The influence of spatial setting and socioeconomic profile in inner-city and suburban areas on the diffusion of residential PV systems

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Outline

- Motivation
- Introduction
- Literature review
- Empirical analysis
- Conclusions and Implications

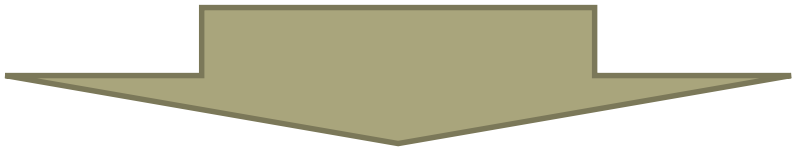
Introduction

- Support in US has increased the past few years
- High upfront capital costs, PV driven by:
  - information flows between peers and
  - through social networks
- Price continues to fall therefore, information-based drivers, and the role of non-monetary barriers becomes more important shifting to low-carbon options
- Need of improving the understanding of non-monetary adoption factors in order to
  - better incorporate solar systems into utility planning
  - increasing resilience throughout the electricity network.

Research question & motivation

- What is the role of the jurisdictional and built-in environment in the adoption of PV systems?

- What degree of generalization can be reached by analysts when studying social and spatial drivers to adoption of PV systems?



Does underlying human and physical geographies influence peer effects and diffusion?

General findings

- Differences related to urban geography, jurisdictional fragm., and socioeconomic levels, affect the dynamics of diffusion
- The interaction among socioeconomic demographic and spatial elements does not always follow the same patterns because mediated by institutional and social factors
- Policies aimed at expanding the base of adopters overcoming the distortions generated by interaction of policies and the human geography are needed (e.g. target more densely populated and lower income areas, multi-family buildings, and easing solar community gardens).
- A better understanding of profile adopters and adoption patterns within areas at the bottom of their adoption curve, which would make it easier for utilities and policymakers to address potential needs within the power grid system

