



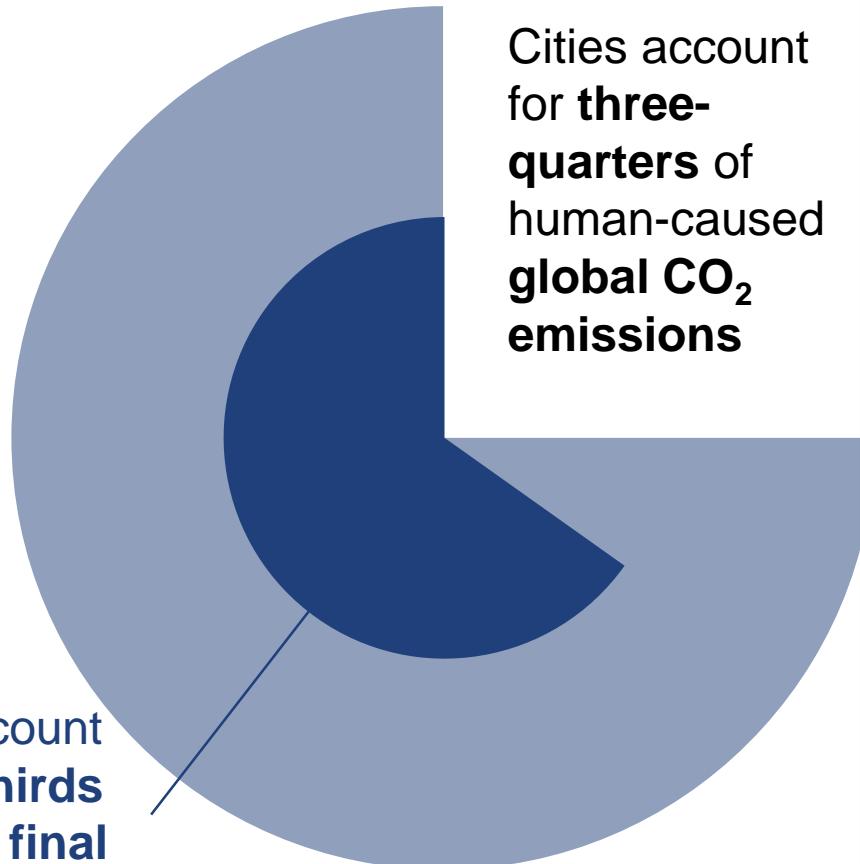
Diffusion of Solar Photovoltaics and Role of Extremists

Jordi Fornt-Mas, Sourya Kovvali, Alejandro Nuñez-Jimenez, Marius Schwarz

Motivation

Cities account for two-thirds of global final energy use

REN21, 2019



Cities account for **three-quarters** of human-caused global CO₂ emissions

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A high-resolution geospatial assessment of the rooftop solar photovoltaic potential in the European Union

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ABSTRACT

Rooftop solar photovoltaic (PV) systems can make a significant contribution to Europe's energy security. Realising this potential raises challenges at policy and electricity system planning levels. The authors have developed a geospatially explicit methodology using up-to-date building stock to quantify the available rooftop area for PV systems. To do this, they used statistical data sources with machine learning to provide a reliable assessment of rooftop PV electricity production with a spatial resolution of 100 m across the EU. The results show that the EU rooftops could potentially produce 24% of current electricity consumption annually (representing 24.4% of current electricity consumption), two thirds of which at a cost lower than current residential tariffs. Country aggregated results illustrate existing barriers in countries with low electricity prices and high investment interest rates, as well as how to address these.

1. Introduction

Decentralised electricity generation with renewable technologies such as rooftop PV systems can contribute significant power capacity additions through a large number of smaller-scale installations, taking advantage of the continuously decreasing cost of PV installations [1]. This category covers a wide range of sizes, from residential roofs with systems of a few kW to large-area commercial roofs. The owners are typically prosumers and include citizens acting as private individuals or in energy communities or cooperatives, as well as businesses. In 2017, the PV contribution to the EU electricity demand was 114 TWh, from an installed capacity of 107 GW. Considering that the share of residential and commercial rooftop systems is estimated at 28% and 18% respectively,

EU will thus need to increase its use of renewable energy in the power sector to at least 65%, with the contribution of solar being of the order of 440 TWh/year [3]. This implies scope for tens of millions of new rooftop systems.

In parallel is the aim to minimise or phase support schemes as renewables become market competitive. The EU has shifted from feed-in tariff (FIT) subsidy schemes towards more market-driven mechanisms (e.g. competitive auctions) aiming to eventually reach subsidy-free energy systems' deployment. The European Commission (EC) guidelines on state aid for environmental protection and energy [4] describe the conditions under which aid for energy may be considered compatible and does not adversely affect trading conditions. It also foresees specific exceptions for installations of a "certain size", a measure af-



Solar PV on the rooftop of buildings could generate 24% of Europe's electricity demand

Motivation

Policies focus on **energy communities** to boost the diffusion of renewable energies



EU 2019/944
CH 2019 EnG, EnV

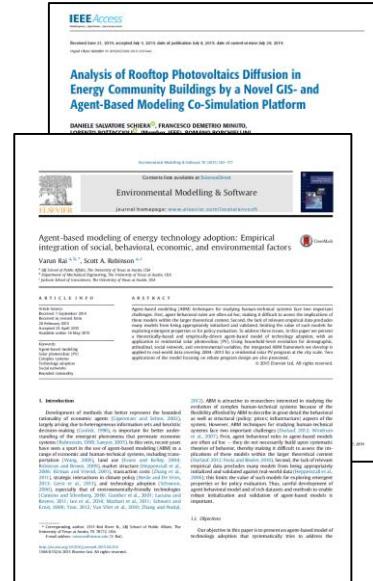


Empirical studies show **importance of active peer effects in solar communities**

Noll et al. 2014

ABMs on opinion dynamics highlight the **impact of extremism**

Deffuant et al. 2002



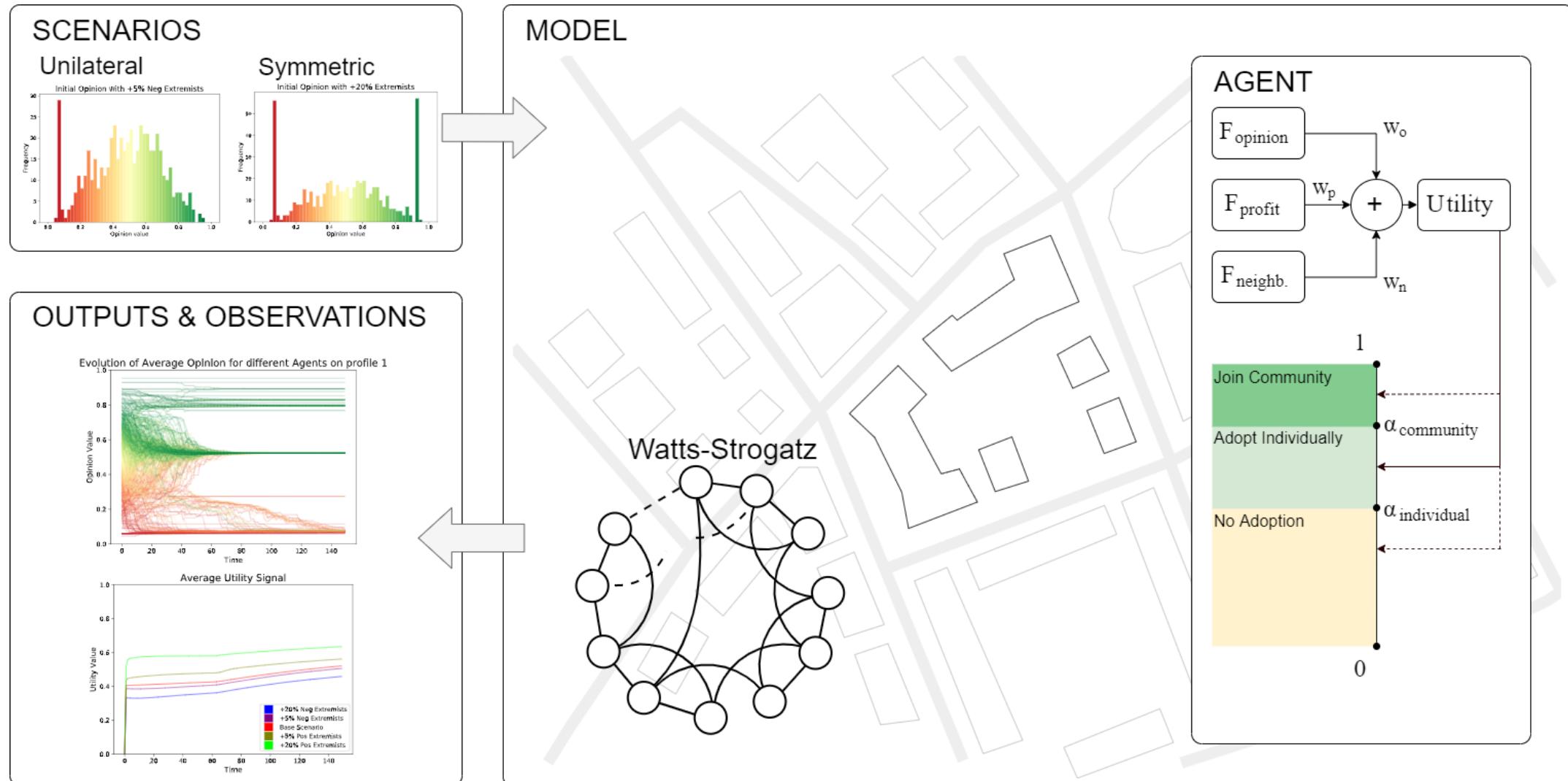
ABMs on solar PV diffusion focus on individual adoption or one-building communities

