What Influence the Wealth Inequality in Sugarscape Model: Exploring the Effects of Initial Wealth, Metabolism, Vision and Intergenerational reset

1. Introduction and Aim

Focusing on Sugarscape 3 and 2, this investigation examines how individual parameters, specifically initial wealth, metabolism, and vision, affect wealth inequality in the Sugarscape model. By modifying these parameters, we record their impacts on the Gini index (Gini 1912), which measures wealth inequality, and in Model 3, we also consider the proportion of young agents in the top 20% wealth group to gauge intergenerational wealth gaps. Next, the comparison of both models will reveal the role of intergenerational reset mechanisms in wealth distribution. Consequently, the research question is: how initial wealth, metabolism, vision and intergenrational reset inclucence the wealth inequality in Sugarscape model?

2. Methods

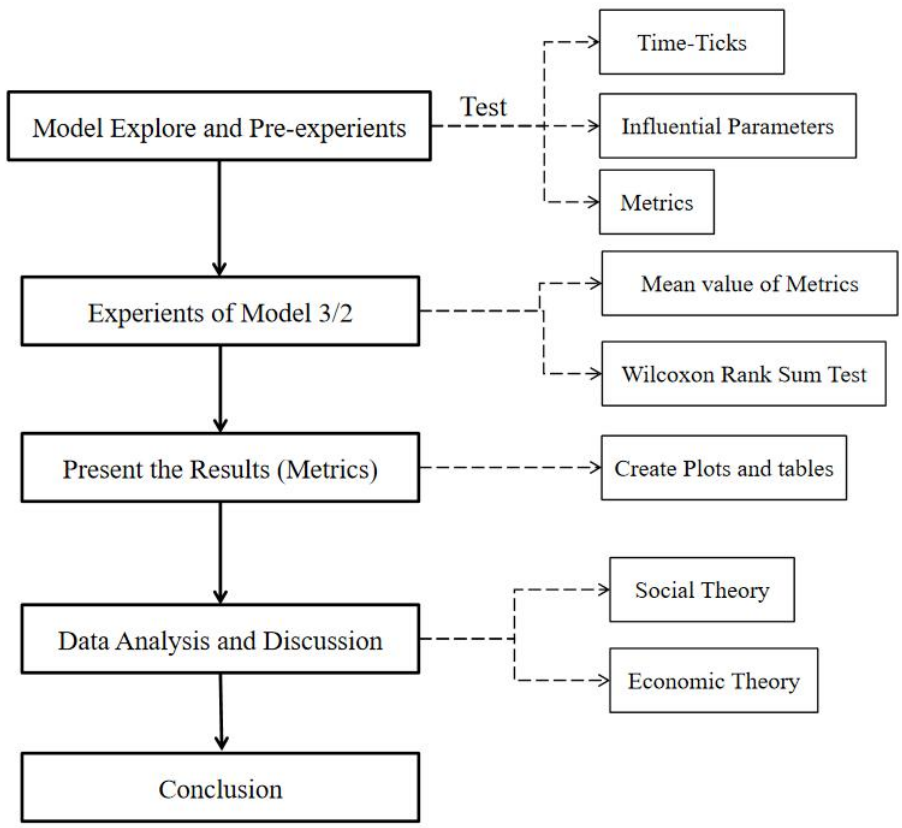
Experiments adjust initial wealth, metabolism, and vision, altering one at a time and observing their effects on wealth disparity in both models (Table 1). This research also investigates the impact of "intergenerational reset mechanisms" on wealth inequality, through comparing Sugarscape 3 with Sugarscape 2.

Table 1: Experiment Settings

Variable	Value range	Other settings
Initial wealth	1-50	metabolism:1-4 vision:1-6
	100-150	
	250-300	
	350-400	
Metabolism	1-2(high survivability society)	initial wealth:50-100 vision:1-6
	3-4(low survivability society)	
Vision	1-3	initial wealth:50-100 metabolism:1-4
	25-30	

We used the Gini-index and the proportion of young agents in the top 20% wealth as metrics, with a constant population of 500. We designed 17 distinct experiments for both models, setting parameters within a preset range (Table 1). Model 3 ran for 500 ticks and Model 2 for 5,000 ticks till their metrics keep stable, repeating each experiment five times for consistency. To compare Model 2 and 3, we'll keep parameters consistent and compare their Gini-index to examine how intergenerational reset affects wealth inequality. We recorded the metrics at each experiment and each tick, averaging the results for final analysis. The Wilcoxon rank-sum test is applied to measure group differences, which is used with mean value to evaluate parameter impacts on wealth inequality. Graphs of the metrics' changes will from each experiment will be plotted for analysis. The overall workframe is shown below (Figure1).

