Act grants caused some of this**
   - Annual cost to make a river-mile fishable: $1.5 million
   - Complete pass-through of grants to local spending (no crowd out)
   - Limited heterogeneity in cost-effectiveness

3. **Change in housing values $<$ costs**
   - Mean ratio of measured housing benefits to costs: 0.25
   - Larger ratios in areas where fishing is popular
   - Interpretation: Lower bound? Incomplete info, general eqm, nonuse values

Motivation: Water Pollution

- **A textbook externality (Stigler 1952, 1966)**

Cuyahoga River, Ohio, 1952

Motivation: Water Pollution

- **A textbook externality (Stigler 1952, 1966)**

Cuyahoga River, Ohio, 1952

- Ruckelshaus (first EPA head): "Even if our rivers are not fishable or swimmable, at least they're not flammable."

Existing Research and Contributions

What is new here?

- Water Pollution Trends (Smith et al. 1983; USEPA 2000; Smith & Wolloh 2012)
  - New here: national pollution changes since pre-1972
- Effects of the Clean Water Act (Earnhart 2004a,b; Robotyagov et al. 2014)
  - New here: effects on ambient pollution
- Willingness-to-pay for water quality (Smith & Desvouges 1986; Hausman et al. 1995; Keiser 2015; Mendelsohn et al. 1992; Leggett & Bockstael 2000; Walsh et al. 2011; Carson & Mitchell 1993; Kling et al. 2012; Hausman 2012)
  - New here: effects of Clean Water Act on home values
- Subsidies for pollution control equipment
  - Common policy globally, some existing theory (Kohn 1992, Aidt 1998, Fredriksson 1998), first empirical analysis

Overview

- **Background: water pollution and regulation**
- Data
- Pollution trends
- Clean Water Act and pollution
- Clean Water Act and home prices
- Conclusions

Clean Water Act Background

- **Goals:**
  - All waters safe for fishing and swimming by 1983
  - Zero water pollution discharge by 1985

- **Activity 1: Grants for municipal wastewater treatment plants**
  - In mid 1970s, largest public works program in U.S.
  - Focus of analysis

- **Activity 2: Industrial Regulation**
  - National Permit Discharge Elimination System (NPDES)
  - Controls; not the focus of analysis

Clean Water Act Background

- **Wastewater treatment plants**
  - About 15,000 plants, unchanged since 1970s
  - Goal: process wastewater before discharge to river/lake/ocean

Los Angeles Hyperion Treatment Plant

Clean Water Act Background

- **Research Design: upstream versus downstream**
- **Indirect tests of validity**
  - Event study
  - Compare across pollutants
  - Add controls: nonattainment, NPDES, population
  - DDD and DD estimators

Grant Distribution Rules

Water Pollution Background

- **Dissolved oxygen deficit**
- **Fishable**
- **Other pollutants**:
  - Swimmable
  - Biochemical oxygen demand (BOD)
  - Fecal coliforms
  - Total suspended solids (TSS)

Perceptibility

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Data

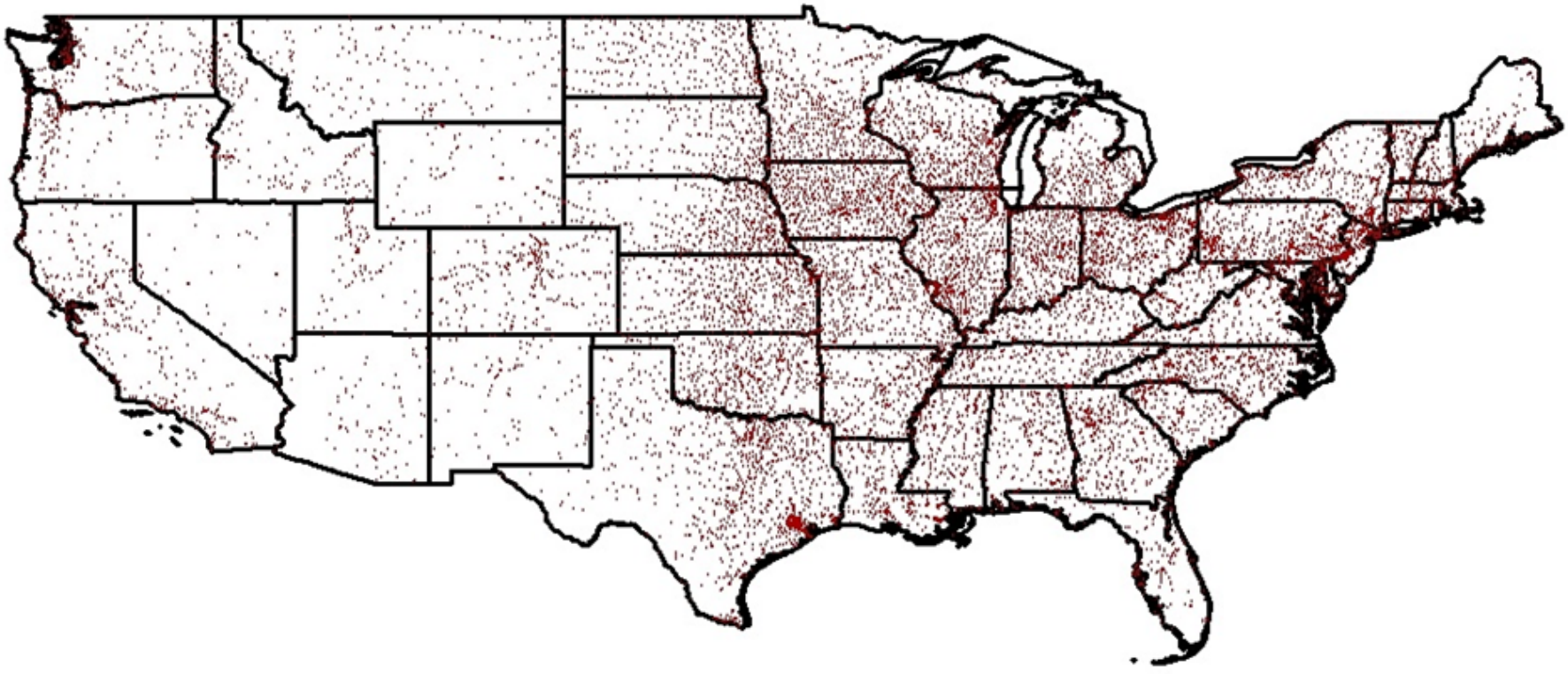
- **Treatment plants; grants; river network; water pollution; population/housing census; industrial sources; recreational distances; municipal spending; other environmental data**

- **Data hard to get**
  - Freedom of Information Act requests
  - C++ with hydrology software developer
  - Interviews with EPA, USGS, private engineers

