Behavioral responses to two-part tariffs:
Evidence from the introduction of volumetric water pricing

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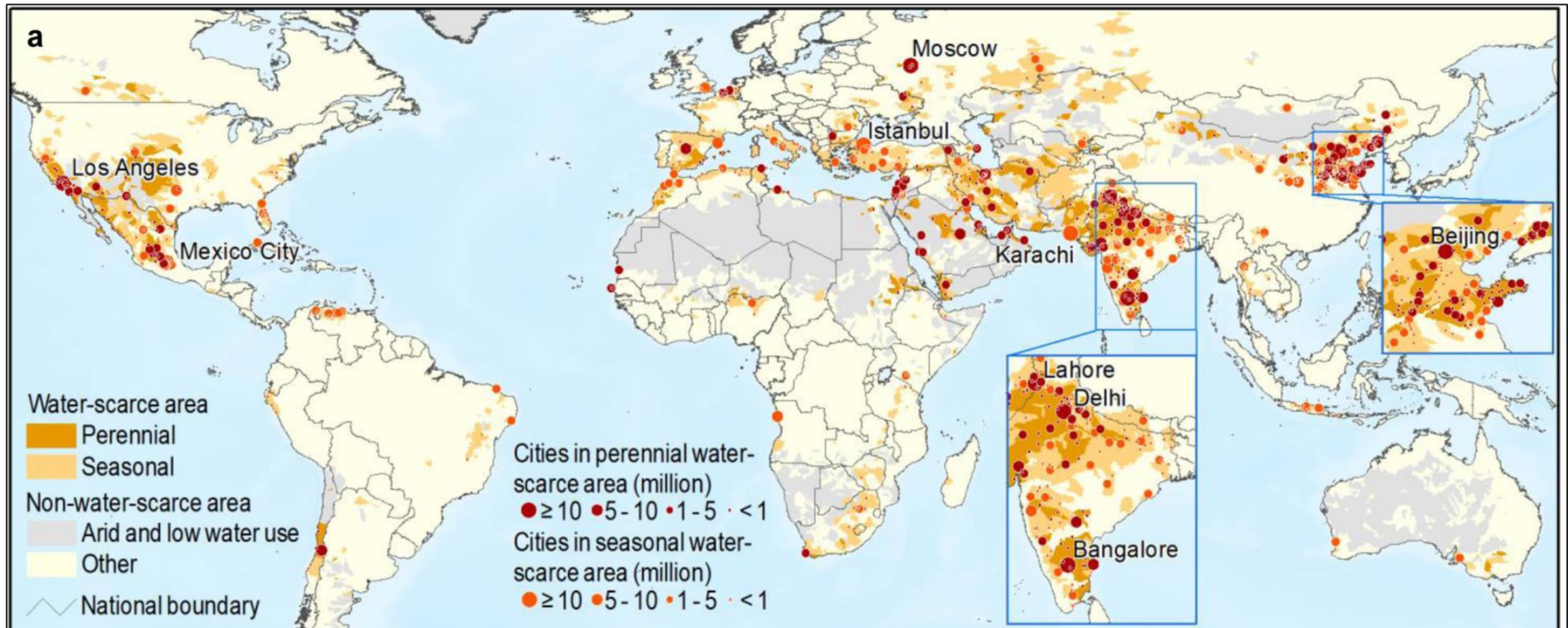Daniel A. Brent[1],

Casey J. Wichman[2,3]

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[2]Georgia Institute of Technology
[3]Resources for the Future

Introduction | Water stress

- **Two billion** people worldwide lack access to safe drinking water today (SDG Report 2022)

- **Half of the world's population** faces severe water scarcity for at least part of the year (IPCC).

He et. al, (2021) (Nature Communications)

Background

- Increasing water stress requires water conservation across usage.

- Economists advocate for using price signals to encourage water conservation

But challenges persists regarding…

1. Political feasibility and social acceptability of water pricing
2. Concerns for equity vs conservation
3. Justifying capital expenditure on infrastructure
4. Water pricing is complex
   - <u>Tariffs:</u> Two-part tariffs, income-based tariffs, increasing block rates
   - <u>Billing cycles:</u> Consumers do not see the water bills regularly
   - <u>Household Cost:</u> Small portion of expenditure

- **How consumers respond to water metering and volumetric pricing?**

Motivation & Literature

How do consumer respond to complicated rate structures?

❖Average Price vs Marginal Price

- Ito (2014) [Energy]; Wichman (2014) [Water]; Cook and Brent (2021) [Water]
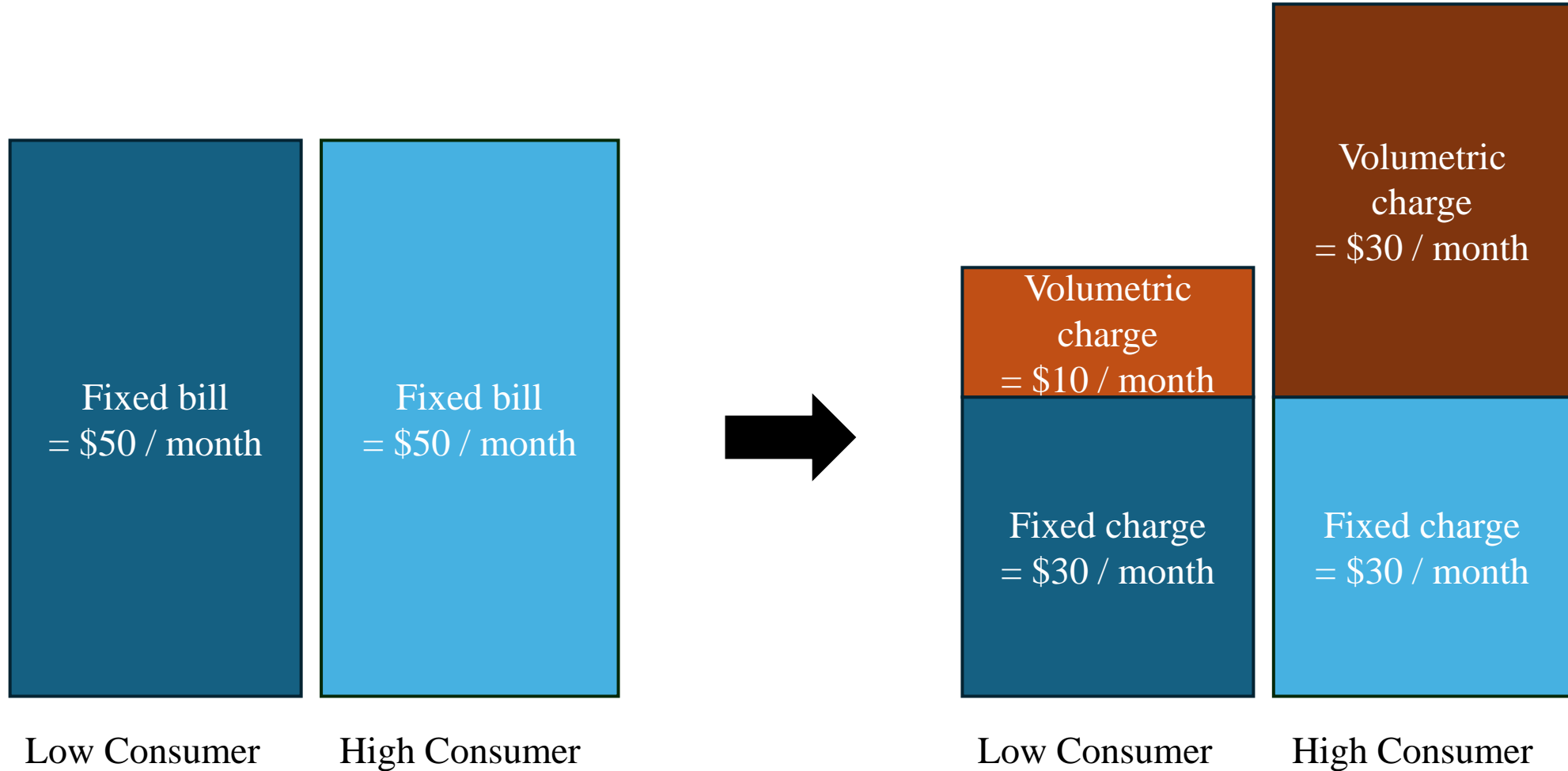- Nataraj and Hanemann (2011) [Water]; Elinder et al. (2024) [Hot Water]

❖Price Perceptions

- Wichman (2017) [Water]; Brent and Ward (2019) [Water]

❖Heuristics

- Liebman and Zeckhauser (2004) [Schmeduling];
- Rees-Jones and Taubinsky (2020) [Taxation] ; Ito and Zhang (2024) [Energy]

Background | Illustrative policy setting

Fixed bill = $50 / month

Fixed bill = $50 / month

Volumetric charge = $10 / month

Fixed charge = $30 / month

Volumetric charge = $30 / month

Fixed charge = $30 / month

Low Consumer

High Consumer

Low Consumer

High Consumer

$$Bill_0 = F_0 + p_0 w_0,$$
$$\text{where: } p_0 = 0$$

$$Bill_1 = F_1 + p_1 w_1$$
$$\text{where: } p_1 > 0$$

Setup| California AB 2572

Mandating water metering & volumetric pricing

- California:
  - Passed a law in 2004 that utilities **need to meter and price water for all consumers by volume** by 2025. (AB 2572)

- Sacramento:
  - Transitioned from **flat bill** to **Two-part tariff** [flat + volumetric pricing].

- <u>Single Family Households</u>:
  - Meters were installed in staggered manner based on engineering feasibility plan.