Figure 1: Research Framework



3. Results

3.1 Model 3: the Influence of Parameters

By manipulating 8 sets of parameters, we conducted 8 categories of experiments to measure the influence of three varying parameters on the Gini-index and the proportion of young within the top 20% of wealth. The experimental results and graphs of the metrics for each experimental group obtained are as follows (Table 2):

Table 2: Experiment Results for Model 3

Variable	Value range	Gini-index		Young-Top-20%-Wealth		Other settings
		Mean	Wilcoxon Rank Sum	Mean	Wilcoxon Rank Sum	
Initial wealth	1-50	0.426	1-50 vs. 350-400 statistic = 27.40 p-value < 1e-164	0.628	statistic = 24.18 p-value < 1e-128	metabolism:1-4 vision:1-6
	100-150	0.251		0.129		
	250-300	0.135		0.077		
	350-400	0.100		0.061		
Metabolism	1-2	0.293	statistic = 25.42 p-value < 1e-141	0.226	statistic = -20.38 p-value < 1e-91	initial wealth:50-100 vision:1-6
	3-4	0.228		0.535		
Vision	1-3	0.326	statistic = 22.51 p-value < 1e-111	0.312	statistic = 14.00 p-value < 1e-44	initial wealth:50-100 metabolism:1-4
	25-30	0.300		0.238		

Altering Intial wealth

Figure 2: The Gini-index (left) and Young-in-Top-20%-Wealth (right) plot, with initial wealth 1-50

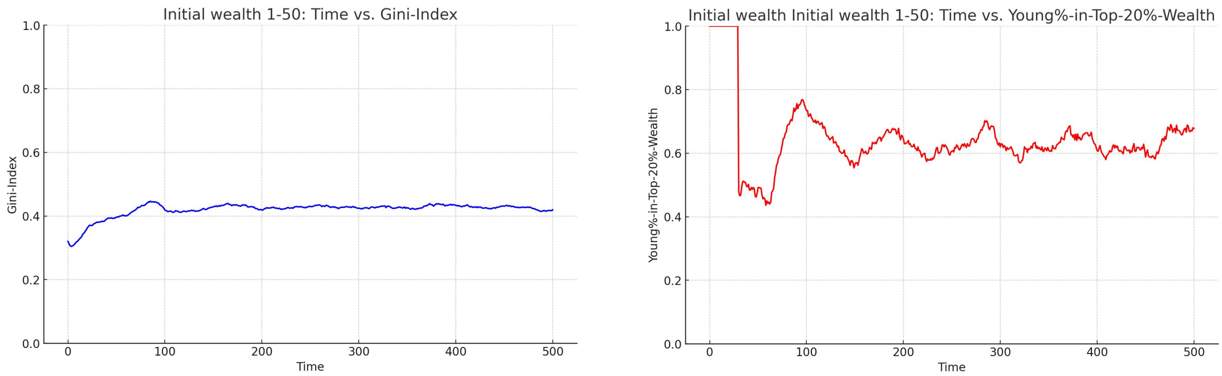
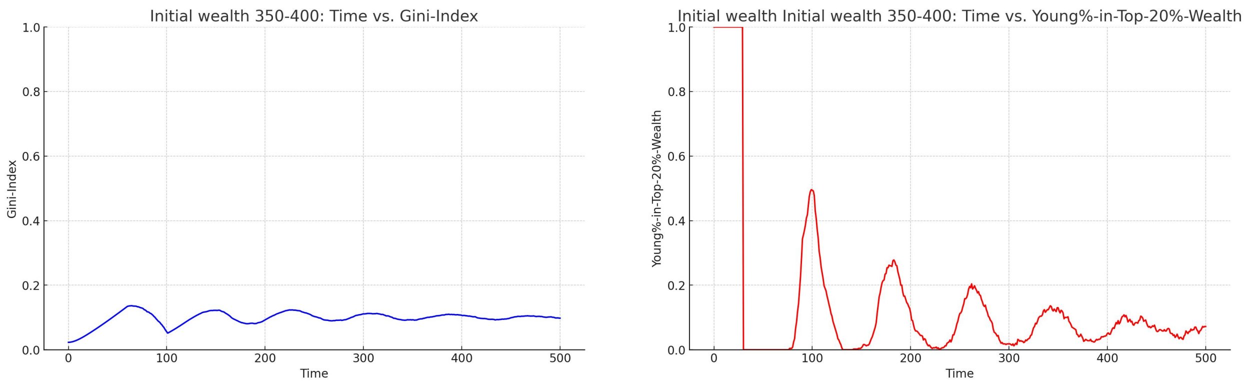