Data: Municipal Pollution Sources

- **Clean Watershed Needs Survey 1976-1996 Panel**

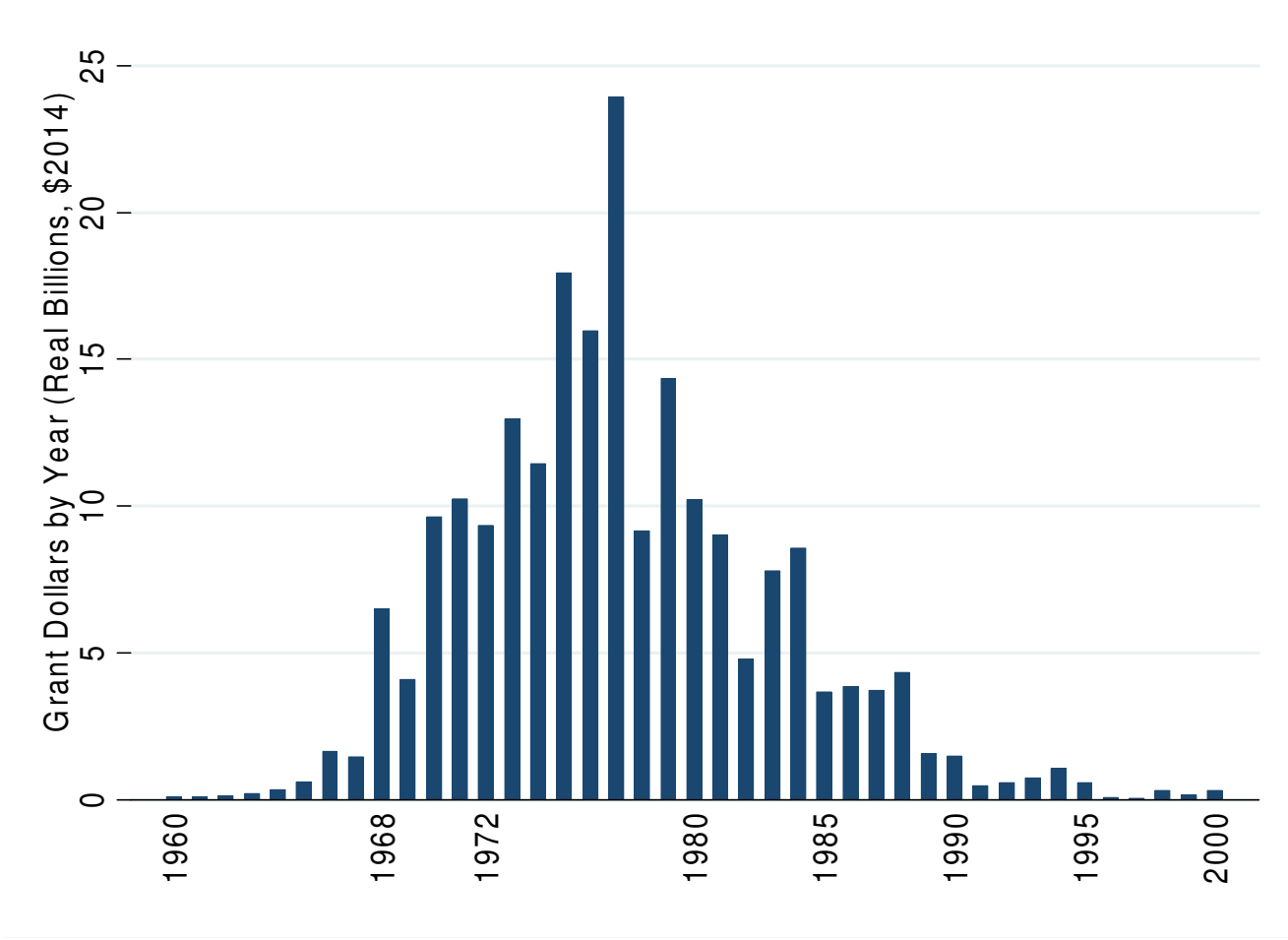
  Trends over time



Data: Clean Water Act Grants

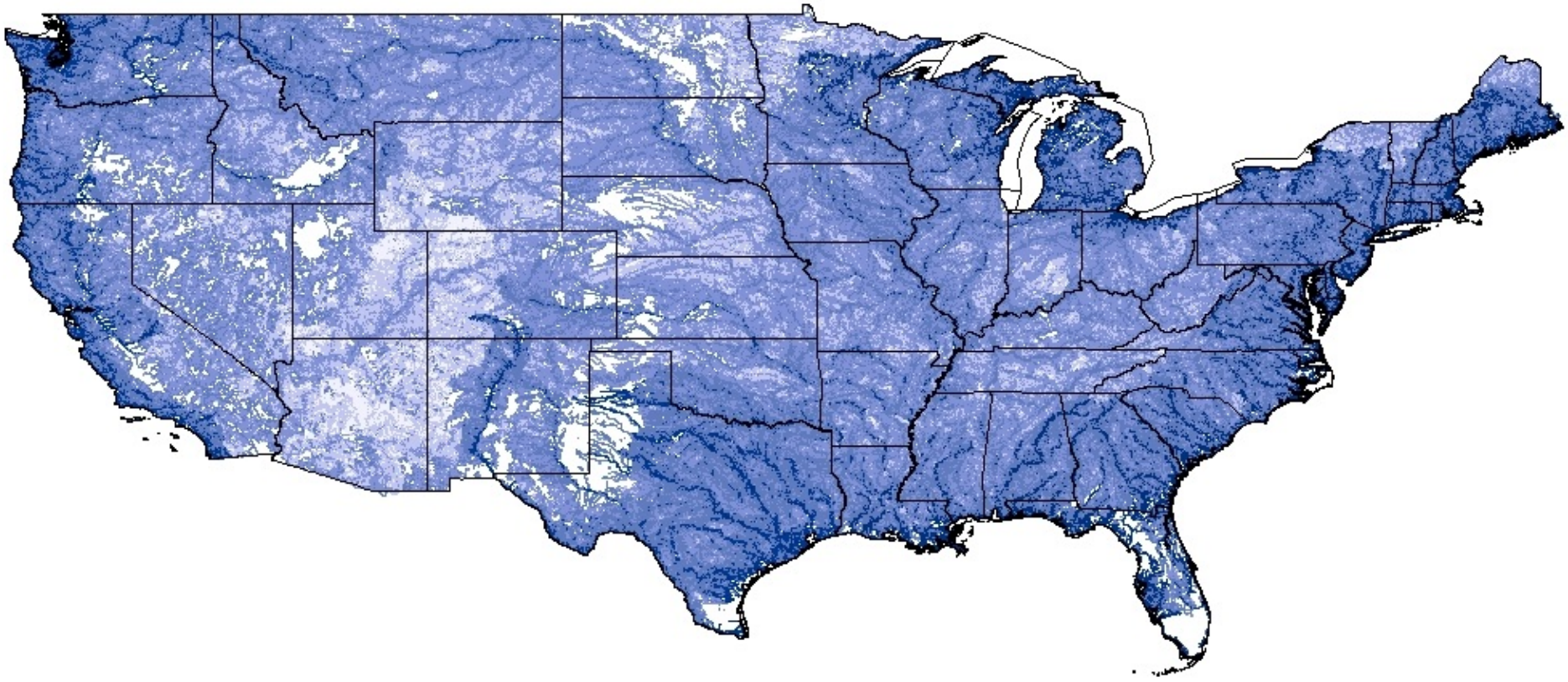
- **Grants Information and Control System (archived version)**
  - 35,000 grants

Figure: Clean Water Act Grant Dollars ($2014)



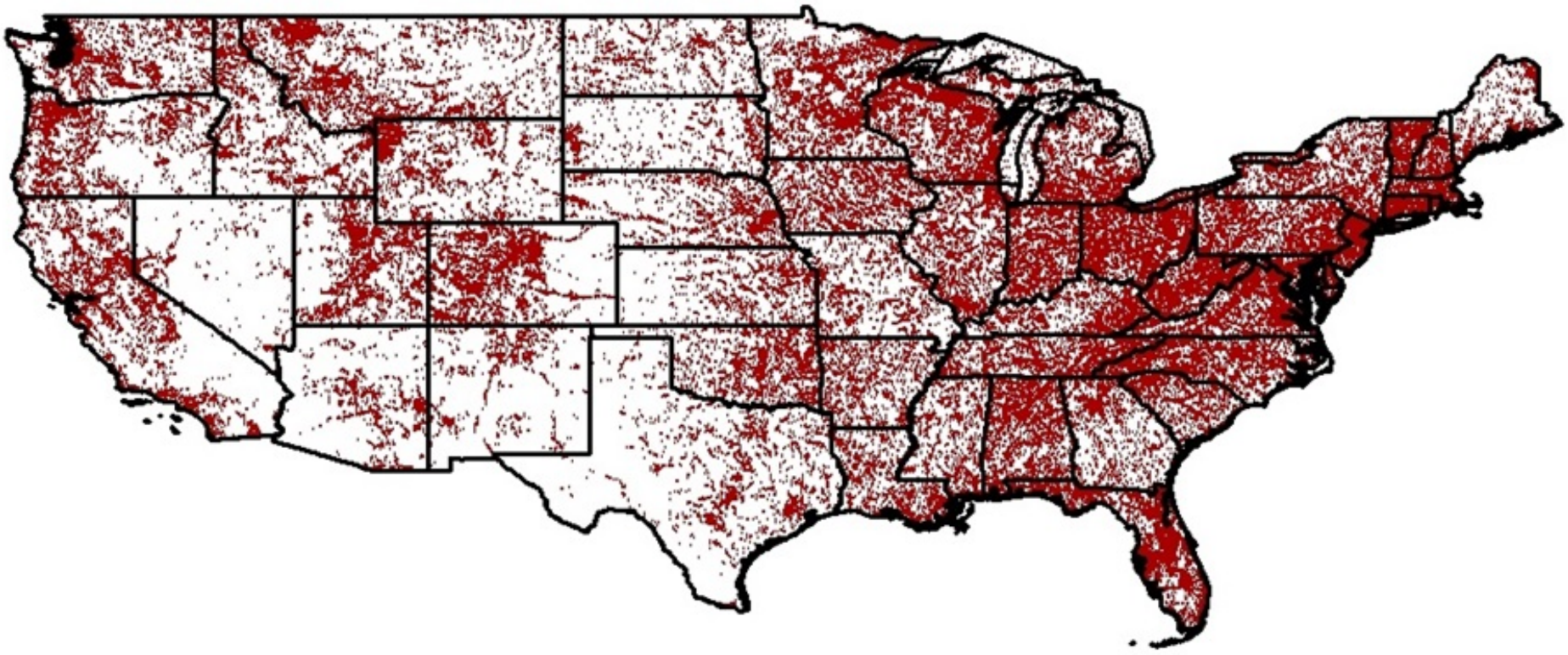
Data: Spatial Rivers and Lakes

- **National Hydrography Dataset Plus, v2.1**
  - 70 million river nodes, flow network



Data: Ambient Pollution

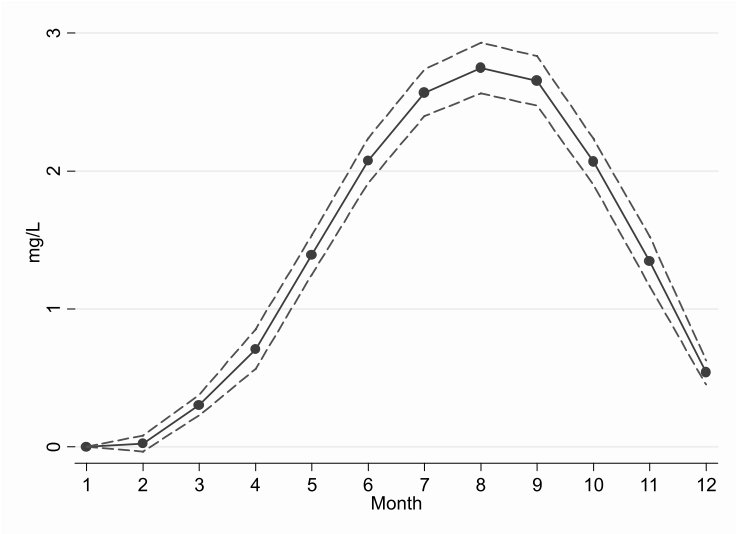
- **Combine three repositories**
  - Storet Legacy; Modernized Storet; National Water Information System
  - 50 million observations, 170,000 monitors, years 1962-2001



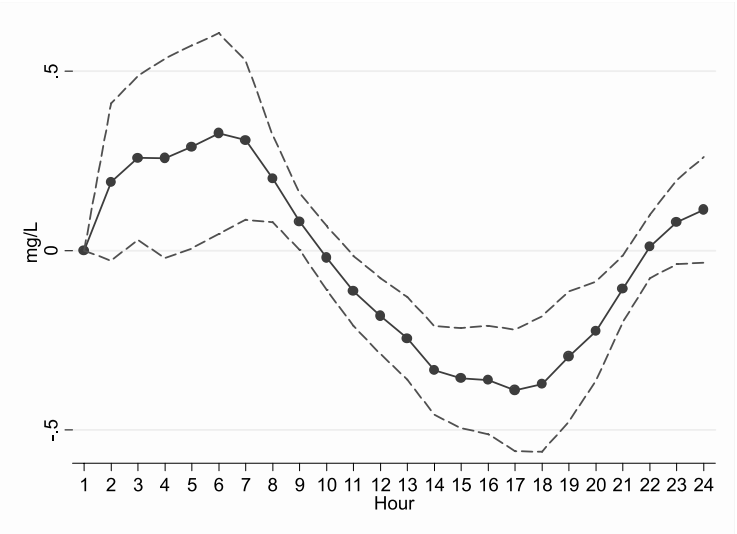
- Sample selection and cleaning. Limit to routine ambient monitoring; water samples; rivers/streams and lakes; surface water; comparable parameter codes; non-missing date, latitude, longitude; winsorize at 99th percentile.