Metering Timeline

- Not metered
- 2018
- 2015
- 2010
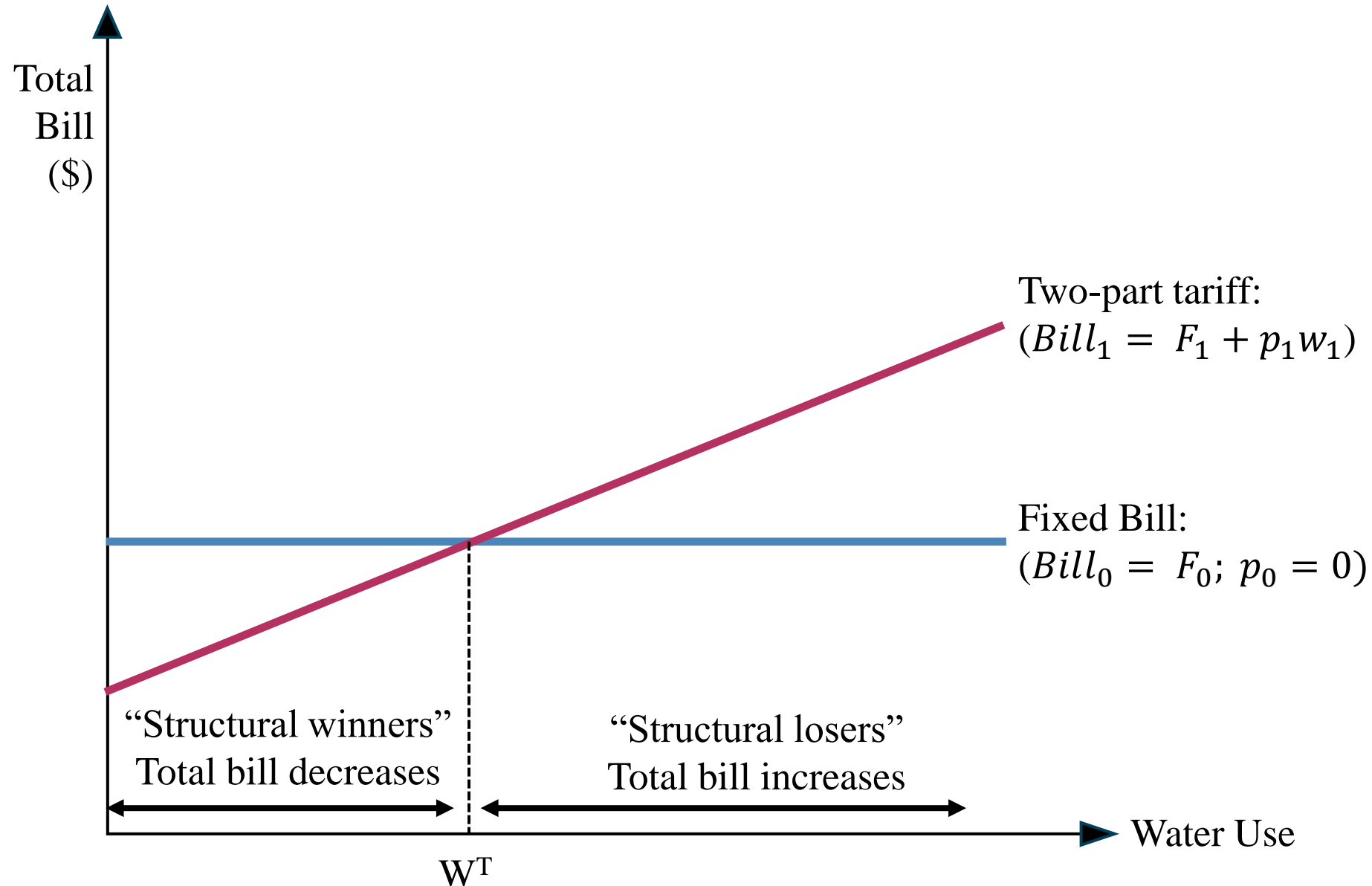- 2005
- Non-residential
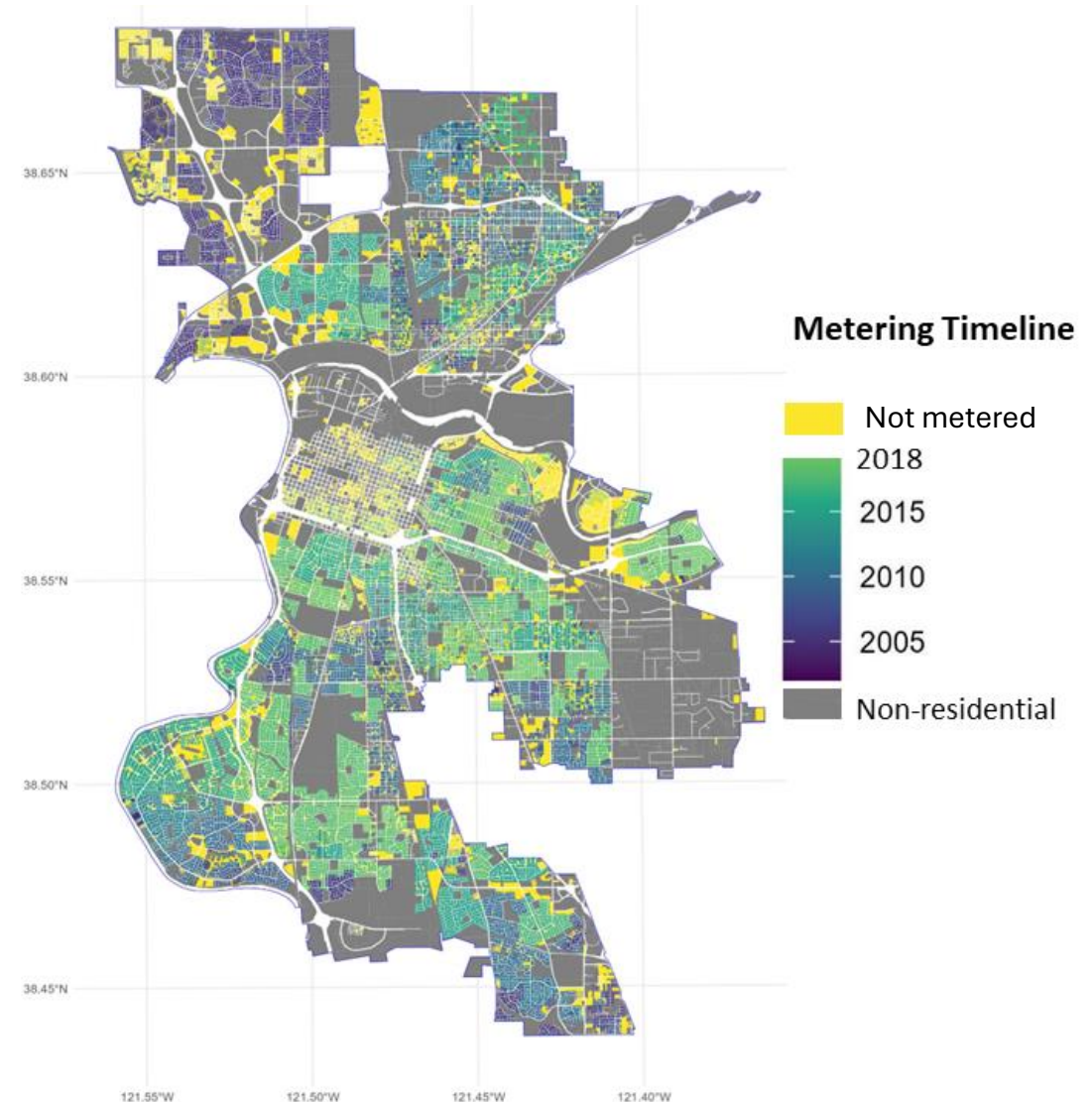
Research Questions

1. How do consumers respond when **switching from flat to volumetric water pricing**?

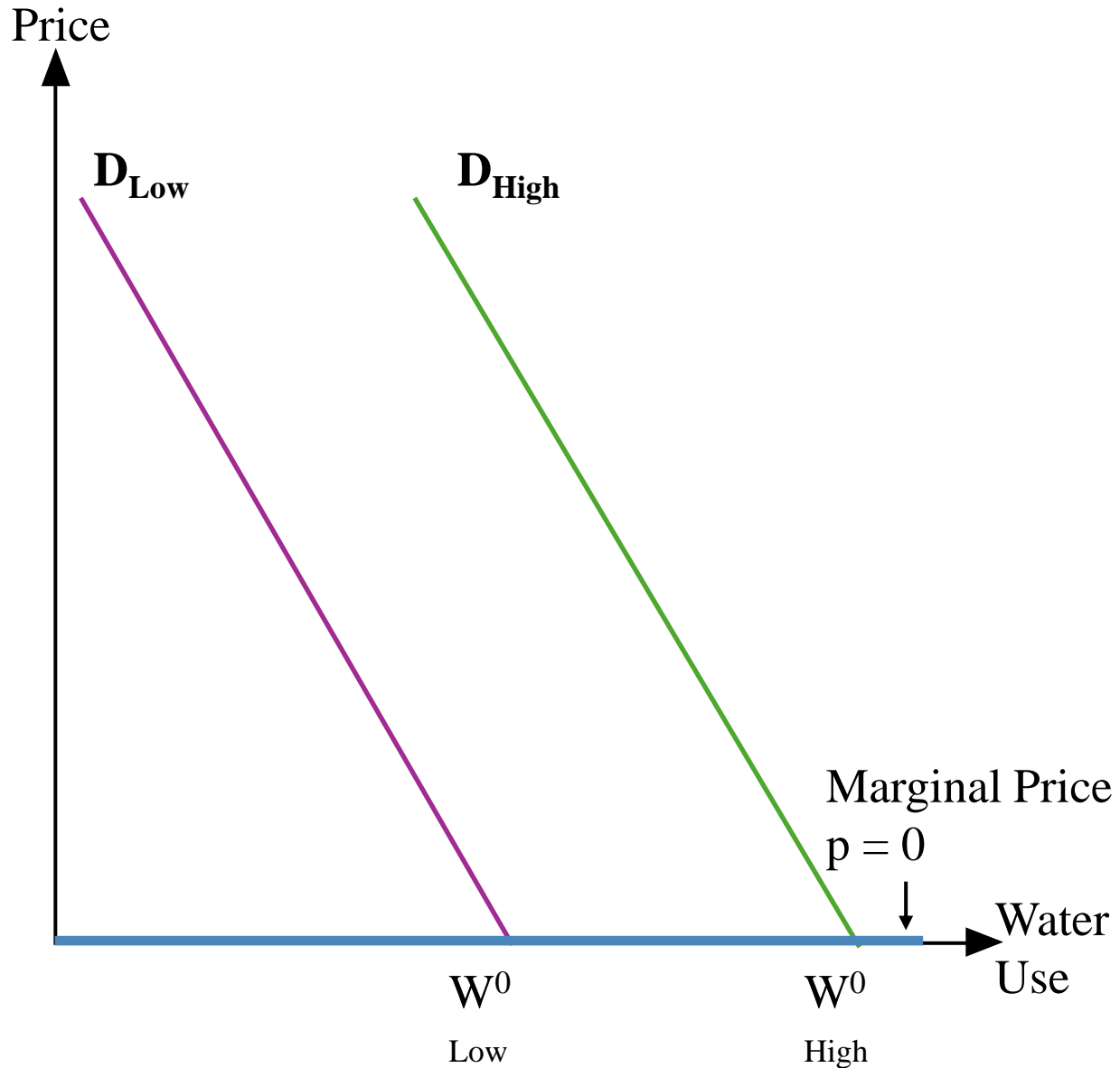2. What does this tell us about <u>consumer behavior</u> more generally?

Preview of results

1. Overall average consumption **decreased**

2. Response is **heterogeneous** across the user groups

    i. **Lower** consumers **increase** their consumption

    ii. **Higher** consumers **decrease** their consumption

Background | Illustrative policy setting

Two-part tariff:
$(Bill_1 = F_1 + p_1 w_1)$

Fixed Bill:
$(Bill_0 = F_0; p_0 = 0)$

Total Bill ($)

