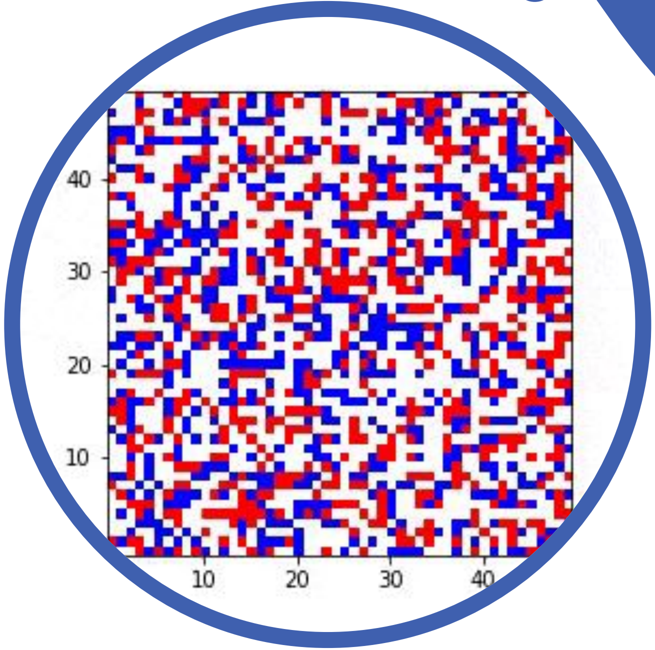
The effects of segregation on the distribution of wealth

Group 8: “Schelling’s Segregationists”

(Just to be clear, we aren’t advocates of racial segregation.)



Presentation Overview

1. Background & Research Questions
2. Model Design
3. Analysis Techniques
4. Experimental Set-up
5. Results
6. Conclusions

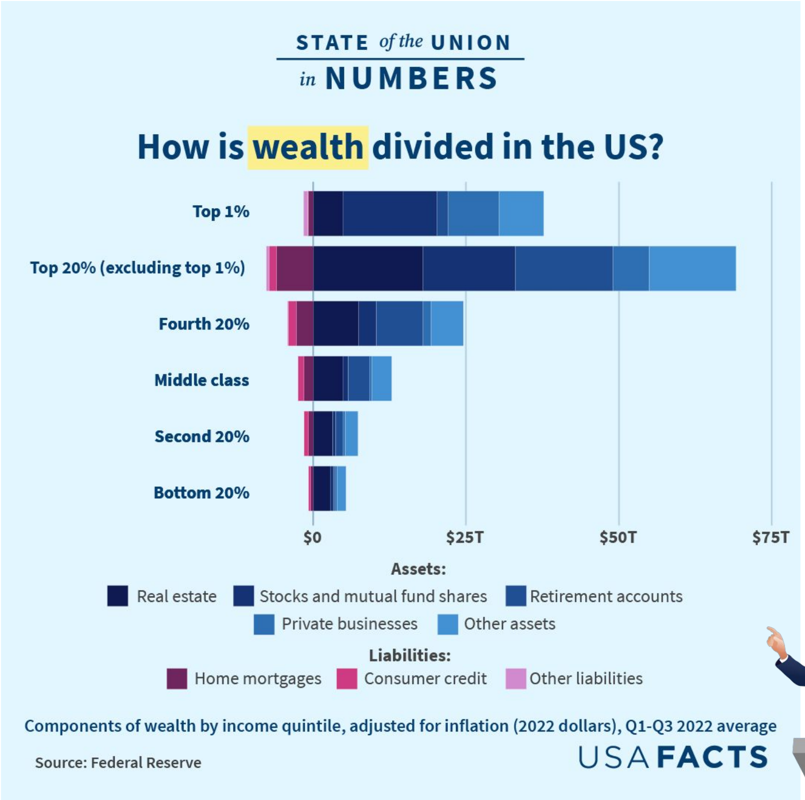
Background

Wealth/Income Inequality in US

→ Many Reasons

Our Focus: Segregation

Main Assumption: Your proximity to the wealtiest determines the likelihood of you gaining more/less wealth.



Research Questions

Main RQ:

- Will segregation influence the wealth distribution between different population groups?

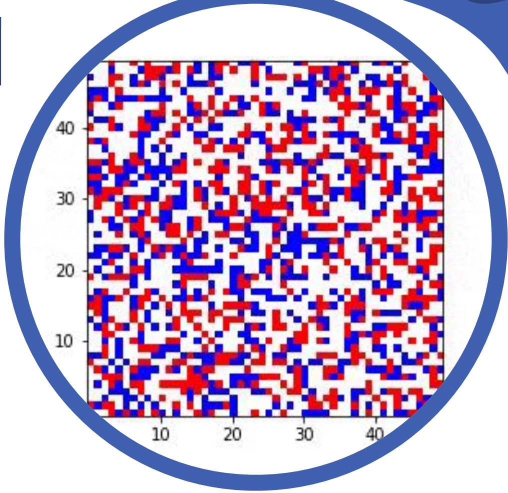
Sub RQs:

- RQ 5: What is the critical population density where percolation happens?
- RQ 3/4: Does wealth cluster, and is it correlated to segregation?
- RQ 7/8/9: When does wealth clustering occur?