Data: Ambient Pollution

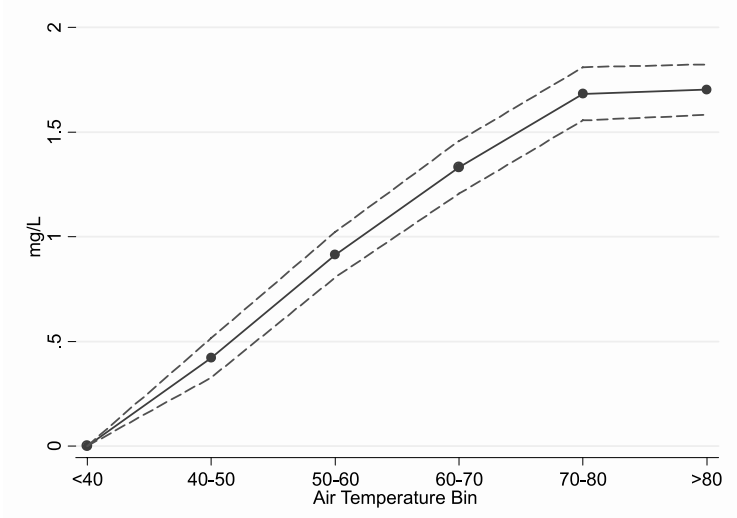
(a) By Month



(b) By Hour



(c) By Air Temperature Bin

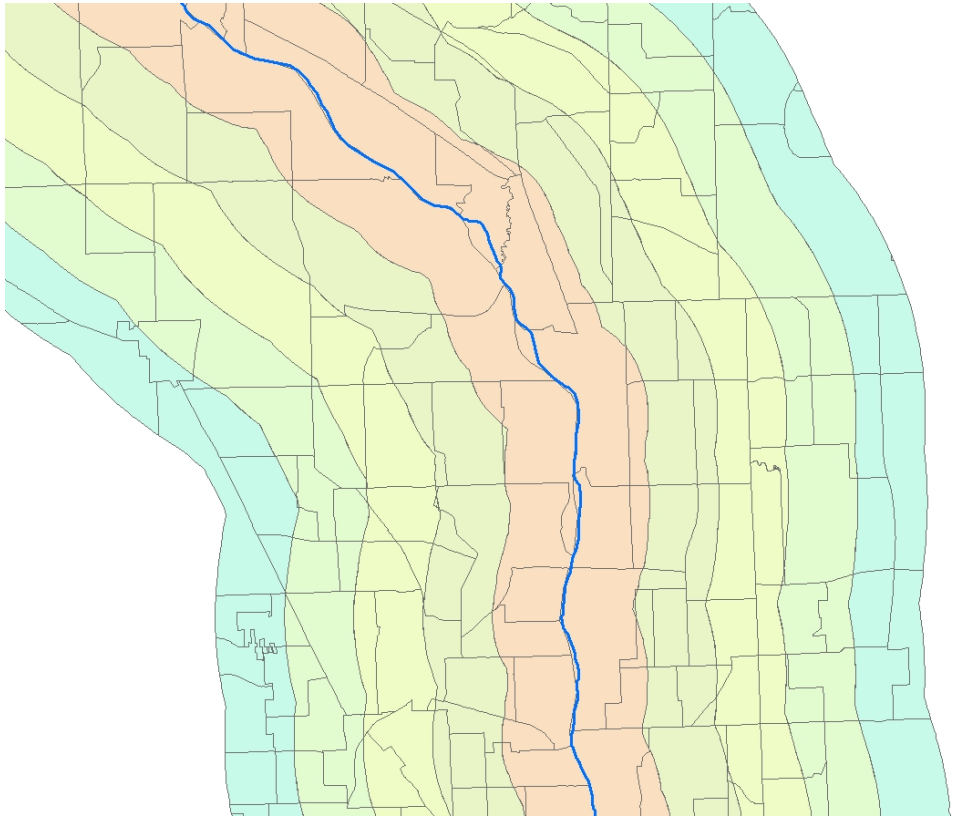


Data: Industrial Water Pollution

- **Survey of Water Use in Manufacturing (SWUM)**
  - Confidential, at Census Research Data Center (RDC)
  - Number of manufacturing plants in 1972 with large water use
- **Permit Compliance System (PCS)**
  - Cumulative permitted plants in a county, by year

Data: Census of Housing and Population

- **Geolytics Neighborhood Change Database 1970-2000**
  - Mean home values and rents, by tract



Mississippi River in Northern Minneapolis

Recreational Distances

- **Nationwide Personal Travel Survey**
  - 95th percentile of recreational trip distance: 34 miles
- **Mean ratio of road to straight-line distance: 1.4**
  - NHTS (2009), Boscoe et al. (2012)
- **Final radius: 25 miles ($\approx$ 34/1.4)**

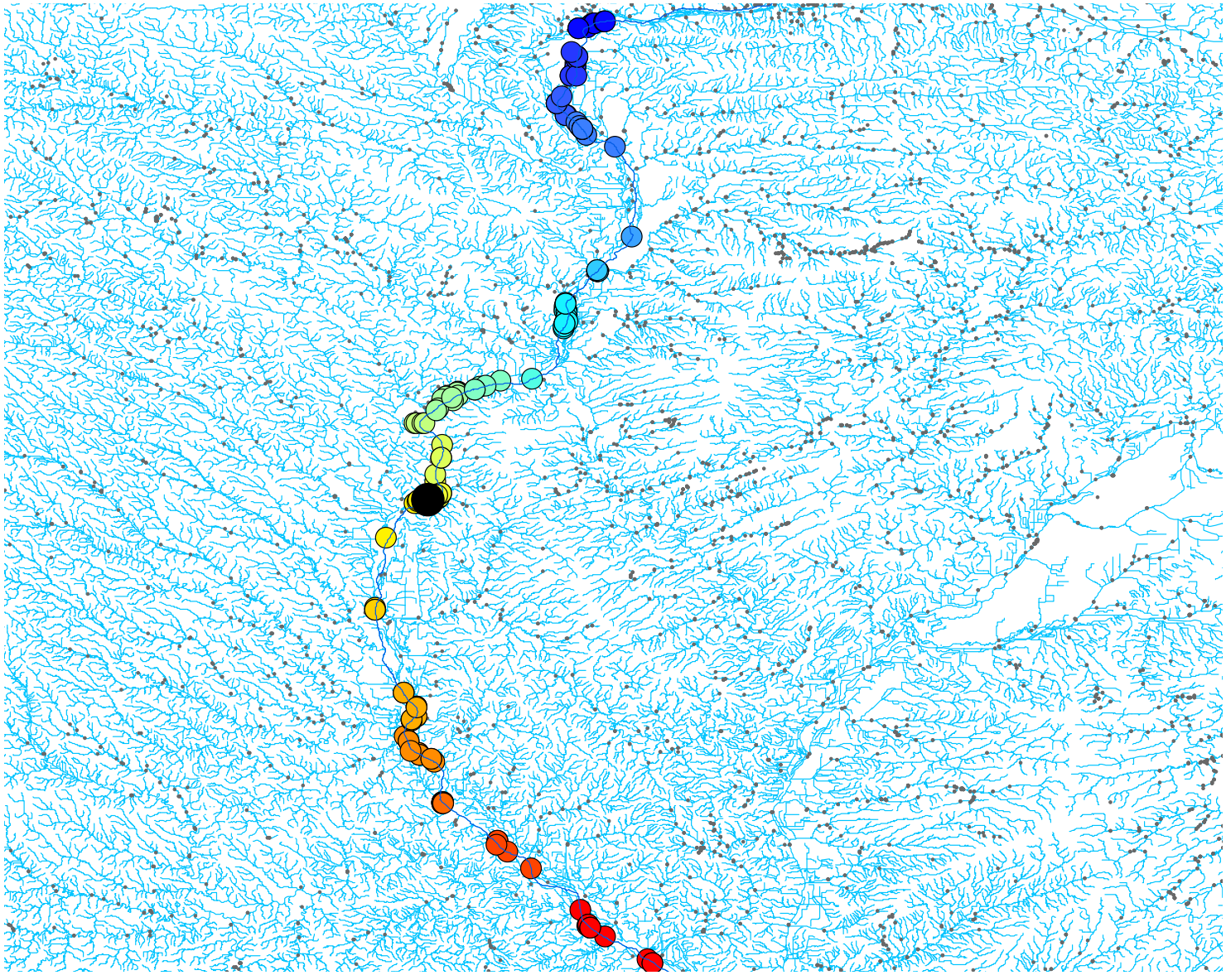
Municipal Spending

- **Census of Governments, Annual Survey of Governments**
  - Total annual investment in sewerage capital
  - 1972-2001, balanced panel of 198 cities

Data: Environmental Controls

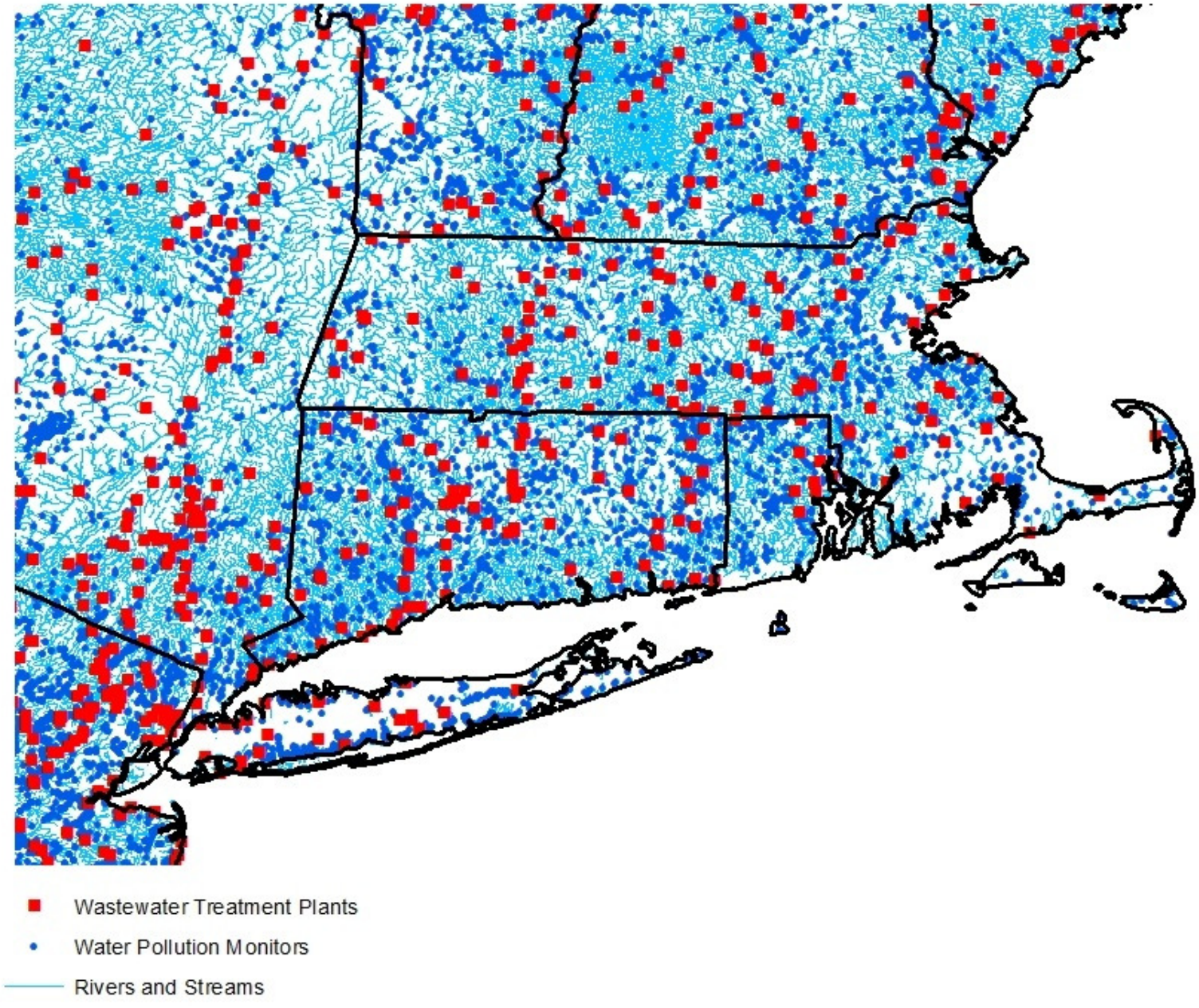
- **Temperature and Precipitation**
  - National Climate Data Center Summary of the Day files (TD-3200)
- **Air pollution regulation**
  - Nonattainment designations, by pollutant

Data: Summary Picture



Mississippi River, Northern St. Louis

Data: Summary Picture, Many Plants



Overview

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- **Pollution trends**
- Clean Water Act and pollution
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Pollution Trends: Econometrics