Figure 3: The Gini-index (left) and Young-in-Top-20%-Wealth (right) plot, with initial wealth 350-400



Altering Metabolism

Figure 4: The Gini-index (left) and Young-in-Top-20%-Wealth (right) plot, with metabolism 1-2

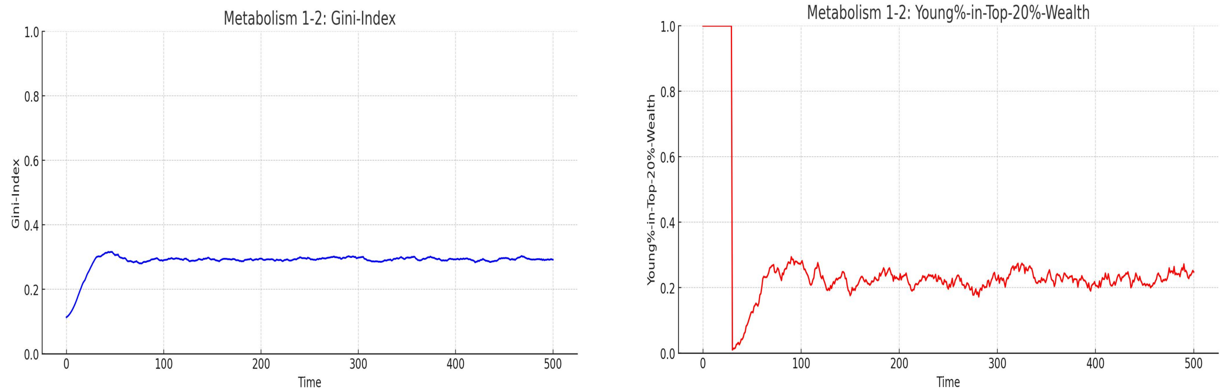
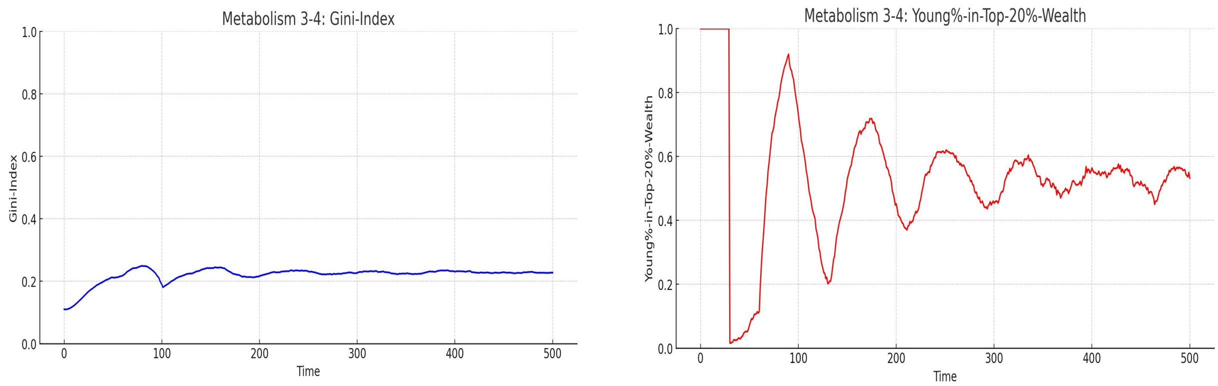


Figure 5: The Gini-index (left) and Young-in-Top-20%-Wealth (right) plot, with metabolism 3-4