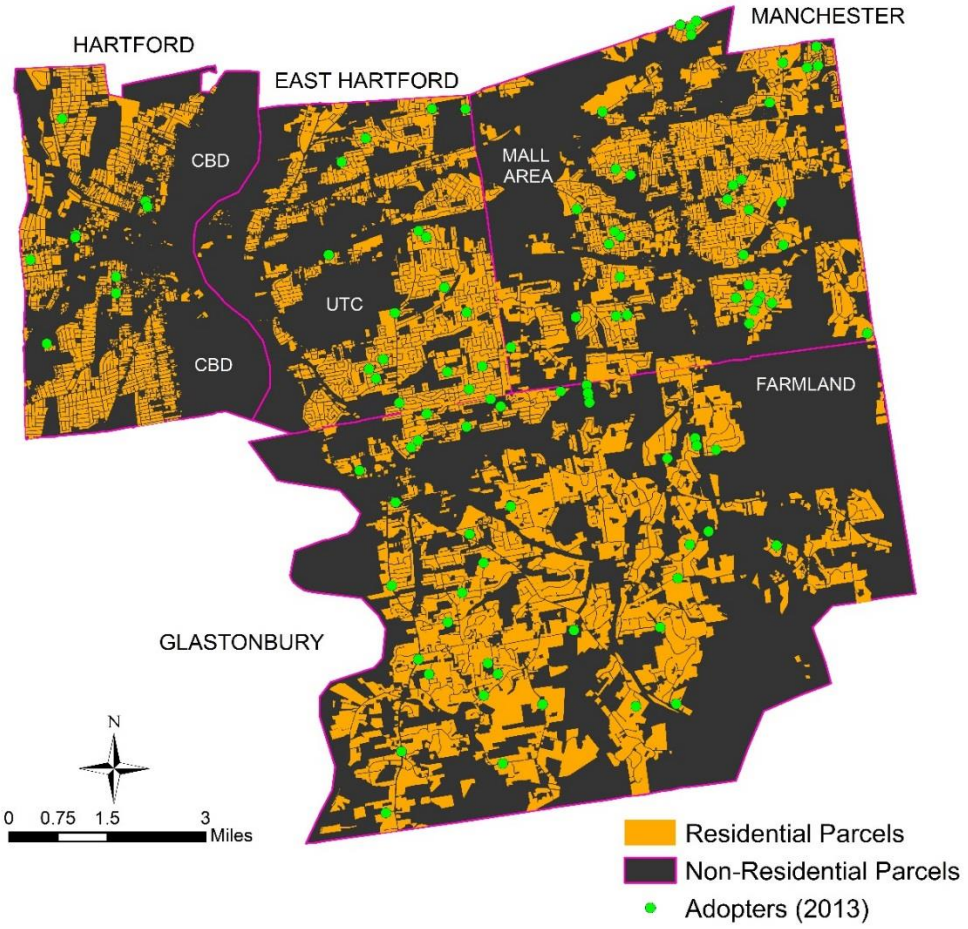
Policy recommendations

- Differences in the adopter's neighborhood profiles among the towns, and between each town
  - policies promoting the adoption should account for multi-family housing units, possibly through solar cooperatives or community organizations
- Spatial peer effect within 0.5 miles, but within-block group effects are stronger than those from neighboring block groups
  - spatial peer effect can be used as way to accelerate the adoption, at least at the early stages of adoption)
- As the spatial peer effect fades, other variables come in to play to influence adoption, mainly in relation to race and age
- Lack of influence of the controls for the general state of the economy (DJ CPI; unemployment rate)
  - It suggest a strong, independent resilience of PV diffusion wrt to the macroeconomic fluctuations of the local economy

Policy recommendations

- Spatial gaps does matter
  - In towns with large spatial gaps between residential areas , group-based programs should be replicated within the same spatial region.

Study area and context



Data sources & methodologies

- Block group level when possible
- The time period is January 2005 - September 2013 (35 qrts)

Variable	Mean	Std. Dev.	Min	Max	Source
Number of new Adoptions	0.05	0.22	0.00	1.00	CEFIA (2013)
Cumulative Installed Base	0.16	0.54	0.00	7.00	CEFIA (2013)
Average Neighbors within 0.5 Mile (6 months)	0.01	0.11	0.00	3.00	Calculated from CEFIA (2013)
Average Neighbors within 0.5 Mile (12 months)	0.02	0.29	0.00	16.00	Calculated from CEFIA (2013)
Average Neighbors within 1 Mile (6 months)	0.01	0.18	0.00	5.50	Calculated from CEFIA (2013)
Average Neighbors within 1 Mile (12 months)	0.03	0.53	0.00	30.00	Calculated from CEFIA (2013)
Average Neighbors within 1.5 Mile (6 months)	0.01	0.08	0.00	2.50	Calculated from CEFIA (2013)
Average Neighbors within 1.5 Mile (12 months)	0.01	0.26	0.00	14.00	Calculated from CEFIA (2013)
Average Neighbors within 4 Miles (6 months)	0.05	0.61	0.00	19.00	Calculated from CEFIA (2013)
Average Neighbors within 4 Miles (12 months)	0.10	1.74	0.00	102.00	Calculated from CEFIA (2013)
Number of Housing Units (000s)	0.62	0.40	0.05	3.65	U.S Census
% of Rent-occupied Houses	51.32	33.76	0.00	100.00	U.S Census
% of Houses >5 bedrooms	3.49	6.29	0.00	65.86	U.S Census
Gross Housing Density	1561.32	2230.40	9.50	28908.94	U.S Census
Number of Housing Units (000s)	0.62	0.40	0.05	3.65	U.S Census
Median Household Income ($10,000)	5.47	3.62	0.15	25.57	U.S Census
Dow Jones Level (1,000)	11.66	1.59	8.89	14.87	U.S Census
% pop who are white	52.07	28.75	0.00	100.00	U.S Census
% pop who are black	25.82	25.14	0.00	100.00	U.S Census
% pop who are Asians	5.41	8.00	0.00	73.12	U.S Census
Median Age	36.62	9.42	11.61	80.00	U.S Census
% Registered to minority parties	0.42	0.46	0.00	2.82	CT SOTS
% Registered to the Democratic Party	53.44	16.36	21.80	75.23	CT SOTS
Static Variables					
Net Housing Density	886.49	523.23	0.00	2753.67	Calculated
Share of Single-Family Houses	55.67	35.12	0	100.25	Calculated

Data sources & methodologies

- Spatiotemporal variable developed Graziano and Gillingham: it aggregates at block group level the number of PV installations within 6 and 12 months from each actual PV system location at various spatial distances starting 0.5 miles.
- Parcel data to calculate the net housing density (rather than using only the gross measure).
- Single-family houses within each block group

To capture the differences of users within the study area we use three methodologies:

- Hierarchical clustering (Dendrogram with 4 optimal clusters)
- Spatial inference
- Panel data

Adopter's profile

Characteristic	East Hartford	Glastonbury	Hartford	Manchester	Study Area
Income	High income	Middle income	Middle-lower income	High income	High income
Race	White	Diverse	White	Diverse	White
Home Ownership	Homeowner	Homeowner	Homeowner	Non-homeowner	Homeowner
House Size	Large houses	Smaller houses	Large houses	Large houses	Large houses
Housing Age	Recent houses	Old houses	Recent houses	Old houses	Recent houses
Residents Age	Relatively old	Relatively young	Relatively old	Relatively old	Relatively old
Housing Density	In sparsely populated neighborhood	In sparsely populated neighborhood	In densely populated neighborhood	In sparsely populated neighborhood	In sparsely populated neighborhood
Housing Type	Single family	Single family	Mixed	Single family	Single Family