"Structural winners"
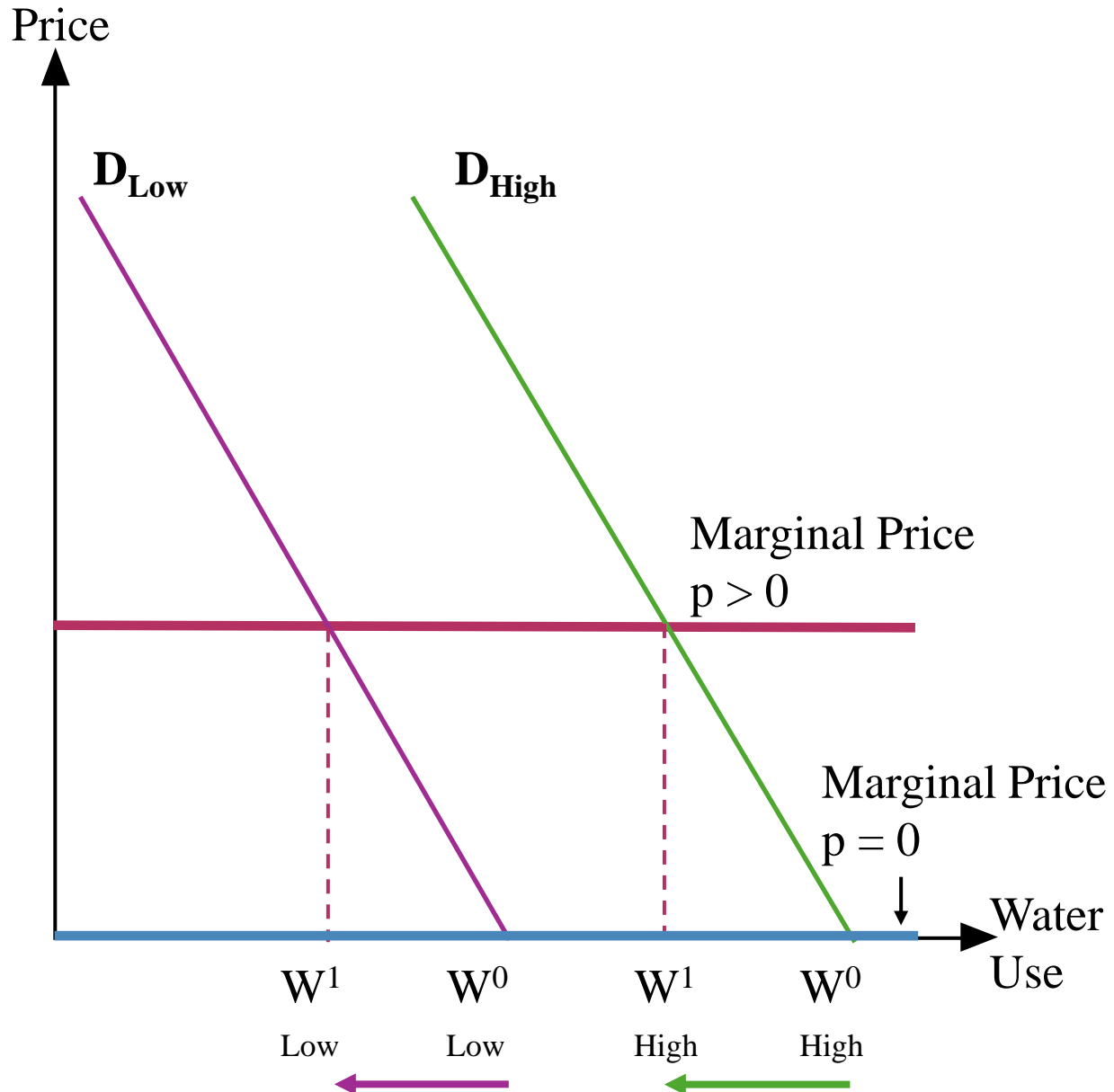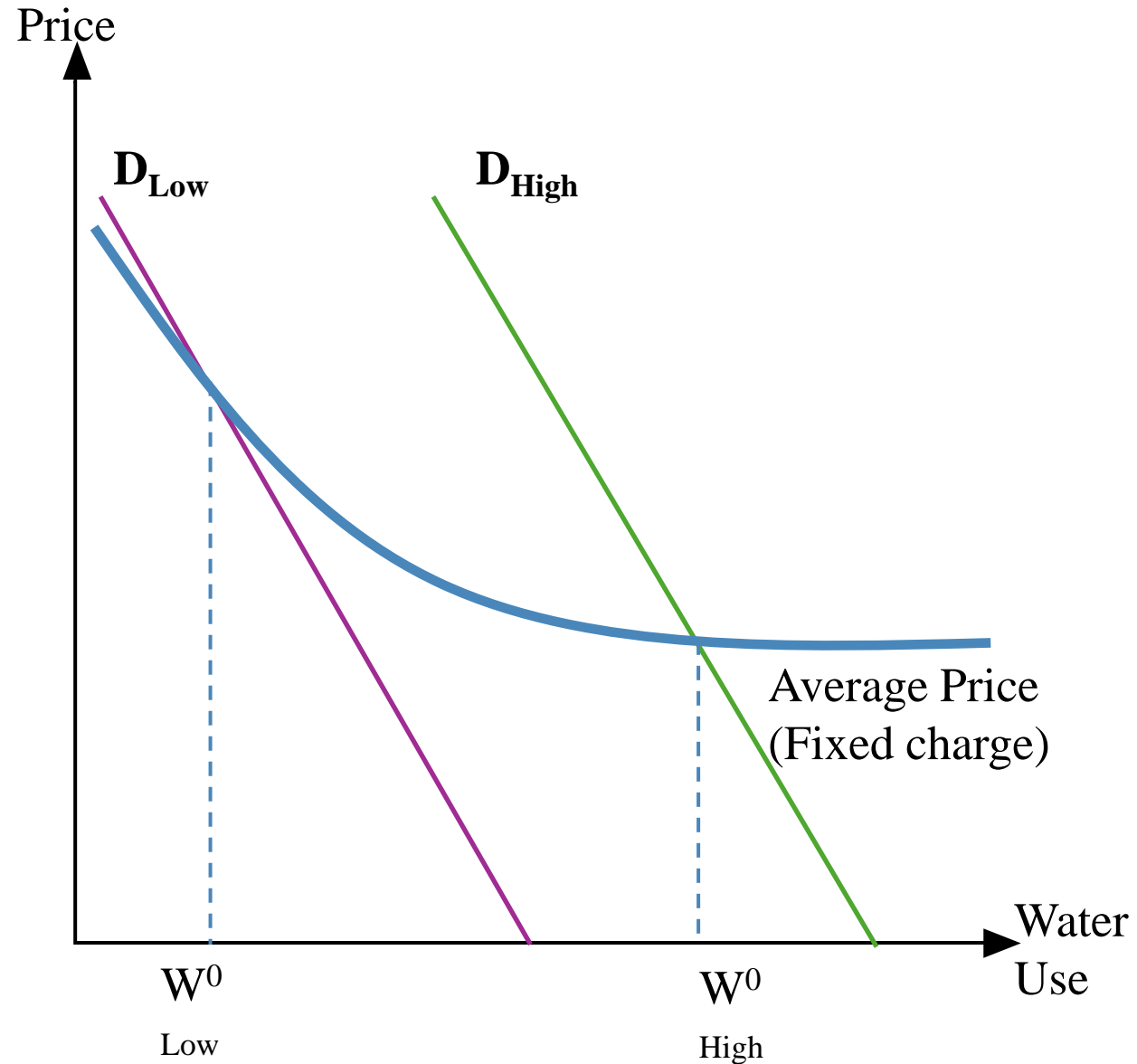Total bill decreases

