Bargaining Model: Enhancing the Wealth and Survival of the Poor by Finding a Better Long-term Strategy

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Abstract Inequality and poverty are often associated with irrational behaviour. In previous research a combination of taking risk and using rationale has been suggested as being a good strategy in a setting of iterated bargaining games. By using an agent-based simulation this thesis strives to find a strategy that enhances the wealth and survival of poor agents in comparison to known strategies. This paper claims that there is one combination of strategies that outperforms all other strategies in high cost environments. In this paper I argue that, by taking more risk in gaining more information, one can improve the expected utility maximization and achieve a greater degree of survival.

Keywords: Bargaining Model · Inequality · Rationality · Agent Based Simulation

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1 Introduction

Inequality has been an ongoing major issue in philosophy, economics and social sciences for many years (Salverda et al., 2009). Effects evolving from inequality have been identified and a comprehensive overview of social psychological research has been made concerning educational, sociopolitical and economic effects (McLeod et al., 2014). These effects have a negative influence on lifestyle and social happiness and widen the gap between *rich* and *poor* (Carvalho et al., 2016). Improving equality and solving poverty is what most people agree with as a major goal that man must strive. However, reaching this goal is something that has not been achieved in the last decades.

Often people dedicate poverty to irrational behavior, because of lower quality of education and intelligence. However, this conclusion is short-sighted. Klein et al. aspired to show how unequal outcomes can emerge from different strategies that are all contextually rational (Klein et al., 2020). A study done by Riley et al. states that the risk-aversion between poorer and richer people differ. It suggests that a higher degree of risk-aversion is shown by ones with lower incomes (Grable, 2000; Riley & Chow, 1992). This is held up by Rehm due to the fact that the relative position of someone in the national risk distribution, is a big factor in the influence of someones attitude to a situation. This can be seen by a higher exposure to existential financial risks in everyday lives for the poorer compared to wealthier persons (Rehm, 2011). This results in different bargaining strategies between the *poor* and *rich*. To evaluate these different strategies, a bargaining model was created (Klein et al., 2020). In this agent-simulation model, different strategies were randomly matched against each other. These players had to divide a certain amount of utility by bargaining the division. Different parameters for toughness, cost of living and wealth were tested to compare results between short and long-term strategies. Concluded was that the *poor* had a more short-term strategy because of survival. There is only a small chance for *poor* to survive in the long run against the *rich*. Context of the environment is important in whether an agent acts rational or not. Growing up in poverty or having parents that are lower educated, result in lower educational and occupational skills and thereby create a different context in which rationality is assessed (Dubow et al., 2009).

Bargaining is one of the games in which different strategies can be analysed using agent-based simulations, which is a major topic in Artificial Intelligence. In this paper multiple aspects and skills developed during my AI studies will be used, like programming, agent-based simulation, strategy optimization, iterated prisoners dilemma and analysing. Goal of this thesis is to find and test two strategies that may enhance the survival and wealth of the *poor* in a bargaining game. The question central within my thesis is whether I can *find a strategy that enhances the wealth and survival of the poor in a bargaining game on the long-term compared to strategies suggested by Klein et al. (2020).*

To find an answer to this question, I have come up with multiple sub-questions that are helping me to evaluate the results:

1. What is the current best strategy for the *poor* found by Klein et al.?
2. Which factors are involved in the differences in outcome between different strategies?
3. Can a combination of parts of good strategies, form an even better strategy?
4. Are the *poor* able to improve at all?

For this I will combine strategies used by Klein et al. and come up with new ones. Goal is not to find the best bargaining strategy at all, but to find a realistic strategy that works best for the *poor* on the long-term, resulting in a higher degree of survival and more wealth. With the results found in this thesis, I hope I can help future research narrow the inequality gap between *rich* and *poor*.