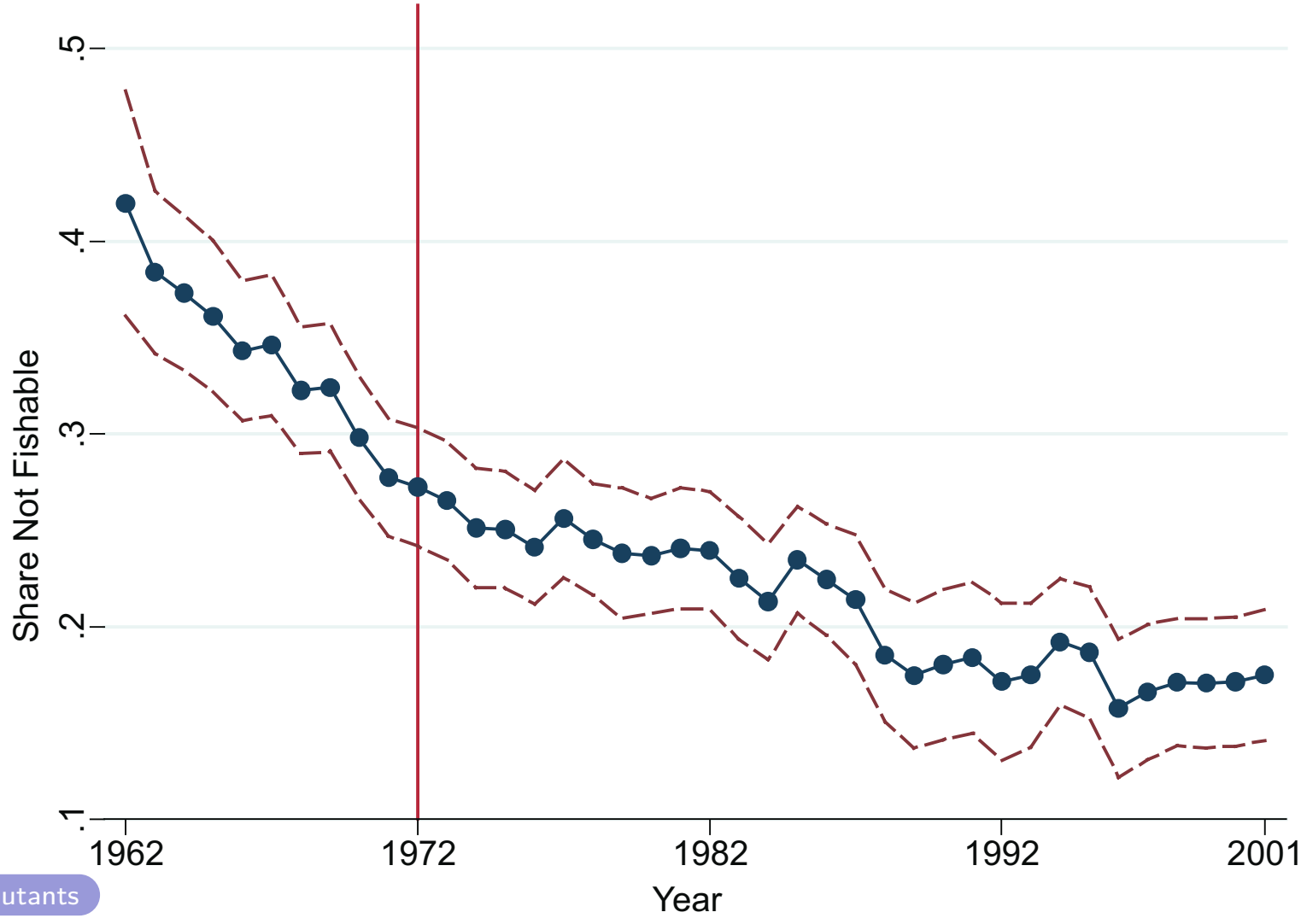
$$Q_{icy} = \alpha Y_y + X'_{icy}\beta + \delta_i + \epsilon_{icy}$$

$$Q_{icy} = \sum_{\tau=1963}^{\tau=2001} \alpha_\tau 1[Y_y = \tau] + X'_{icy}\beta + \delta_i + \epsilon_{icy}$$

- Station i, year y, date c
- X_{icy}: hour-of-day, day-of-year
- Cluster by watershed
  - Watershed $\equiv$ 8-digit Hydrologic Unit Code ("cataloging unit")
  - Land area in which all water flows to a point

Pollution Trends: Graph (Not Fishable)

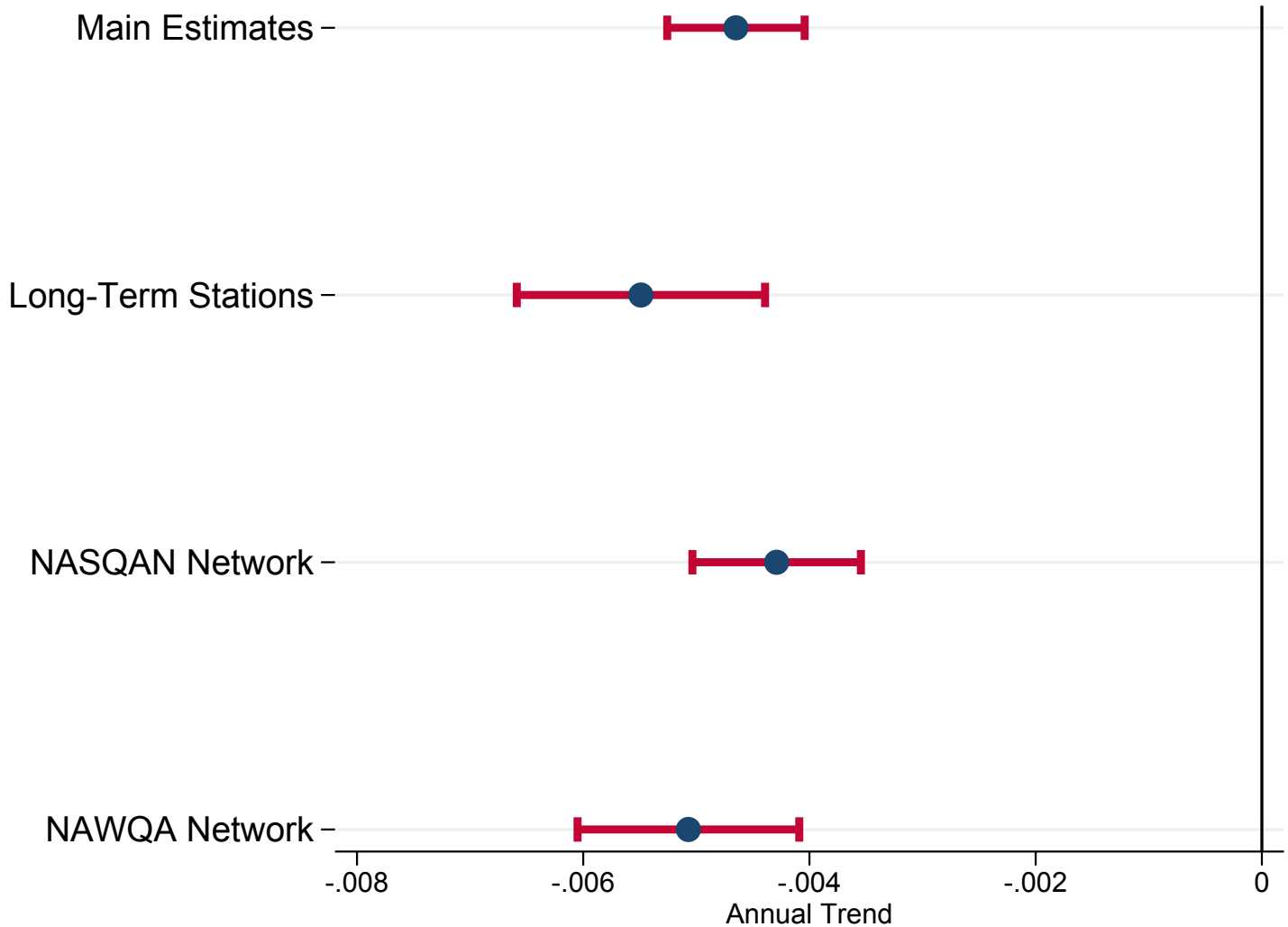
$$Q_{icy} = \Sigma_{\tau=1963}^{\tau=2012} \alpha_\tau 1[y = \tau] + X_{icy}^{'} \beta + \delta_i + \epsilon_{icy}$$



Other Pollutants

Pollution Trends: Sensitivity Analyses (Not Fishable)

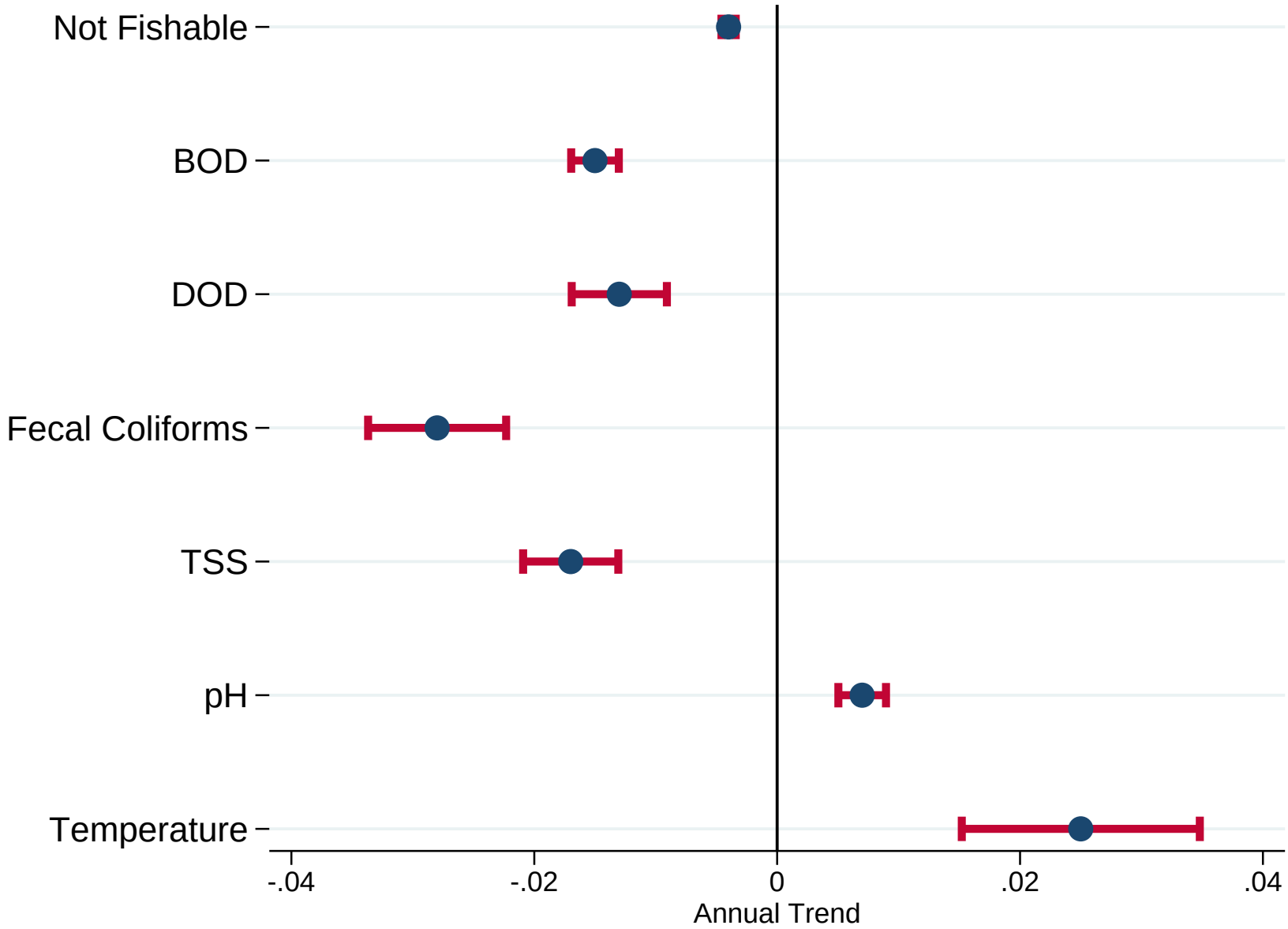
$$Q_{icy} = \alpha Y_y + X'_{icy}\beta + \delta_i + \epsilon_{icy}$$