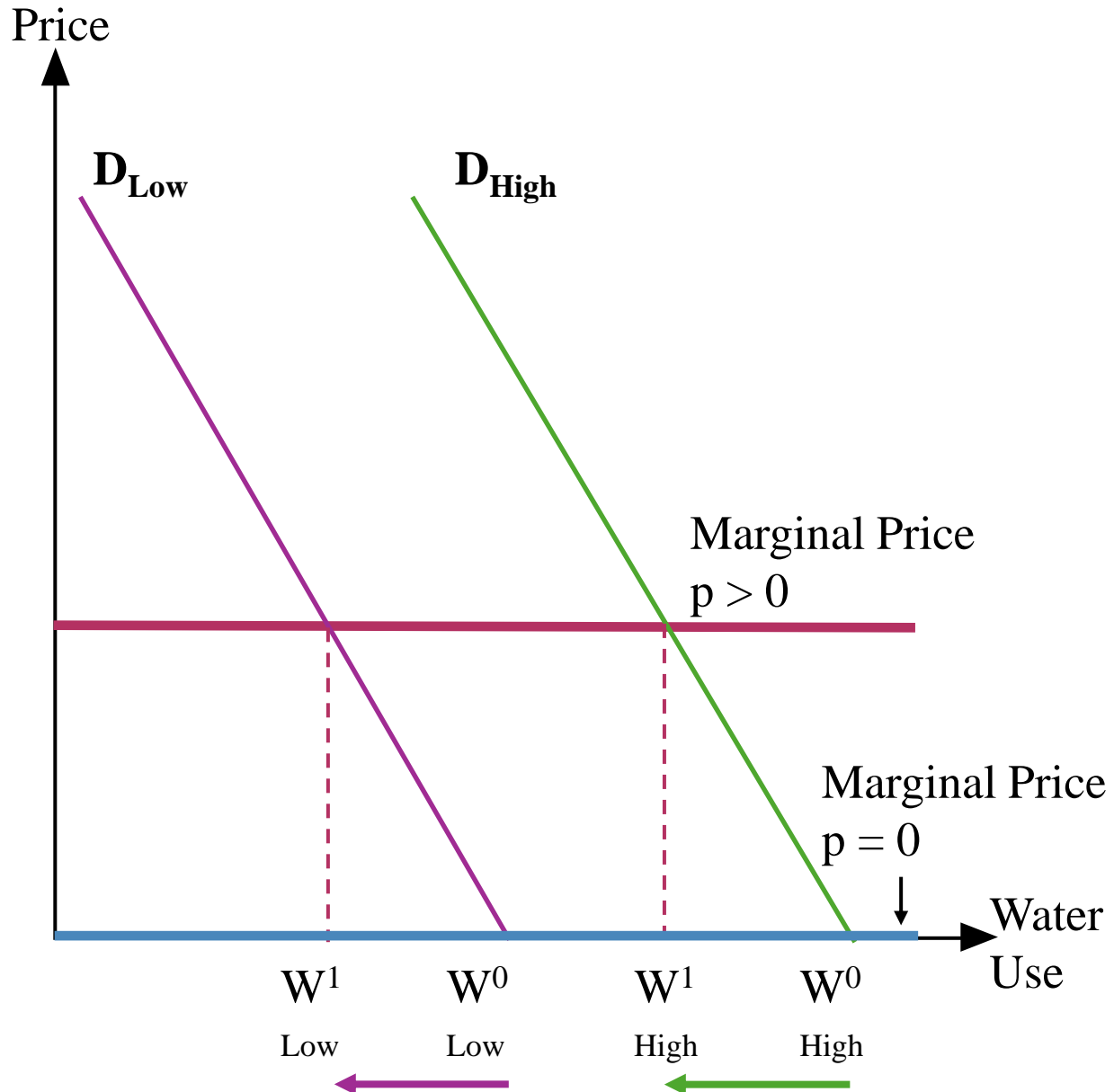"Structural losers"
Total bill increases

W^T

Water Use

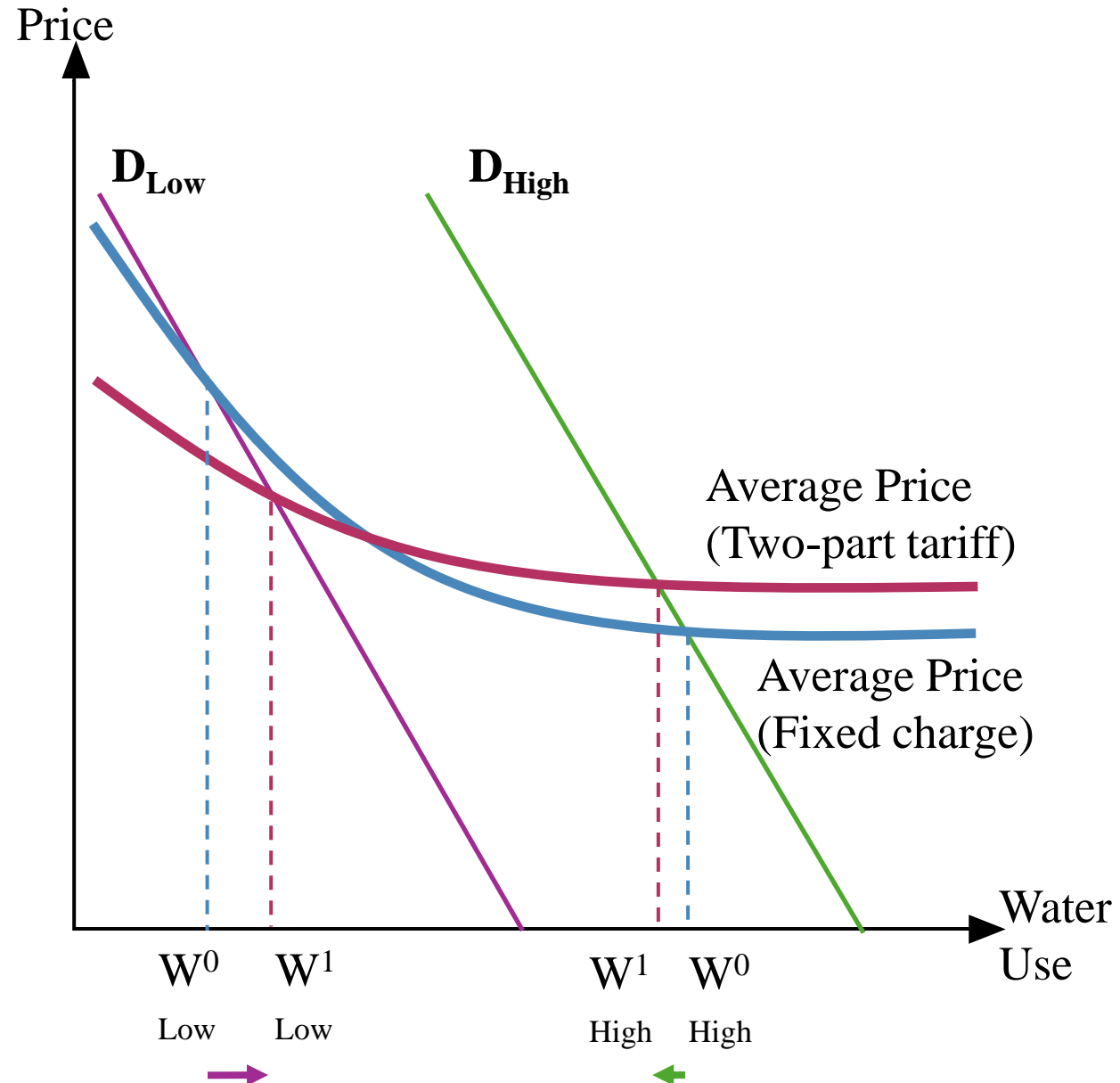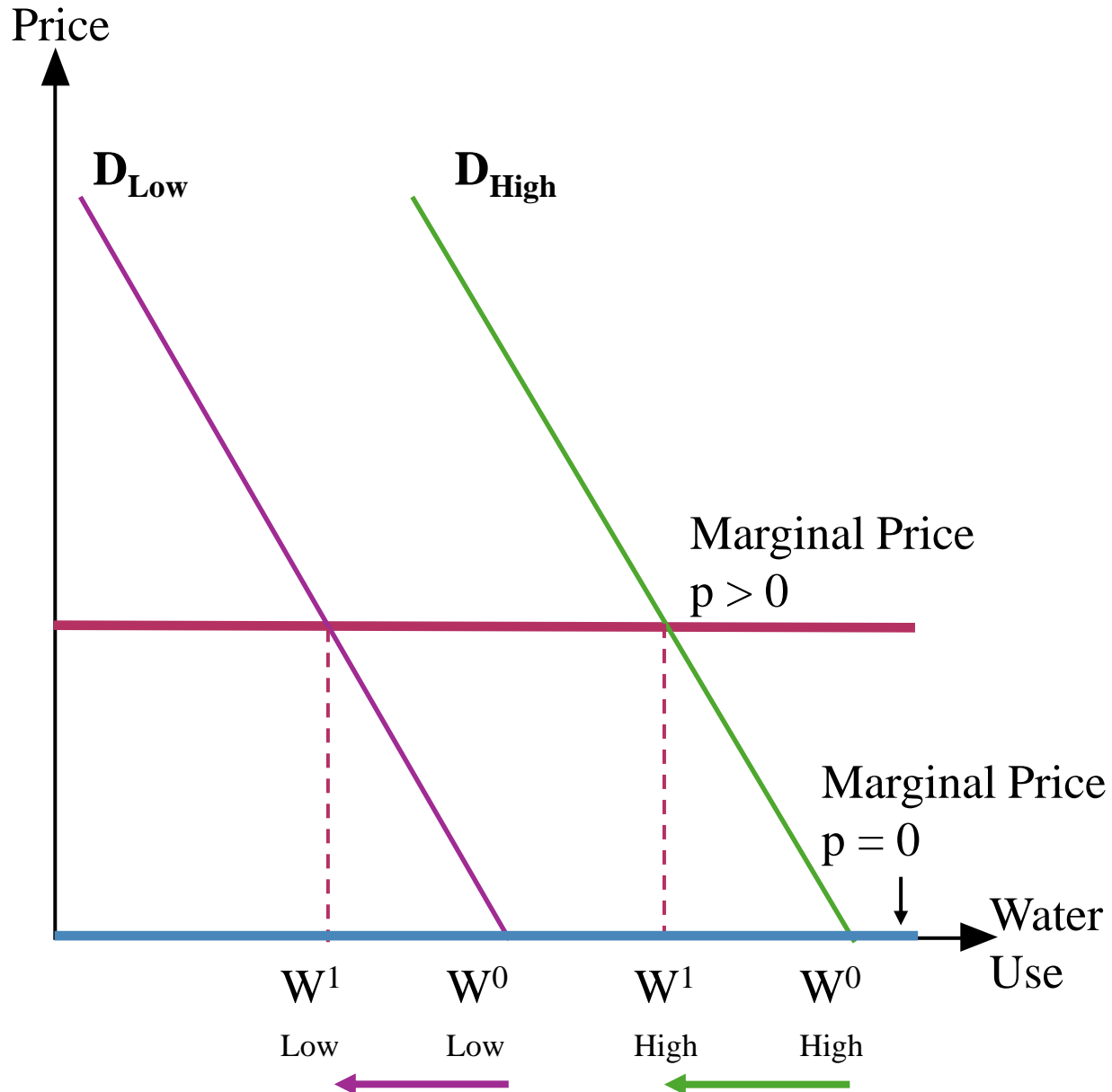# Marginal vs. Average Price Responsiveness

Marginal vs. Average Price Responsiveness

Marginal vs. <u>Average</u> Price Responsiveness
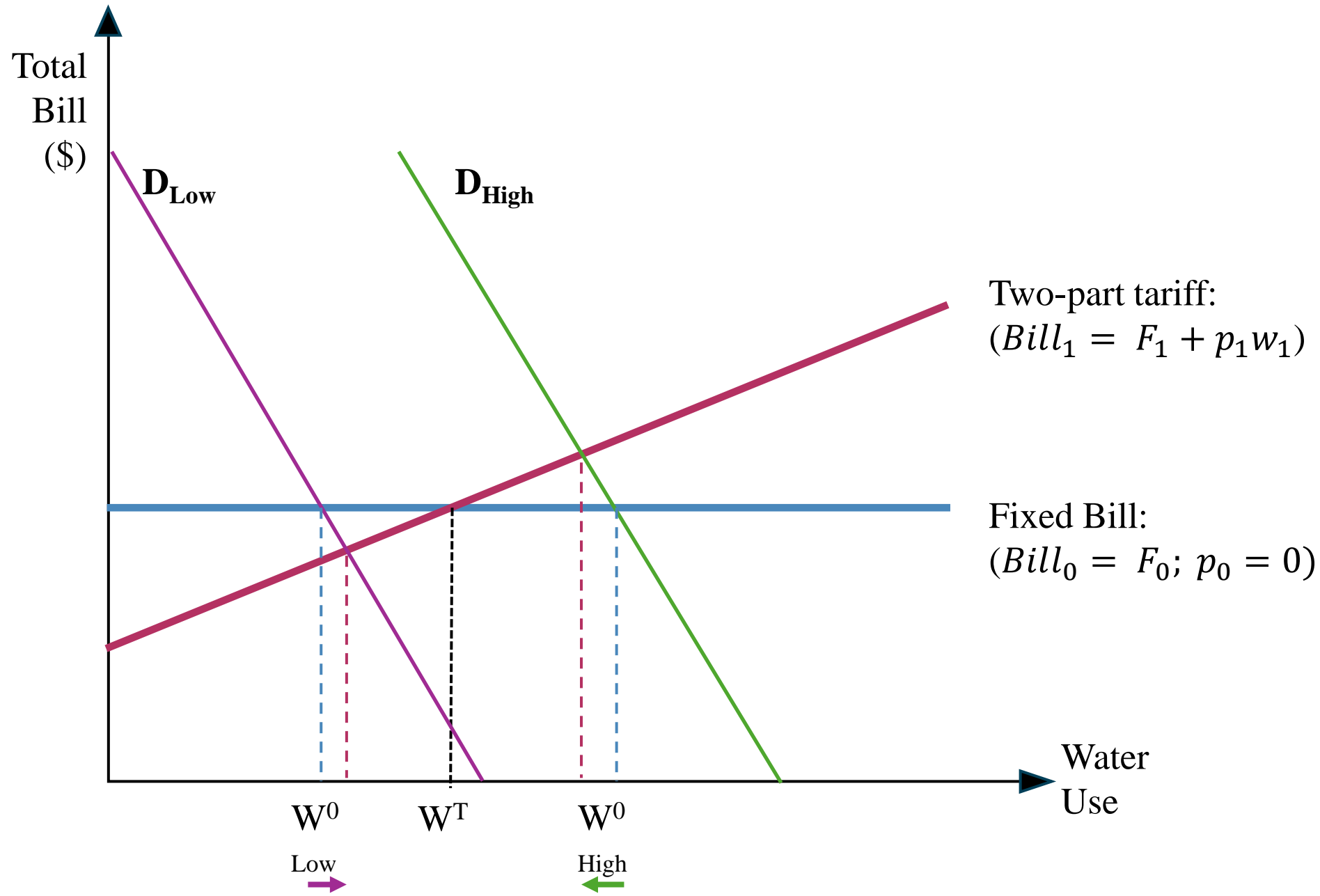
Marginal vs. <u>Average</u> Price Responsiveness

Total Bill Responsiveness

Total Bill ($)

D_{Low}

D_{High}

Two-part tariff:
$(Bill_1 = F_1 + p_1 w_1)$

Fixed Bill:
$(Bill_0 = F_0; p_0 = 0)$

Water Use

W^0 W^T W^0

Low   High

Background| Household Water Use & Awareness

Quick Questions!

How much did you pay for water last month?

Do you know your fixed fee and price of the water?

How much water you used during last billing period?

Setup| Bill Template

City of
SACRAMENTO
Department of Utilities

Billing or Service Questions? Call (916) 808-5454
www.cityofsacramento.org/utilities

📞 CALL 我們講中文 · Hablamos Español · Мы говорим по-русски · ผมพูดไทยพูดลาวได้ · Peb hais lus Hmoob · Chúng tôi nói tiếng Việt

CUSTOMER NAME
Account Number: 1234567890
Billing Date: July 25, 2019

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Important Customer Messages

Effective July 1, 2019, your bill will include City Council approved rate increases of 9% for Wastewater and 10% for Water Service.

As your account is billed in arrears, the July bill may include prorated billing, in which the full increase in monthly service charges should be reflected on the August bill.

Account Summary as of July 25, 2019	
Previous Balance	167.66
Payment Received - 7/22/2019 - Thank You!	-$167.66
Balance Forward	**$0.00**
Current Charges - Due 8/14/2019	$174.37
Total Due	**$174.37**

Legal Owner: CUSTOMER NAME
Service Address: 123 MAIN ST - A Single Family Dwelling

APN: 123-0000-000-0000
Council District: 2

Utility Services

Service from 6/27/19 - 6/30/19	
Water - Flat charge 5 rooms (for 4 days)	7.72
Wastewater - Flat charge for 5 rooms (for 4 days)	3.33
Subtotal	**$11.05**
Service from 6/27/19 - 7/25/19	
Storm Drainage - Flat charge for 5 rooms	9.58
Subtotal	**$9.58**
Service from 7/1/19 - 7/25/19	
Water - Flat charge 5 rooms (for 25 days)	53.09
Wastewater - Flat charge for 5 rooms (for 25 days)	22.66
Subtotal	**$75.75**
Service from 6/27/19 - 7/25/19	
Garbage - 1 90 gallon @ $23.00 per can	23.00
Recycling - 1 96 gallon @ $5.90 per can	5.90
Yard Waste - 1 container @ $10.75	10.75
Street Sweeping - Single Family Dwelling	1.34
Subtotal	**$40.99**

Utility Services - Tracking Meters

CF Consumption History GAL

Service from 6/25/19 - 6/30/19

Water - Residential Tracking Only	
Base service charge	6.49
399 cubic feet @ $0.013261 per cubic foot	5.29
Subtotal	*$11.78*

Comparison Purposes Only

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Utility Services - Tracking Meters (continued)

Meter Number	Meter Size	Meter Read		Reading Difference	Meter Mult.	Usage	
		Current	Previous			Cubic Feet	Gallons
10000000	1.0	49846	48182	1,664	1	1,664	12,447

CF Consumption History GAL
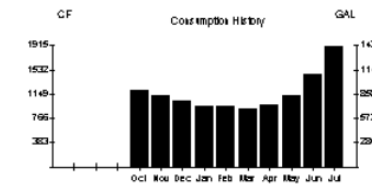
Service from 7/1/19 - 7/19/19