Altering Vision

Figure 6: The Gini-index (left) and Young-in-Top-20%-Wealth (right) plot, with vision 1-3

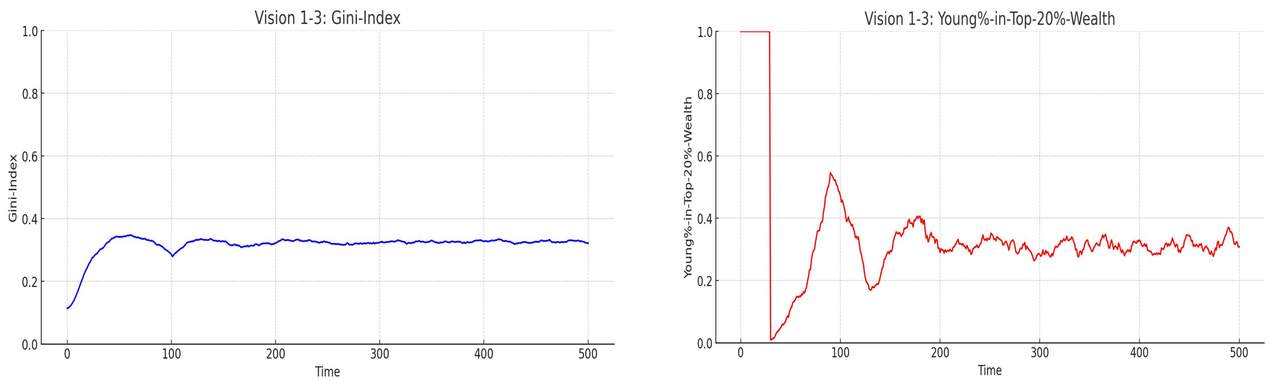
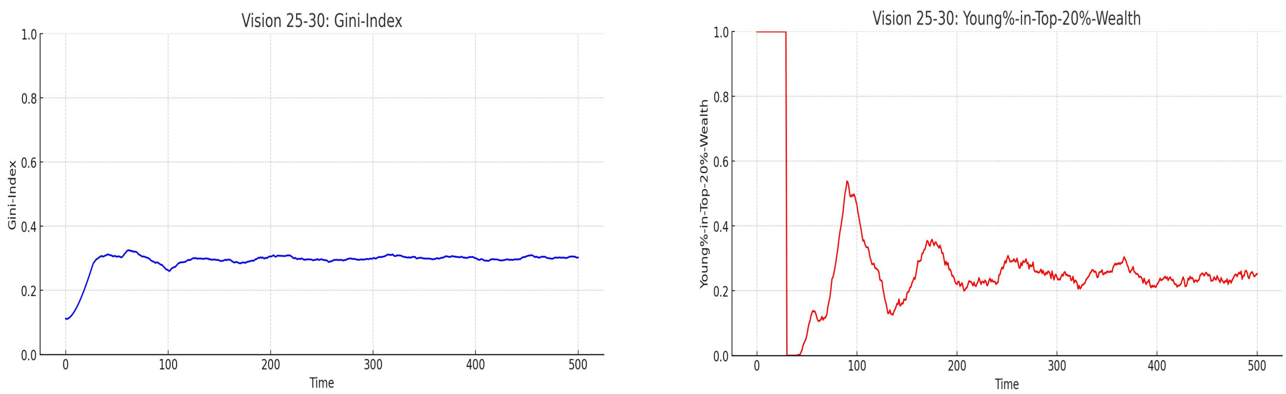


Figure 7: The Gini-index (left) and Young-in-Top-20%-Wealth (right) plot, with vision 25-30



The results of the Wilcoxon rank-sum test for each group indicate significant differences ($P << 0.05$), and the sign of the test statistic delineates the relative magnitude between groups. Mean values are employed to measure the gradient level of metrics in response to parameter variations. The findings reveal that with an increase in the initial wealth level, both the Gini index and the Young-top-20%-wealth metrics decrease significantly, indicating a reduction in wealth inequality level and an increase in intergenerational wealth disparity. As metabolism increases, the Gini index decreases significantly, while the Young-top-20%-wealth metric increases. A substantial increase in vision does not notably ameliorate wealth inequality (the Gini-index decreased by approximately 0.026) but results in a slight increase in intergenerational wealth disparity.