Schiera et al. 2019
Rai, Robinson 2015



What is the role of opinion extremists in the diffusion of individual and community solar photovoltaics in cities?

Model and Agents



Agent Profitability and Neighbourhood Pressure

Profitability Factor

$$F_{\text{profitability}} = 1 - PT_i / PT_{\max}$$

PT_{\max} Maximum Bound Payback time

PT_i Payback time for agent i

$PT_i = I_{PV,i} / CF_{PV,I}$

$$= \frac{\text{price-per-watt} \cdot \text{size}}{CF_{AC} + CF_{FIR} + CF_{OM}}$$

AC

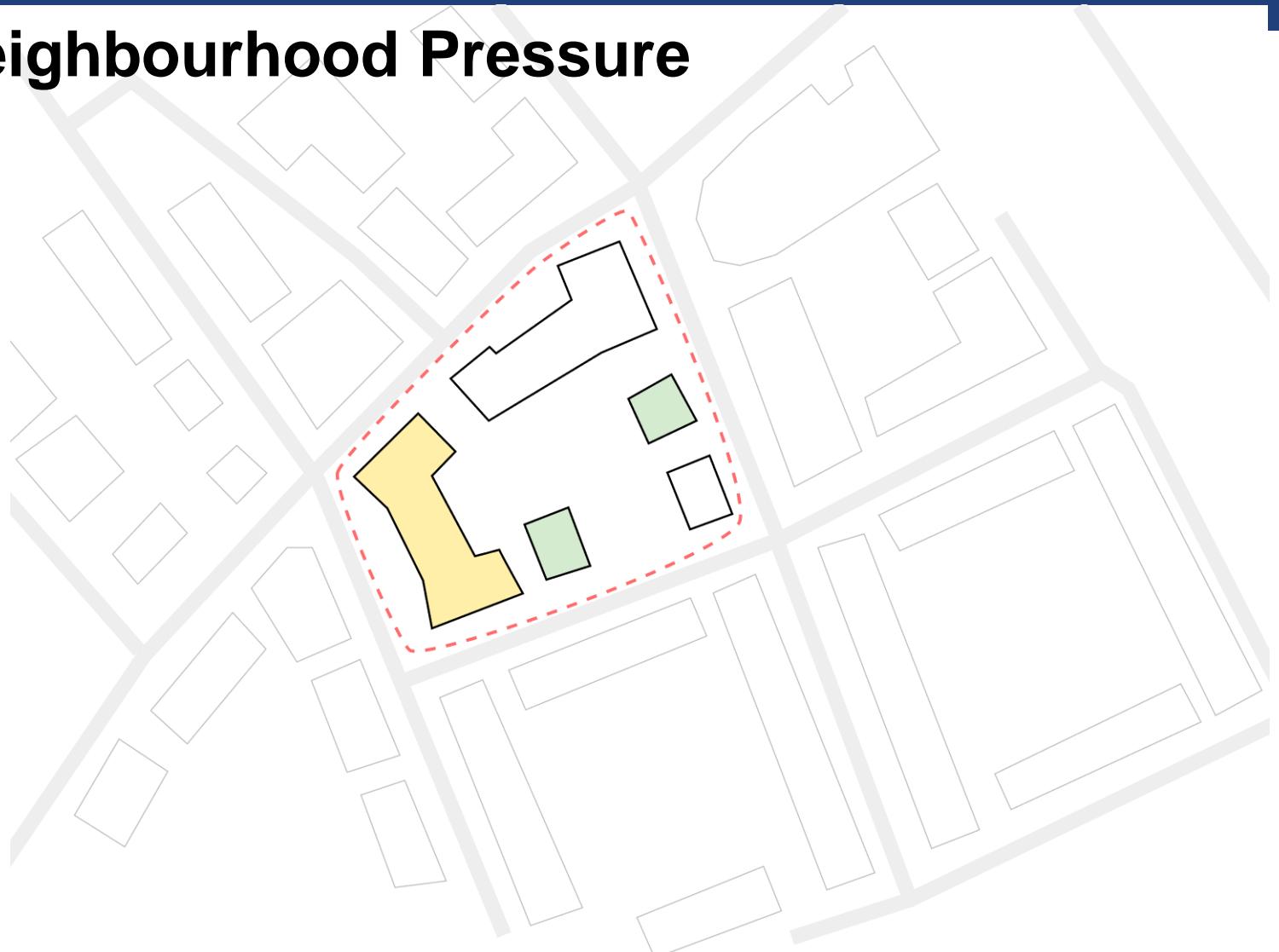
Avoided Costs

FIR

Feed-in Remuneration

OM

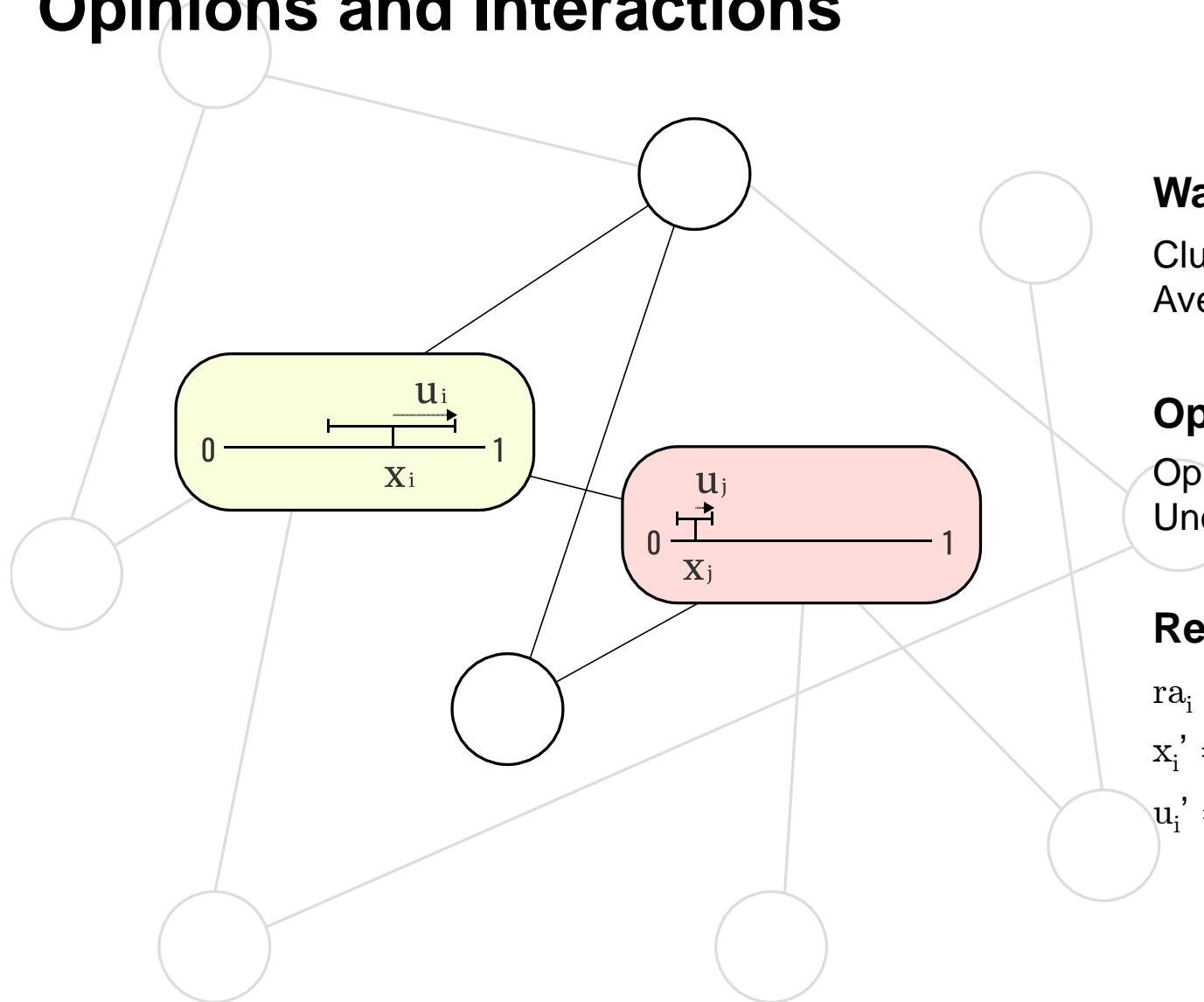
Operation and Maintenance Costs



Neighbor Factor

$$F_{\text{neighbor}} = n_{\text{community}} / n_{\text{total}}$$

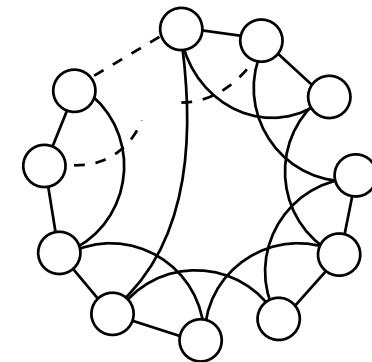
Opinions and Interactions



Watts-Strogatz SWN

Clustering Coefficient
Average Shortest Path

0.24
3.65



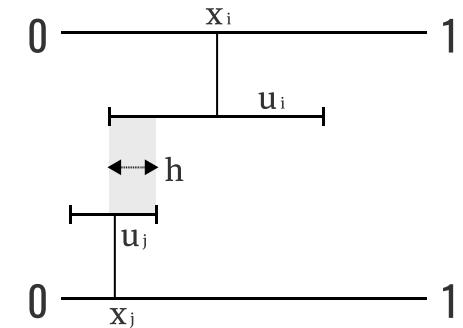
Opinion and Uncertainty Model

Opinion of Agent i (F_{opinion})
Uncertainty

$$x_i \\ u_i = x_i (1 - x_i)$$

Relative Agreement Algorithm

$$ra_i = \max(0, h/u_j - 1) \\ x_i' = x_i + \mu ra_i (x_i - x_j) \\ u_i' = u_i + \mu ra_i (u_i - u_j)$$

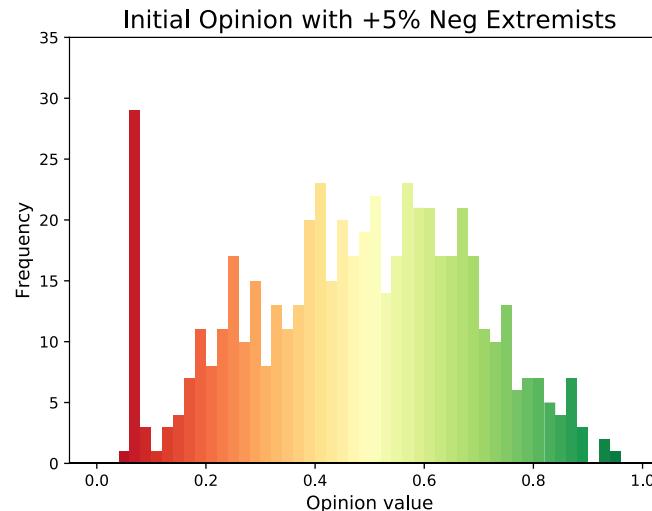


Tested Scenarios

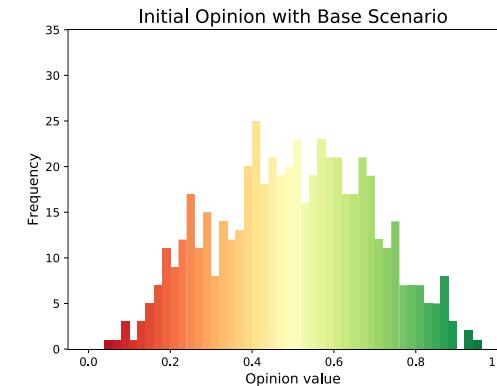
Question: What is the role of opinion extremists in the diffusion of individual and community solar photovoltaics in cities?