Main hypothesis:

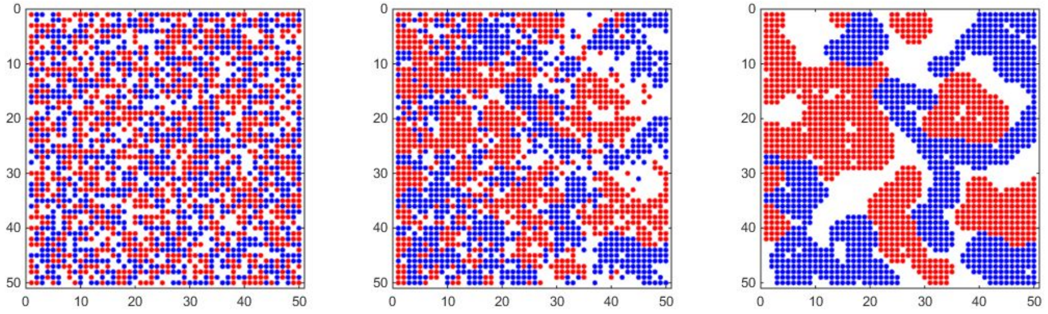
- Segregation and the distribution of wealth are linked, thus segregation will change the distribution of wealth over time according to the level of segregation.

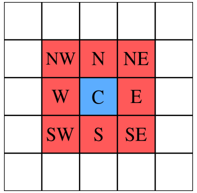
Base Model



Schelling's Model of Segregation (1970)

→ Agent's move randomly
→ Stay put when *"tolerance threshold"* is satisfied





Agents' tolerance is calculated with Moore neighborhood

Note: Sample simulation result for tolerance threshold of 50% and time steps 0, 4, 30

Economic Component (1)

We designed an economic model on top of the base model:

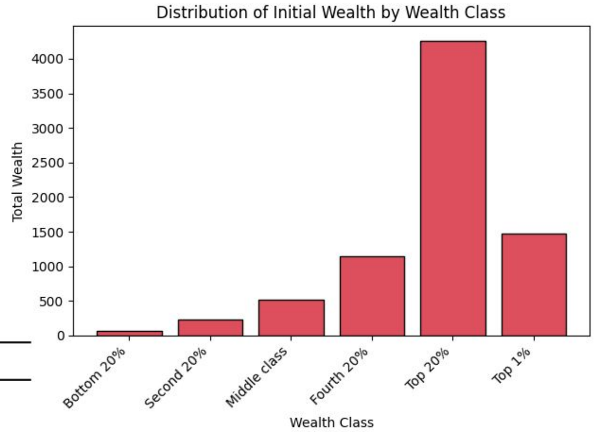
1. Introduced **α parameter**: determines the wealth transfer based on the similarity between agents based on wealth

2. Agents were given an initial amount of *"**wealth**"* (Log-normal distribution: μ=1.0/σ=1.5)

3. Agents' ***wealth*** are **updated** at each model step according to these rules

Algorithm 1: Algorithm that updates agents' wealth

if *Agent has neighbors and is happy* **then**
  if $1 - \alpha \leq \frac{\textit{current agent's wealth}}{\textit{avg. neighbors wealth}} \leq 1$ **then**
    New agent wealth $=$ 0.5 $*$ current agent wealth $+$ 0.5 $*$ avg. neighbors wealth
  else
    No wealth update
  end
else
  No wealth update
end



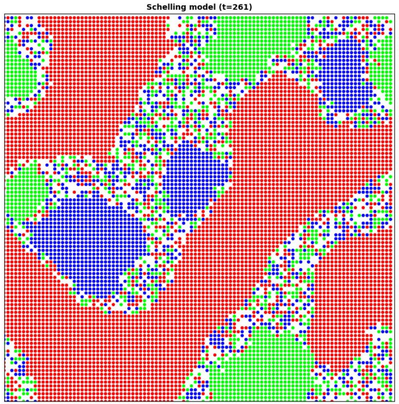
Economic Component (2)

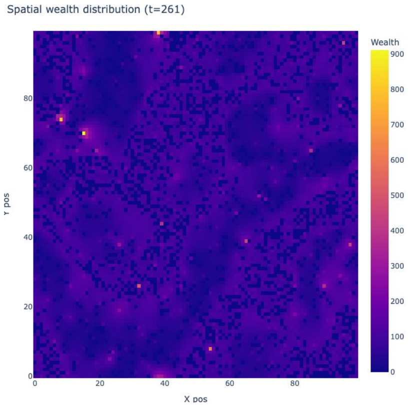
Emergent Behaviors:

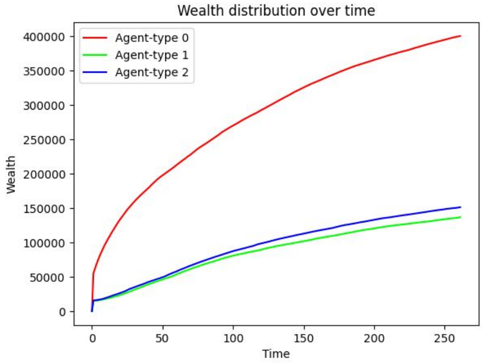
- Happy agents tend to accumulate more wealth.
- Total system wealth can only increase (bounded).
- Richest agents don’t accumulate any additional wealth.
- The wealth distribution can change overtime.

Analysis Techniques (1)

Segregation Analysis	**Spatial Visualization** To monitor the segregation patterns	**Percolation** To monitor the emergence of percolation
Wealth Analysis	**Spatial Visualization** To monitor the spatial distribution of wealth	**Wealth Distribution Plot** To monitor the evolution of the wealth distribution

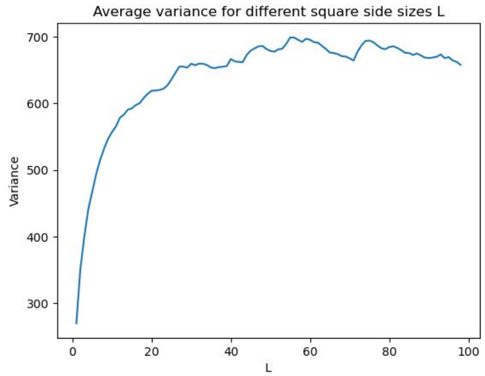


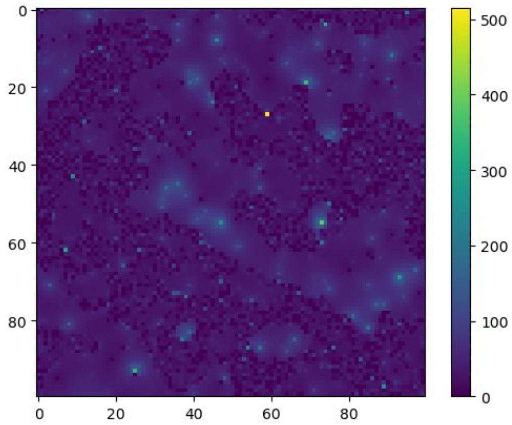




Analysis Techniques (2)