3.2 Model 2: the Influence of Parameter and "intergenerational reset"

When agents in the model reach max-age or deplete their sugar, they die and are replaced on the patch with a new agent generated with initial settings; this mechanism is referred to as "intergenerational reset". The mechanism constitutes the primary distinction between Model 3 and Model 2. Controlling for identical parameters within a reasonable range for both models, the results of the Wilcoxon rank-sum test and the average Gini-index show the Gini-index of Model 3 is significantly lower than that in Model 2 (Table 3). This suggests that the intergenerational reset mechanism is conducive to wealth redistribution, effectively reducing the level of wealth inequality.

Table 3: Comparison experiment: Model 3 Vs. Model 2

Variable			**Metric**		**Wilcoxon Rank Sum**
Initial wealth	Metabolism	Vision	Gini-index (Model 2)	Gini-index (Model 3)	statistic = -26.92 p-value < 1e-159
100-150	1-4	1-6	0.376	0.251	

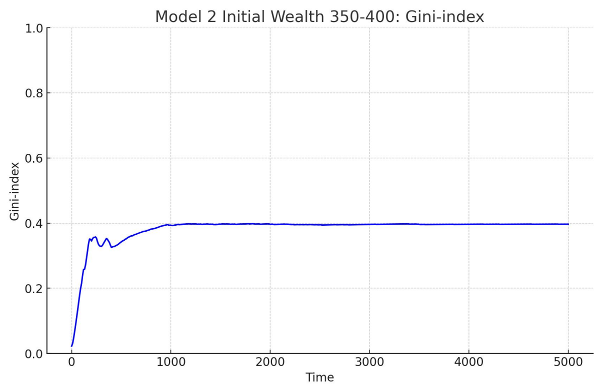
Same to previous experiments, we manipulate the parameters to observe the effects of various parameter changes on the Gini-index in Model 2 (Table 4) and graphs of the change in the Gini-index for the different experimental groups is plotted:

Table 4: Experiment Result for Model 2

Variable	Value range	Gini-index		Other settings
		Mean	Wilcoxon Rank Sum	
Initial wealth	1-50	0.362	1-50 vs. 350-400 statistic = -20.58 p-value < 1e-93	metabolism:1-4 vision:1-6
	100-150	0.373		
	250-300	0.374		
	350-400	0.382		
Metabolism	1-2	0.348	statistic = -22.69 p-value < 1e-113	initial wealth:50-100 vision:1-6
	3-4	0.310		
Vision	1-3	0.392	statistic = -27.17 p-value < 1e-162	initial wealth:50-100 metabolism:1-4
	25-30	0.197		

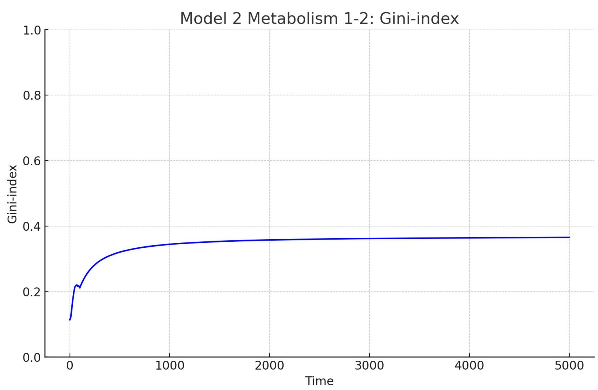
Altering Initial wealth

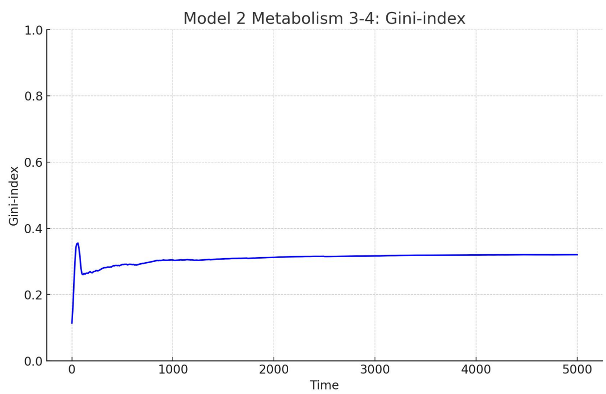
Figure 8: The Gini-index plot, with initial-wealth 1-50 (left) vs.350-400 (right)