One-Sided Extremism

- +N% of Pos or Neg Extremists

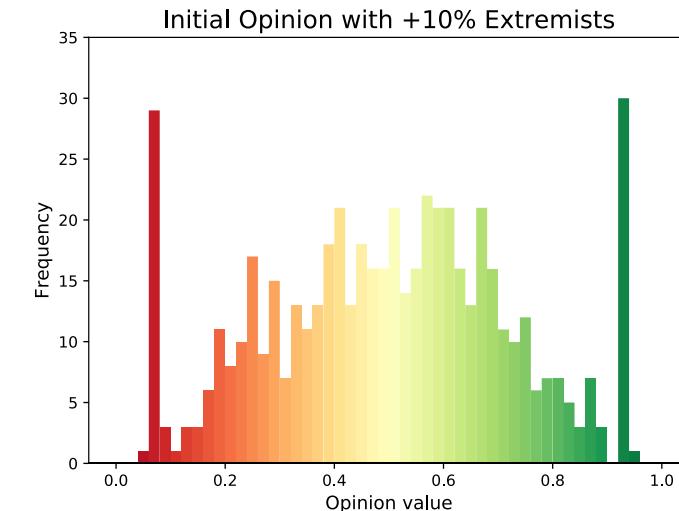


- Experiments:
- 20% N
 - 5% N
 - Base
 - 5% P
 - 20% P



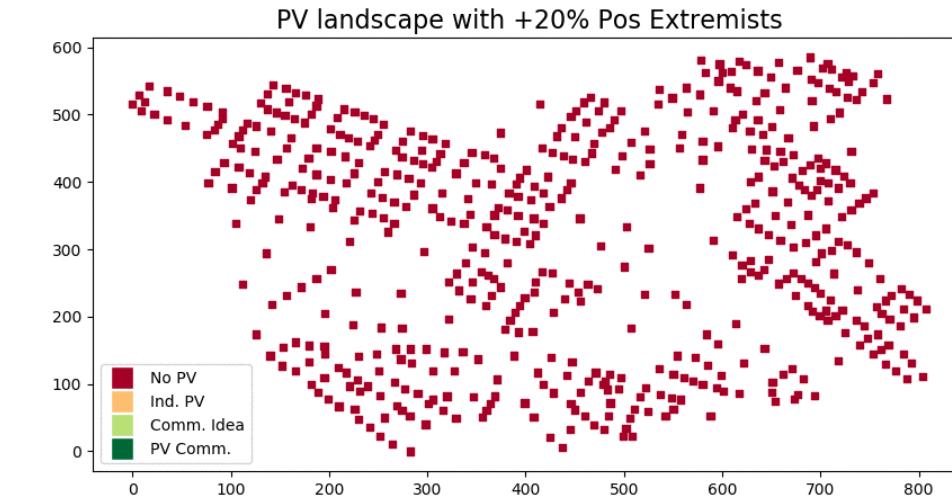
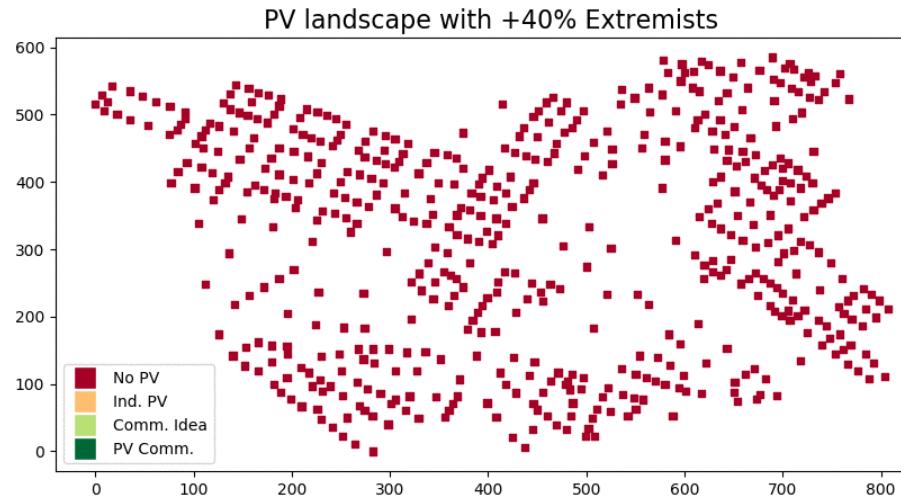
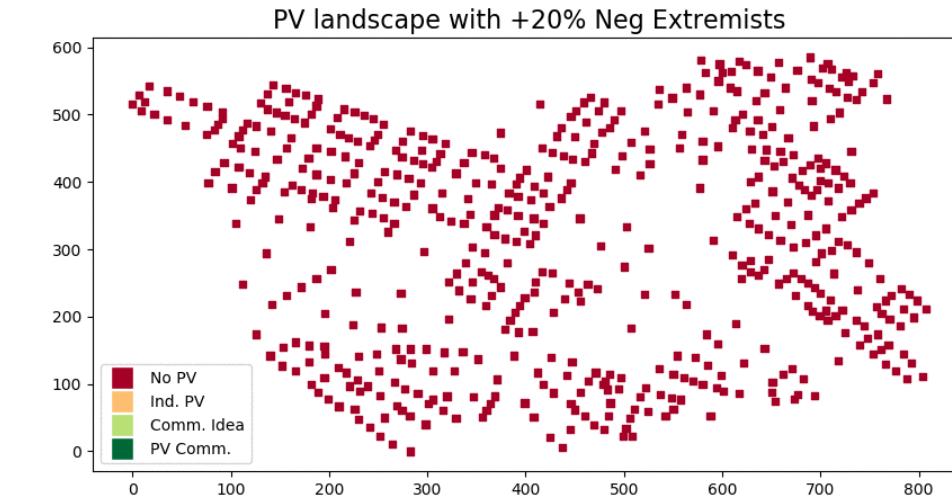
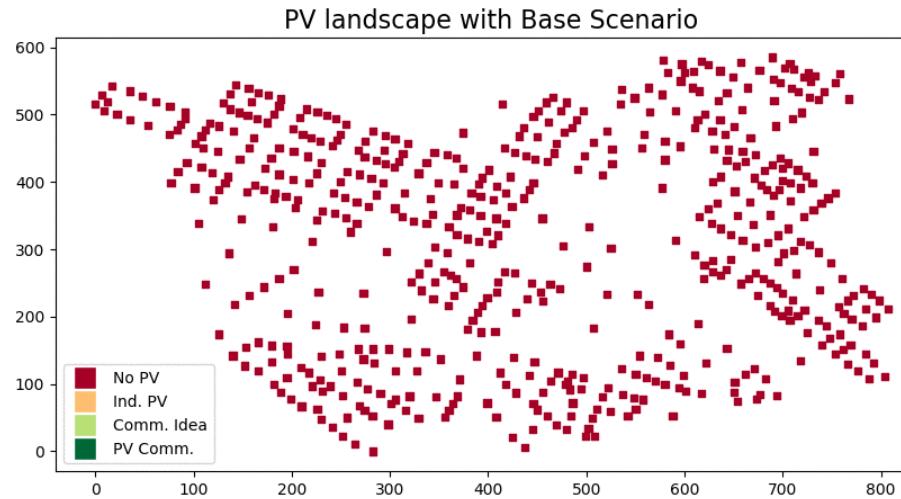
Symmetric Extremism

- +N% of Pos+Neg Extremists



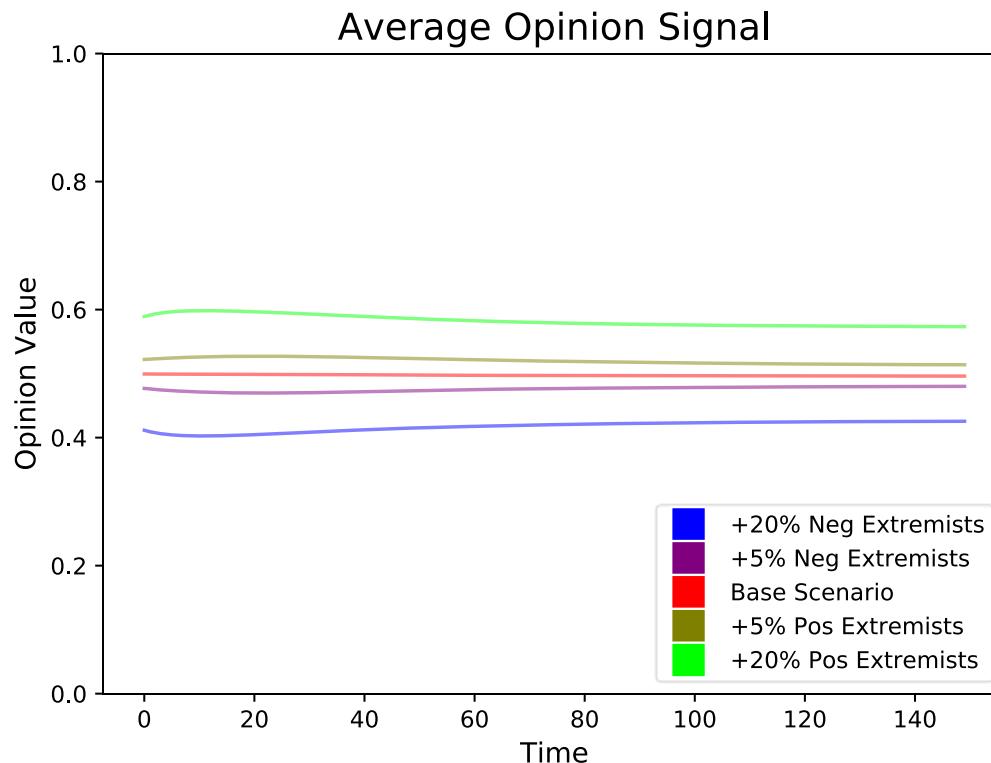
- Experiments:
- Base
 - 5% (2.5%+2.5%)
 - 10% (5%+5%)
 - 20% (10%+10%)
 - 40% (20%+20%)