- Additional analyses in paper: (1) Areas with home values data; (2) Drop infrequent stations; (3) Streamflow controls; (4) July-August only; (5) Exclude dam areas; (6) Recode below-detectable-limit; (7) Levels, not logs; (8) River-year means; (9) 50% fishable cutoff; (10) Water quality index; (11) Two-way cluster; (12) Lakes; (13) Population weighted

Pollution Trends: Other Pollutants

$$Q_{icy} = \alpha Y_y + X'_{icy}\beta + \delta_i + \epsilon_{icy}$$



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Grants and Pollution: Econometrics

$$Q_{pdy} = \gamma G_{py} d + X'_{pdy}\beta + \eta_{pd} + \eta_{py} + \eta_{dwy} + \epsilon_{pdy}$$

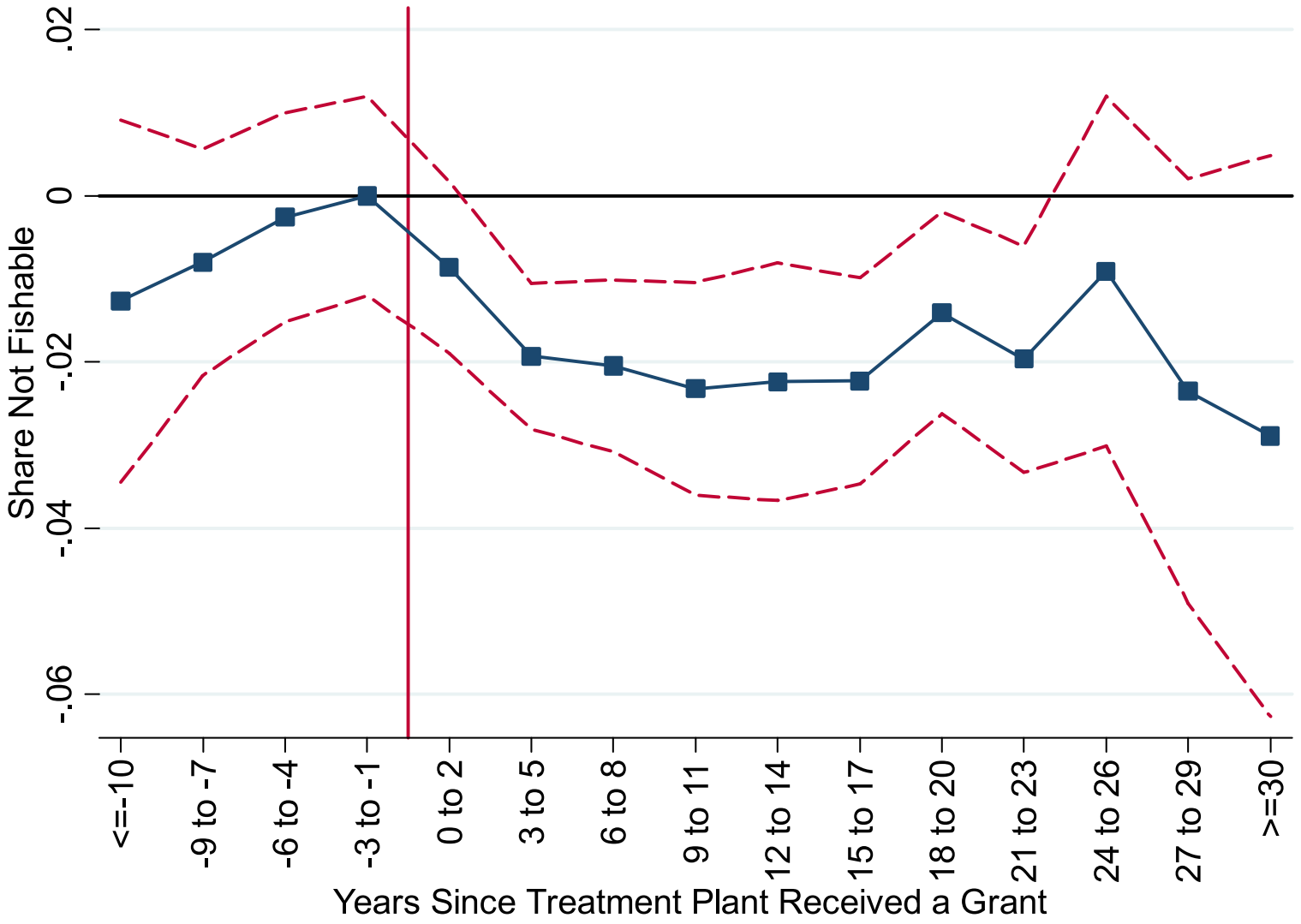
- Plant p, downstream d, year y
- G_{py}: cumulative number of grants for a plant
- η_{pd}: Plant-by-downstream fixed effects
- η_{py}: Plant-by-year fixed effects
- η_{dwy}: Downstream-by-hydrologic-region-by-year fixed effects
- Assumption:

$$E[G_{py} d \cdot \epsilon_{pdy} | \eta_{pd}, \eta_{py}, \eta_{dwy}, X'_{pdy}] = 0$$

Cross-sectional upstream v. downstream

Grants and Pollution: Event Study

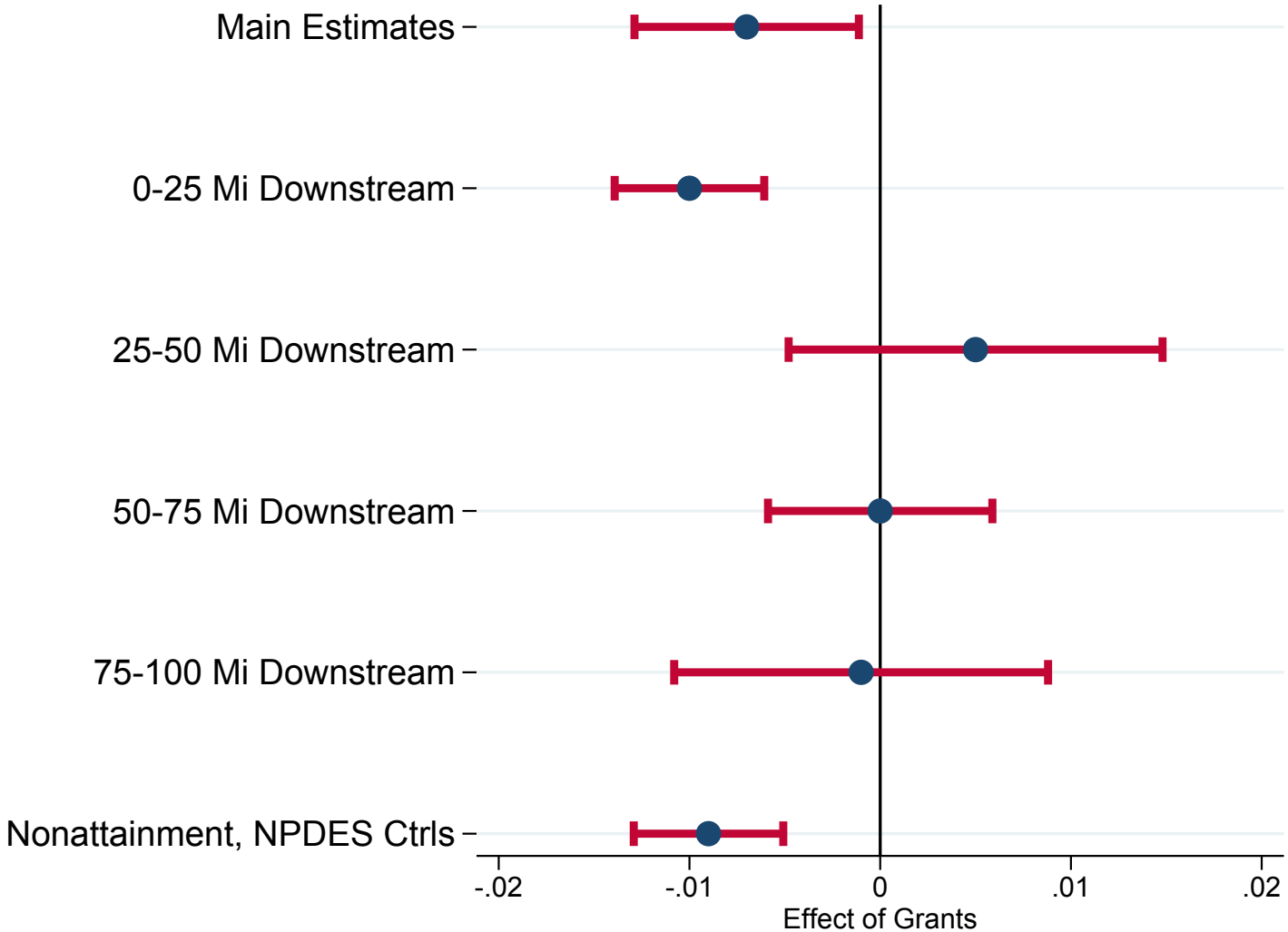
$$Q_{pdy} = \Sigma_{\tau=-10}^{\tau=25} \gamma_\tau 1[G_{p,y+\tau} = 1] 1[d = 1] + X_{iy}^{'} \beta + \eta_{pd} + \eta_{py} + \eta_{dwy} + \epsilon_{pdy}$$



Other Pollutants

Grants and Pollution: Sensitivity Analyses (Not Fishable)

