An agent based model of sex ratio at birth distortion caused by gender income gap

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Abstract: The sex ratios at birth (SRB) in many Asian countries are biased. This paper presents an agent-based model to study the relationship between the SRB and gender income gap. This model connects the individual's marriage and household's reproduction plan to sex ratio at birth in the society. We assume that every household intents to maximise a utility function that measures a specific reproduction plan's benefit. The utility function not only affects family size but decides offsprings' income in our experimental environment. Such interaction forms a feedback loop among agents and connects local decision to macro population bias. Sensitivity analysis, including One-Factor-at-A-time and Sobol's method, is discussed in details on this model. Besides, model parameters were estimated to operate the final experiments based on the sensitivity analysis results. The experiment results show that SRB positively correlates to the gender income gap and households' self-adaption to the social pressure can bring the overall gender proportion to an equilibrium. More importantly, raising women's average earnings is an effective way to reduce the problem of society's gender differentiation.

1. Introduction

The natural sex ratio at birth(SRB) in humans usually varies between 104 and 107 males per 100 females [1]. However, many Asian countries have shown biased SRB for a long time, being estimated at 115 in China and 111 in India in 2017. Distorted SRB could be explained by strong son preferences, gender-selective abortion after prenatal sex determination and female infanticide [2]. And the consequences constant biased SRB are obviously damaging, leading to the possible marriage squeeze in the future, the increase of crimes of violence and civil unrest [3].

A straightforward consequence of the bias SRB is the "missing women". Many studies about "missing women" in Asian countries have found positive relationships between female wage and the preference for girls. A cross-sectional study based on Indian state found that sex ratio is favorable to women in places where women works more [4]. Regarding to China, Xue(2015) utilised SRB as an indicator of gender inequality and found that gender equality rises in places where women are more productive [5]. Boy preference is stronger in poor, rural areas where agriculture is the main source of income [6].

These findings can all be explained by a model in which households maximize a utility function that is closely related to children's income. Qian (2008) build a mathematical model and conclude that increasing the household income does not affect sex ratio whereas increasing the relative female income increase the survival rate for girls [7]. The mathematical model is based on the assumptions that all households have exactly one child and a child's income is strongly correlated to a parent of the same gender. These assumptions make it easier to derive the model and are reasonable in post-Mao reforms. However, these assumptions are not valid anymore. Nowadays, households can decide the number of children they want to have and the income of a child is affected by many factors, such as the education investment on the child, comprehensive ability and the city where s/he lives, etc. Since the household's reproduction decision is complex and income of an individual depends on the local environment, we build an agent-based model to study how gender income gap influences SRB.

This report is organized as follows: Section 2 will introduce our model in details and the description of our model follows the ODD protocol [8]. Section 3 and section 4 present the sensitivity analysis of our model and our experiment result respectively. Finally, section 5 concludes this report with some insights for future work.

2. Model Overview

2.1. Purpose

The first goal of this project is to develop an agent-based model that connects individual's marriage and household decisions to macro-level consequence in the society. We believe this model can help illuminate part of the core dynamics that drive the skewed SRB in many countries. We investigate how gender income gap will influence SRB when the number of children in a household is more than 1 and the income of a child is affected by local environment and the household's income.

Secondly, the model shows the tipping point for extinction and can provide insights on how to decrease the skewed SRB. It may serve as an additional tool in policy making.

2.2. Entities, State variables and Scales

Our model consists of three types of entities, Male, Female and Family. Male and Female can freely move in a continuous plane, whereas families stay at particular positions and execute reproduction processes. The types of entities are discriminated by gender and marriage. If the marriage property is marked as True, the agent represents a family, and gender is neglectable in the following actions. If the agent has not married, they are classified by gender property. Agents will die if they fail to get married in three steps. All agents share identical properties but with different values. The properties are presented in Table. 1.

Table 1: agent properties

Properties	Description	Value
gender	agent's gender	True (female), False (male)
income	individual income	$[20,000, 100,000]$
marriage	marriage state	True, False
education_quality	agent's education quality	$(0, 1)$
children	children number of current agent	$\{1,2,3,4\}$
current_step	step count of non-marriage state	$\{0,1,2,3\}$
social_pressure	pressure when agent born	$\mathbf{R}^+$

All agents share identical properties but with different values. There are also environment forces affecting the agents' actions. Our central assumption is that every female suffers the gender income gap. Hence the environment set a property, initial_utility, to give a fixed income gap when agents are created. Besides, we introduce pressure coefficient indicating the social pressure, which subsequently affects families' reproduction plan.