Segregation Analysis	**Population Segregation Measure (Moran's I)** $$I = \left(\frac{N_{tot}}{\sum_i \sum_j w_{i,j}}\right)\left(\frac{\sum_i \sum_j w_{i,j}(z_i - \bar{z})(z_j - \bar{z})}{\sum_i (z_i - \bar{z})}\right)$$ To quantify the amount of segregation clustering in the system.
Wealth Analysis	**Wealth Segregation Measure (Halftime)** Using average variance. To quantify the amount of wealth clustering in the system.





Analysis Techniques (3)

Segregation Analysis	**Phase Transition** Second-order derivative of percolation probability for different grid sizes. To find critical population density where percolation happens.
Wealth Analysis	**Correlation Wealth Clusters and Segregation Clusters** Using numpy's 'corrcoef' to find correlation between the two segregation measures. To determine whether wealth clusters and segregation clusters are the same.

Experimental Set-up

Fixed Parameters

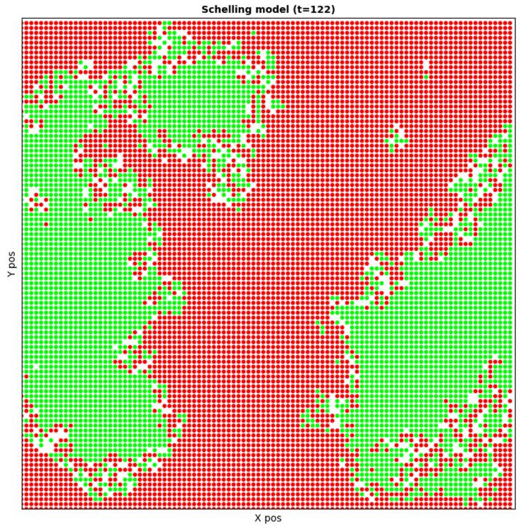
Grid-size:	100x100
Populations:	2
Population fractions:	{0.6, 0.4}
Tolerance threshold:	5/8
Cluster size threshold:	4
Stopping steps:	5

Control Parameters

Population density:	(0, 1)
Tolerance threshold:	(0, 8)
α:	[0, 1]

Order parameters

Percolation:	{True, False}
Moran’s I:	[-1, 1]
Halftime:	(0, 100]

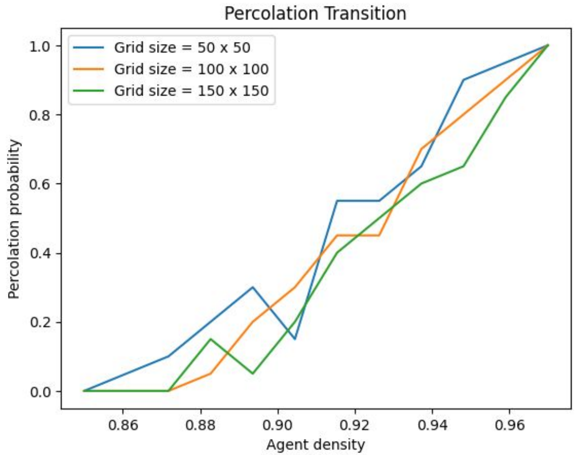


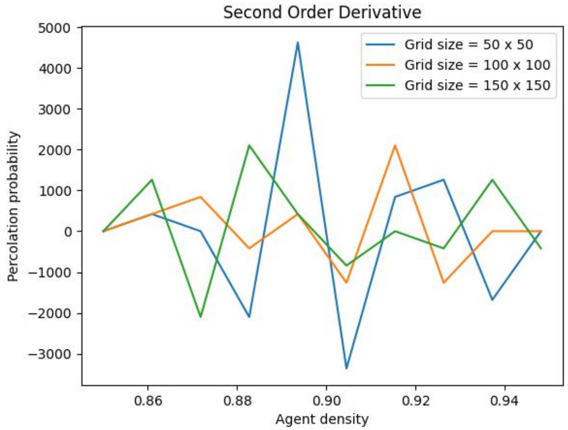
Note: Typically these parameter values would converge to these maps.