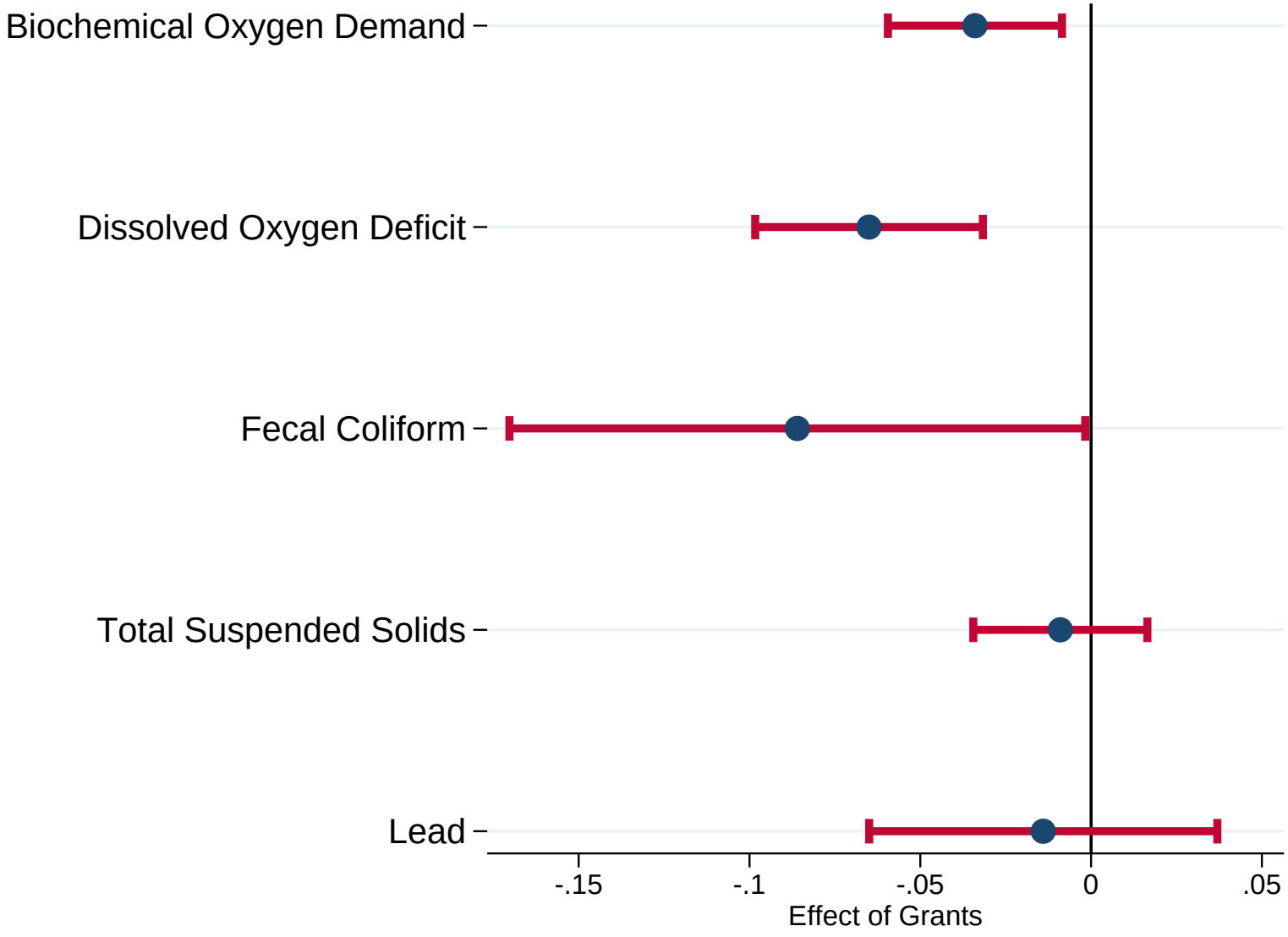
$$Q_{pdy} = \gamma G_{pdy} d + X'_{pdy}\beta + \eta_{pd} + \eta_{py} + \eta_{dwy} + \epsilon_{pdy}$$



- Additional analyses in paper: (1) All 16 sensitivity analyses reported for trends; (2) Plants with monitors $\geq$ 10 mi. upstream and downstream; (3) Grants for construction; (4) Dummies for # grants; (5) Control for cumulative upstream grants; (6) Cumulative real grant dollars; (7) Diff-in-diff, downstream only; (8) Include monitors on other upstream/downstream rivers; (9) Monitor-level, station FE; (10) Monitor-level, downweight duplicates

Grants and Pollution: Other Pollutants

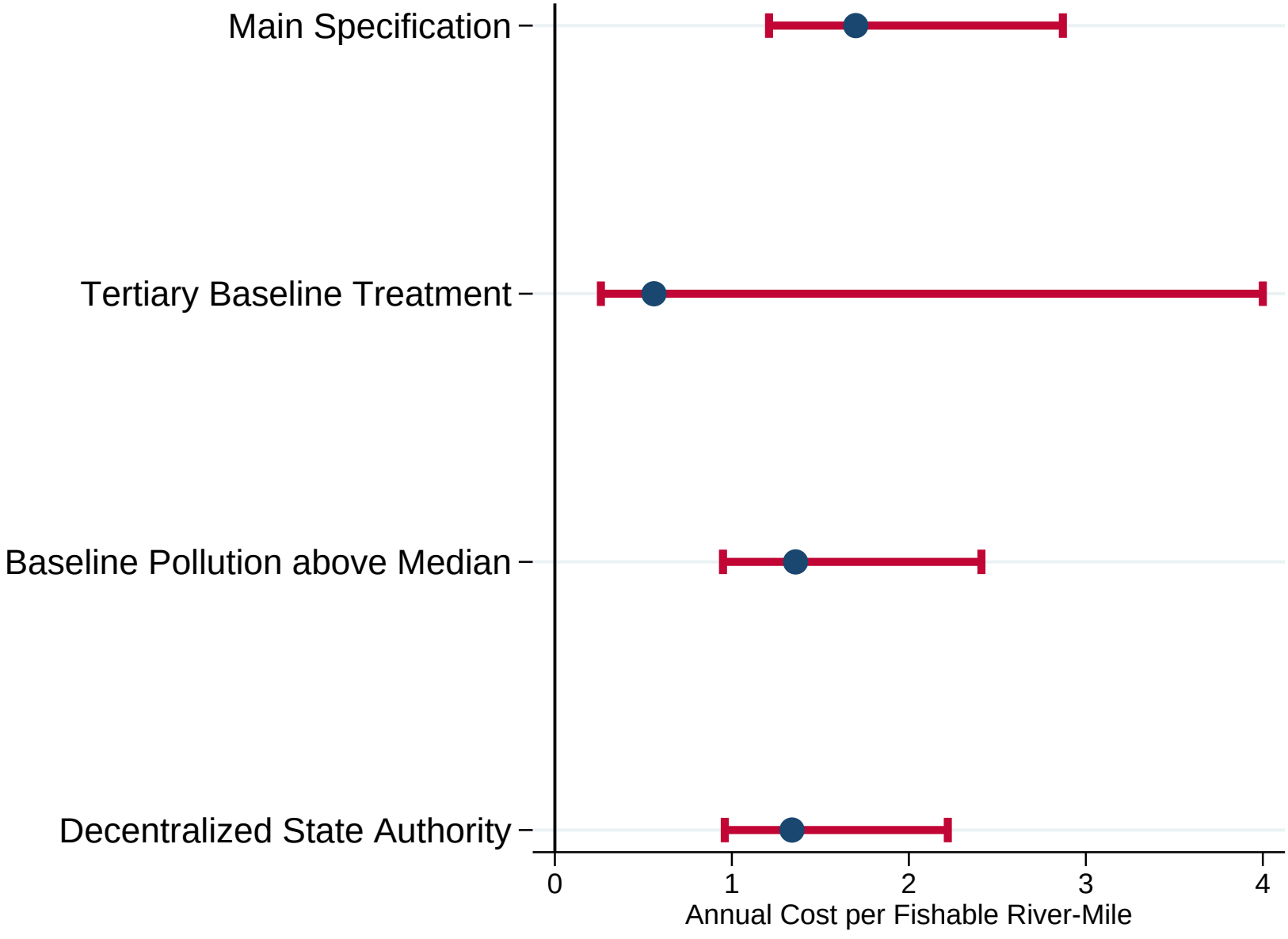
$$Q_{pdv} = \gamma G_{pdv} d + X'_{pdv}\beta + \eta_{pd} + \eta_{py} + \eta_{dwv} + \epsilon_{pdv}$$



Grants and Pollution: Cost Effectiveness

	(1)	(2)	(3)
Annual Cost to Make a River-Mile Fishable	1.91	1.47	1.50
	[1.35 , 3.22]	[1.04 , 2.48]	[1.06 , 2.53]
Total Costs	296,757	396,802	549,890
Federal Capital Costs	87,926	117,691	164,413
Local Capital Costs	37,296	49,958	68,309
Operation & Maintenance Costs	171,536	229,153	317,168
River-Miles Made Fishable	5,188	9,000	12,260
Plants with Water Quality Data	Yes		
Georeferenced Plants		Yes	
Assume 25 Miles Downstream			Yes

Grants and Pollution: Cost Effectiveness Heterogeneity



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  - **Municipal spending**
- Clean Water Act and home prices
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Clean Water Act Grants and Municipal Spending

- **How did CWA grants affect wastewater treatment spending?**
  - Our measure: reported project costs
  - Crowding out? Crowding in?

- **Approach: estimate effects on municipal wastewater treatment investment**

$$E_{cy} = \beta D_{cy} + \upsilon_c + \eta_{wy} + \epsilon_{cy}$$

Clean Water Act Grants and Municipal Spending

$$E_{cy} = \beta D_{cy} + \upsilon_c + \pi_y + \eta_{wy} + \epsilon_{cy}$$

	(1)	(2)	(3)	(4)
Panel A. Federal Grant Funds				
Federal Grant Funds	1.52***	1.26***	1.13***	1.19***
	(0.29)	(0.22)	(0.27)	(0.31)
Panel B. Grant Project Costs				
Grant Project Costs	1.09***	0.93***	0.84***	0.89***
	(0.21)	(0.16)	(0.19)	(0.23)
City FE and Year FE	Yes	Yes	Yes	Yes
Real Costs		Yes	Yes	Yes
Basin-by-Year FE			Yes	Yes
Propensity Score Reweight				Yes

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Housing: Theory

$$P_i = P(z_1, \ldots, z_J)$$

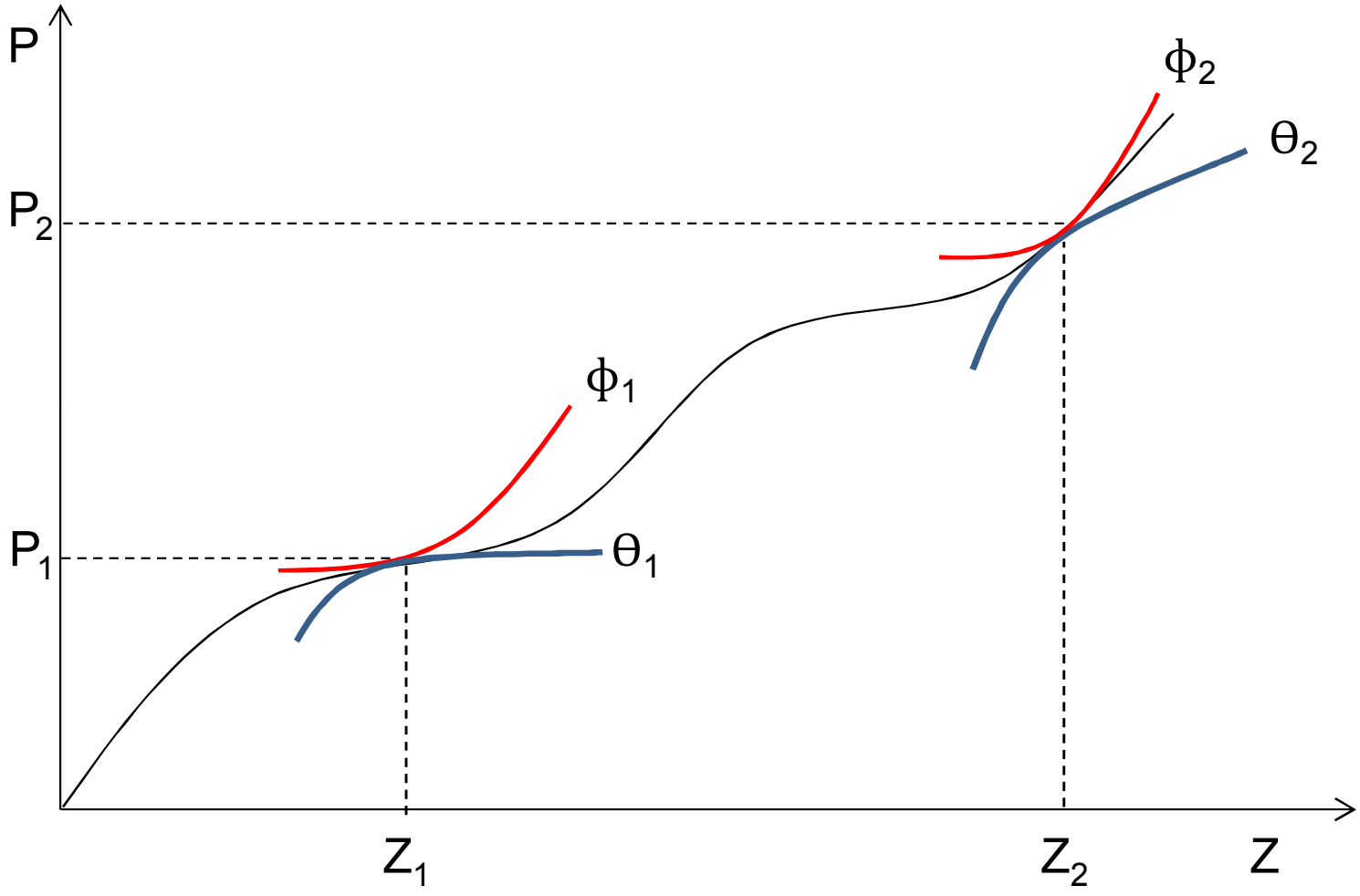
- i **House**
- P_i **Price**
- $z_1, \ldots, z_J$ **Attributes**
  - Dwelling features (e.g., square footage)
  - Local public goods (e.g., school quality)
  - Environmental amenities (e.g., clean rivers)
- $P(\cdot)$ **Hedonic price schedule**
  - Equilibrium of firms supplying housing, consumers consuming it
  - Assume competitive housing markets, each consumer rents one house

