Measuring the Energy Savings from Tree Shade

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Camp Resources
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Question & Motivation

Research Questions

- Does tree shade reduce household electricity use?
- Do the energy savings from tree shade coincide with peak electricity demand during summer months?

Demand Side Management

- Trees cool homes during peak demand for air-conditioning
- Generation capacity built-up to meet peak summer demand

Policy Relevance

- Tree ordinances exist in 3,213 U.S. cities
- 2012 California "solar-ready" building code discourages shade trees

Past Literature

Donnovan & Butry (2009) ; Pandit & Laband (2010)

- Identification: cross-section, small sample, few controls
- Problems: omitted variable bias, endogeneity

New Contributions

- Quasi-experimental (DD) approach identifies change in residential electricity use caused by a tree removal
- Matching estimator

Gainesville Data (2000-2011)

Tree Removal Permits *(Gainesville City Arborist)*

- 3,500 tree removal permits, required for all mature tree removals
- Issue date, property address, tree species, replanting mandates

Household Billing Data *(Gainesville Regional Utility)*

- 30,000 households matched to property address
- Monthly electricity, natural gas, and water use

Housing Characteristics *(Alachua County Property Appraisal Office)*

- Structural (sqft, age) + Energy (HVAC, insulation, materials)
- Building permits including installation date and type of upgrade

Data Cleaning

- 21,929 homes >90% balanced panels from 2000-2012
- 519 tree removal treatments matched to billing data

Two-Way Fixed Effects Model

$$y_{it} = \lambda_t + c_i + \tau_1 w_{it} + w_{it}\psi_s\tau_2 + \psi_s\gamma + \varepsilon_{it},\ t = 1, ..., T,\ s = 1, 2, 3$$

$$\varepsilon_{it} = \rho\varepsilon_{i,t-1} + u_{it} \quad and, \ |\rho| < 1$$

y_{it} : electricity consumption (kWh) for household i in month t
λ_t : indicator variable for month of billing period ($year * month$)
c_i : indicator variable for household
w_{it}: indicator variable equal to one in **periods after tree removal** for household where a tree was removed.
ψ_s : indicator variable for season s (*fall/spring*, *summer*, *winter*)
ε_{it} : error term with AR(1) correction (to capture unobserved seasonal variation in use of heating and cooling systems).
u_{it} : spherical error term
τ_1 : average treatment effect (which persists over time).

Descriptive Statistics

Baseline electricity use and home size

	Treatment		Control			
			Census		Matching	
Variables	**Mean**	**S.D**	**Mean**	**S.D.**	**Mean**	**S.D.**
winter (kWh)	1,058	777	1,076	779	1,048	728
spring (kWh)	842	467	857	519	861	488
summer(kWh)	1,359	827	1,363	848	1,366	837
fall (kWh)	1,119	610	1,128	623	1,118	597
square feet	1,789	672	1,751	724	1,746	668
N months	131	4	131	4	131	4
N homes	519		21,929		519	

*kWh variables reflect average monthly electricity use by season in 2001

Results

Dependent variable: monthly electricity usage (kWh)				
	(1)		*(2)*	
	Census		*Matching*	
aftertreat	*27.1*	***	*34.7*	***
	(8.0)		*(9.1)*	
*aftertreat*summer*	*17.1*	**	*21.8*	**
	(6.8)		*(8.6)*	
*aftertreat*winter*	*-19.4*	***	*-15.5*	*
	(6.7)		*(8.5)*	
summer	*721.0*	***	*732.6*	***
	(5.1)		*(25.4)*	
winter	*406.3*	***	*420.2*	***
	(4.6)		*(23.0)*	
constant	*620.1*	***	*577.5*	***
	(1.9)		*(10.6)*	
Fixed Effects				
household	*YES*		*YES*	
*year*month*	*YES*		*YES*	
N observations	*2,949,541*		*135,312*	
N homes	*22,448*		*1,038*	

Extensions

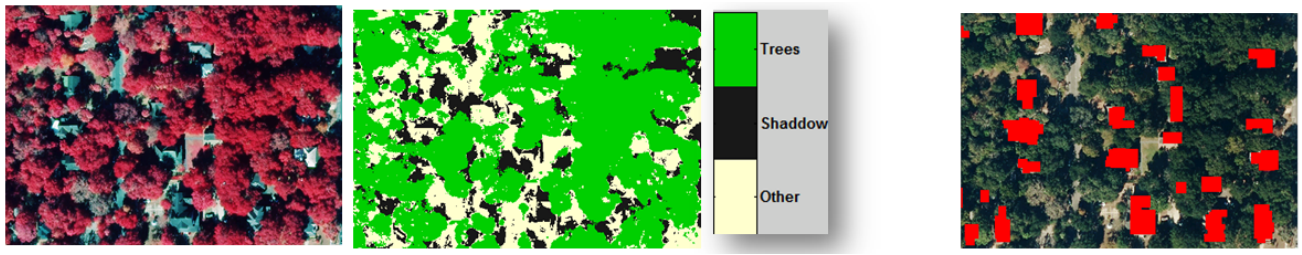
Tree Shade Change

$$\Delta Shade = f(tree\ location,\ tree\ height,\ house\ orientation)$$

$$\Downarrow \qquad \Downarrow \qquad \Downarrow$$

$$aerial\ imagery,\ LiDAR\ data,\ GIS\ building\ footprint$$

$$\Downarrow \qquad \Downarrow$$



- falsification test (or new control group) using no-shade removals
- spillovers analysis (change in shade on neighboring property)

Building Permit Data

- control for time variant structural changes

Future Study

Energy Savings from Retrofits

- 15,000 retrofits (installation date, cost, rebate)
- Solar panels, high-efficieny AC, duct-repair, energy star
  - Tradeoff between solar panel and tree shade
  - Cost-effectiveness comparison to tree ordinance

Conclusion

Objective

- Quasi-experimental design establishes a causal link between trees and energy use

Results

- Summer energy penalty about 4 percent of baseline electricity use

Future work

- Tree shade metric & policy analysis

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† *Thanks to US Forest Service for grant to classify aerial imagery*