Results

- **What is the critical population density where percolation happens?**

→ No critical density point found



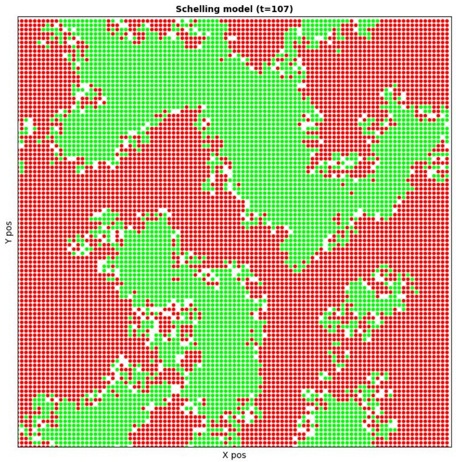


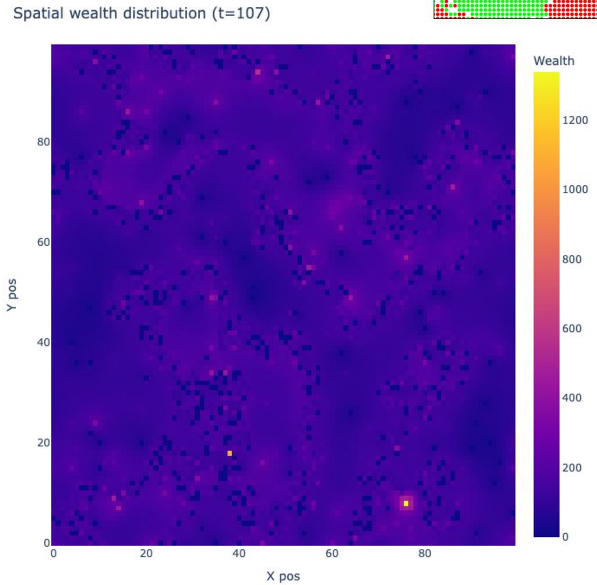
Results

Does wealth cluster, and is it correlated to segregation?

→ Yes according to the spatial visualizations

→ Correlation: 0.71

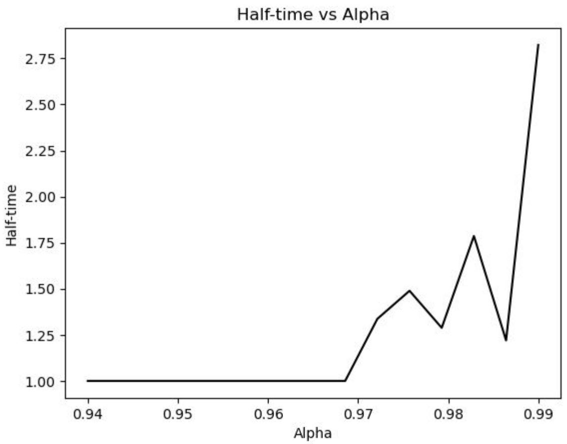


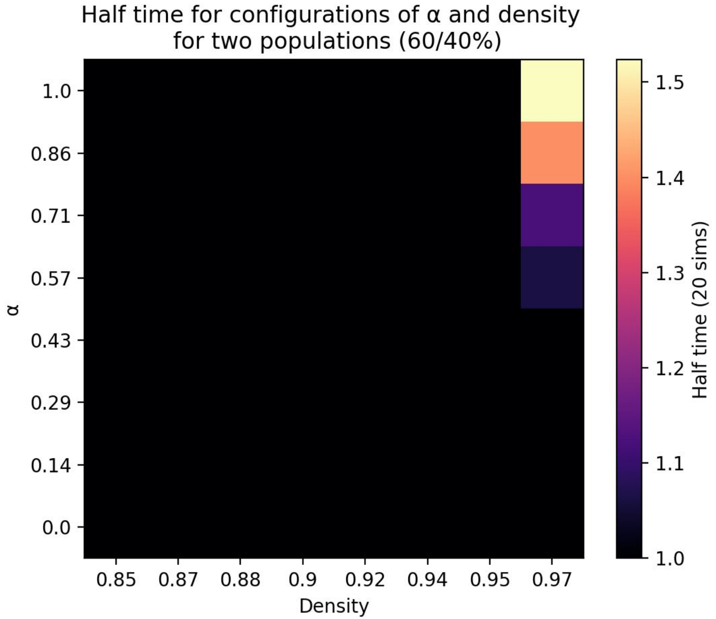


Results

When does wealth clustering occur for different α and population density?

→ Wealth clusters when economy is “opened” and the population is very dense





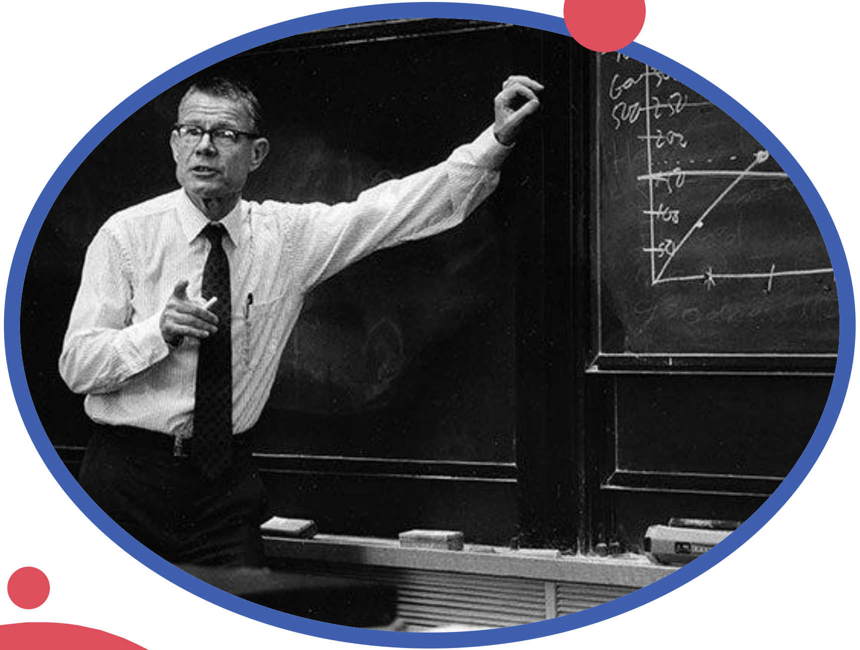
Conclusions

Findings:

- Critical agent density for occurrence of percolation not found
- Wealth clusters when α and population density is high
- Segregation and the distribution of wealth are correlated according to spatial visualizations
- A proposed method that can simulate the interaction between segregation and wealth distribution

Limitations:

- Moran's I not computable for Population N>2
- Pearson correlation limited because shapes aren't accounted for
- More analysis on interaction between α of tolerance threshold needed



Thank you for listening!

