HETEROGENEITY IN HOUSEHOLD RESPONSE TO NON-PRICE WATER CONSERVATION POLICIES: EVIDENCE FROM PANEL MICRO DATA

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Motivation

- Price vs. non-price conservation policies
  - "…using price increases to reduce demand, allowing consumers to adjust their end uses of water, is more cost effective than implementing nonprice demand management programs." (Olmstead & Stavins, WRR, 2009)
  - But in practice, price-based water conservation policies are rare. Why?

Rationales for Non-Price Conservation Policies

- Consumers are insensitive to price
- Changing municipal rate structures is costly
- Distributional effects
  - Tied to the notion that water is a basic necessity, some uses have less social value than others

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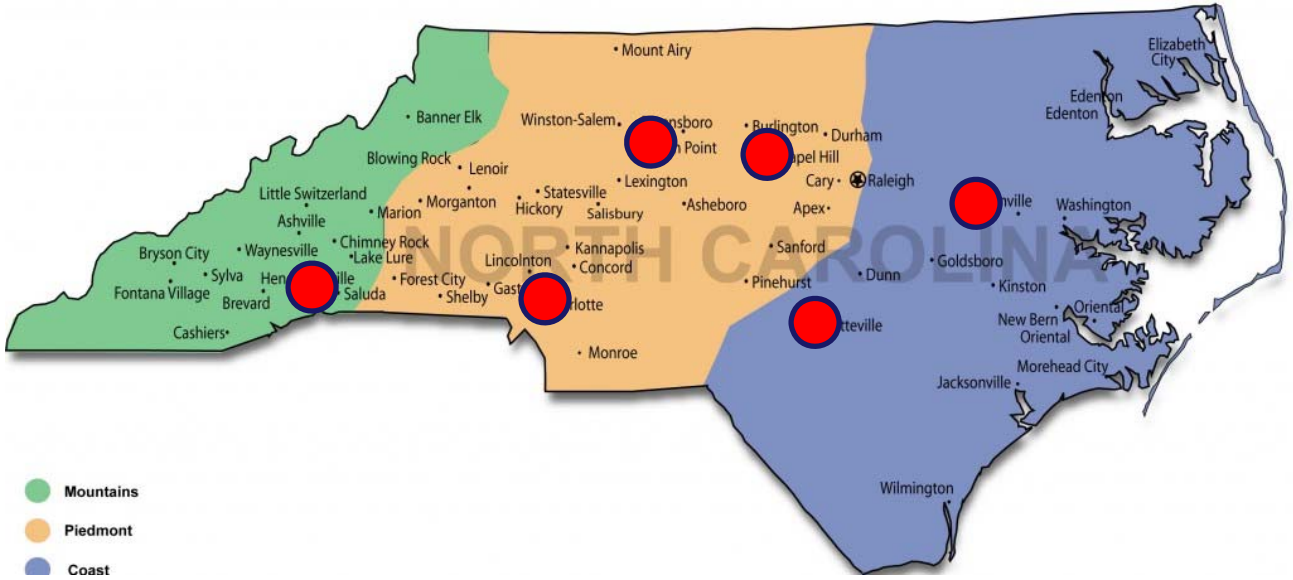
Research Question

- Existing empirical evidence suggests that poorer households are more responsive to price policies, but:
  - Are wealthier households more responsive to non-price policies?

Data

- Household water billing data
  - Monthly quantity consumed for ~17,000 households
  - July 2006 to December 2008 (30 months)
  - Chapel Hill, Charlotte, Fayetteville, Greenville, Hendersonville, High Point



Data

- Survey data
  - Household demographics and landscape characteristics
    - Single family detached homeowners
    - Lot size, square footage, irrigation habits, income, household occupancy
- Weather data
  - Monthly rainfall, maximum monthly temperature
- Price data
  - Gathered from utility rate sheets
  - Includes base service fees & sewer charges
  - Marginal and average price