2 Theoretical background

2.1 Rationality and inequality

Not a lot of literature about the relation between rationality and inequality can be found. One overview provides some crucial insights on the relationship between socioeconomic status and the processes that underpin decision-making (Sheehy-Skeffington & Rea, 2017). This report states that the attention in research

is changing. It is increasingly focusing towards the individual decisions made in low-income contexts and its potentially damaging role. Media and public opinion propagate stereotypes and they often accuse lower-income people of putting less effort into their career and socioeconomic position in society (Sheehy-Skeffington & Rea, 2017). However, emerging academic research on this topic is coming up with more and more robust evidence in replacing these stereotypes regarding decision-making in poverty, as cited by the above report. Poverty has a great influence on one's ways of navigating life's challenges. Life throws up a range of challenges and these challenges differ depending on ones socioeconomic contexts. It starts with the struggles to find one's identity in adolescence, continues as pressure during your academic career and holds while finding a relationship (Apostolou & Wang, 2020; Sheehy-Skeffington & Rea, 2017). Sheehy (2017) states that the response to these challenges depends on one's belief in itself: "expressing confidence in one's self-worth in relation to others, one's ability to succeed in tasks, as well as faith that one's actions will have a meaningful impact on future outcomes" (Sheehy-Skeffington & Rea, 2017). Navigating challenges in life is difficult and could be influenced by health and social circumstances (Goodman et al., 2001). These circumstances could be a person's socioeconomic position, as well as what one thinks of oneself. This term is called self-appraisal and it includes both a person's image of himself and also how other people estimate him in relation to other humans (Goodman et al., 2001). This paper also comes up with one point of consensus that low-income or low-education level persons, experience a lower 'subjective social status' abbreviated to SSS. It is an adolescent specific measurement for which subjects where ranked on a society ladder (Goodman et al., 2001). Results of this indicator show that social stratification, a society's socioeconomic ranking based on factors like wealth, education and race, is strongly associated with depression and obesity (Goodman et al., 2001; Oyekola & Eyitayo, 2020). These subjective constructions matter for deep evaluation of self-worth. A large Canadian study held by Quon et al. (2015) also found that subjective social status is positively correlated with young people's self-esteem. Same holds for parental education, the income of a household and the school district one lives in, depending on whether it is in poverty (Quon & McGrath, 2015). This framework of subjective construal theory can be overlayed onto the findings on decision-making in state of poverty. It not only allows us to group these findings, but also gives us new insights. We can come up with reasons why one would make sub optimal decisions, which actually might not be irrational ones. That is, focusing on the context of the environment when a person makes a decision can be of great value to finding why one would make certain (ir)rational decisions. Focusing on the here and now is one of the reasons why a person might shift into a so called proximal mindset, especially when a pressing threat of immediate need is experienced (W. Frankenhuis & Weerth, 2013). Having a clear and distal mindset, which is when one's mind and worries are relaxed and free to dream about future goals and inspirations, can be seen as a privilege. People from supportive environments will experience help in navigating immediate challenges, as opposed to ones born in unstable environments (W. Frankenhuis & Weerth, 2013; W. E. Frankenhuis et al., 2016). These social comparisons result in relative deprivation experienced and since a person adapts its expressions of self-esteem to local norms, it makes rational sense for the increase of inequality (Moscatelli et al., 2014). This way we can say that rational behaviour in poverty is not the same as rational behaviour in non-poverty. This may be one of the reasons for inequality to be a thing.

2.2 Bargaining game

Current economics consists of endless transactions in which demand and supply are an everlasting search of balance. Both suppliers and demanders strive to achieve the optimal utility. Not only between businesses, but also between humans. Bargaining is a ubiquitous feature in daily economics. It takes place at each economic transaction, especially when distributional issues are determined. Bargaining frequently occurs in people's daily lives: in discussing a wage for a job, or negotiating a service with a car mechanic when a car is broken. More recently, games of bargaining have been going on between governments and pharmaceutical companies in producing COVID-19 vaccines. These negotiations lead to political and ethical dilemmas, since the more wealthy countries are able to buy more vaccines, which is at the expense of the nations in poverty. These competitions for vaccines have lead to inequality and therefore has been a worldwide point of discussion (BBC-News, 2021).