Table 2: The attributes of the entities

Attributes	Explanation	Value
base_population	the basic population	100
pressure	fixed pressure sensitivity in an arbitrary society	0.08
gender_control_coverage	fraction of families who can control newborn's gender	0.1
sex_ratio	the initial sex ratio of base_population	$[0.8, 1.2]$
planning	the maximum number of children in a family	$\{2,3,4\}$
min_distance	the requirement of meeting for two agents	$[0.2, 0.8]$
vision	the vision of an agent	$[1.0, 1.7]$
initial_utility	the income gap between genders	$[0.5, 1.5]$

2.3. Process overview

In the marriage stage, agents with male and female types seek marriage under a particular criterion. When an agent successfully gets married, it will transfer to a family agent and proceed to the next stage. Otherwise, the current step is terminated after the agent moving to a new position. In the second stage, the family agent tries to find a reproduction plan to maximise the utility function, which takes income and fertility plan as parameters and investment ratio as the variable. After the optimal reproduction plan is found, the agent starts to initialise its offsprings' properties and place the new agents to the random picking position. Fig. 1 illustrates the action logic.

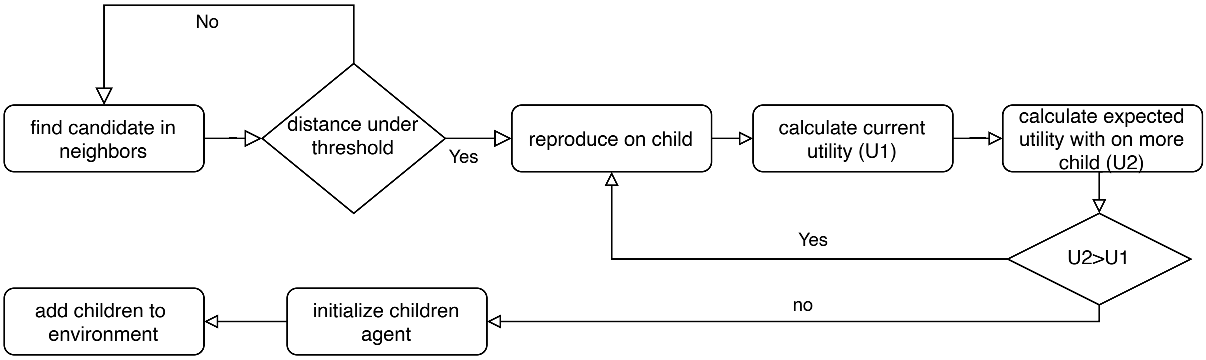


Fig. 1: Agent's action process

A noteworthy detail is that optimising process is implemented by enumerating potential plan. Based on current children number, the agent will trial the plan with one more son and one more daughter. Since the next children's gender is undetermined, the agent will check the potential plans' expectation value. This process loops until the agent cannot find a plan higher than the current situation or the total children number touches the limitation.

2.4. Design concepts

2.4.1. Basic principles

We assume that the gender income gap affects families' reproduction decisions, which subsequently affects the macro-level gender ratio. To connect the income gap with reproduction plan, we need a quantitative method to measure a specific plan's benefit. Some population research presents quantitative utility functions to model decision processes involving population phenomenon. Classic economics assumes individuals are rational when they make decisions, which means humans have an implicit utility model; every decision they make maximises the utility. This hypothesis has been expanded to social science research. Becker [9] constructed a utility function to model the trade-off between quantity and quality of children. The author's succeeding research [10] takes children number as variable, and factorise the reproduction utility into two elements: children's education quality and family life quality. Given education investment, raising more children means less education investment per capita, which usually indicates lower education quality. To maintain the education quality, parents might invest more in education, which leads to lower cost on daily life expense. Hence, a trade-off between life quality and education quality is the core decision spot of a reproduction plan. The decision process becomes a programming problem. Based on this hypothesis, we decomposite the utility function and gave a formal definition to submodels: education quality and life quality. We present factors involved in reproduction decision as Fig.2