Altering Metabolism

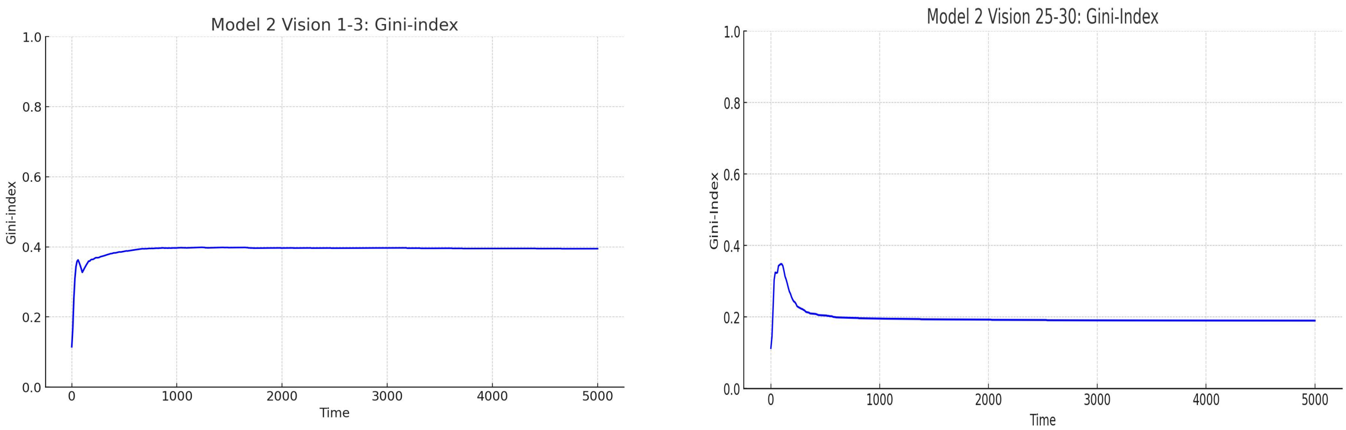
Figure 9: The Gini-index plot, with metabolism 1-2 (left) vs.3-4 (right)





Altering Vision

Figure 10: The Gini-index plot, with vision 1-3 (left) vs. 25-30 (right)



The Wilcoxon rank-sum test results across groups indicate significant differences ($p \ll 0.05$). The variation in initial wealth has very little effect on the Gini-index. Although the rank-sum test results are significant, the change in mean values is negligible. A higher metabolism caused a lower Gini-index similar to its impact on Model 3, thereby reducing the level of wealth inequality. Different to model 3, a higher vision can significantly decreases the Gini-index, and contributes to the reduction of wealth inequality.

4. Discussion

4.1 Model 3: Initial wealth/Metabolism/Vision

Sugarscape's basic social dynamics reflect core social principles to some extent. Therefore, the result of our experiments has the potential to be interpreted from sociological and economic viewpoints.

Piketty (2014) notes that initial wealth distribution critically impacts wealth accumulation, aligning with our findings that higher initial wealth markedly diminishes wealth inequality and intergenerational gaps. De Nardi (2004) posits that greater starting capital might prompt riskier investments. In our model, such wealth serves as a risk cushion, allowing high-metabolism individuals more chances to seek out better resources, avoiding premature death due to depletion of sugar. Essentially, more initial wealth lowers early "deaths" from resource scarcity, potentially smoothing wealth distribution.

The results also support the discussions about "Universal Basic Income" (UBI) policy in the real world. UBI provides all citizens with a regular, unconditional cash payment, which theoretically could elevate people's initial wealth level. Studies indicate that such a policy might reduce poverty and inequality (Van Parijs & Vanderborght 2017).

In Model 3, higher metabolic consumption decreased wealth inequality, analogous to rising consumer demand in economics. Keynesian macroeconomic theory (Pigou 1936) posits consumption as the main economic driver. When consumer demand increases, it potentially equalizes wealth distribution. Increased consumption often redirects the utilise of individual wealth from accumulation to survival needs, which may limit the wealth concentration of the “rich group” and result in more balanced wealth distribution, though this may cause more death and accelerate the generation, as our experiments corroborate.