Model selection

- Panel fixed-effect and static models:

$$PVcount_{i,t} = \alpha + \beta N_{i,t} + \gamma B_{i,t} + \vartheta D_{i,t} + \mu_i + \psi_t + \varepsilon_{i,t}$$

- Spatial Autoregressive Model (SAR):

$$PVcount_{i,t} = \rho W PVcount_{i,t} + \beta N_{i,t} + a_i + \gamma_i + \varepsilon_t$$

Panel data

	Cumulative Base, Block FE (1)	0.5 mile, 6 Months, Block FE (2)	0.5 mile, 12 Months, Block FE (3)
# PV installed	0.716*** (0.154)		
Spatial Peer Effect		4.125** (1.221)	1.082** (0.241)
Minority* Proximity (0.5 miles)	-0.083 (0.059)	-0.161** (0.035)	-0.072 (0.040)
Minority*Proximity (1.0 miles)	0.150** (0.060)	0.139 (0.065)	0.140* (0.052)
Minority* Proximity (4 miles)	0.012 (0.015)	0.012 (0.015)	0.014 (0.014)
Median HH Income * Proximity (0.5 miles)	0.141 (0.103)	-0.127 (0.113)	0.120* (0.040)
Median HH Income * Proximity (1.0 miles)	-0.128* (0.074)	-0.038 (0.066)	-0.135** (0.034)
Median HH Income * Proximity (4 miles)	0.072** (0.034)	0.083* (0.034)	0.077* (0.029)
If income >$100,000	-0.007 (0.091)	-0.051 (0.076)	-0.043 (0.046)
Built Environment	Y	Y	Y
Socio-Demographics	Y	Y	Y
Political Affiliation	Y	Y	Y
Quarter dummies	Y	Y	Y
Constant	-0.302 (0.239)	-0.317 (0.506)	-0.141 (0.481)
R-squared	0.450	0.419	0.481
Observations	7,175	7,175	7,175

Static model

	Installed Base (1)	0.5 mile, 6 Months, Block FE (2)	0.5 mile, 12 Months, Block FE (3)
# PV Installed	0.4425*** (0.0348)		
Spatial Peer Effect		6.8583*** (0.8446)	0.4057** (0.0837)
Number of Housing Units (1,000s)	-0.0600 (0.0934)	-0.0043 (0.0622)	-0.0265 (0.04449)
If income >$100,000	-0.1105 (0.3056)	0.2059 (0.4952)	0.4839 (0.2990)
% of Renter-occupied Houses	0.0016 (0.0016)	-0.0038** (0.0011)	-0.0035** (0.0008)
% of Single-family parcels	0.0015 (0.0021)	0.0002 (0.0016)	-0.0004 (0.0008)
Net Housing Density (# residential parcels/sq.km of residential parcels)	0.0004 (0.0002)	0.0001 (0.0001)	0.0001** (0.0000)
Socio-Demographics Controls	Y	Y	Y
Built Environment	Y	Y	Y
Socio-Demographics	Y	Y	Y
Political Affiliation	Y	Y	Y
Constant	-1.525 (0.653)	-0.897* (0.290)	-0.553* (0.192)
R-squared	0.2872	0.2046	0.4988
Observations	205	205	205

Spatial Insight

	SEM (1)	SAR (2)	SAC (3)
Average Neighbors within 0.5 Miles (6 months Average)	0.57424*** (0.07432)	0.57522*** (0.07460)	0.57764*** (0.07804)
% of Renter-occupied houses	-0.00025 (0.00021)	-0.00026 (0.00021)	-0.00022** (0.00011)
Built environment Controls	Y	Y	Y
Socio Demographic Controls	Y	Y	Y
Race Controls	Y	Y	Y
Political Affiliation	Y	Y	Y
Lambda	0.05146** (0.02022)	N/A	-0.06670 (0.14950)
Rho	N/A	0.06106*** (0.00770)	0.14215 (0.11921)
Variance	0.01153* (0.00648)	0.01152* (0.00647)	0.01197* (0.00651)
R-squared	0.26060	0.26056	0.27338
Observations	7,175	7,175	7,175

Spatial Insight

	SAR Model
Main	
Average Neighbours within 0.5 Miles (6 months Av.)	0.57899*** (0.07591)
Spatial Effects	
Rho	0.06147*** (0.00988)
Variance	0.01159*
σ^2	(0.00654)
Direct	
Average Neighbours within 0.5 Miles (6 months Av.)	0.28987*** (0.06139)
Indirect	
Average Neighbours within 0.5 Miles (6 months Av.)	0.03798*** (0.00804)
Total	
0.5 miles, 6 months	0.61618*** (0.06885)
R-squared	0.27042
Observations	7,175