Reproduction utility

The reproduction utility finds a trade-off between life quality (f_l) and education quality (f_e). The utility u is given by:

$$u(ic,iv,n) = \left(\frac{\sum_1^n f_e(ic,iv,n)}{n}\right)^{\alpha} * f_l(ic,iv,n)^{1-\alpha} \tag{1}$$

where ic, iv, n represents agent's income, investment ratio and children number. α quantifies a trade-off coefficent, We introduce an environmental pressure parameter to adjust α dynamically. The adjusted trade-off coefficient is given by:

$$\alpha = -\frac{sp}{2log(\frac{c\_num}{n\_num})+1} \tag{2}$$

where c_num is children number of this family. n_num is number of neighbors in the agent's vision. The empirical parameter sp implies the social pressure sensitivity in a particular society. A proper value guarantees that the population runs without extinction.

A large n_num means high local population density and highly competitive society. The utility of education is low because parents have to pay much higher to make their children outstanding, which cause damage to their life quality. Hence, a rational family would concentrate more on life quality and only expect an average education quality.

Given the Equation 1 , the only variable of an arbitrary agent is iv. The objective of an family agent is finding a optimal investment ratio to maximise the utility function. The details of two empirical submodels, f_e and f_l, will be given in section 2.7 .

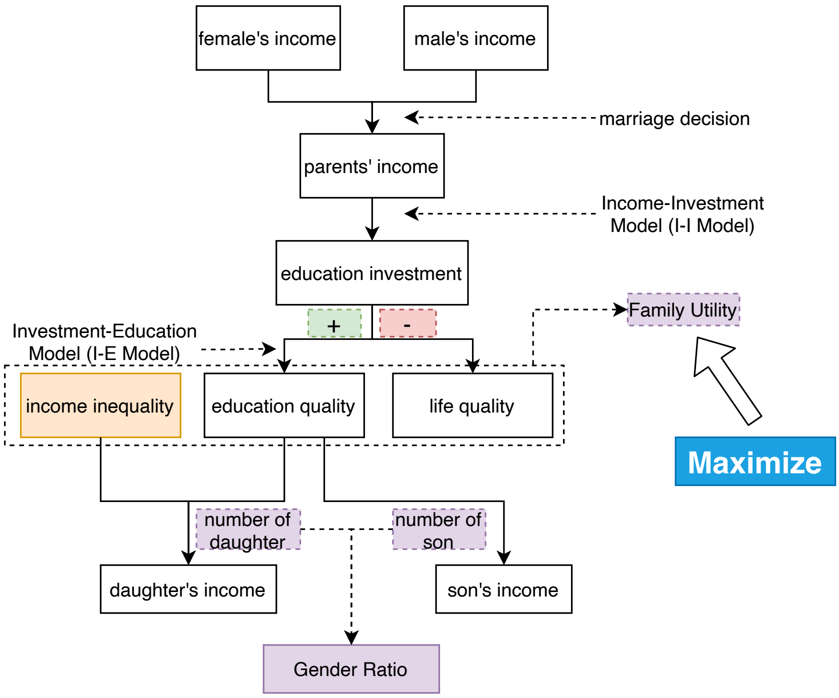


Fig. 2: Interactions among factors

2.4.2. Adaptation and emergence

As we mentioned in the last section, the unit population density affects the reproduction plan. High density leads to low fertility. Besides, as the core assumption, females have inherent disadvantages against male, reflected by lower female quality than male. When we calculate education quality, we add a discount on female to mapping gender discrimination into the quantitative utility function. Considering all these adaptations, agents prefer sons, leading a gender ratio distortion. Although the gender ratio may fluctuate across steps, the overall gender ratio is expected to converge to a stable value.

2.4.3. Interaction

In section 2.3, we give an overview of agents action. Here we present details for agents' interactions.

Agent-Agent

Marriage: When a male or female agent is activated, it starts seeking a candidate for marriage in its vision according to a particular criterion. If there is no appropriate candidate in its neighbours, the agent will move randomly and terminate its round.