Classically, bargaining games are a one-round thing only. Most famous is the Nash bargaining game, invented by John Forbes Nash in 1953 (Thomson, 2009), which is a non-cooperative demand game between two opponents used for the modeling of bargaining interactions and finding the Nash Equilibrium (Nash,

1953). In this setup, two players demand a portion of some good, usually it is some amount of money. If the two players requested amount combined is less than the amount available, they both get their request. If the players do not come to an agreement on how to divide the money, then each receives their disagreement value, which is often lower than the amount when they would have agreed. The length of the bargaining process influences the time remaining for the actual production. The longer it takes to come to an agreement, the less money they can achieve during production. This puts actors in a situation in which they both try to achieve the outcome that favors their own benefits (Scheller, 2016). One way of achieving as much as possible is to bargain for as long and as hard as possible to secure a good deal. Do not give in to the demands of the opponent, rather wait till the opponents accepts your terms first. In this thesis I have tweaked this setup for turning them into iterated games. Instead of playing one round, each agent acts against random other agents for multiple iterations. This way we have introduced a rational aspect into the game. Agents can use their rational to tweak their strategy to achieve a more optimal solution. We have adapted the following parameters from Klein (2020) and Scheller (2016) in the bargaining simulations:
Toughness. This is an agent's key strategy parameter. This determines the number of rounds an agent is willing to hold a high demand, until cooperation is achieved. The higher the toughness, the later she is willing to give in.
Wealth. The accumulated amount of wealth of the agent. After every round the players achieve their pay-offs, which are added to their wealth.
Cost of living. To simulate evolutionary pressure, we have added a cost that agents must pay at the beginning of each round. This cost has to be paid by agents for maintaining their lives through each round. Agents that have reached a wealth of zero, die because of evolutionary pressure. The agent is removed from the simulation and is replaced by a new agent mimicking the strategy of one of the remaining survivors.
Class. The class of an agent: poor or rich. At the start of each simulation run, an agent has an initial value of wealth. The poor and rich agents differ in their initial wealth endowments. This parameter simulates the inequality factor in bargaining situations.

2.3 Current strategies

From the paper published by Klein et al. we can conclude four strategies that outperform the others: MaxEU, MaxiMax, Experimenter and MaxiMin. These strategies are described as follows:

- MaxEU: Agents with this strategy always pick the toughness which optimizes its expected utility. Its expected utility naturally depends on the agent's own toughness and its opponent's toughness. It uses the learning mechanism outlined in subsection 3.3 to determine the toughness to play. Starting with no information, she gradually updates her information based on the toughness of her opponents. This strategy simulates the optimal rational, risk-neutral player.

- MaxiMax: This strategy does not use any rational and never gives in. These agents are willing to outwait their opponents at any cost. It performs the highest possible toughness, by taking the most risk. Instead of working together, they try and achieve the maximal possible pay-off of 3 without losing to the opponent, i.e., it represents the strategy of an agent who is maximally risk-seeking.

- Experimenter: Experimenter is a mixture of MaxEU and MaxiMax. Before each game it chooses between these two strategies to adopt, with a 90% probability for MaxEU and a 10% probability for MaxiMax. The main reason to use a bit of MaxiMax is to gain information about their opponents' behavior, which can be used later to make better choices when playing the MaxEU-strategy. An agent can gain the most information if it outwaits the opponent, since only in this situation the agent knows exactly what toughness to opponents plays. Therefore, it can make the most accurate possibility distribution.

- MaxiMin: When a player performs the MaxiMin strategy, it always plays a toughness of zero. It does not take any risk, since is gives in immediately after the game starts. This player is infinitely risk-averse. Instead of bargaining for a higher price for itself, it takes a guaranteed pay-off of 1 per round rather than risking any incompatibility.

3 Description of the situation

3.1 Current situation

Currently, poor people do not have the same opportunities to achieve wealth and survival. These lead to different outcomes: the income gap between rich and poor widens. In the paper published before, we saw the four current strategies doing well. They state that for a cost-of-living up to 1.2, the MaxiMin strategy did best. This is due to the fact that this strategy does receive a pay-off of 1 point per round, no matter what the opponent's toughness is. So, up to and including a cost-of-living of 1, it does not make a loss. At higher cost-of-livings, the loss increases drastically resulting in a poor performance. This is when the Experimenter strategy comes in. It performs very well when the cost-of-living is 1.3 or 1.4, but works medium when it's lower or higher than that. From these results we can say that in the current situation, the cost-of-living is a big factor in the quality of the performance one strategy has. I will take these into account when I will evaluate my own results.

