Legacy and Shockwaves

A spatial analysis of strengthening resilience of the power grid in Connecticut

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Introduction

- The electric grid is a network connected across space
  - Interactions with one part of the grid can have implications down or up stream
- Understanding how costs or benefits (outages or avoidance) propagate throughout the state
- Finding those links between TTOs and tree-caused power outages (>5 minuets) within Connecticut from 2009 to 2015
- Specifically:
  - We want to investigate whether spatial spillovers throughout the grid increase the spatial extent of TTO benefits previously found by Parent et al. (2019) and Graziano et al. (2020)
  - Are these benefits pervasive in time?
  - Do TTO benefits last four years?

Data sources

Variable	Observations	Mean	Std. Dev.	Min	Max	Source
Distribution Lines in m	21,623	8,842.60	6,536.00	3.00	43,710	Eversource Energy
Four-year legacy of TTOs	21,623	0.29	0.45	0.00	1	Eversource Energy
Number of tree outages	21,623	4.84	9.28	0.00	142	Eversource Energy
Log duration of tree outages in min	21,623	5.49	3.69	0.00	13.54	Eversource Energy
Customers affected by tree outages	21,623	210.62	622.77	0.00	17,356	Eversource Energy
Squared sum of average precipitations	21,623	86.78	36.89	0.00	243.72	Thornton (2017)
Squared sum of average maximum temperature	21,623	340.01	32.83	0.00	425.32	Thornton (2017)
Squared sum of average minimum temperature	21,623	117.13	11.39	0.00	154.12	Thornton (2017)
Cooling degree days	21,623	24,684.57	3,498.14	0.00	34,478.10	Author derived
Heating degree days	21,623	36,973.24	12,535.94	0.00	73,446	Author derived
Percent forested	21,623	52.43	24.01	0.00	96	USGS GAP

[1] Thornton, P. E., Thornton, M. M., Mayer, B. W., Wei, Y., Devarkonda, R., Vose, R. S., & Cook, R. B. (2017). Daymet: Daily Surface Weather Data on a 1-km Grid for North America, Version 3. ORNL Distributed Active Archive Center. https://doi.org/10.3334/ORNLDAAC/1328.

[4] USGS GAP. https://www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap

Modeling TTOs and Tree-caused Power Outages

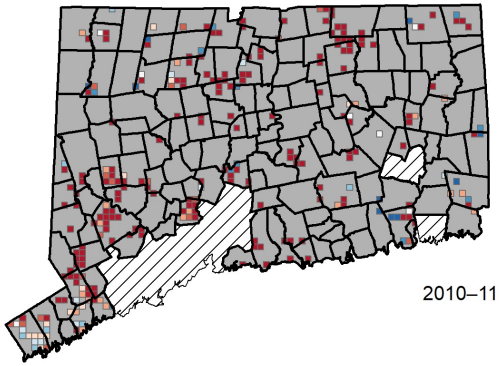
Temporal Modeling

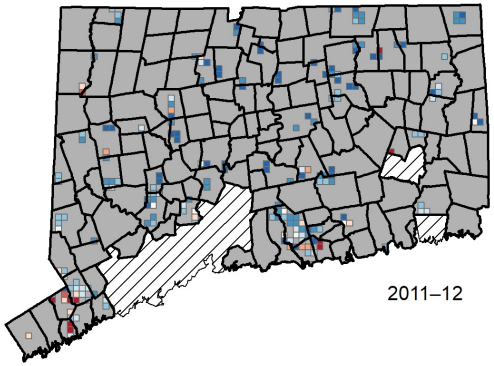
- Panel regression at 2 and 4km
- OLS, Poisson, Negative Binomial
- Dependent variables
  - Tree-cased outages, duration, customers affected
- Independent variables
  - Percent forested, four-year trimming legacy, metrological, and error term