If the agent has found the candidate, it first checks their relative distance. Suppose the distance is farther than a threshold, the agent move towards the candidate and terminates its activity. Otherwise, the agent gets married to the candidate. Marriage action will change marriage property to True value, and merge two agents' incomes as family income. The source agent will be regarded as the representative of a family; the candidate is removed from the environment. After all actions above, the family agent will turn into reproduction decision stage.

Reproduction: Family agents in this stage reproduce offsprings according to the reproduction plan. Reproducing is partial random. A small fraction of families can decide the newborns' gender, representing that they have access to the gender selection technology. Then families generate properties for their children and then distribute children randomly in the space.

Agent-Environment

A fundamental interaction with the environment is moving. Overlapping is allowed. Besides, reproduction also affects social pressure defined Equation 2, which conversely affects families' reproduction decision.

2.4.4. Stochasticity

Agents starts their actions in random order. The core reproduction processes, including gender of child and positions of new agents, are dominated by uniform distribution.

2.4.5. Observation

Our observation data is Sex Ratio at Birth(SRB) and newborn children number.

2.5. *Initialization*

Lorenz curve is often used to represent income distribution, showing the inequality of income that the bottom X% holds Y% of the total income. We simply added up five-segment Poisson distribution function to fit this curve. In each segment of Poisson distribution function($f(k;\lambda) = \frac{\lambda^k e^{-\lambda}}{k!}$), we assign the expected value λ as the expected income and the number of occurrences k represent the number of people that possess the income. According to that, we divided the society into five levels based on their incomes, 31% of the females and males(separated by the initial sex ratio of the basic population) have the expected income of 20,000, 22% of 23,000, 17% of 25,000, 20% of 60,000 and 10% of 100,000.

2.6. *Submodels*

2.6.1. Education quality

Education quality (f_e) is positively correlated with education investment. In our model, all agents interact within an identical environment. Hence the comparability of education quality is essential. In reality, children participate in the national examination as a unified measurement of their education quality. Although standardised exam neglect individual characteristics, we still adopt a similar concept to standardise measurement.

A qualified standard exam should distribute scores as a skewed bell curve. We empirically assume that the relation between education investment and learning outcome fits a logistic model, an approximated CDF of the score distribution. As the score approaching the max score, the marginal utility of education investment decreases. Based on observing and analysing education survey data, we express f_e as:

$$f_e(ic, iv, n) = \frac{n}{e^{-c_1(iv*ic+c2)}+1} + b_1 \tag{3}$$

c_1, c_2, b_1 are constant estimated via actual data.

2.6.2. Life quality

In[fertility choice], authors integrate macroeconomic data, formalising life quality as a function of income and commodity price. We simplified this model by introducing an empirical model (denoted as f_i) which sketches the relation between income and investment ratio. Given family income and investment ratio, we use actual data to regress f_i to predict the expected investment ratio, $\bar{i}$.

As we discussed in f_e model, the education quality has an upper bound. A rational education investment should follow the trend as f_e. Hence, f_i should also have an upper bound. Moreover, as the marginal benefit of investment is descending, $\frac{df_i}{d(ic)}$ should approach 0. We give f_i as:

$$f_i(ic) = \frac{ic}{c_3 * ic + c_4}$$

Because we only consider investment ratio (iv) when we construct f_l, we get the expected investment ratio given the family income:

$$\bar{iv} = \frac{1}{c_3 * ic + c_4} \tag{4}$$

With the exact $\bar{iv}$, we can compare it to iv. If $iv > \bar{iv}$, the family's education investment exceed the budget, which means the family's life quality will be negatively affected. To reflect the correlation between investment and life quality, f_l need to guarantee the following properties:

$$\frac{\partial f_l}{\partial iv} < 0, \quad \frac{\partial f_l}{\partial n} < 0, \quad \frac{\partial f_l}{\partial x} > 0 \tag{5}$$

Moreover, middle class is more sensitive to life quality shift because they have strong intention but inferior ability to maintain their social level, comparing to upper class. By defining an income threshold I, the trait is quantified as:

$$\begin{cases} \frac{\partial^2 f_l}{\partial iv^2} \leq 0 & ic \leq I \\ \frac{\partial^2 f_l}{\partial iv^2} > 0 & ic > I \end{cases} \tag{6}$$

Cooperating equation 4, 5 and 6, we construct f_l as:

$$f_l(iv,n) = (c_5 - \frac{1}{e^{-c_6 * iv * n} + 1})/(c_5 - \frac{1}{e^{-c_6 * \bar{iv} * n} + 1}) \tag{7}$$

2.7. *Parameter estimation*

We have discussed submodels of reproduction utility. To estimate constant parameters in Equation 3, 4 and 7, we use a family survey data (CFPS [11]).