3.2 Computer model

To test the strategies, I use a simple bargaining NetLogo computer model to simulate different strategies and their outcomes. The NetLogo computer model was provided to me by my thesis instructor dr. Dominik Klein. In this program, one can simulate different values of parameters in an agent-based simulation environment. The model allows to scrutinize the success of different strategies in a simple bargaining model. This is only a very short description. A detailed outline is given in the Master's thesis by Simon Scheller: *Simulating Bargaining Processes with Agent Based Modeling* (Scheller, 2016).

3.3 Background of learning mechanism

Agents can use the information they have gained from previous games for choosing their level of toughness. They do not learn information about specific opponents, but they do remember what toughness the previously encountered opponents played. The learning mechanism is the information gain an agent achieves at every game. When an agent loses its game, it knows that the opponent has at least a higher toughness. If it wins, it knows the exact toughness of the opponent. From this information, an agent can learn the probabilities of the opponents' toughnesses and react to that, by changing its own level of toughness.

Based on the observation and her previous beliefs about the distribution of toughness, an agent can calculate a probability distribution P_{obs} about the possible levels of toughness the opponent may play. This distribution P_{obs} is derived from her initial distribution P_{old} by means of conditionalisation:

$$P_{obs} = P_{old} \mid \text{Observation.}$$

After every game, the agent's subjective probability distribution is updated. Agents employ their own experience in bargaining situations to assess the overall distribution of toughness within society. However, this distribution may change over time, as other agents adapt their toughness or agents may die or new ones see the light. That's why, agents will discount older information in favor of their most recent pieces of information, which are more accurate. Following these considerations, the learning mechanism can state the updating rule explicitly. The agent incorporates her new piece of information through updating her initial probability distribution P_{old} about the opponents level of toughness to P_{new} by the rule: $P_{new} := 0.9 \cdot P_{old} + 0.1 \cdot P_{obs}$. It does this for every level of toughness t, this amounts to:

$$P_{new}(t) = \begin{cases} 0.9 \cdot P_{old}(t) + 0.1 \cdot \frac{P_{old}(t)}{T}, & \text{if } t \text{ is compatible} \\ 0.9 \cdot P_{old}(t), & \text{if } t \text{ is incompatible} \end{cases}$$

for all toughness levels t. The factor $\frac{1}{T}$ ensures that P_{new} again is a probability distribution, i.e. probabilities sum up to one. At the beginning of a simulation run, agents consider all possible levels of toughness equally likely. Hence, they start with a uniform distribution (see also section 2.2 in Klein et al., 2020).

4 Model description

4.1 Agents

In the simulation model agents act in a bargaining game against each other. At the beginning of each simulation run, players are randomly matched together in pairs for one game consisting of a fixed number of bargaining rounds. Each agent picks a toughness before each game depending on its strategy. When one of the agents gives in, the two agents start their production phase. Whenever the maximal interaction time is reached, the agents are decoupled, new random pairs are formed and then the new couples interact for the same fixed number of rounds. Agents that achieve a negative wealth, do not survive the game and will be replaced by a copy of the left-over agents in the next game, to maintain a constant total number of agents. Per run, each agent will play a total of 100 games, against different opponents. When an agent gives in, it will receive a pay-off of 1 point per left over bargaining round in that game with this opponent. So for example, when it gives in at round 3, it will receive 7x1=7 points in this game. If the toughness of the agent is higher than its opponent, so the opponent gives in first, the agent will receive a pay-off of 3 points per left over bargaining round. So when the opponent gives in at round 3, it will receive 7x3=21 points in this game. At the end of each run, a mean total wealth is achieved per strategy.