Results and Discussion

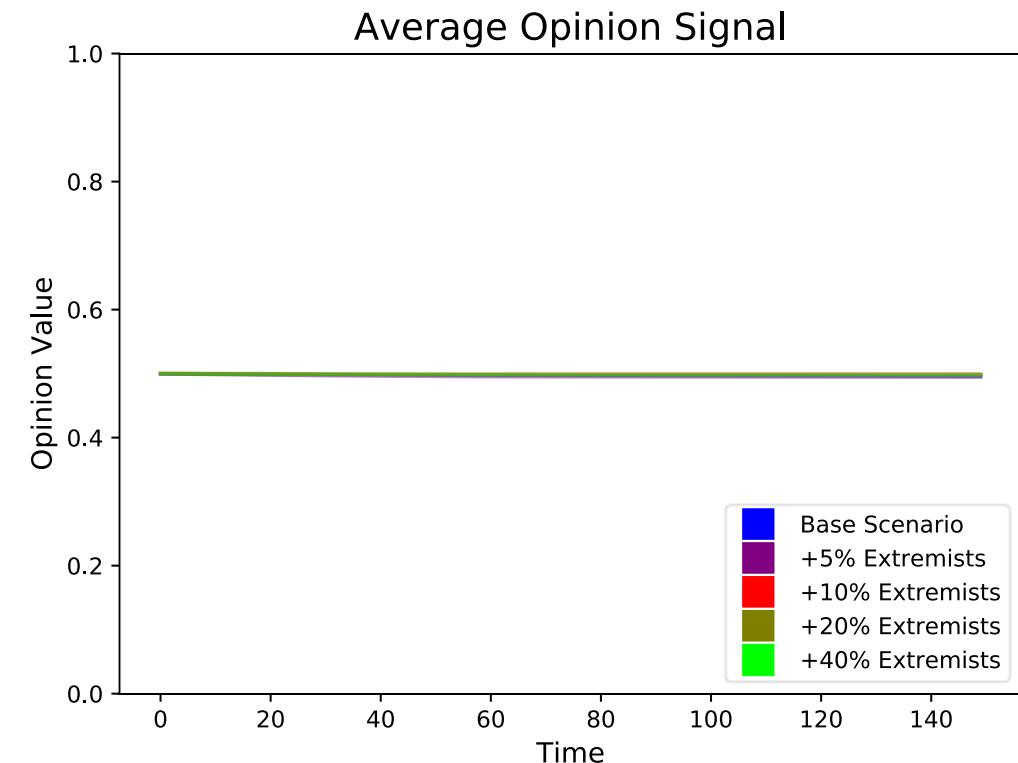


Results and Discussion

One-Sided Extremism

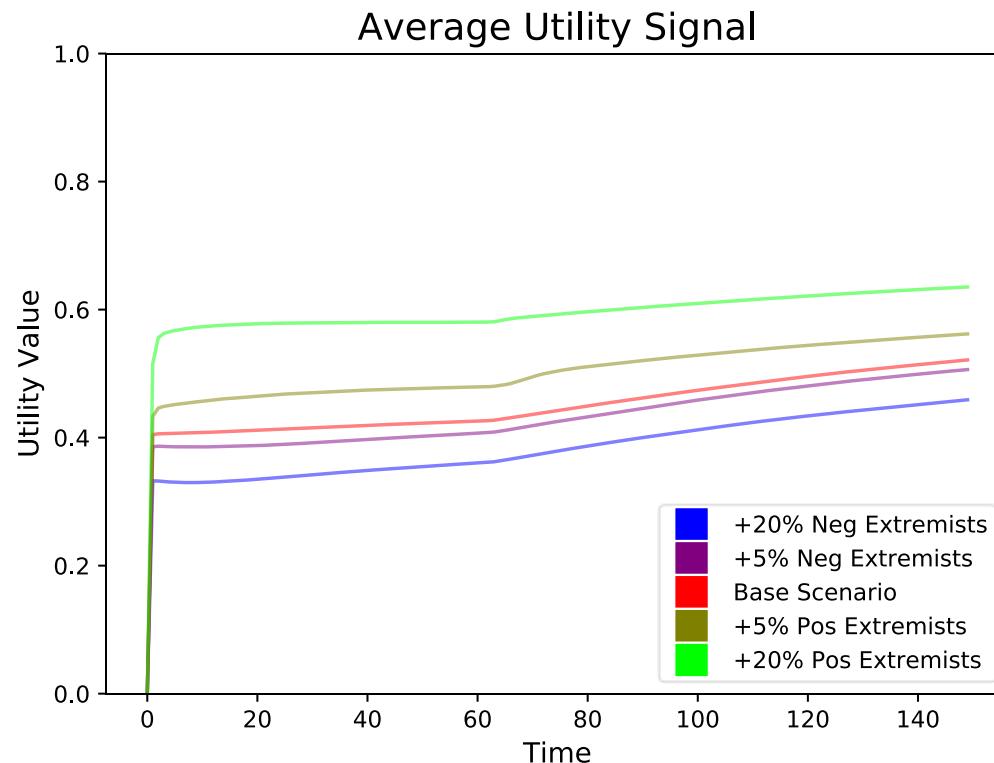


Symmetric Extremism

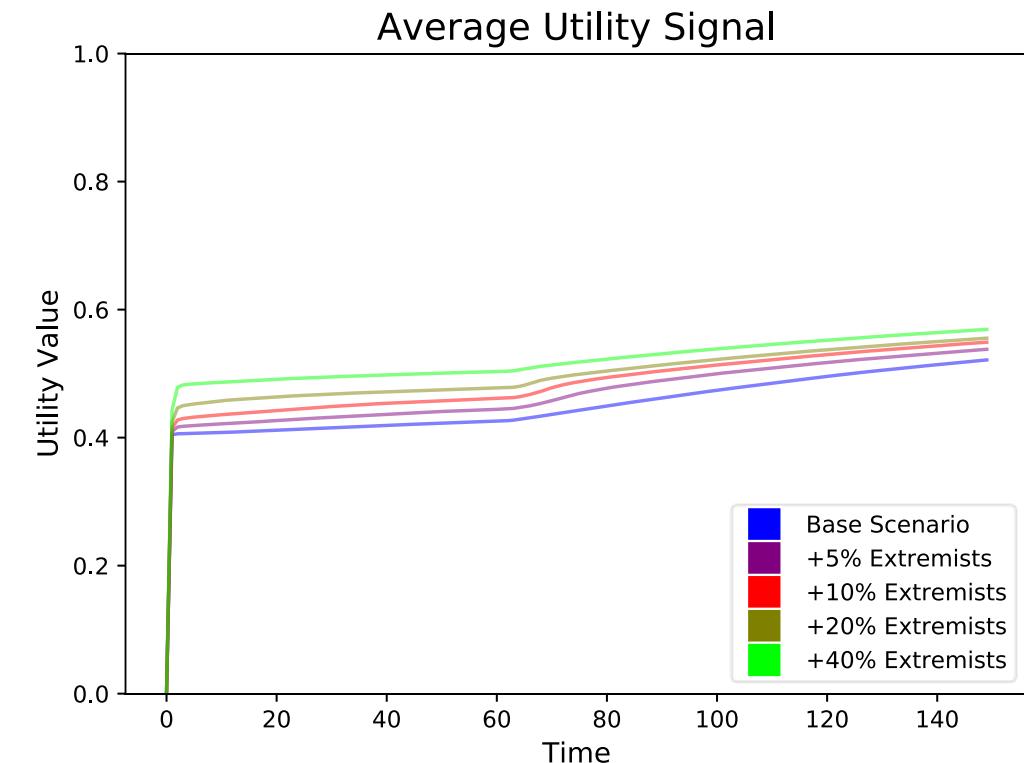