Water - Residential Tracking Only	
Base service charge	22.62
1,265 cubic feet @ $0.014587 per cubic foot	18.45
Subtotal	*$41.07*

Comparison Purposes Only

Meter Number	Meter Size	Meter Read		Reading Difference	Meter Mult.	Usage	
		Current	Previous			Cubic Feet	Gallons
10000000	1.0	49846	48182	1,664	1	1,664	12,447

Setup| Sacramento Water Authority
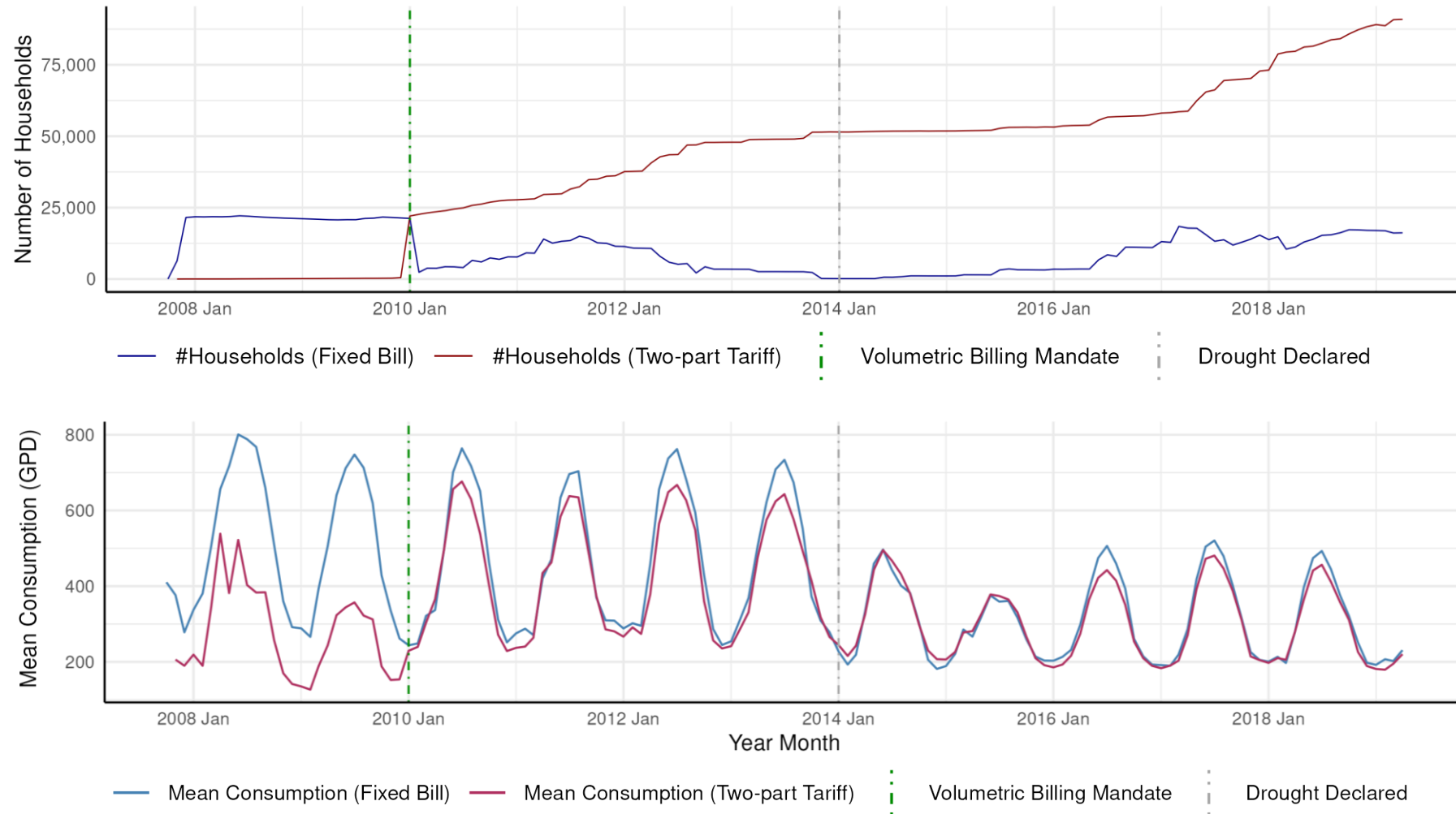
Implementation Strategy & Data availability

1. **Meter installation**

2. **Tracking period (~12 months)**
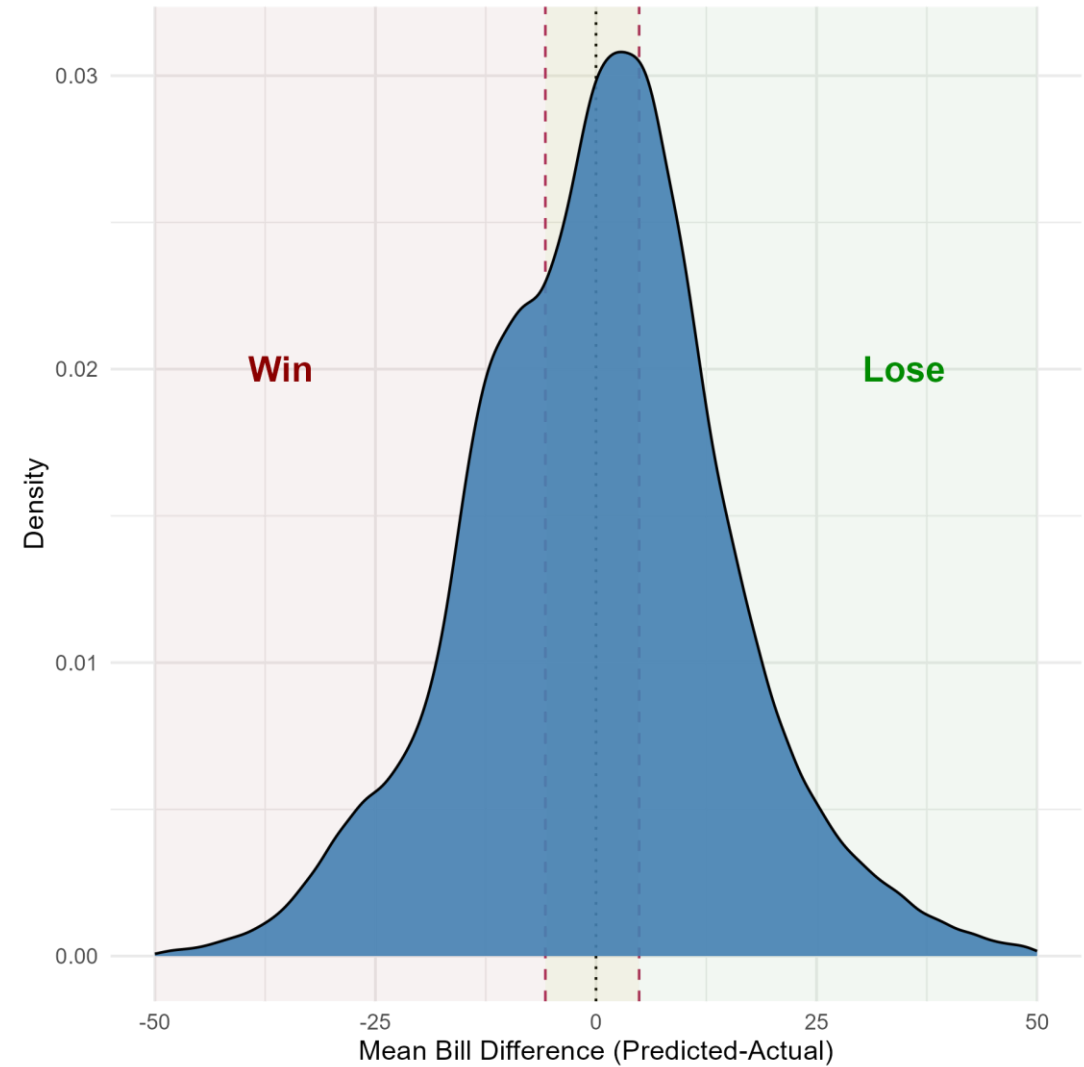
3. **Volumetric billing**

Setup| Defining Heterogeneity

Based on bill difference

- Structural winners and losers.
- Consider small bill changes as neutral.

Empirics

Basic two-way fixed effects:

$$\ln(GPD_{it}) = \alpha_i + \boldsymbol{\delta}\mathbf{1}[Vol_{it}] + \tau_t + \epsilon_{it}$$

- GPD_{it} = water consumption (gallons per day) for each household-month.
  - i = Households
  - t = Month of sample
- $\mathbf{1}[Vol_{it}]$ = Indicator for whether household is billed on the two-part tariff.

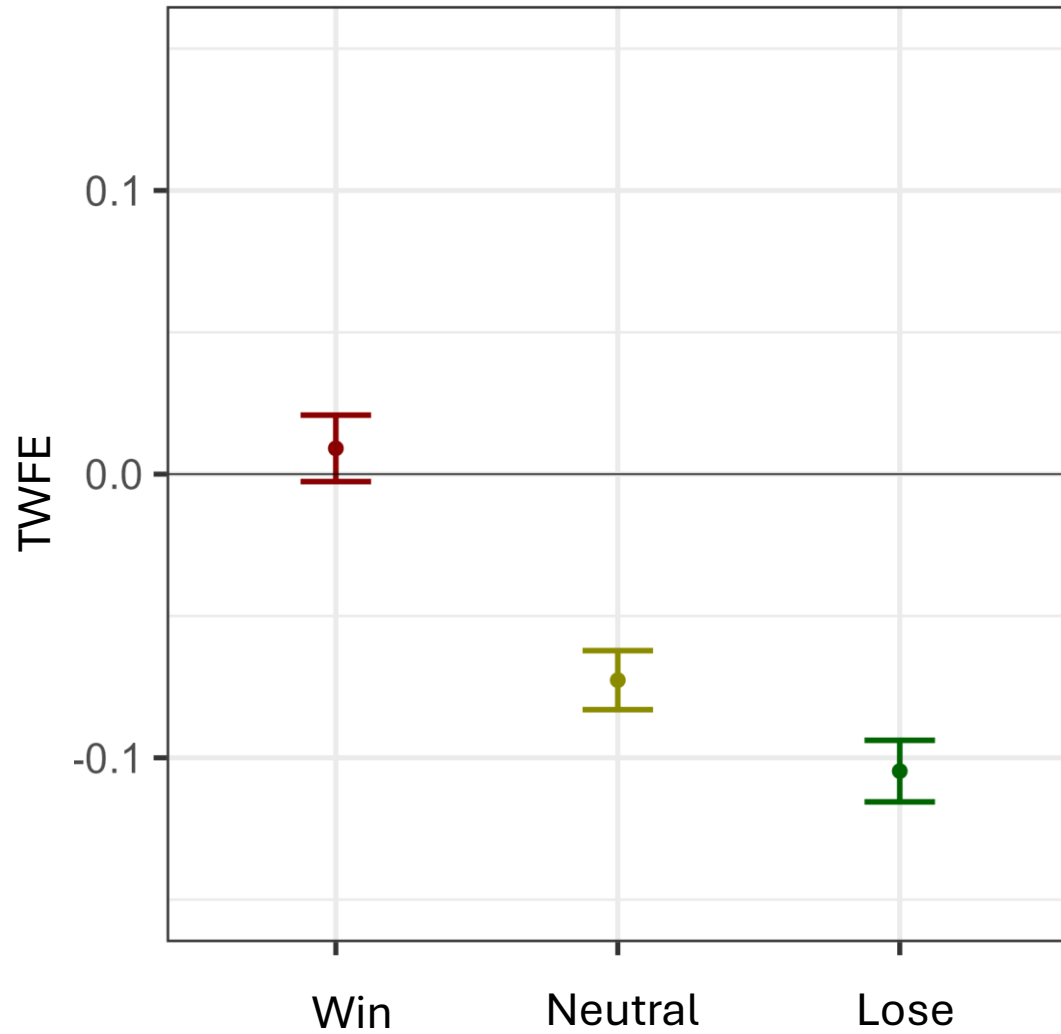- Assume $\boldsymbol{\delta}$ is biased because of staggered pricing roll out.