4.2 Formal description of the new strategies

By evaluating the results found by Klein et al. I have found some potential properties that make up good strategies. It's a combination of using rationale and having a high toughness to gain more information about the opponents. I have come up with two potential strategies that are realistic and can be performed in a real world situation:

1. **Experimenter20**: this strategy looks like the known Experimenter strategy, but instead of 10%, it performs a MaxiMax strategy in 20% of the rounds and a MaxEU strategy in 80% of the rounds. This will increase the information gain during high toughness, but at the cost of using its rationale in picking the toughness with the most expected utility.

2. **CurrentWealth**: agents with this strategy determine its toughness depending on its current wealth. If its wealth is below a certain threshold, it will perform a more aggressive toughness by going all-in. When it has a higher wealth, it will perform the MaxEU strategy and use its rationale and come up with a toughness with the highest probability.

5 Method

This thesis has been divided into two sections. In the first part I have investigated and built potential strategies that would enhance the *poor* on the long-term. For this I have searched for strategies used in the past, by for instance Klein et al. and come up with new strategies that looked promising to me. I have come up with two promising ones. I have coded and built these strategies in the bargaining simulation in NetLogo that was provided to me by my thesis instructor dr. Dominik Klein. This model was built for his paper.

Next I have run multiple simulations on the different combinations of strategies and examined the results for the different strategies. These have been compared to the strategies that have been used by Klein et al.(2020). Expectations were there would be at least one strategy that is better than the known ones. With the results I have found, I am hoping to give an answer to my research question.

The experiments are divided into two parts. In the first experiment the Experimenter20 strategy will perform against the three best ranked strategies as found by Klein et al.: MaxiMax, MaxEU and Experimenter. For comparison I have added the MiniMax strategy as well as this one performs well at low values of cost-of-living. In the second experiment the CurrentWealth strategy will perform against the four above given strategies. This way I can analyse which strategy works best.

Each run will consist of 100 players, 20 of each strategy as described above. Each player is paired up in a couple with one opponent, playing 10 bargaining-rounds which make up 1 game. These can be opponents from all strategies, even the same one as the player. All agents are playing the iterated bargaining game for 100 games per player, resulting in 10000 games per run. For each simulated experiment, I have run 990 runs

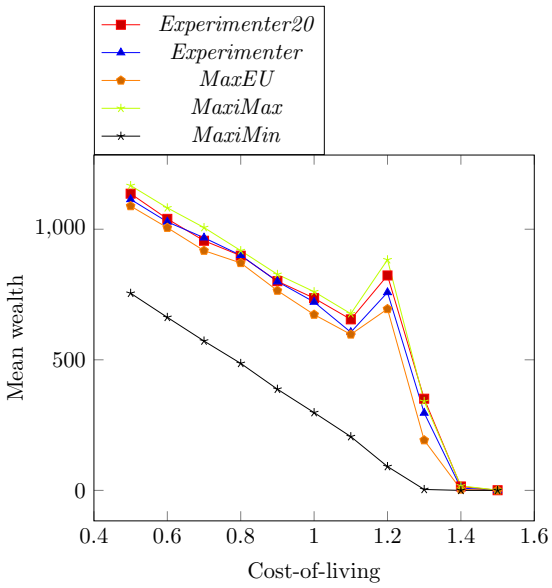
with different values for the parameters cost-of-living (0.5 up to 1.5) and percentage of rich agents (10% up to 90%). For the output measures, I have chosen to evaluate the mean wealth per strategy and the mean survival of the agents per strategy. These agents are all from the class "poor", to show the differences in performance between the strategies and give an answer to my research questions.

6 Results

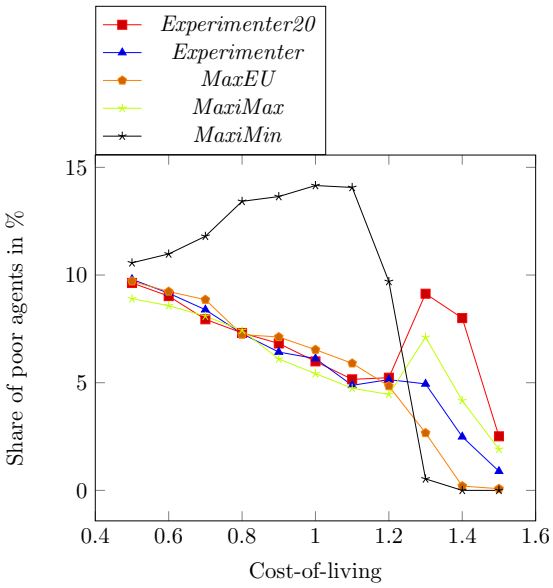
In the following sections I will show the results produced by the two simulation experiments I have run in NetLogo.