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  - Household demographics and landscape characteristics
    - Single family detached homeowners (avg income = $122k)
    - Lot size, square footage, irrigation habits, income, household occupancy
- Weather data
  - Monthly rainfall, maximum monthly temperature
- Price data
  - Gathered from utility rate sheets
  - Includes base service fees & sewer charges
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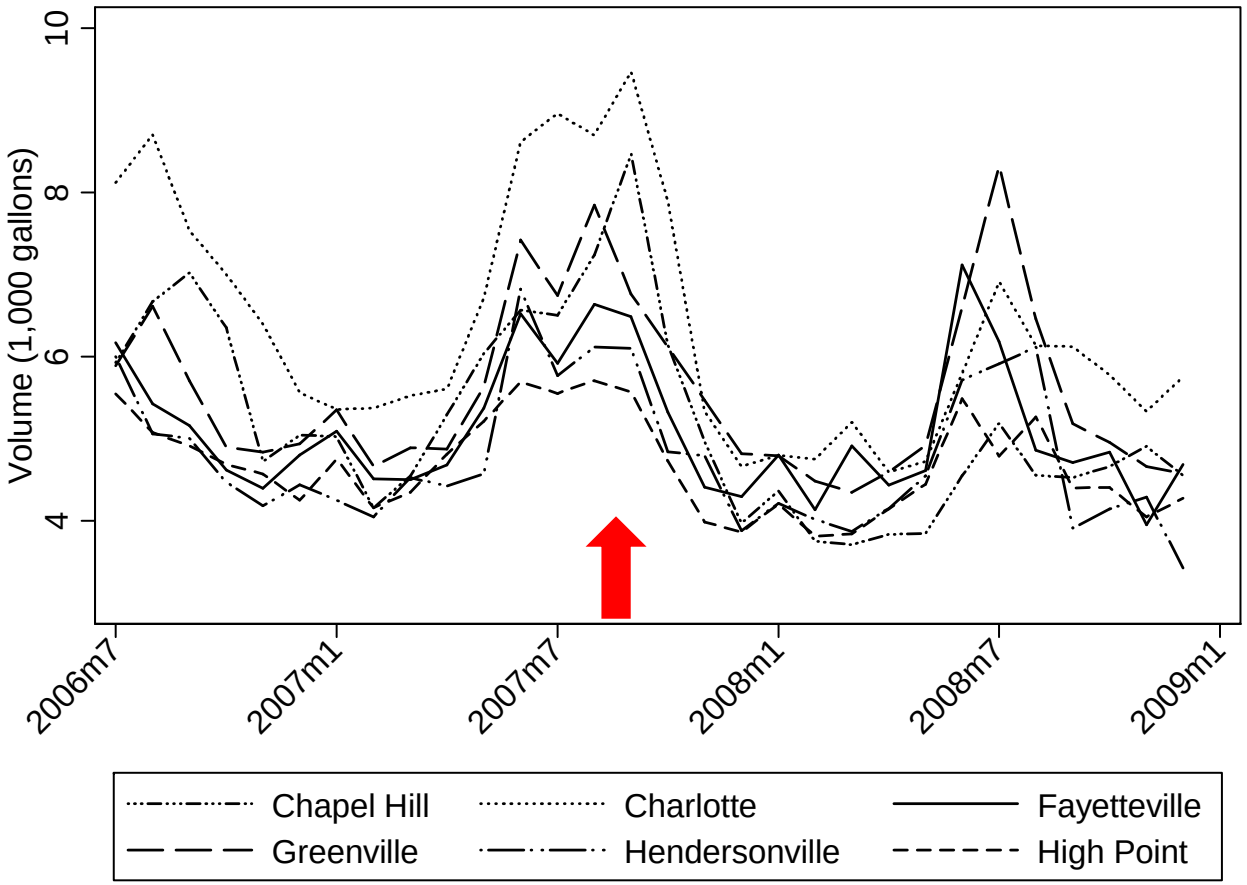
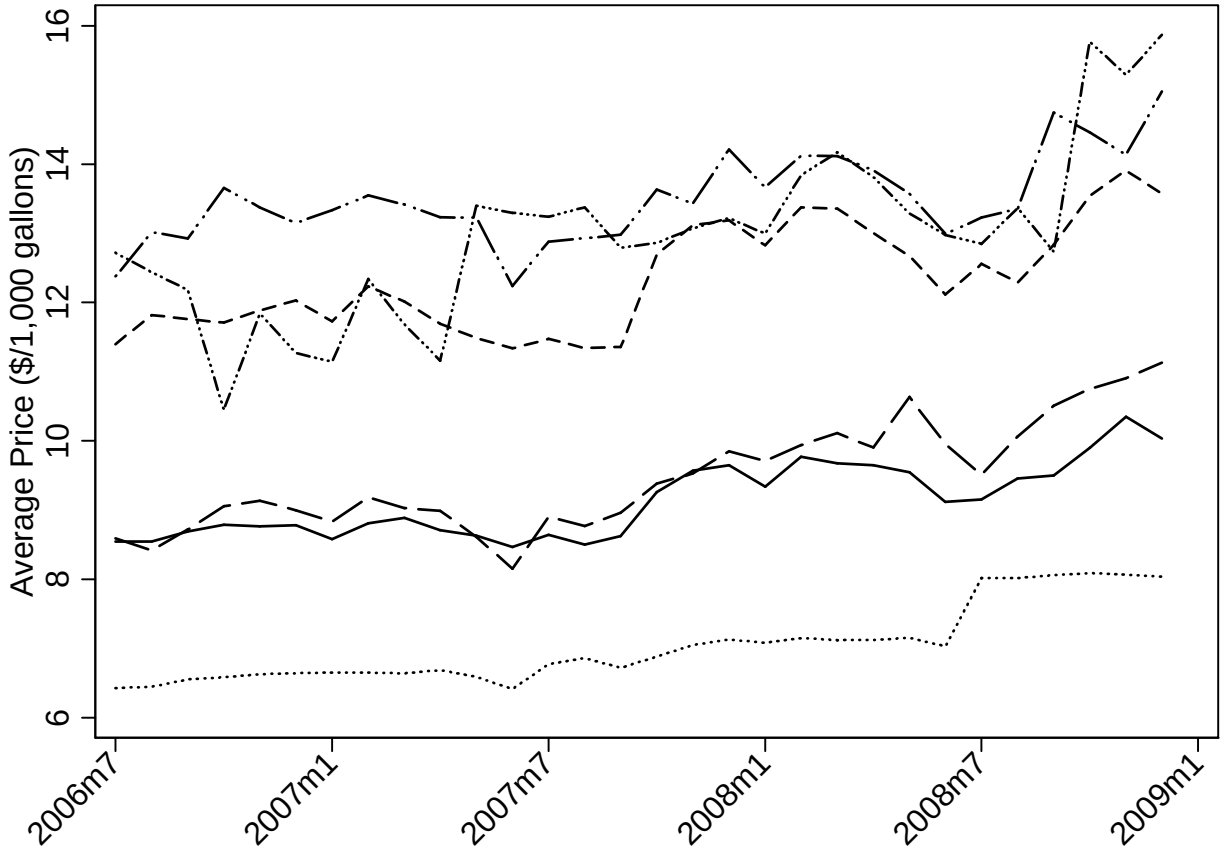
Mean Monthly Consumption