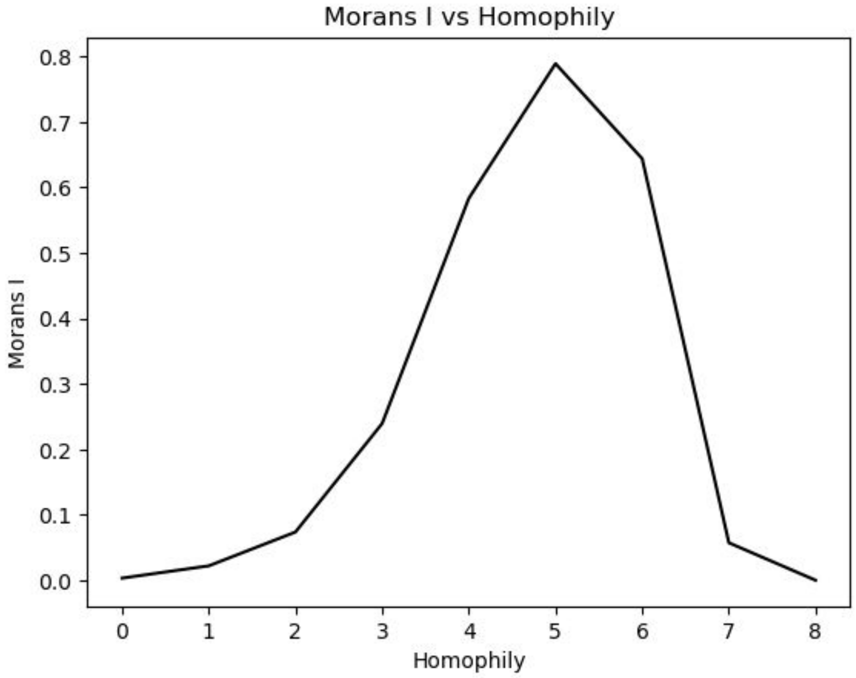
Does anyone have any questions?

Appendix RQ1

At what tolerance threshold does segregation occur?

→ Grid size: 100x100
→ Density: 0.97
→ Pop. weights: {0.6, 0.4}

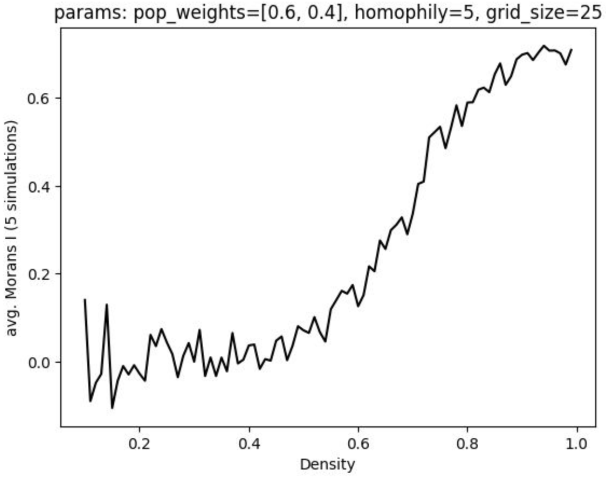
→ Segregation is highest for a tolerance threshold of 5, below and above that segregation decreases.

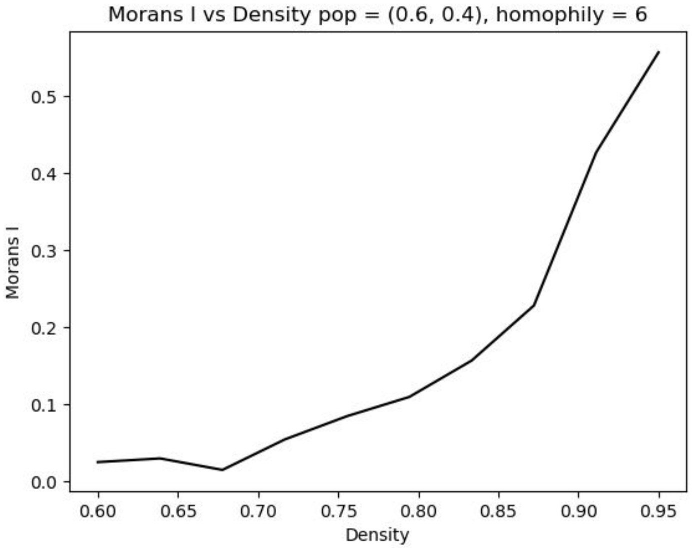


Appendix RQ2

At what population density does segregation occur?

→ The higher the population density, the higher the segregation.



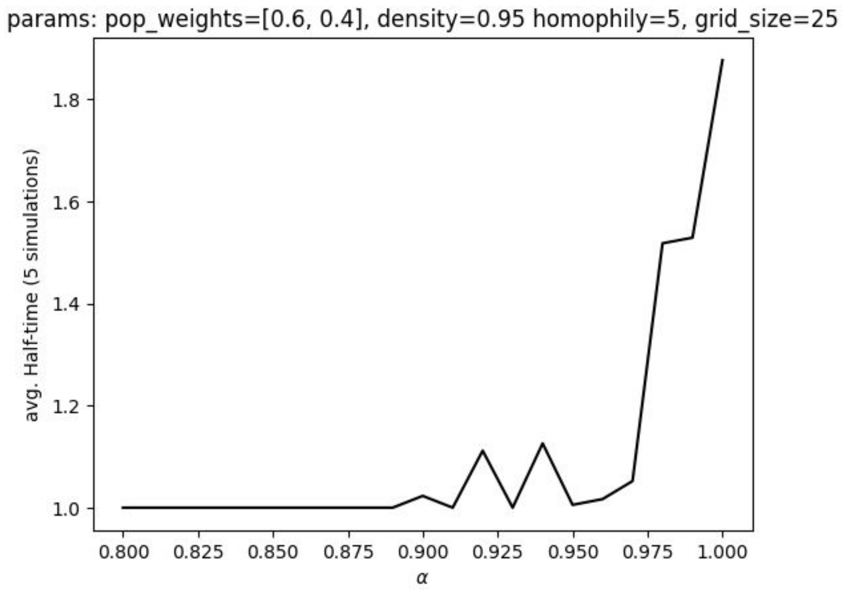


Note: Grid size: 100x100

Appendix RQ3

At what alpha does wealth clustering occur?