Results and Discussion

One-Sided Extremism

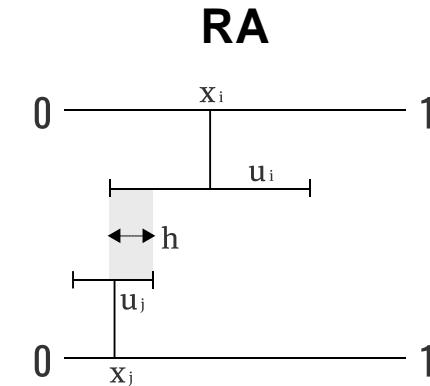
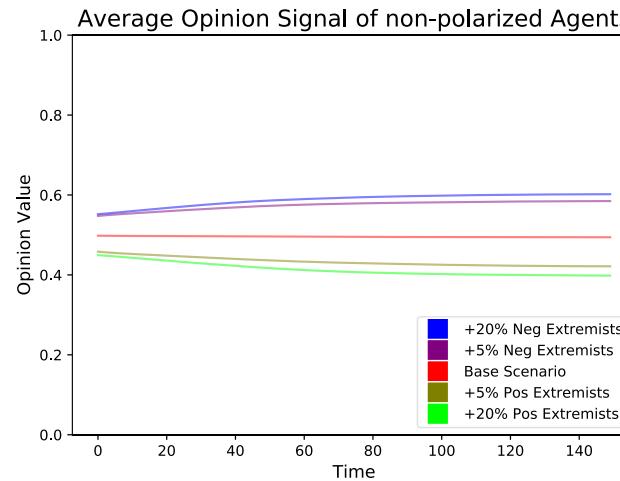
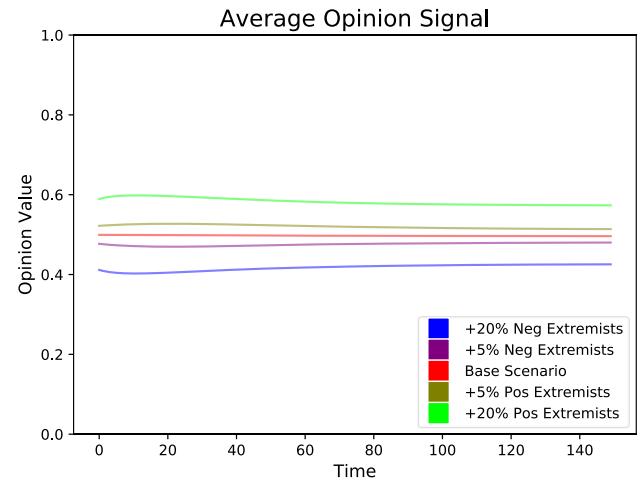
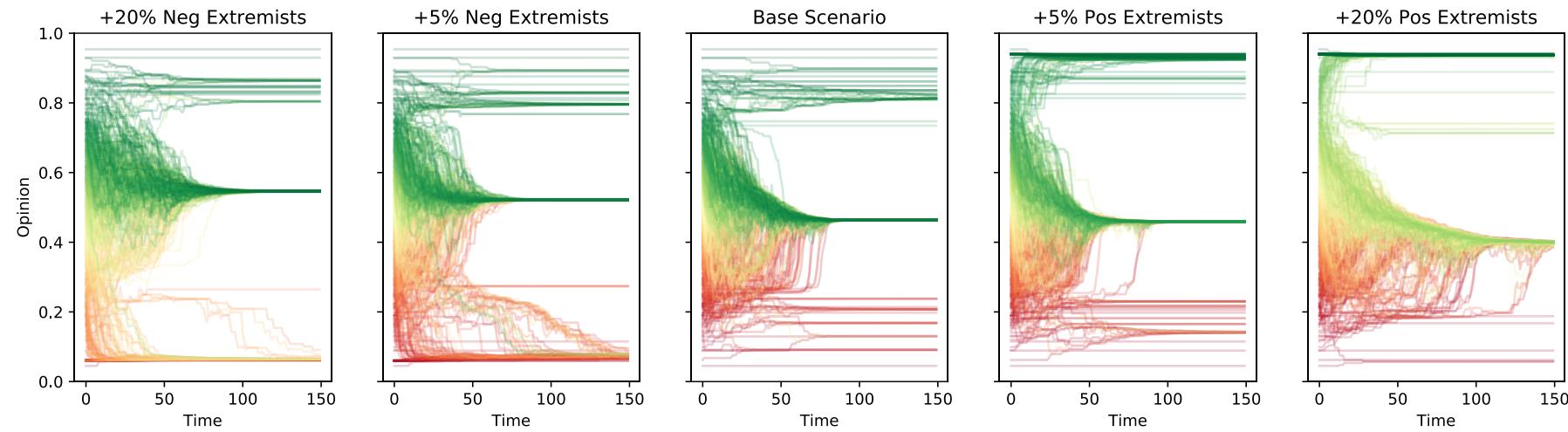