China Family Panel Studies (CFPS) is a nationally representative families, and individuals launched in 2010 by the Institute of Social Science Survey (ISSS) of Peking University, China. The studies focus on the economic, as well as the non-economic, wellbeing of the Chinese population, with a wealth of information covering such topics as economic activities, education outcomes, family dynamics. The survey covers almost 15,000 families and 30,000 individuals within these families. Beside family income and family education investment, this survey contains a standard test for children to measure their mathematical and verbal ability. With fruitful data, we apply OLS to estimate c_1-c_6, and plot the fitted results in Fig. 3, Fig. 4 and Table 3.

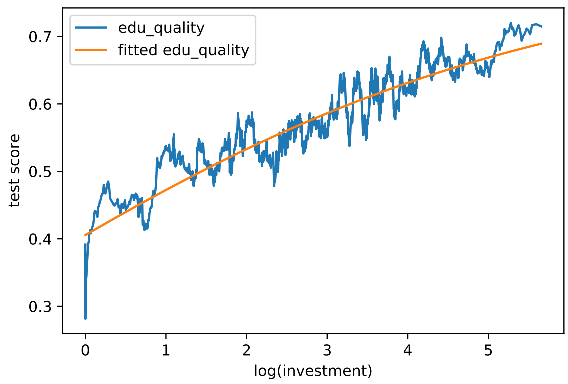


Fig. 3: Fitted curve of f_e

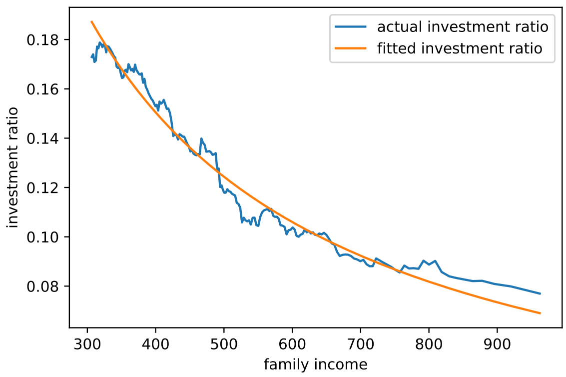


Fig. 4: Fitted curve of f_i

Table 3: Constant parameter value

c_1	c_2	b_1	c_3	c_4	c_5	c_6
0.2892	1.4360	-0.1968	0.0238	0.2306	0.93	0.3

Regarding Fig.3, test scores fluctuate along the fitted curve. Part of the reason might be that the survey's standard test is not mandatory. Children hardly have the motivation to do their best. Besides, outliers exist at low-level investments. A potential explanation is that samples at a low investment level are at their primary level. Primary children do not cost much in education and have disadvantages to other higher grade children in the same exam.

3. Sensitivity Analysis[1]

In agent-based modeling, the model input's uncertainty could lead to the error in the model output. To assess the nondeterminacy of our model outcomes and identify the most influential parameters, we were supposed to imply sensitivity analysis. Hence, we implemented OFAT and Sobol sensitivity analysis to prioritize and adjust the five parameters saying initial_utility, sex_ratio, min_distance, planning, and vision. Chances are that making sure parameters setting for experiments later and some factors with less influence might be fixed or removed from our model. Before we perform the sensitivity analysis, we would like to set the parameters in a particular range. Thus we chose initial_utility=[0.5,1.5], covering both situations of male has higher income and in turn female's

[1] For source code, please visit: https://github.com/wenbo1212/agent_based_modeling

earnings is higher; sex_ratio=[0.8,1.2] means different sex ratio of the initial population; Planning=[2,4] was the maximum number of children for each family. The reason why we excluded planning=1 was that intuitively the population will not die out only if each family have two children. Otherwise the population would extinct sooner or later after few generations. Vision determined the maximum distance in which each agent can find a partner. The vision was [1,3] here based on a 10*10 continuous space map. Since our model is not discrete grip-based, we define two agents meet if the distance between them is within min_distance. We set the initial agent number at 100 and ran the model for 80 max_steps, which was sufficient to reach a steady state in our model.