→ A bigger alpha, means more wealth segregation. So when people can more easily gain money as a result of a wealthy network the wealth segregation increases.



Appendix RQ4

Is wealth clustering correlated to segregation clustering?

⟶ Pearson correlation coefficient between half-time and MoransI is: 0.267

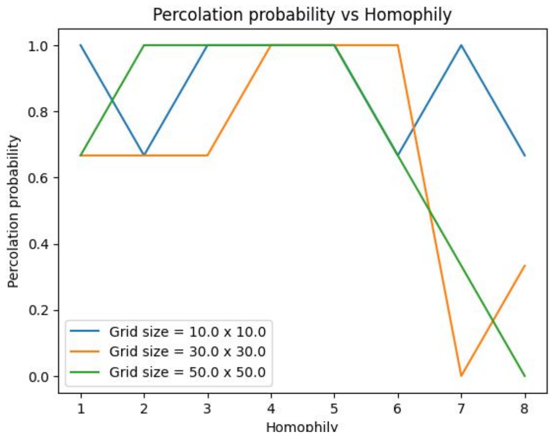
N.B: This result differs from slide 13 because for this result we had the time to do multiple model runs and average the results. Also, this result is gained from running the model for a much smaller grid-size.

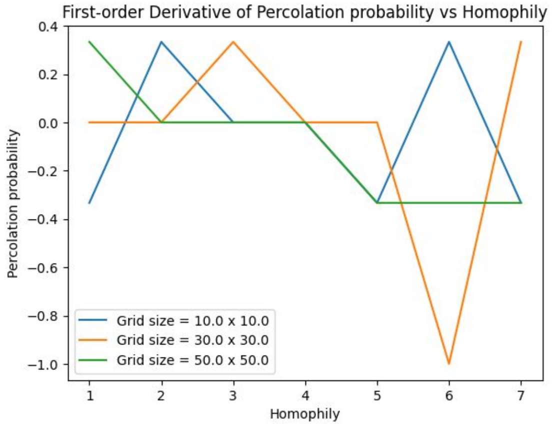
Appendix RQ6

What is the critical tolerance threshold where percolation happens?

→ Percolation is more likely with lower tolerance thresholds, as agents are easier to satisfy.

→ Note that we didn’t have time to run this experiment for larger grid sizes, and more model simulations.

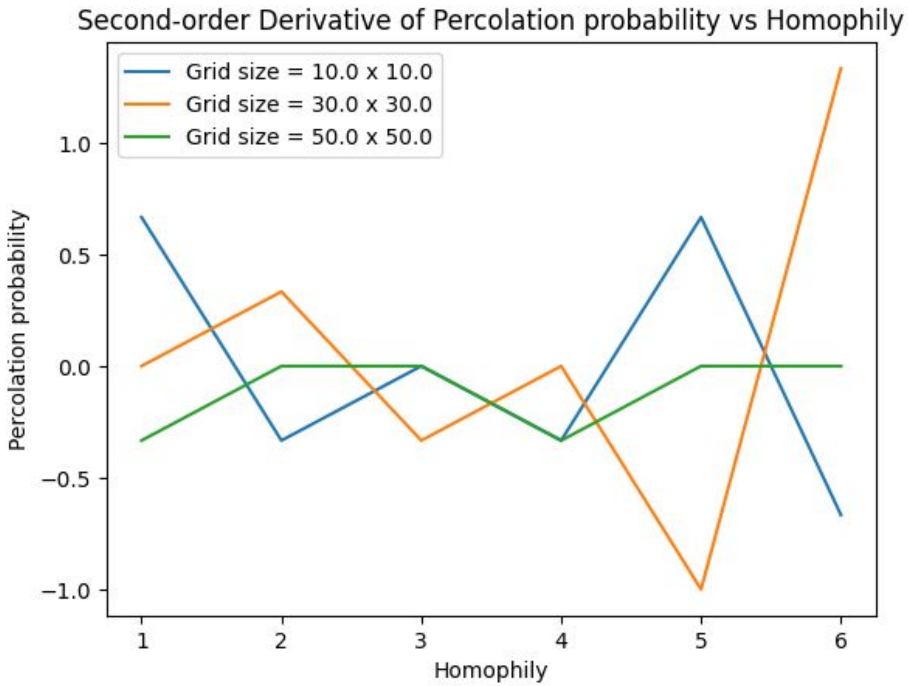




Appendix RQ6

What is the critical tolerance threshold where percolation happens?