Housing: Theory

- **Marginal implicit price of attribute j : $\frac{\partial P}{\partial z_j}$**
  - Marginal: partial deriviative, holding other attributes fixed
  - Implicit: can't buy attributes separate from a house
- **Reflects tangency between consumer bid functions and firm offer functions**
- **Reveals marginal willingness to pay for amenity**

Housing: Theory

Figure: Hedonic Model



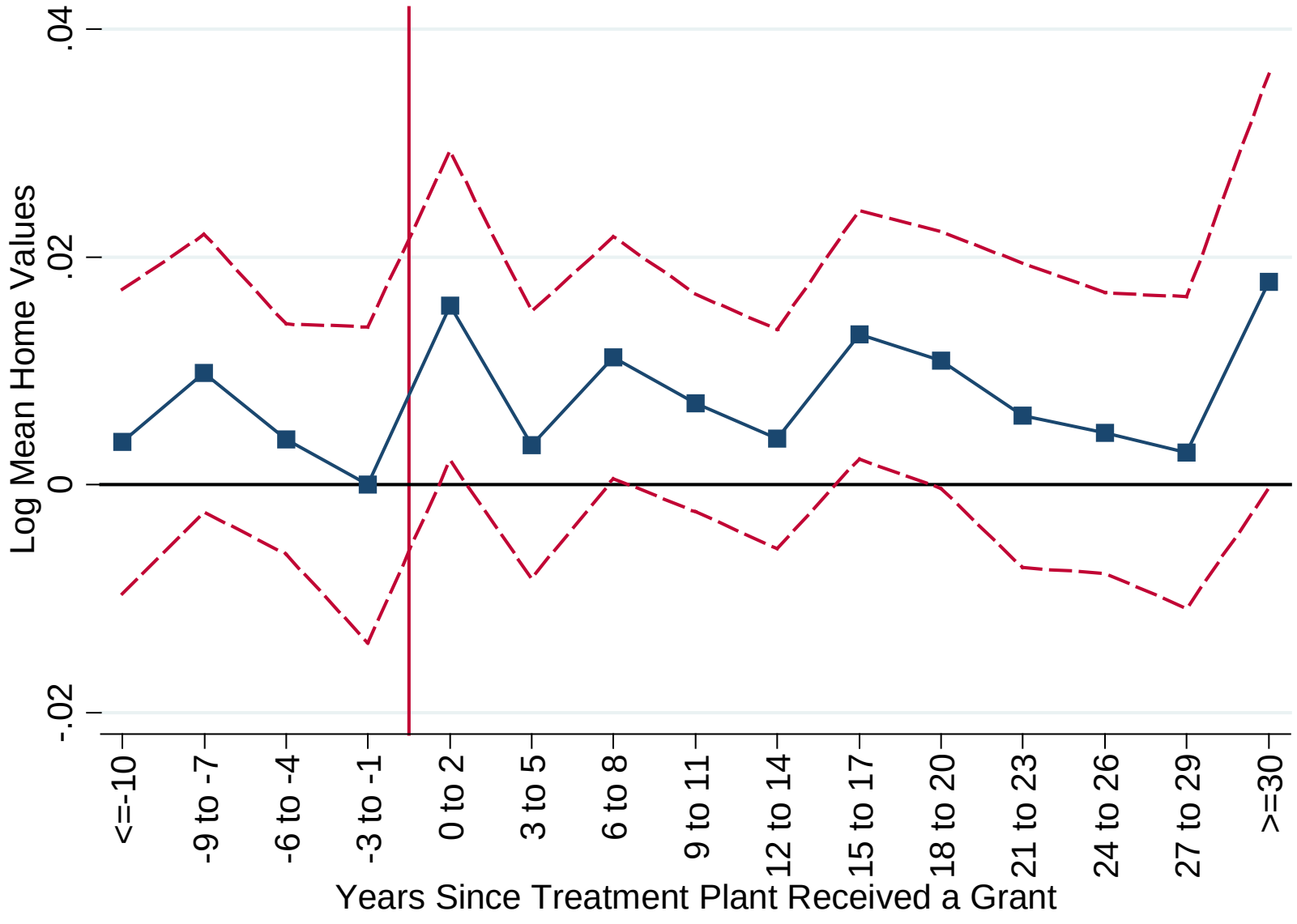
Housing: Econometrics

$$V_{pt} = \gamma G_{pt} + X_{pt}^{'}\beta + \eta_p + \eta_{wt} + \epsilon_{pt}$$

- Plant p, year t
- G_{pt}: cumulative number of grants for a plant
- $X_{pt}^{'}$: housing structure characteristics
- η_p: Plant fixed effects
- η_{wt} : Region-by-year fixed effects
- Generalized least squares. Weights reflect census sampling probabilities and housing units in an observation
- DD, not DDD

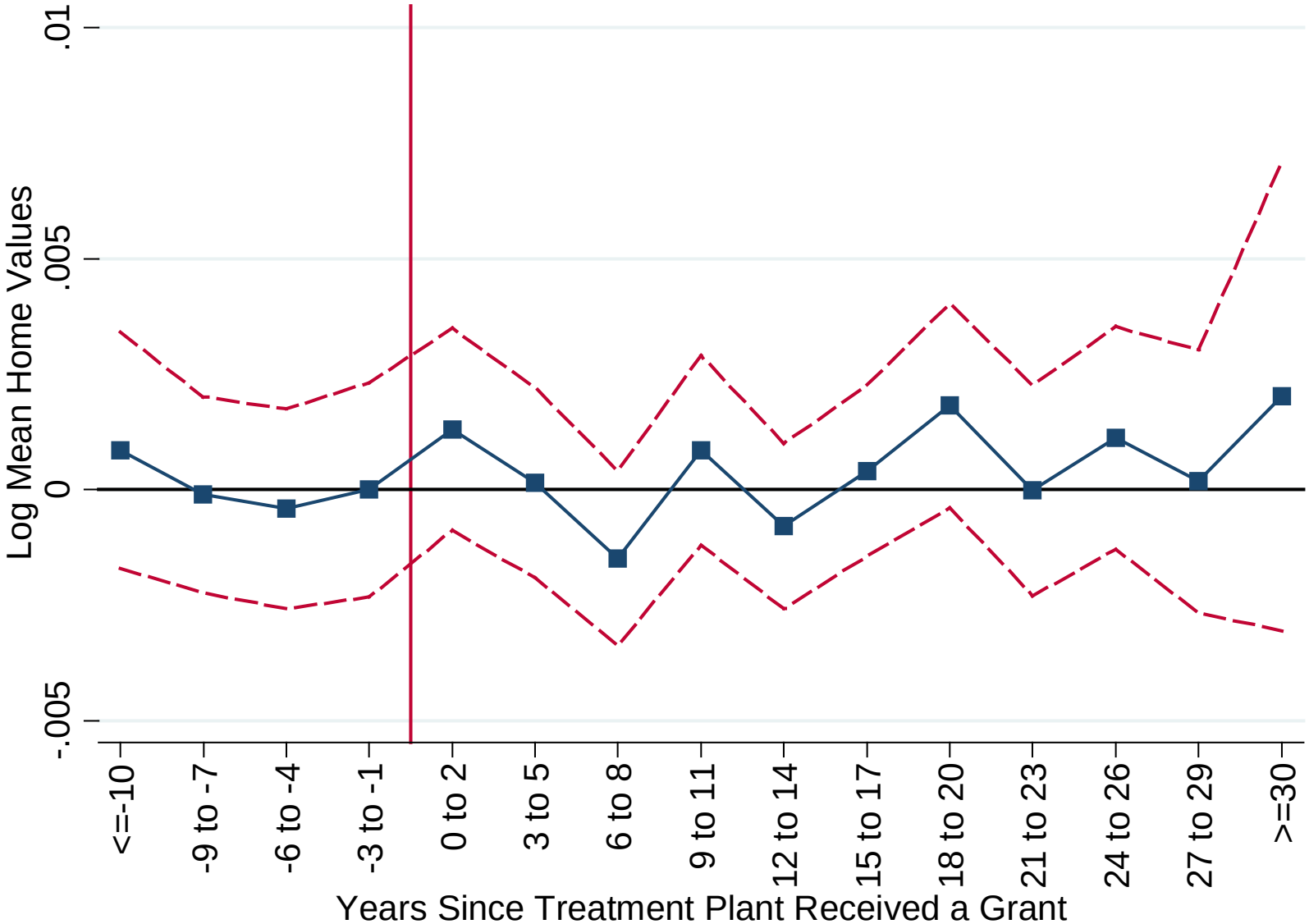
Housing: Event Study, 0.25 Mile Bandwidth

$$V_{pt} = \gamma G_{pt} + X_{pt}^{'}\beta + \eta_p + \eta_{wt} + \epsilon_{pt}$$



Housing: Event Study, 25 Mile Bandwidth

$$V_{pt} = \gamma G_{pt} + X_{pt}^{'}\beta + \eta_p + \eta_{wt} + \epsilon_{pt}$$



Event Study in Space

Housing: Tables

$$V_{pt} = \gamma G_{pt} + X_{pt}^{'}\beta + \eta_p + \eta_{wt} + \epsilon_{pt}$$