Symmetric Extremism



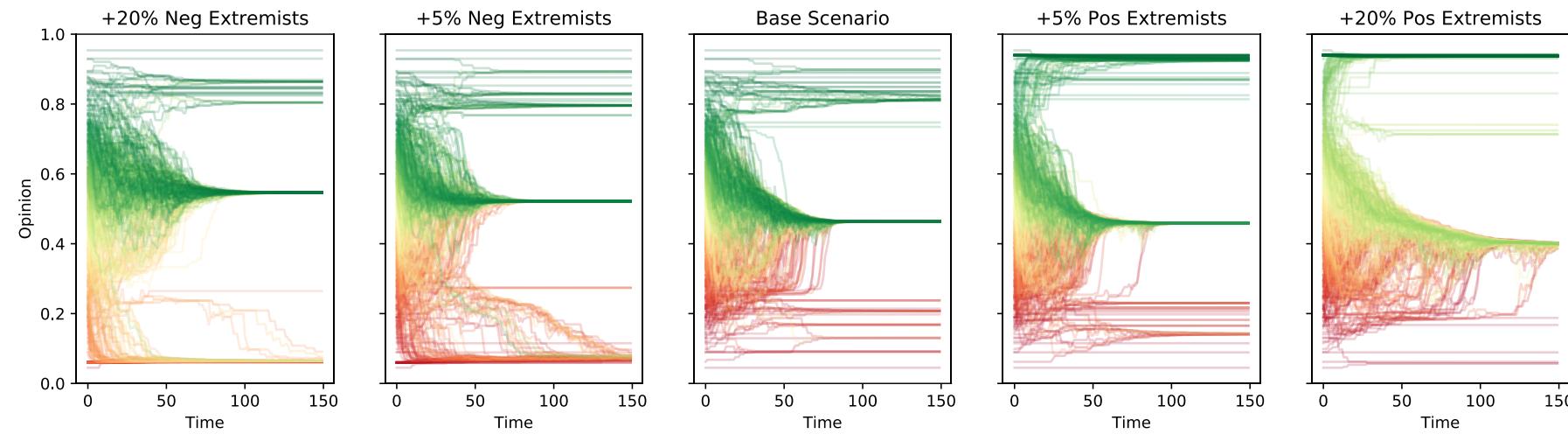
Results and Discussion

One-Sided Extremism

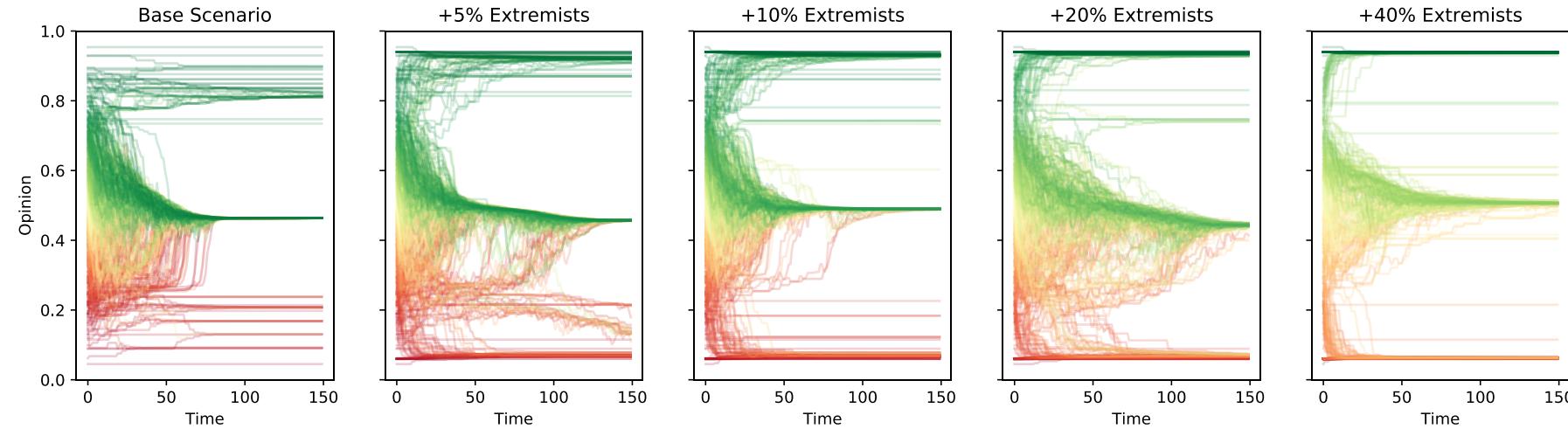


Results and Discussion

One-Sided Extremism

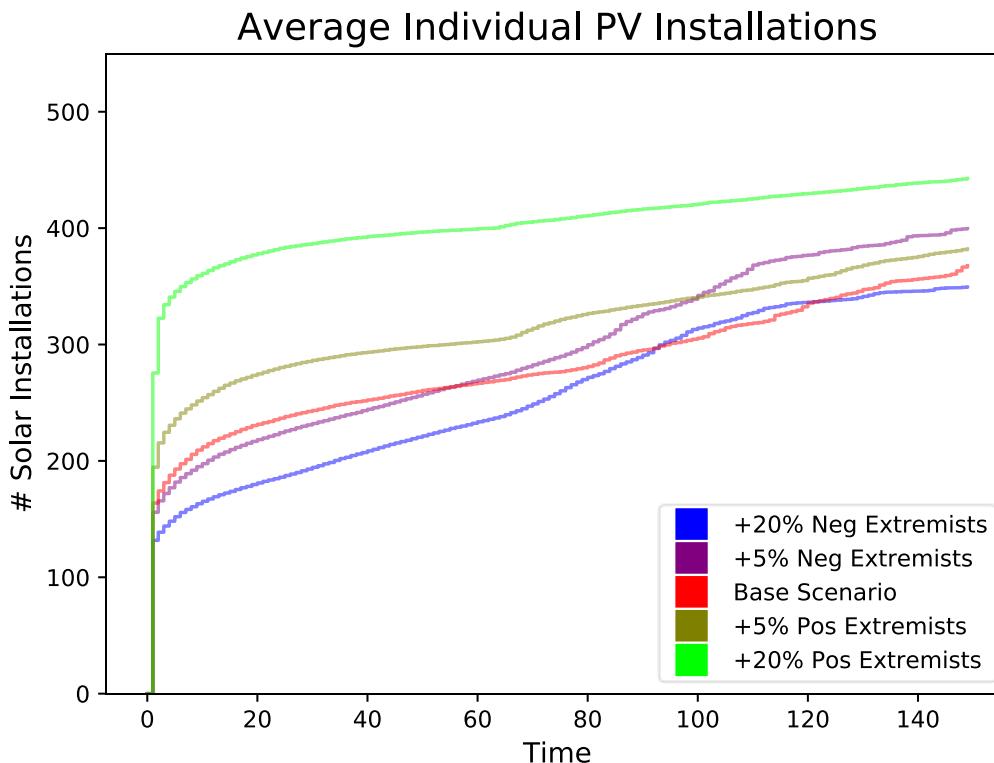


Symmetric Extremism

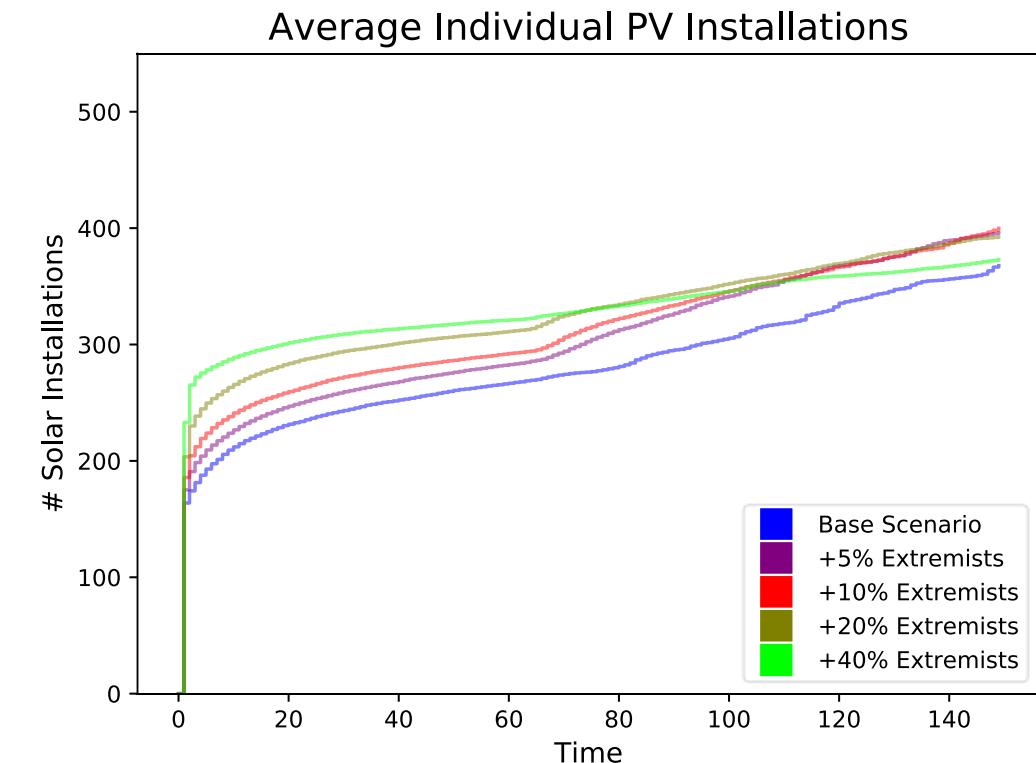


Results and Discussion

One-Sided Extremism

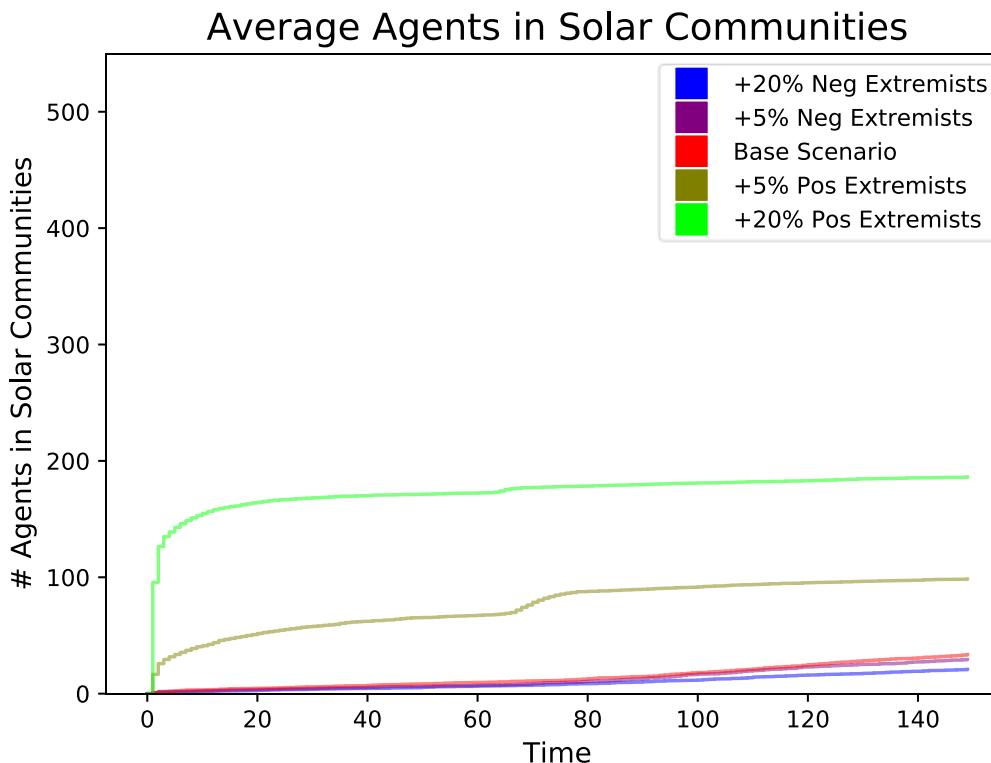


Symmetric Extremism

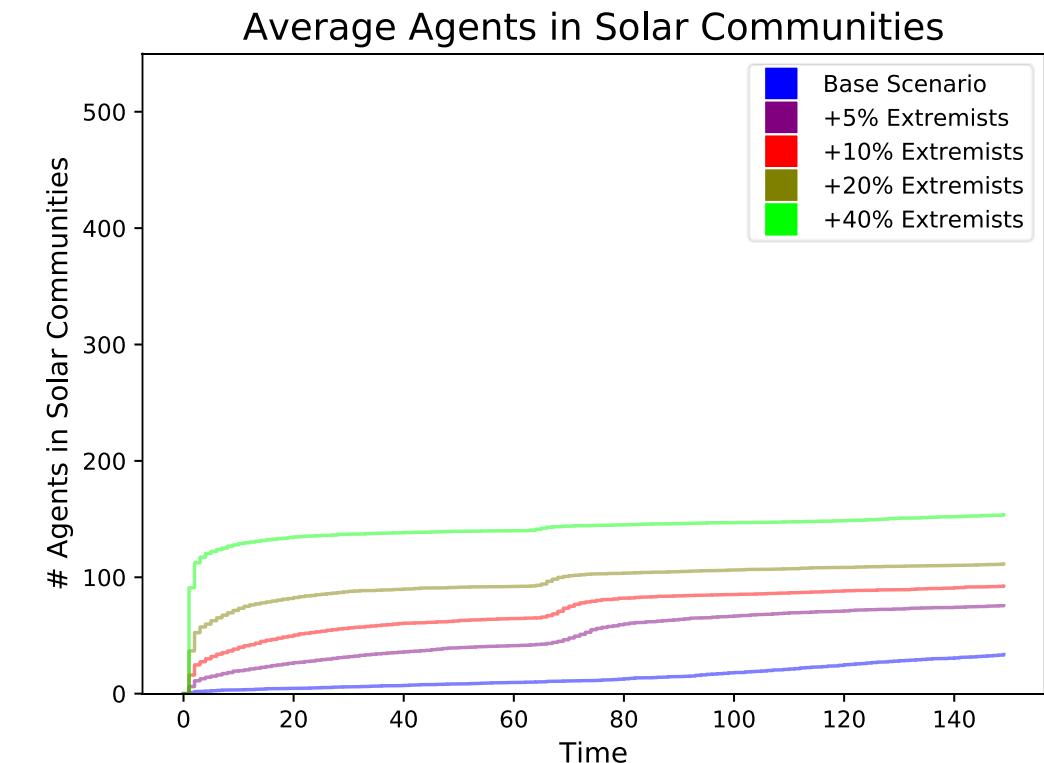


Results and Discussion

One-Sided Extremism



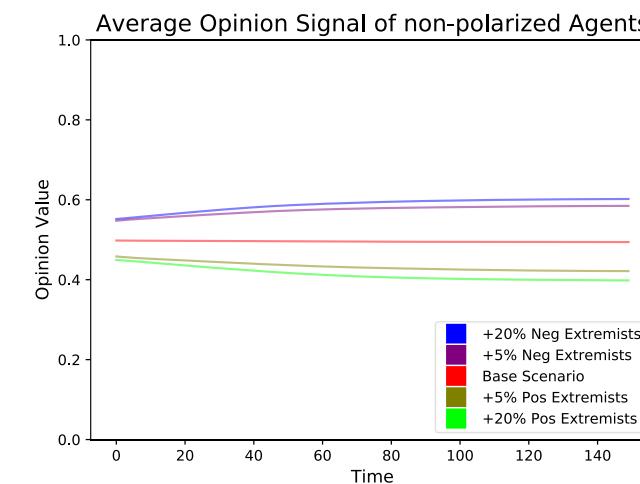
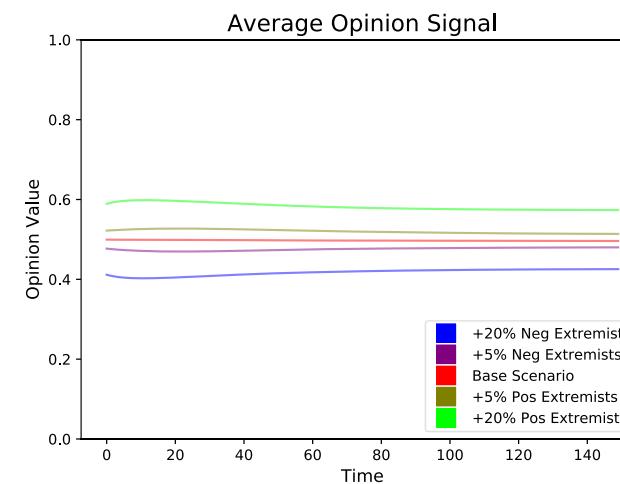