Preliminary Results| Two-way Fixed Effects

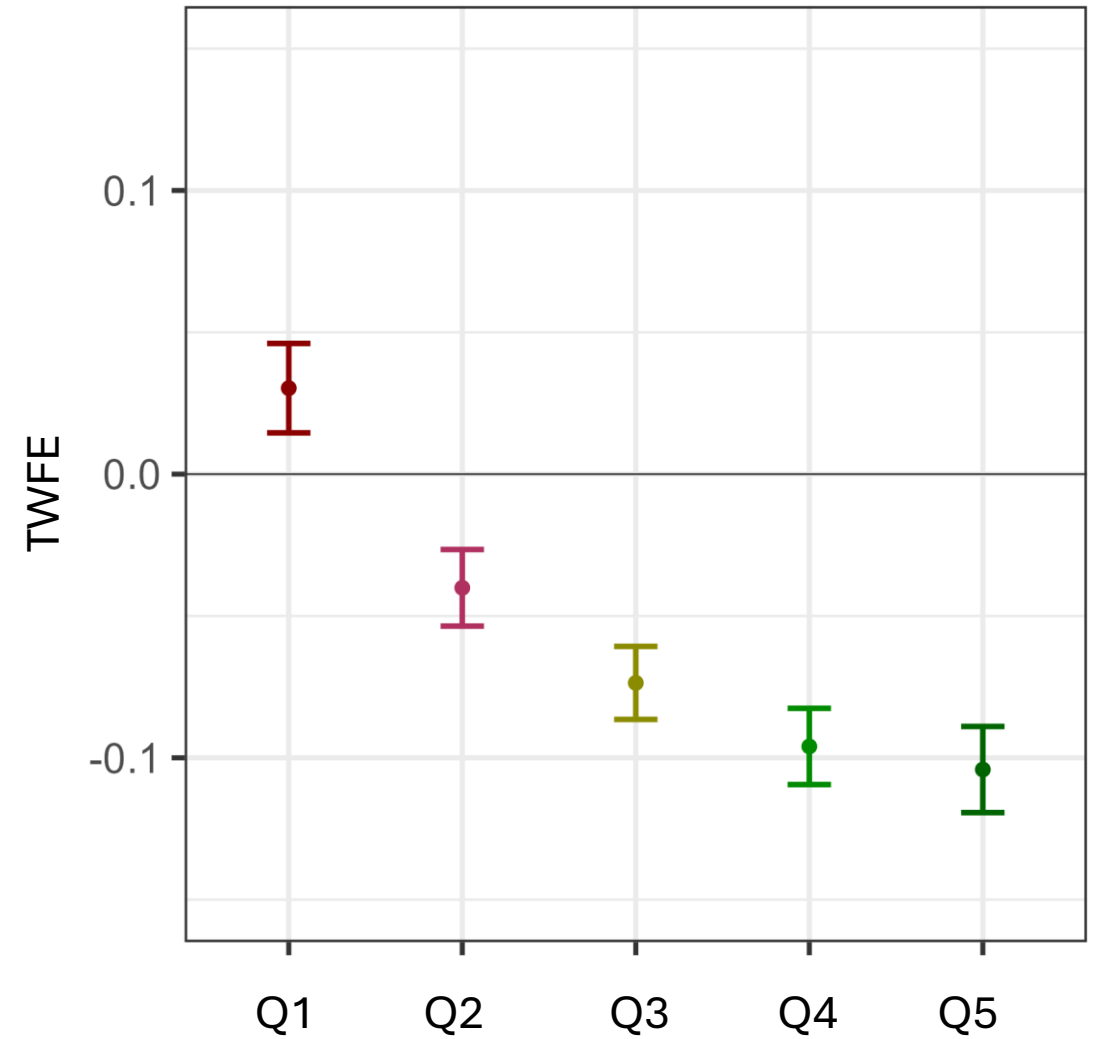|	**All Records**	**No Always Treated Control**
	(1)	**(2)**
Volumetric	-0.100**	-0.076**
	(0.002)	(0.002)
# Account	150,823	93,606
Observations	6,794,267	4,567,680

**: p-value < 0.01

# **Preliminary Results|** Heterogeneity

(a) Structural Winners

(b) Consumption Quintile

Staggered Adoption| Peculiar Setup

1. **Staggered :** <u>108 groups with non-uniform roll out.</u> Treatment Effect Heterogeneity Across Groups and Overtime

2. **Imbalanced panel :** Only 12 months pre-period data

3. **Seasonality in water use :** Water usage in June are very different from use in January
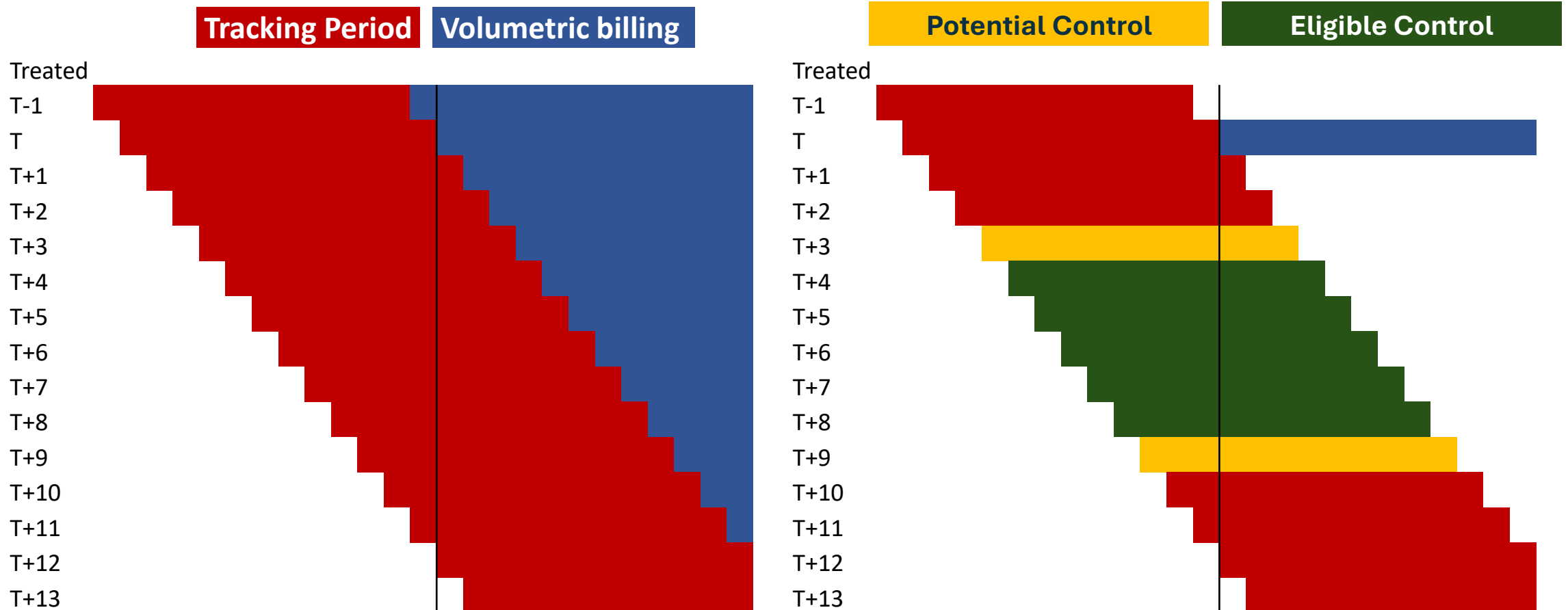
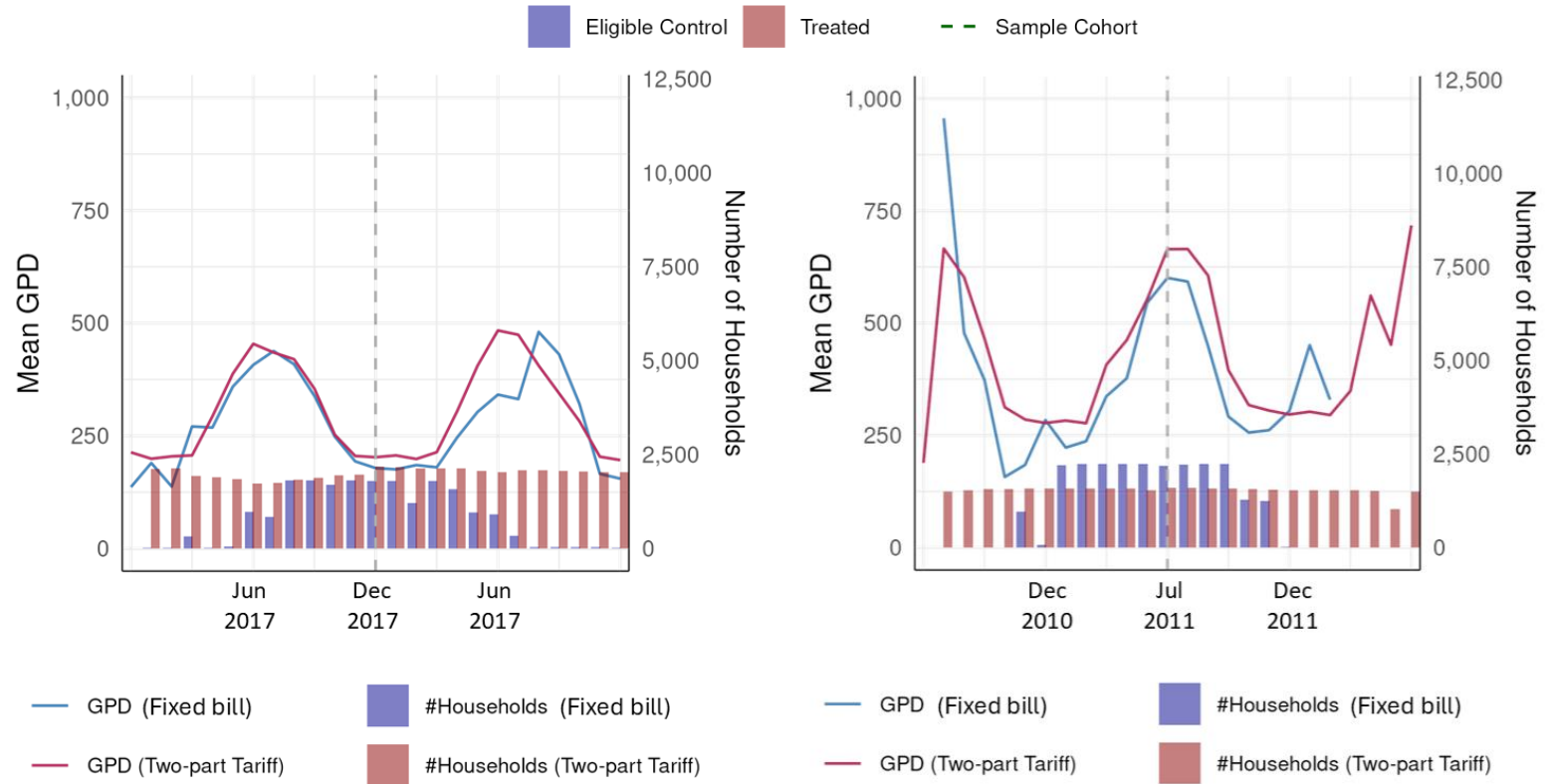# **Staggered Adoption|** Peculiar setup
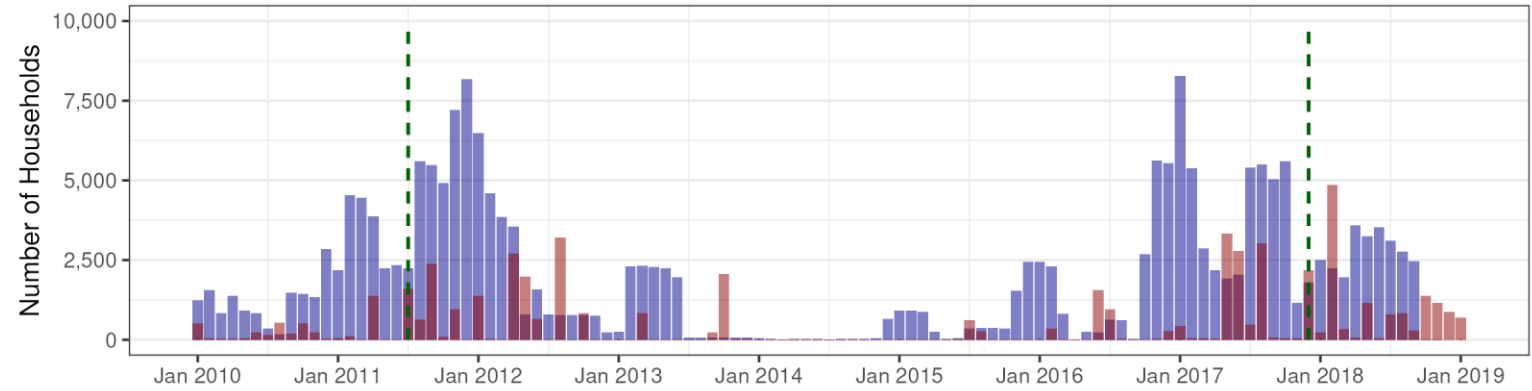
1. **Staggered**
   - ✓ Define Group-level treatment effects.