3.1. OFAT

One-Factor-at-A-Time(OFAT) sensitivity analysis is a straightforward method to analyze a specific ABM model's qualitative behavior. It selects a base parameter setting and changes one parameter while keeping other parameters fixed [12]. To reveal the potential linearity or tipping point in our model, we varied each parameter individually, namely sex-ratio, planning, min-distance, vision, and utility, within a particular range as mentioned before.

During OFAT analysis, we had ten distinct samples for each of the five parameters, and for each parameter, we repeated ten simulations. Note that the label Y "gender_ratio" of Fig.5 means SRB we introduced before. As can be seen in Fig.5e, the utility had a significant effect on the sex ratio at birth. The SRB decreased continuously as initial_utility went up from 0.5 to 1.5, with a steep decline near 1. The overall negative correlation between utility and SRB is intuitively clear because parents always prefer children having higher incomes, which meant utility here. As for the effect of the sex ratio of the initial population, we did not observe a clear converge behavior neither in SRB nor in output error throughout the process. This phenomenon was caused by environment pressure introduced in Equation 2. The α coefficient would adjust according to the number of a certain gender, and it could balance the gender ratio. However in Fig.5b and Fig.5c we could obtain that. When planning was larger than three and min_distance was larger than 0.6, there was a clear decrease in output error. The number of children would not affect the mean SRB significantly, but the uncertainty clearly shrunk. Similar in min_distance, the SRB only fluctuated while min_distance was smaller than 0.55 then kept almost unchanged afterward. Fig.5d showed that larger vision only cause larger uncertainty in the sex ratio at birth. Accompanied by enlarged error, the rate deviated away from 1 as vision turned larger. This could explained by the increased stochasticity that agent have more options if they have larger vision in their neighbourhood.

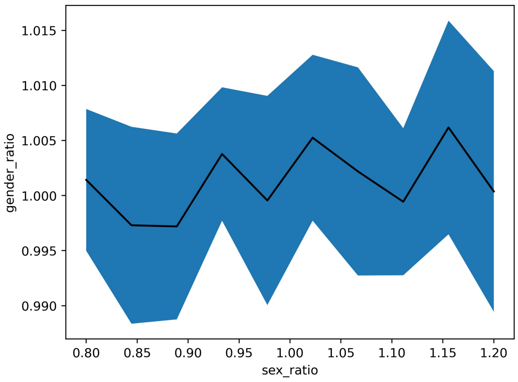
3.2. Sobol

In the global sensitivity analysis, all parameters are varied simultaneously over the entire input range, allowing to investigate both their individual and interaction effects on model dynamics. During this process, global sensitivity analysis would help us learn which part of parameter space contributes most to the overall system behavior. One of which is Sobol's method, based on the decomposition of the model output variance into summands of the input parameters' variances in increasing dimensionality [13], calculating the effect of each parameter and their interactions to overall output variance.