Symmetric Extremism



Results and Discussion

Conclusions

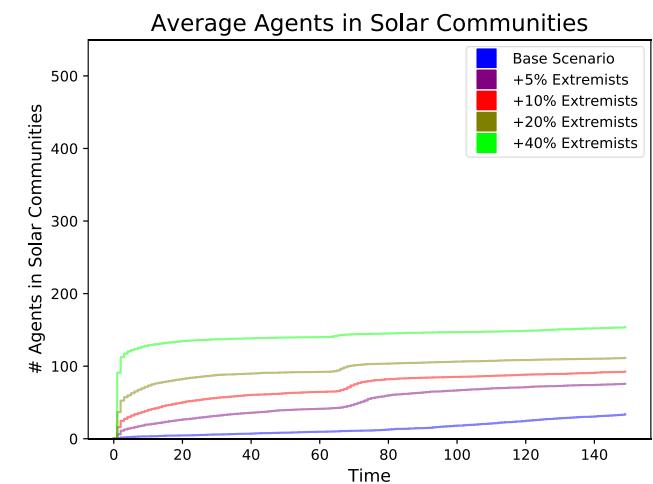
- “Single-Sided” extremism
 - **Unbalances** average opinion towards that extreme
 - However, average opinion of non-polarized nodes **shifts to the opposite extreme**



Results and Discussion

Conclusions

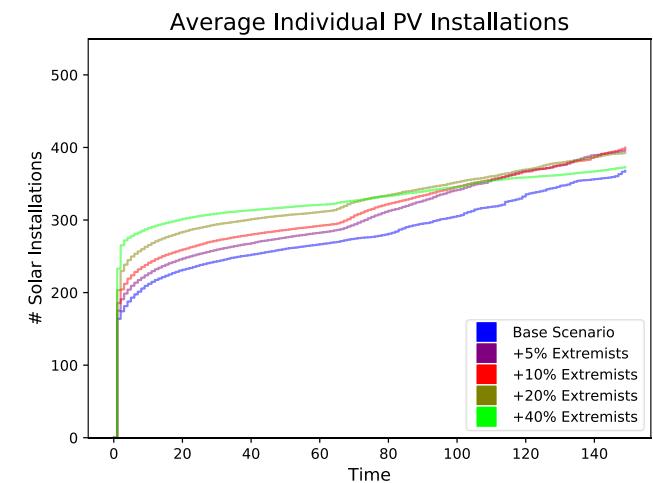
- “Single-Sided” extremism
 - **Unbalances** average opinion towards that extreme
 - However, average opinion of non-polarized nodes **shifts to the opposite extreme**
- For Communities: Benefits of Pos. Extremists > Detriment by Neg. Extremists
 - Neighbor Factor



Results and Discussion

Conclusions

- “Single-Sided” extremism
 - **Unbalances** average opinion towards that extreme
 - However, average opinion of non-polarized nodes **shifts to the opposite extreme**
- For **Communities**: Benefits of Pos. Extremists > Detriment by Neg. Extremists
 - Neighbor Factor
- For **Individual ideas**: Relationship with Extremism is more complicated...
 - Pos. Extremists → Install immediately and try to form communities
 - But... Non-polarized nodes tend to compensate to the other extreme



Questions and Answers