2. **Imbalanced Panel**
   - ✓ Control group with at least 4-month overlap around switching.
   - ✓ Estimate short-term treatment effects

3. **Seasonality in water use**
   - ✓ Define Group-level treatment effects.
   - ✓ Limit ATT to within 6-month.

Methods| Defining new estimators

1. **Prepare Group-wise Data**

   - Treatment Cohort:

     - At least 4 months and not more than 14 months tracking period observations

   - Eligible Control Group:

     - Overlap of at least 4 months pre-treatment period data and 4 months post treatment data

2. **Matching Steps**

   1. No-matching

   2. Matching on pretreatment outcome

   3. Matching on household characteristics

      [Price, # Bathrooms, Swimming Pool, Potential Lawn Area]

3. **Estimate Group Average Treatment Effect [GATE]**

   - Use Group-wise *TWFE* model *(with matching weights)*

4. **Average Treatment-effect on Treated [ATT]**

   - Weighted average of the GATE.

5. **Inference**

   - Bootstrapped standard errors
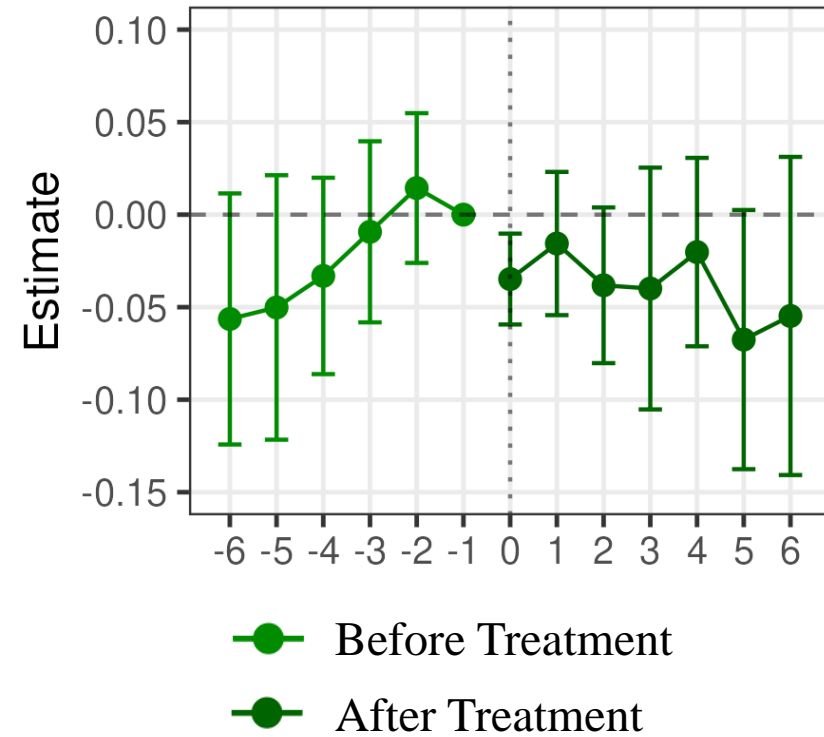
Results | ATT estimates

	log(Gallons per day)					
	TWFE			**Aggregate-GATE**		
	All Records	No Always Treated	No Always Treated [Within 6-months]	No-Matching	Matching on Pre-treatment Outcome	Matching on Household Characteristics
	(1)	(2)	(3)	(5)	(6)	(7)
Volumetric Pricing	-0.100**	-0.076**	-0.028**	-0.033	**-0.052****	-0.001
	(0.002)	(0.002)	(0.004)	(0.026)	**(0.006)**	(0.01)
Accounts	150,823	93,606	93,550	93,606	**93,606**	93,606
Treated	73,941	73,941	73,885			
Matched				48,254	**41,024**	48,254
Std. Errors	Clustered at account level	Clustered at account level	Clustered at account level	Bootstrapped	**Bootstrapped**	Bootstrapped
Dropped Accounts	-	No Always Treated	No Always Treated	No more than 14 months or less than 4 month tracking	**No more than 14 months or less than 4 month tracking**	No more than 14 months or less than 4 month tracking

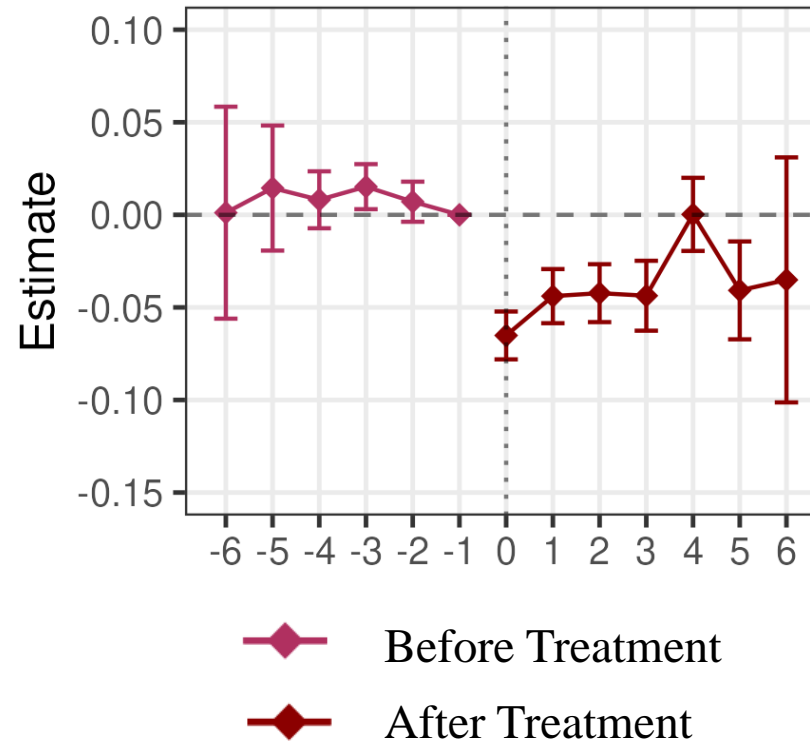**: p-value < 0.01

Preferred Estimator

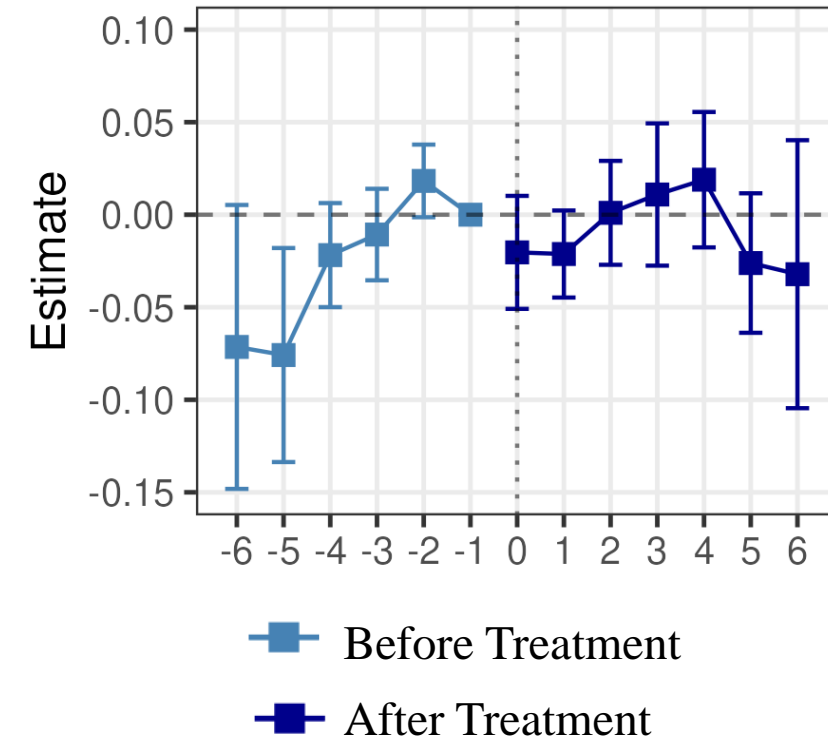# **Results|** Identifying preferred estimator

(a) No matching

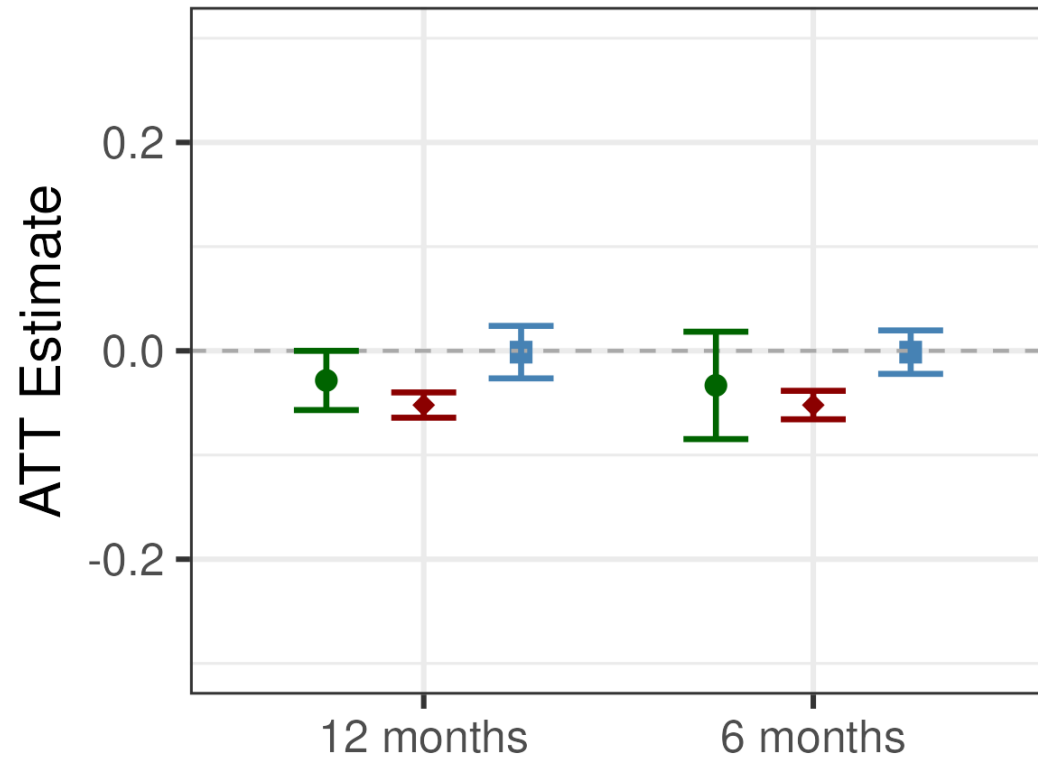**(b) Matching on pre-treatment outcome**