Mean Average Price



Summary Statistics

	Chapel Hill (n=234)	Charlotte (n=363)	Fayette-ville (n=388)	Green-ville (n=226)	Hender-sonville (n=245)	High Point (n=271)	Total (n=1,727)
	Monthly Household Water Consumption: 30 Month Average (1,000 gallons)						
Mean	5.240	6.384	5.119	5.579	4.792	4.688	5.344
Median	4.000	5.236	4.000	4.480	3.800	3.740	4.488
(std. dev.)	(3.852)	(5.021)	(3.702)	(4.165)	(3.764)	(3.062)	(4.056)
[5th – 95th Percentile]	[2.0–12.0]	[1.5–15.7]	[1.0–11.0]	[1.5–13.5]	[1.4–11.2]	[1.5–9.7]	[1.5–12.4]

Conservation Policies

	Voluntary Restrictions			Mandatory Restrictions		
	Turf irrigation	Other outdoor use		Turf irrigation	Non-turf irrigation	Other outdoor use
Chapel Hill	Odd-even	X		X	X	X
Hendersonville	Limited	X		X	Limited	X
Greenville	Limited	X				
High Point	Odd-even	X		X	Limited	X
Fayetteville				Odd-even		X
Charlotte	Limited			Odd-even	X	X

Note: "Odd-even" denotes an alternating watering schedule based on household's street address; "Limited" denotes that there are some time or quantity restrictions on water use; and "X" denotes a full restriction.

Policy Response

Water Restrictions

	2006						2007																		2008											
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Chapel Hill																V	M	M	M	M	M	V	V												
Hendersonville															V	V	V	V	V	V	V	V	V	V	V	M	M	V	V	V					
Greenville																		V	V	V	V	V	V												
High Point															V	M	V	V	V	V															
Fayetteville	M	M	M								M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Charlotte												V	V	V	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M

Drought Conditions

	2006						2007																		2008											
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Chapel Hill	0	0	0	0	0	0	0	0	0.8	0.5	1.2	1	1.8	2.5	3.8	4.2	3.5	5	4	4.3	3	1.8	0.3	1.3	2	2	2	2	1.5	0.4					
Hendersonville	1.5	1.4	0.5	0	0	0	0	0	0.8	1	1.6	2	2	3.5	4	4.8	5	5	5	5	4.3	3.8	3.3	4	4	4	2.4	2	1.5	0.4					
Greenville	0	0.2	0	0	0	0	0	0	0.8	0.5	1.6	2	2	2.8	4	4.6	3.8	5	5	4.8	3.3	2	1	1.8	2.2	1	0.2	0	0	0					
High Point	0	0.8	0.5	0	0	0	0	0	0.8	0.5	1	1	1.8	2.8	4	4.6	4.3	5	5	5	4.3	3.2	2.3	2.8	2.4	2.8	1	0	1	0.4					
Fayetteville	2	1.8	0.5	0	0	0	0	0.8	0.8	1.8	2.2	3	3	4.3	4	4.6	5	5	5	4.8	3.3	3	3.8	4.5	5	4.8	4	4	4.8	4.2					
Charlotte	0	0.8	0.5	0	0	0	0	0	0.8	0.5	1	1	1.8	2.8	4	4.6	4.5	5	5	5	4.3	3	1.5	2.3	2.2	2.8	0.8	0	0	0					

Empirical Model

- IV fixed effects demand specification:

$$\ln(q_{ikt}) = \beta_1 \ln(\hat{p}_{ikt-1}) + \beta_2 C_{kt} + \beta_3 (C_{kt} \times I_i) + \beta_4 \ln(W_{kt}) + \theta_t + \alpha_i + \epsilon_{ikt}$$

- where:
  - q_{ikt} is monthly consumption for household *i* in municipality *k* at time *t*
  - $\hat{p}_{ikt-1}$ is lagged price instrumented by rate schedule
  - C_{kt} is a vector of conservation dummies, I_i is household income
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Baseline Results

ln(VOLUME)	Average Price	Marginal Price
ln(AP)	-0.471***	
	(0.036)	
ln(MP)		-0.373***
		(0.041)
ln(DIFF)		-0.001***
		(0.000)
VOL_POLICY	-0.018***	-0.039***
	(0.005)	(0.006)
MAND_POLICY	-0.067***	-0.087***
	(0.006)	(0.007)
ln(RAIN)	-0.028***	-0.029***
	(0.003)	(0.003)
ln(TEMP)	0.512***	0.642***
	(0.049)	(0.051)
FE and Month Dummies	Yes	Yes
Observations	48,166	48,166
Within R-squared	0.123	0.070
Number of Households	1,727	1,727

Note: Fixed effects at the household and monthly level. Robust standard errors are presented in parentheses *, **, and *** represent significance at the 0.10, 0.05, and 0.01 level, respectively.