⟶ No divergence of second-order derivative
⟶ No critical tolerance threshold found

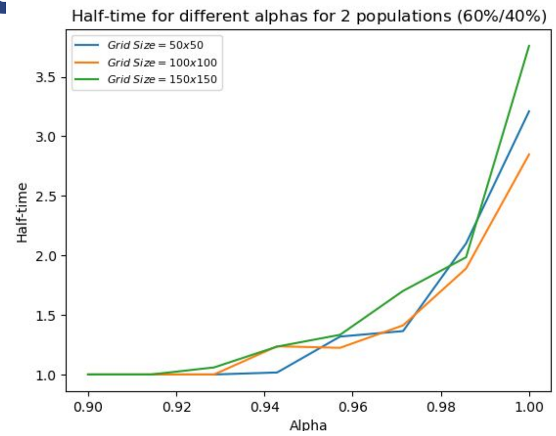


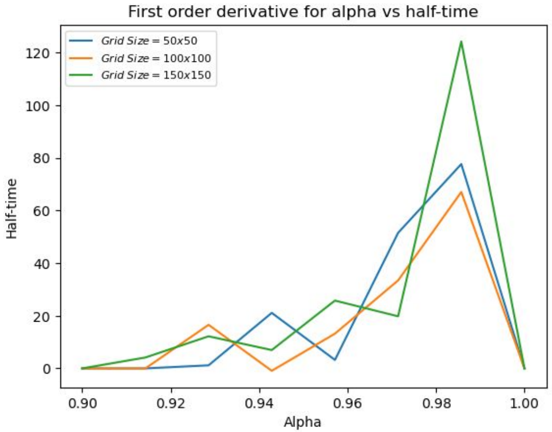
Appendix RQ7

What is the critical alpha where wealth clustering happens?

→ Wealth clusters more when alpha increases.

→ Alpha is very sensitive, as for $0<\alpha<0.9$ the half time remains 1.



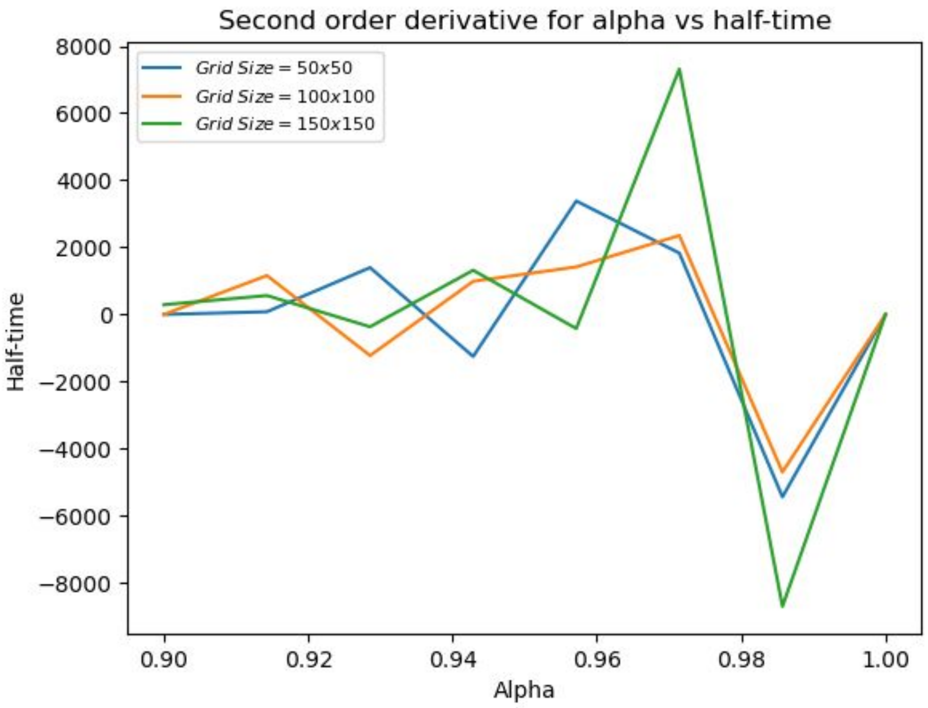


Appendix RQ7

What is the critical alpha where wealth clustering happens?

⟶ It does look like some divergence around 0.98. Green line goes to (+-)8000.

⟶ Maybe if we zoomed in on this area we would have seen more divergence.



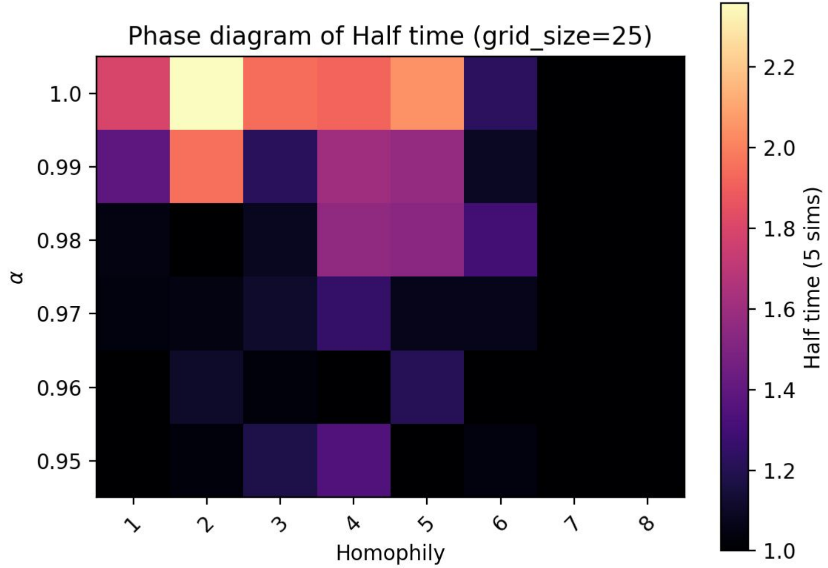
Appendix RQ8

What is the effect of alpha and homophily on the halftime?

→ Wealth clusters more for high alphas and low tolerance thresholds.

→ This is because wealth only gets transferred if agents are happy, agents with a low tolerance threshold are easier to satisfy.

→ We didn't have time to produce this heatmap for larger grid sizes.