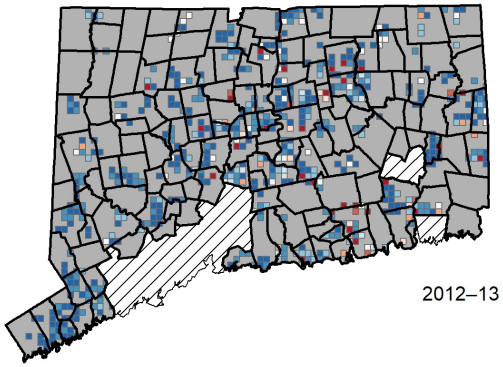
Modeling TTOs and Tree-caused Power Outages

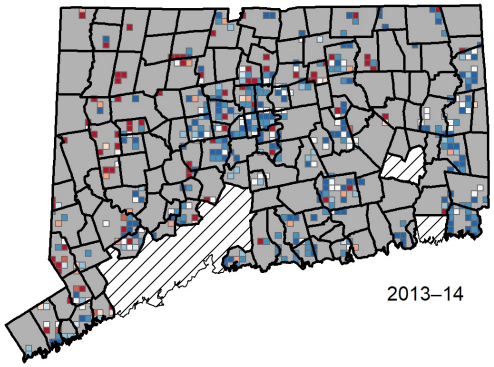
Spatial-Temporal Modeling

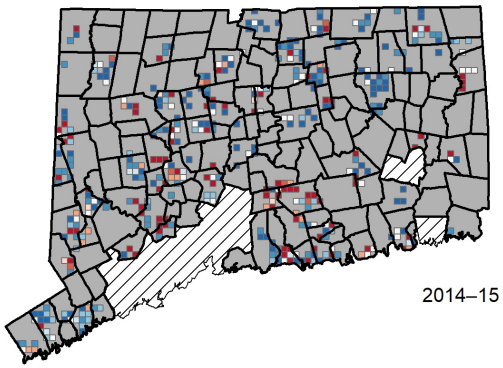
- Spatial-Panel regression at 2 and 4km
- Spatial autoregressive (SAR)
  - Time-dependency
- Spatial Durbin Model (SDM)
  - Spatial heterogeneity
- SAR and SDM share a spatial weighting matrix (queen row standardized)
- Log of X per km of distribution lines per cell









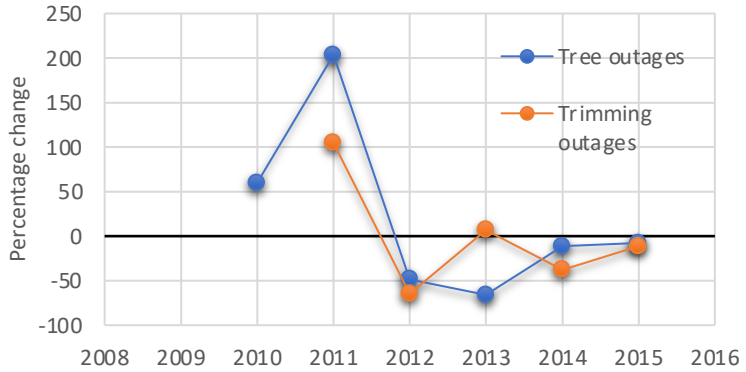


Percentage Change in Tree Caused Power Outages from 2010 to 2015

Percentage change

- < (-75)
- -74–(-50)
- -49–(-25)
- -24–(-1)
- No change
- 1–25
- 26–50
- 51–75
- 76 <

- Towns
- Areas not trimmed
- Not served by Eversource



TTOs in real terms

Spatial-Temporal 2km Results

- Average reduction in outages per year
  - 91 fewer (within a cell)
  - 737 fewer (neighboring cells)
- Average reduction in duration
  - 364.81 (within a cell)
  - 88,142.72 (neighboring cells)
- Average reduction in customers affected
  - 2,134 (within a cell)
  - 19,446 (neighboring cells)

TTOs in real terms

Temporal 2km results

- 900 fewer outages per year
- Reduction of 5,575,898 outage minuets per year
  - 54% of total outages
- 18,186 fewer customers affected per year on average

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Thank you

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EVERSOURCE

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