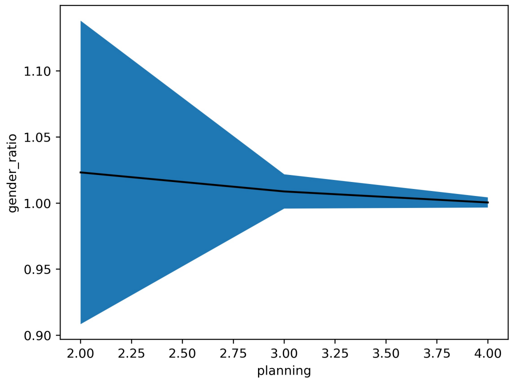
We conducted first and total order Sobol sensitivity analysis to investigate the above two effects in this project, sampling 700 distinct samples for five parameters replicating ten times for each run. Since the model ran for 80 max_steps, meaning 80 generations, extinctions might happen in some parameter settings. We will discuss this in detail in part 4, and now we just excluded those data in Sobol analysis. As Fig. 6 showing, sex ratio, init_utility and vision first order indices mean value were 0.3,0.1,0.12 respectively. The other two parameters min_distance and planning have zero and negative first order indices, thus we assumed they were zero. Fig.7 showed the result of total order; the total indices mean value of sex_ratio, init_utility, vision and min_distance all ranged from 0.8 to 0.9, which were quite high. Slightly smaller than the other four parameters, the index for planning was 0.7. Through analysing the result of first order and total order, we considered that sex_ratio is the most influential parameter as it had highest first order and total order index. This result was clear because the sex ratio of initial population essentially affect the model dynamic. Highly biased initial sex ratio would disturb the SRB because of the lack of male/female agents. Although the first order indices of initial_utility and vision were smaller than sex_ratio, the total order of them were relatively high. Thus their interaction effects combined with other parameters were huge and these two parameters were important. Despite zero first order indices, min_distance and planning still had considerable total order indices when interaction was taken into account. Thus we could not withdraw these two from our model.

4. Experiment Result and Discussion

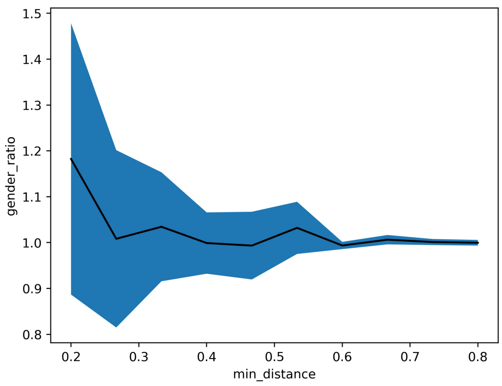
This project's primary purpose is to reveal how the gender income gap could lead to a skewed SRB. According to the result of OFAT and Sobol sensitivity analysis, we could choose a set of parameter with low output uncertainty



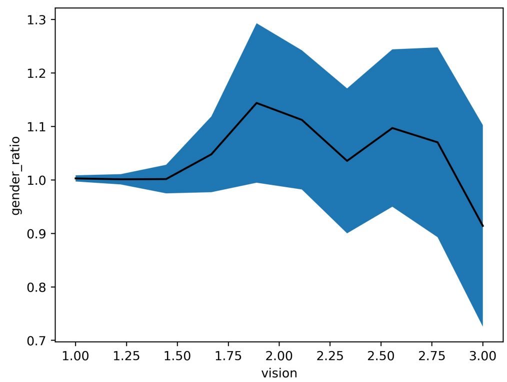
(a) The effect of sex_ratio



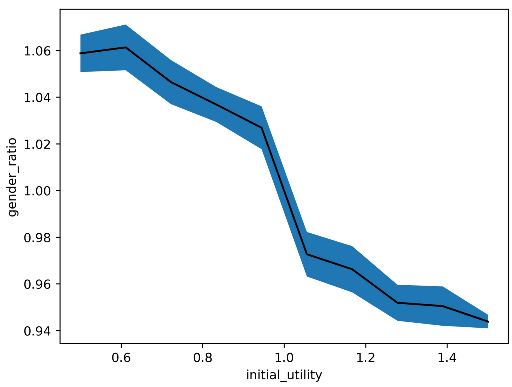
(b) The effect of planning



(c) The effect of min_distance



(d) The effect of vision



(e) The effect of initial_utility

Fig. 5: The OFAT sensitivity analysis result with 10 replicates, 80 max_steps and 10 distinct_samples.