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Heterogeneous Effects

ln(VOLUME)	Voluntary Policy	Mandatory Policy
Chapel Hill	-0.093***	-0.119***
	(0.017)	(0.013)
Hendersonville	-0.027***	-0.112***
	(0.010)	(0.022)
Greenville	-0.040***	-
	(0.011)	-
High Point	-0.039***	-0.083***
	(0.009)	(0.022)
Fayetteville	-	0.008
	-	(0.008)
Charlotte	0.055***	-0.085***
	(0.016)	(0.010)
FE and Month Dummies	Yes	Yes
Observations	48,166	
Within R-squared	0.125	
Number of Households	1,727	

Note: The interaction of Fayetteville and voluntary policies is not identified because Fayetteville did not implement a voluntary policy within the period of the study. The same is true for Greenville and mandatory policies. Fixed effects are at the household and monthly level. Robust standard errors are presented in parentheses. *, **, and * represent significance at the 0.10, 0.05, and 0.01 level, respectively.**

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Heterogeneous Income Effects

ln(VOLUME)	Voluntary Policy	Mandatory Policy
Chapel Hill*Income	-0.037	-0.056**
	(0.028)	(0.022)
Hendersonville*Income	0.012	0.033
	(0.013)	(0.031)
Greenville*Income	-0.026**	-
	(0.012)	-
High Point*Income	0.005	0.026
	(0.014)	(0.032)
Fayetteville*Income	-	0.021*
	-	(0.012)
Charlotte*Income	0.097***	-0.004
	(0.019)	(0.011)
FE and Month Dummies	Yes	Yes
Observations	48,166	
Within R-squared	0.126	
Number of Households	1,727	

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Chapel Hill*Income	-0.036	-0.060***
	(0.029)	(0.022)
Hendersonville*Income	0.020	0.033
	(0.013)	(0.031)
Greenville*Income	-0.018	-
	(0.014)	-
High Point*Income	-0.011	0.012
	(0.016)	(0.034)
Fayetteville*Income	-	0.008
	-	(0.013)
Charlotte*Income	0.043**	0.000
	(0.020)	(0.011)
HH Size, Big Lot, and Irrigation Interactions	Yes	Yes
FE and Month Dummies	Yes	Yes
Observations	48,166	
Within R-squared	0.131	
Number of Households	1,727	

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Heterogeneous Income Effects

ln(VOLUME)	Voluntary Policy	Mandatory Policy
Chapel Hill*(Income>Median)	-0.038	-0.010
	(0.035)	(0.027)
Hendersonville*(Income>Median)	0.029	0.040
	(0.021)	(0.044)
Greenville*(Income>Median)	-0.045**	-
	(0.021)	-
High Point*(Income>Median)	-0.002	0.047
	(0.018)	(0.041)
Fayetteville*(Income>Median)	-	0.015
	-	(0.016)
Charlotte*(Income>Median)	0.166***	-0.011
	(0.031)	(0.018)
FE and Month Dummies	Yes	Yes
Observations	48,166	
Within R-squared	0.126	
Number of Households	1,727	

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ln(VOLUME)	Voluntary Policy	Mandatory Policy
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	(0.036)	(0.029)
Hendersonville*(Income>Median)	0.046**	0.052
	(0.021)	(0.044)
Greenville*(Income>Median)	-0.048**	-
	(0.022)	-
High Point*(Income>Median)	-0.020	0.025
	(0.019)	(0.042)
Fayetteville*(Income>Median)	-	-0.007
	-	(0.017)
Charlotte*(Income>Median)	0.072**	-0.008
	(0.035)	(0.019)
HH Size, Big Lot, and Irrigation Interactions	Yes	Yes
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Conclusions / Extensions

- Consumers sensitive to price
- Non-price policy effects are heterogeneous
  - Differential effects across municipalities
  - Correlation w/ income is weak
- Next steps
  - Price / income interactions
  - Marginal price results
  - Quantile regressions
  - ??