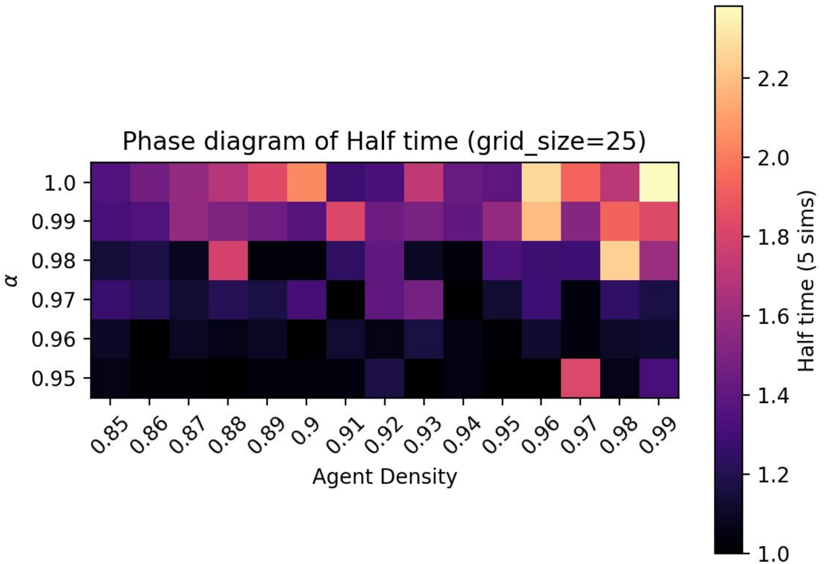
Appendix RQ9

What is the effect of alpha and agent density on the halftime?

→ Wealth clusters more for high alphas and high densities.

→ This is because a higher density ensures there are more potential wealth transfer moments per model step.

→ We didn’t have time to produce this heatmap for larger grid sizes.



(Updated) Conclusions

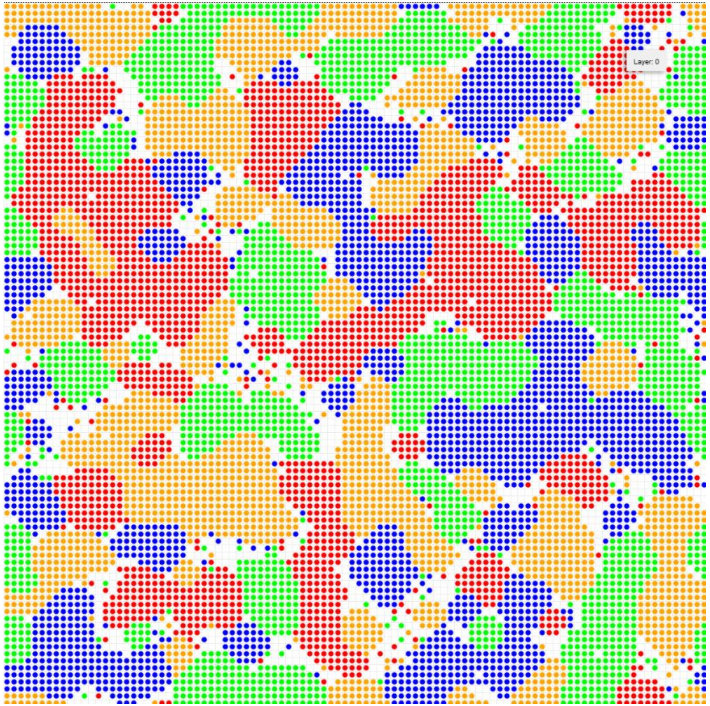
Findings:

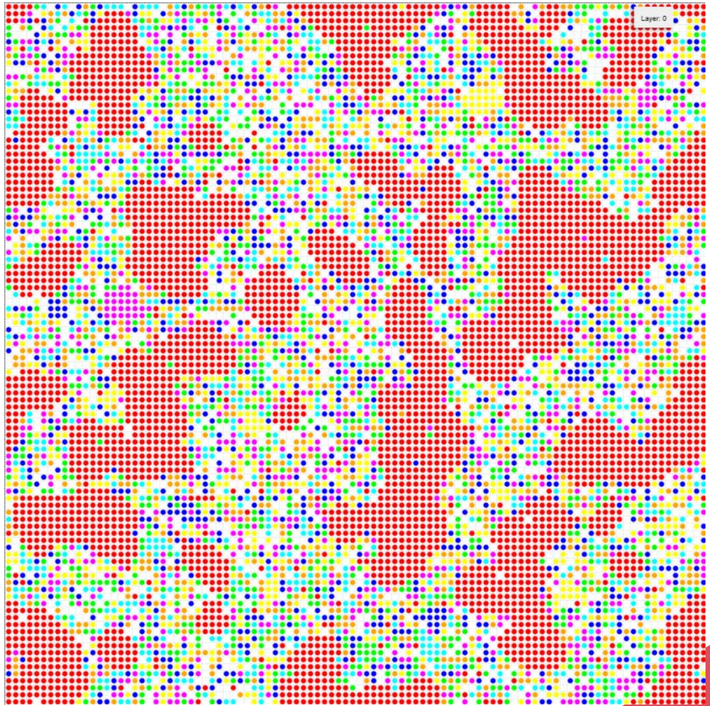
- Wealth clusters when agent density is high.
- Wealth clusters when agents are easy to satisfy.
- Wealth clusters more when alpha increases.
- No critical points found where percolation occurs.
- Segregation increases with agent density
- Segregation is highest for a tolerance threshold of 5.

Limitations:

- The alpha parameter is very sensitive, wealth is only clustering when $\alpha>0.9$.
- Due to randomness in the model, having reliable results requires running the model multiple times and looking at the average outcomes. We did not have time to do this for all results.
- Not all experiments have been conducted over multiple scales. This was due to extensive run times.

Multiple populations





References

- Our Github repository: https://github.com/aM0NKE/ComplexSystemSimulation

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- Dragly, S.-A. (2013, March 25). Working with percolation clusters in Python. Retrieved from dragly: https://dragly.org/2013/03/25/working-with-percolation-clusters-in-python/