Vision in this case, has been considered as the ability of searching for resource. Contrary to the commensense of "Ability creates profit", increased vision level hardly influence inequality, questioning why narrowing information and ability gaps doesn't enhance wealth equality. Pluchino et al. (2018) also concluded in their ABM study that wealth accumulation is less about ability and more about luck, aligning with our results. Space constraints prevent a deeper analysis in this paper, but this intriguing outcome may reflect the true nature of wealth distribution in modern society.

4.2 Model 2 vs. Model 3

In Model 2, the absence of "intergenerational reset" means individuals die only from sugar depletion without newcomers. Different to Model 3, initial wealth barely affects the Gini index due to fixed vision limiting access to high-resource zones. In this case, Initial wealth functions to prolong agents’ suvival time but not provide much chances to reach high-rescource areas, making vision and initial position crucial for getting chance to accumulation. Thus, in Model 2, enhanced vision plays a key role in reaching resources and reducing wealth inequality.

The parameters exert different impacts on wealth inequality across the two models, illustrating the role of intergenerational reset mechanisms on wealth distribution. As shown in Table 3, the presence of intergenerational reset cut the Gini-index by nearly half. In sociology, intergenerational reset is seen as an embodiment of social mobility. It can rupture entrenched social structures and facilitate redistribution of resources among members of society (Sorokin 2019). In economy, intergenerational reset offers opportunities for the resetting of resources, which can diminish the effects of accumulation and long-term wealth inequality (Piketty 2014). In our model, new agents start from a uniform baseline, and this cyclical "reset" can prevent long-term wealth accumulation and reduce the inequality that may ensue.

4.3 Implementation

Based on the analysis, the following policy recommendations are proposed to reduce the level of wealth inequality in society:

1. Implement Universal Basic Income (UBI) to ensure basic living needs of individuals, thereby providing them with more opportunities to explore paths to wealth acquisition.

2. Increase the minimum salary standard. Raising the minimum salary can stimulate market consumption, contributing to the circulation of wealth.

3. Equalize educational opportunities. Education can enhance individual knowledge and skills, thus increasing social mobility, and diminish wealth inequality (Sorokin 2019).

4. Reform tax system. Intergenerational resets in the model can be reflected in real society through inheritance taxes and progressive taxation on high incomes. Such tax reforms can prevent the accumulation of significant wealth within a few families across generations (Piketty 2014), thus reduce wealth inequality.

5. Conclusion

The investigation of Model 3 shows initial wealth, metabolism significantly affect wealth inequality. Higher initial wealth reduces inequality, echoing “Universal Basic Income” theories. Increased metabolism, mirroring consumer demand, supports Keynesian views that more consumption could equalize wealth. Contrarily, improved vision doesn't ensure equitable wealth, disputing the belief that equal information and ability guarantee equal wealth, while echoing the research of Pluchino et al. (2018) that wealth accumulation may be largely determined by luck rather than ability.

On the other hand, comparing two models highlights the role of intergenerational reset in reducing wealth inequality, in line with Sorokin's social mobility concept (2019) and Piketty's stance on “intergenerational resets” curbing long-term inequality (2014). The disparity in parameter effects between models underscores wealth distribution's complexity and implies potential methods to reduce wealth inequality in real world.

Word Count: 1496

Reference

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Appendix

Here is the extra reporter has been added into model 3, which report the proportion of young agents in the top 20% rich group:

```
to-report top-20-percent-new-generation

; define the threshold of young people
  let threshold-age 30

; sort turtles according to sugar
  let sorted-turtles sort-on [sugar] turtles

; caculate the number of top 20% rich group
let top-20-percent-count floor (0.2 * length sorted-turtles)

; get the list of top 20% rich group
  let top-20-percent-turtles sublist sorted-turtles 0
top-20-percent-count

; filter to get the young agents
  let new-generation-turtles filter [a-turtle -> [age] of a-turtle <
threshold-age] top-20-percent-turtles

; transform young agents list to agentset
  let new-generation-agentset turtle-set new-generation-turtles

; calculate the number of young agents
  let new-generation-count count new-generation-agentset

; calculate and retrun the young proportion in top 20% rich group
  report new-generation-count / top-20-percent-count

end
```