6.1 Experiment 1

In the first experiment the Experimenter20 strategy is playing against the strategies that were suggested before. In Figure 1a we can see the mean wealth of the different strategies played by poor agents over the various cost-of-livings. In this figure we can see that the Experimenter20 strategy performs well. It does better than the regular Experimenter strategy, since it does have a higher mean wealth for most of the cost-of-livings. Especially when the cost-of-living is 1 point or more, it performs better. However, the MaxiMax strategy does best.



(a) Mean wealth for varying cost-of-living



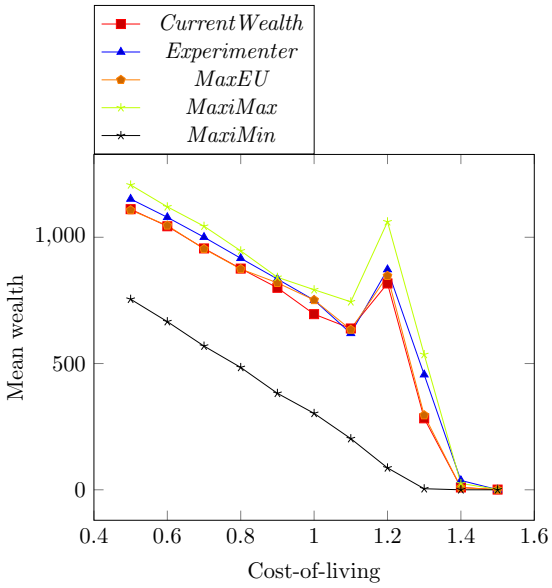
(b) Survival for varying cost-of-living

Figure 1: Results of the simulations of experiment 1

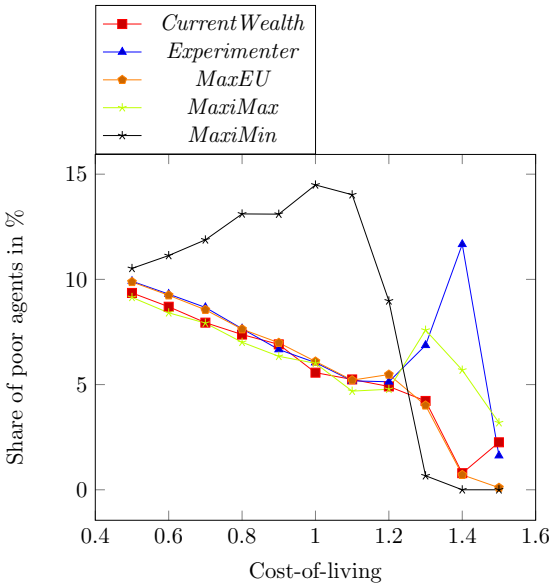
In Figure 1b we can see the share of the poor agents with their respective strategy in percentages. Here we see a large bulk of MaxiMin agents that survive when the cost-of-living is low. This is due to the fact they receive a standard pay-off of one point each round. As said in subsection 2.3, it performs well for low and worse for high cost-of-livings. Interesting to see here, is the fact that the Experimenter20 strategy outperforms all other strategies if the cost per round is 1.3 or larger. It does better than both MaxiMax and Experimenter. This may suggest that the combination of rationale and a risky strategy, improve the survival rate of agents at high cost environments.