	(1)	(2)	(3)	(4)
Panel A. Log Mean Home Values				
Cumulative Grants	-0.00022	0.00076	0.002486*	0.00024
	(0.002507)	(0.001409)	(0.001271)	(0.000328)
Panel B. Log Mean Rental Values				
Cumulative Grants	0.00005	-0.00078	0.00007	-0.00012
	(0.001682)	(0.000832)	(0.000714)	(0.000158)
Plant FE, Basin-by-Year FE	Yes	Yes	Yes	Yes
Dwelling Characteristics		Yes	Yes	Yes
Baseline Covariates * Year		Yes	Yes	Yes
Max Distance Homes to River (Miles)	0.25	0.25	1	25

Housing: Tables

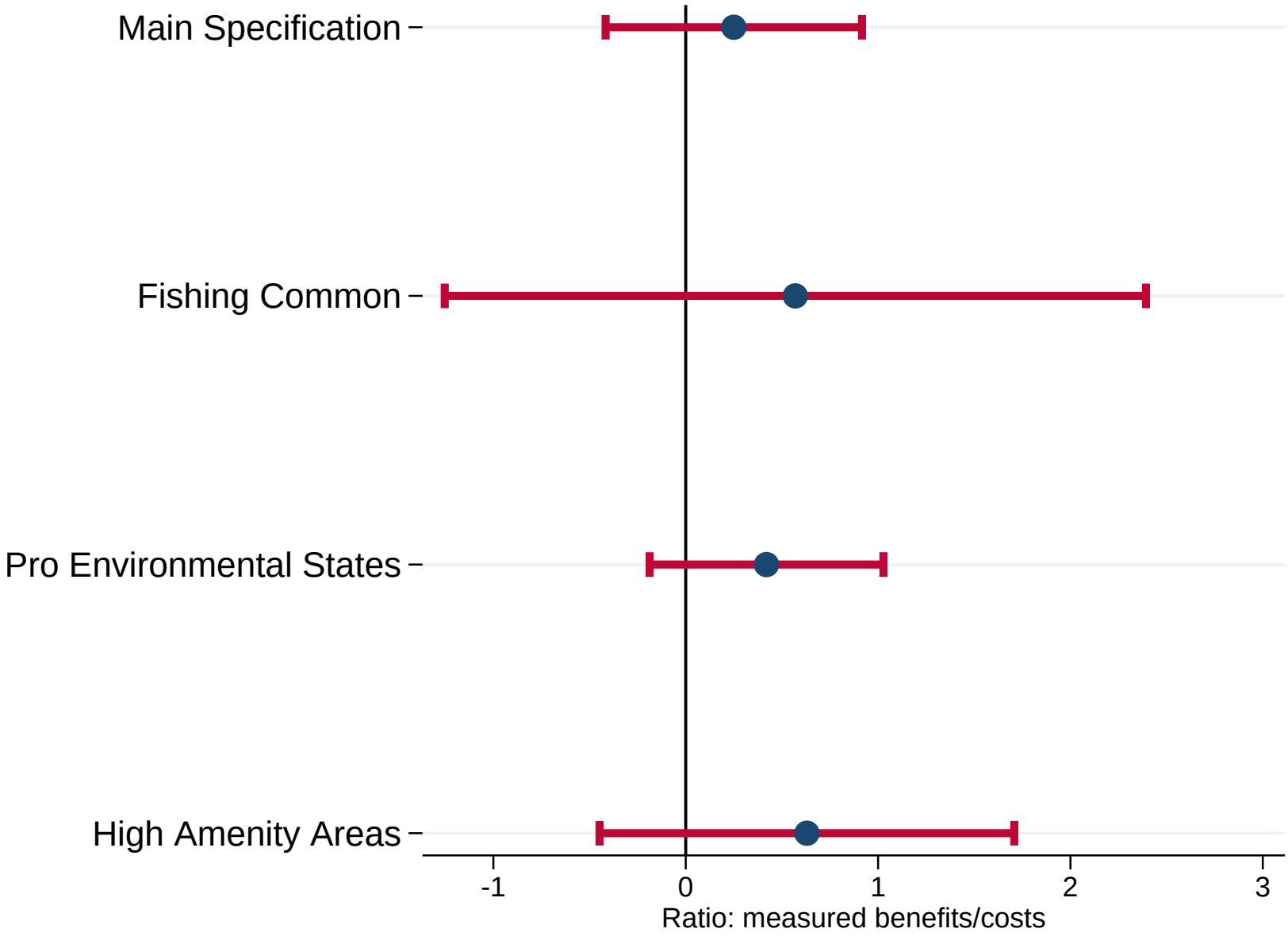
$$V_{pt} = \gamma G_{pt} + X_{pt}^{'}\beta + \eta_p + \eta_{wt} + \epsilon_{pt}$$

	(1)	(2)	(3)	(4)
Panel C. Log Total Housing Units				
Cumulative Grants	-0.006965**	-0.00031	-0.00031	-0.00016
	(0.003180)	(0.001176)	(0.000939)	(0.000241)
Panel D. Log Total Value of Housing Stock				
Cumulative Grants	-0.006356*	0.00010	0.00144	-0.00015
	(0.003275)	(0.001878)	(0.001592)	(0.000461)
Plant FE, Basin-by-Year FE	Yes	Yes	Yes	Yes
Dwelling Characteristics		Yes	Yes	Yes
Baseline Covariates * Year		Yes	Yes	Yes
Max Distance Homes to River (Miles)	0.25	0.25	1	25

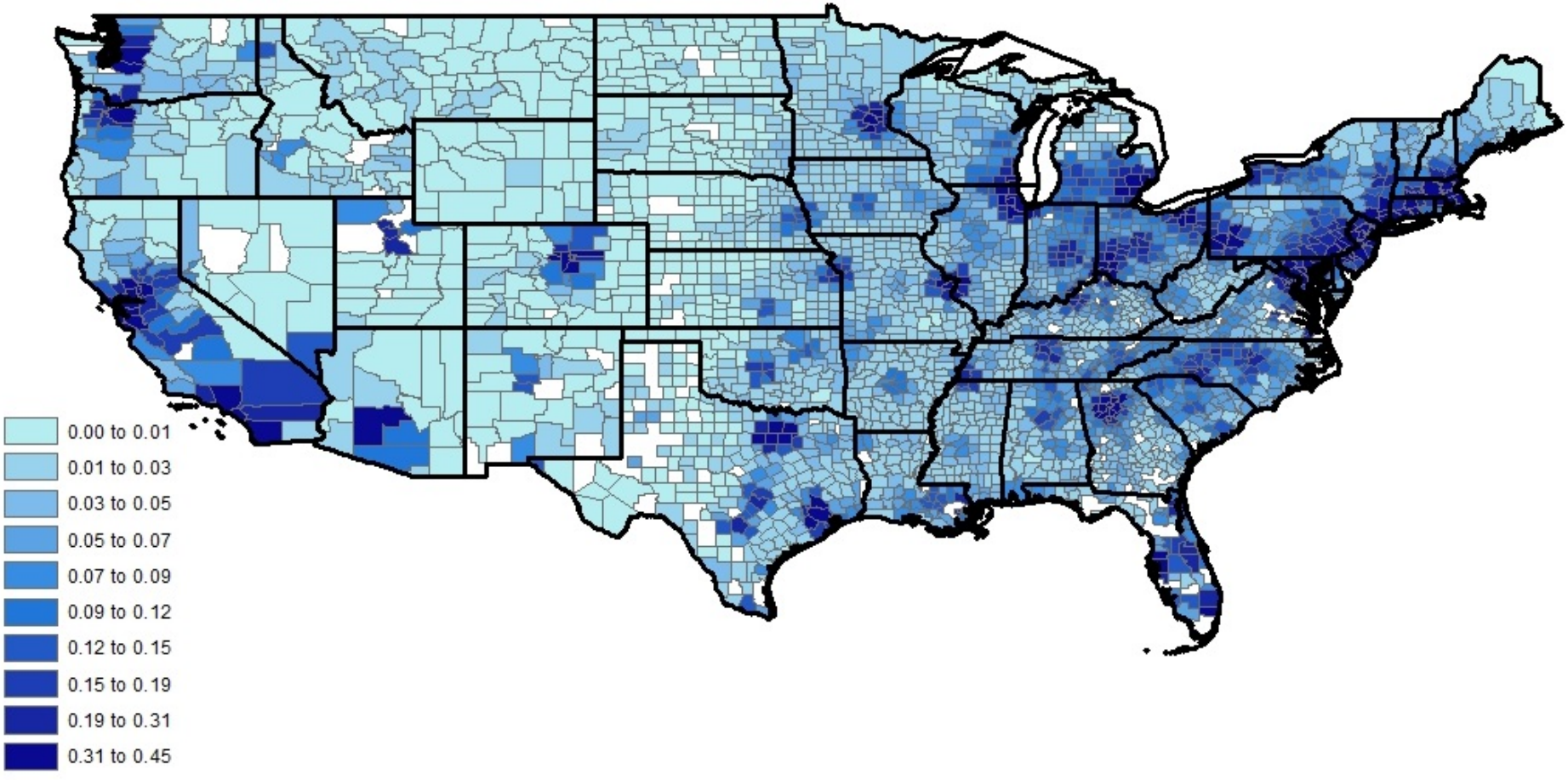
Change in Home Values and Costs

	(1)	(2)	(3)	(4)
Ratio: Change in Home	0.06	0.26	0.22	0.24
Values / Costs	(0.03)	(0.36)	(0.36)	(0.41)
p-value: Ratio = 0	[0.05]	[0.46]	[0.55]	[0.56]
p-Value: Ratio = 1	[0.00]	[0.04]	[0.03]	[0.06]
Change in Value of Housing ($Bn)	15.92	89.25	73.7	91.97
Costs ($Bn)				
Capital: Fed.	86.24	102.26	102.26	114.16
Capital: Local	35.81	41.81	41.81	48.00
Variable	166.1	197.36	197.36	222.81
Total	288.15	341.44	341.44	384.97
Max Distance Homes to River (Miles)	1	25	25	25
Include Rental Units			Yes	Yes
Include Non-Metro Areas				Yes

Ratio of Measured Benefits to Costs: Heterogeneity



Ratio of Measured Benefits to Costs: Heterogeneity



Interpreting Hedonic Estimates

Possible reasons to interpret estimates as lower bound on willingness to pay:

1. Incomplete information (health?)
2. May exclude some types of demand (non-use values?)
3. General equilibrium channels
   - Wages
   - Hedonic price function shifts
   - Substitution across sites
   - Ecology
4. 25 mile radius
5. Incomplete pass-through (crowd-out / displacement)?

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Conclusions

- **Research Questions**
  - How has water pollution changed since 1972?
  - Did Clean Water Act causes changes?
  - How do residents value changes?

Conclusions

1. Pollution has declined substantially

2. Clean Water Act caused some of this
   - Costs $1.5 million per year to make a river-mile fishable
   - Complete pass-through of federal grants to municipal spending

3. Change in home values $<$ costs
   - Overall ratio of measured benefits to costs: 0.25
   - Larger ratios ($\sim$0.6) in areas where fishing is popular
   - Interpret as lower bound?

Conclusions

- Estimated benefit-cost ratios for CWA much lower than for Clean Air Act.
- EPA: Clean Air Act benefit-cost ratio: 42. CWA: <1
- Why?
  1. No market based instruments
  2. Ignores major polluting sectors (agriculture)
  3. Easier to substitute away/defend from pollution
  4. Limited health consequences?