(c) Matching on household characteristics
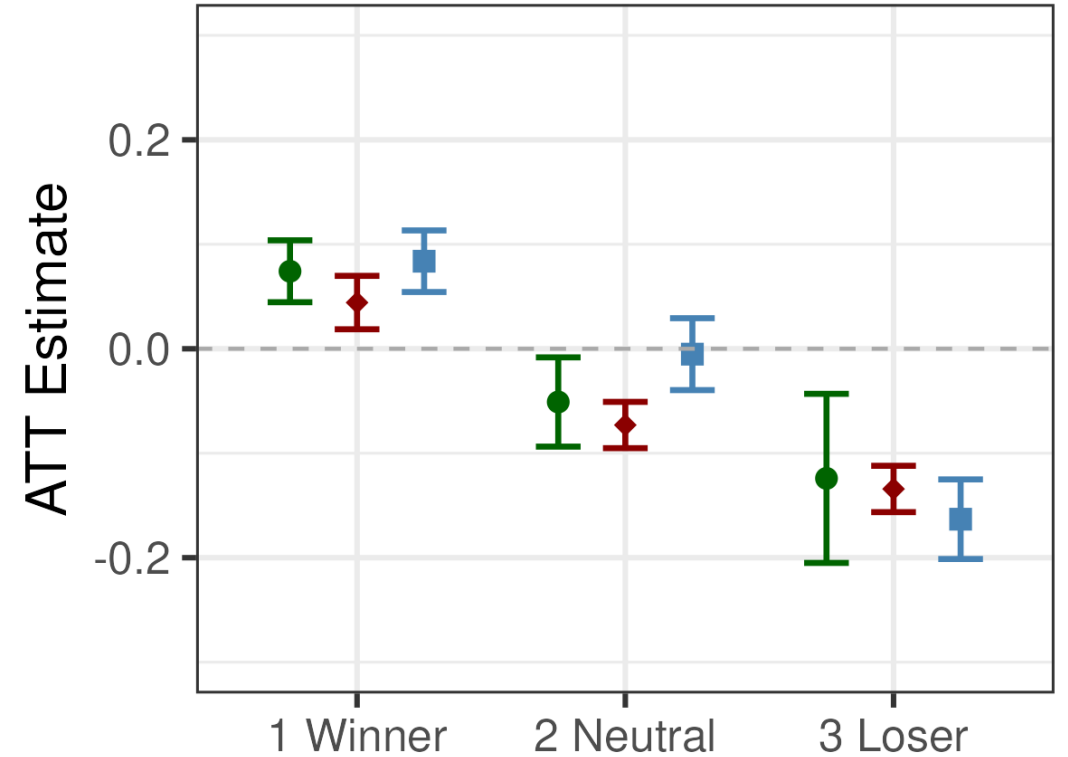
Results| ATT estimates

(a) Overall
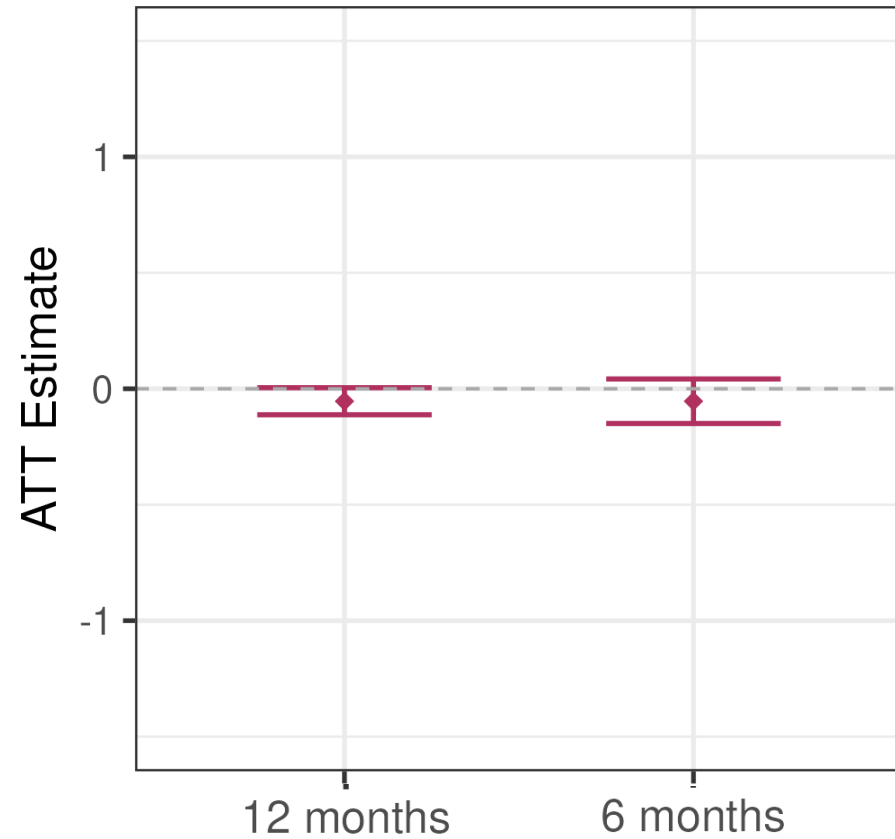
(b) Structural Winners

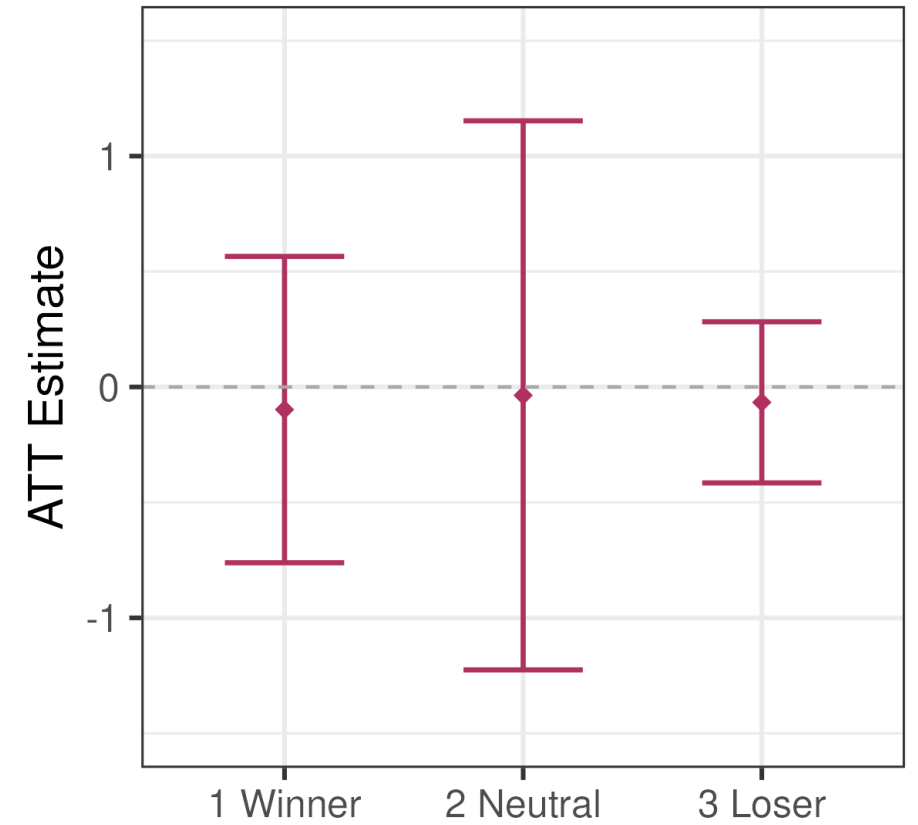No matching

Matching on
pre-treatment outcome

Matching on household
characteristics

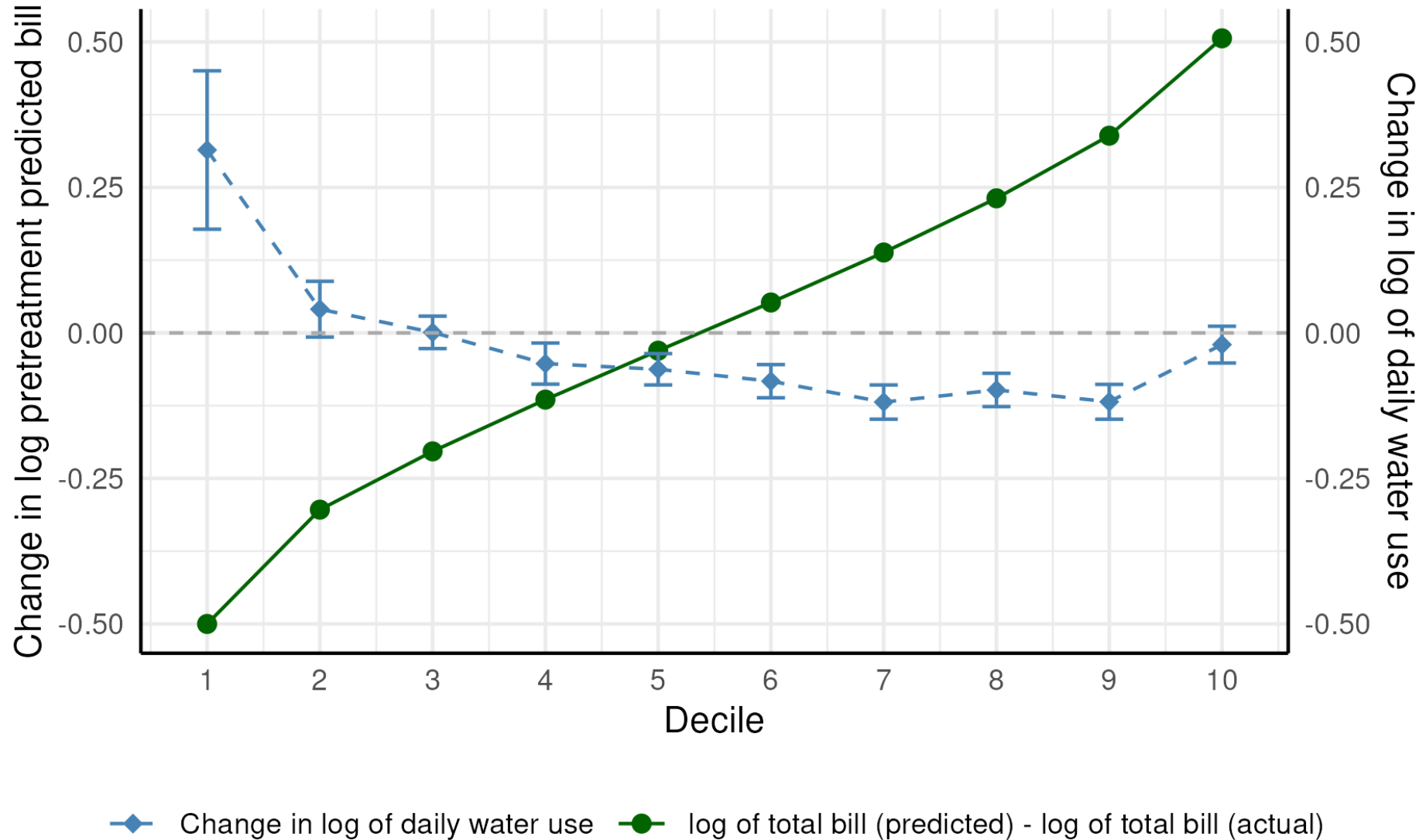# **Testing Mean Reversion|** Placebo test

(a) Overall

(b) Structural Winners

Matching on pre-treatment outcome

Empirical Test| Response to total bill

Conclusion

- Overall, average consumer decreases consumption in response to rate structure change
  - Low consumers / "Structural Winners" increase consumption
    - Total bill has gone down.
  - High consumers / "structural losers" decrease consumption
    - Total bill has gone up.
- Consumers do not respond to marginal price.
- Consumers are potentially responding to changes in total bills
  - Difficult to separate total bills from average price.
  - Highest consumers are less sensitive/elastic to water pricing.

Thank You

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