6.2 Experiment 2

In the last experiment I have tested the CurrentWealth strategy against the formerly suggested strategies. In Figure 2a one can see the influence of the cost-of-living on the mean wealth of the different strategies over 990



(a) Mean wealth for varying cost-of-living



(b) Survival for varying cost-of-living

Figure 2: Results of the simulations of experiment 2

simulation runs. The CurrentWealth strategy did perform worse than the top three strategies as suggested by Klein et al. At all cost-of-livings, the mean wealth achieved by agents following a CurrentWealth strategy, was lower than MaxiMax, Experimenter and MaxEU. We see that the MaxiMax strategy achieved a higher mean wealth at all cost-of-livings than in experiment 1. This result may suggest that changing your strategy when your reach a minimum boundary to a risky all-in strategy is not as good for the poor as just following a MaxiMax strategy right away. If we have a look at Figure 2b, we see again a good survival rate for the poor agents that followed the MaxiMin strategy at a lower cost-of-living. When the cost per game increases, the Experimenter type does very well, whereas the CurrentWealth strategy drastically underperforms equally to MaxEU. The chances of survival for poor agents following a CurrentWealth strategy are slim and do not outclass the strategies found before.

7 Discussion

7.1 Limitations

Some limitations should be noted before discussing the results. One should be cautious as some randomness may be involved. Due to computational limitations, I was only able to do 990 runs per experiment. Even though the number of runs could be higher to improve accuracy, I think there can be drawn several clear conclusion from this data. As I chose to pick only a certain selection of strategies for this simulation to run on, results may differ between other combinations of strategies. For this reason, this study is only concerned with finding the best strategy out of the bargaining plans that are used in the experiments.

7.2 Answering research questions

In the upcoming section, I will try answering the research questions proposed in the introduction of this thesis. The different values of cost-of-living strongly influence the performance of one strategy in comparison with other strategies. Where Klein et al. found that MaxiMin performed well at low costs and Experimenter had a higher rate of survival at high cost-of-livings, my results conclude that adding some more risk in your strategy may give you a higher chance of survival when you start with a lower wealth. The Experimenter20 strategy thus increases the evolutionary performance of the poor. One explanation for this could be the fact that the Experimenter20 strategy gains more information about its opponents when it performs the

MaxiMax strategy and therefore can estimate a more accurate distribution of toughness. This precision could benefit the performance during the MaxEU strategy. On the other hand, the CurrentWealth strategy did not do that well. It is a realistic and perhaps easy strategy to follow. However, one should not expect that throwing your rationale overboard when life gets difficult and going all or nothing has a positive effect on the outcome. A good suggestion would be to maintain using your head and trust the statistics.

The biggest factors involved in the different outcomes between the different strategies, are the cost-of-living, the willingness to take risk and the distribution of the strategies. As can be concluded from the results, the cost-of-livings strongly influences the risk-aversion and rationale performance of one strategy. This suggests that a strategy that performs best in all situations does not exist. Rather, one's ability to achieve high wealth definitely depends on the context in the given situation. The other way around, this context influences the willingness an agent is to take risk, as stated in the introduction. However, the results show taking more risk in most cases slightly increases the wealth and increases the survival rate in high cost environments.

As the Experimenter20 strategy is a combination of two well performing strategies, one would expect it to do even better. This on one hand is the case, as its survival rate is higher. On the other hand, it did not perform best in terms of mean wealth. However, I dare to state that it indeed is the best bargaining strategy to follow out of the six used, since it has the most potential to achieve a higher income than the others. It does give an agent a pretty high wealth and a good chance to survive at high cost environments. We can conclude this discussion by stating that, by using Artificial Intelligence techniques like programming, agent-based simulation, strategy optimization and analysing, my research question can be answered positive: I did find a strategy that enhances the wealth and survival of the poor on the long-term.

7.3 Conclusion

Since the Experimenter20 strategy has good wealth overall and a high degree of survival, it can be concluded that this strategy has a bigger impact in narrowing the income gap between poor and rich. Although one cannot say that the poor achieve a higher wealth than the more affluent people, it does result in a higher chance of gaining more wealth and increasing its survival. I have learned much about the processes of doing research and this thesis has motivated me to continue doing research about what factors may help people in need facing a brighter perspective. My suggestions for future research are testing whether other distributions between MaxEU and MaxiMax may enhance the results. It would be interesting to know at what moment in time an agent has gained enough information and what different strategies there are to follow. I hope these findings will support future research in achieving a more equal world, in which an agent's possibilities do not only depend on the resources it was born with.

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