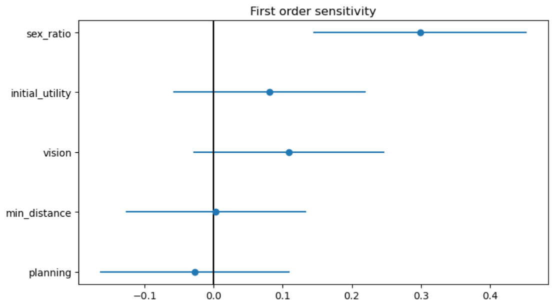


Fig. 6: First order Sobol result

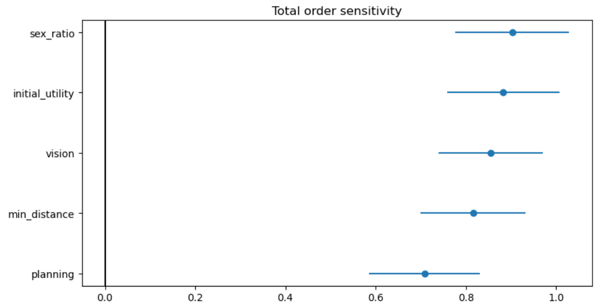


Fig. 7: Total order Sobol result

and consistent with our model assumptions. We set sex_ratio as 1 because intuitively this neutral setting would not affect SRB in the end; the planning was 3 as planning=2 caused considerable uncertainty and planning=3 took unnecessarily long running time; the last two parameters min_distance and vision were 0.7 and 1.1 respectively.

Before running experiments to investigate our research questions, we had to determine when extinction will happen in our model. The SRB would be meaningless if extinction occurred. Hence, we designed settings with different initial_utility and gender_control_coverage, determining the percentage of families which can choose the newborns' gender; this meant parents have access to the gender selection technology as described in section 2.4.3. The adaptive parameter pressure in our model ensures the population's stability here. In another words it would not let the population die out quickly. Especially when the population is small, agents tend to have more children. On the contrary, if the agent population is large, People's pressure to reproduce children will also increase. Fig. 8 shows newborn children number when agent number=100, initial_utility=[0,2]. When gender_control_coverage=0.1, the average newborn Children was 90. Then average newborn declined to 60 with gender_control_coverage increasing to 0.3. When gender_control_coverage=0.5, extinction happens in the situation of initial_utility less than 0.5 and larger than 1.6, with average children smaller than 15. At last, in the circumstance of gender_control_coverage=0.7, most families can decide the next generation's gender by maximizing their utility function. The extinction phenomenon is more pronounced here, where only population with initial_utility from 0.5 to 1.25 can survive. We could interpret this phenomenon from gender_control_coverage as the parameters to influence how much next-generation maximum utility influences a family's reproduction choices. The higher the rate is, subjective children's sex selection based on utility function will account for a more significant proportion. Hence, societies are more likely to die out because of gender inequality, resulting in a decline in suitable mating rate. Hence, we chose gender_control_coverage=0.1 in our next experiment of investigating the relationship between initial_utility and SRB, making sure no extinction would happen.

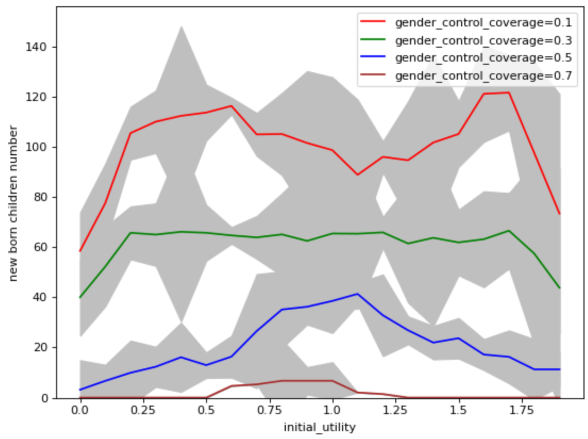


Fig. 8: New born children number with initial_utility=[0,2], gender_control_coverage_rate=0.1,0.3,0.5,0.7

Finally, we performed our experiments to investigate the research question with different initial_utility, covering values of smaller and larger than 1. The simulation repeated 10 runs and stopped at 80 max_steps. It was clear in Fig.9 that after the similar warm-up periods, all the three scenarios finally converged as variance shrank continuously. Each setting had a different equilibrium from the other two. About quantity results, when init_utility=0.5, 1.0 and 1.5, SRB stabilizes at 1.06, 0.99 and 0.95 respectively. This phenomenon matches reality world, and we can start the discussion from an extreme low inital_utility=0.5. In this setting, average male earning is twice as much as average female earning. Since each family decides to reproduce strategy by maximizing the utility function of the next generation, parents tend to prefer boys with higher paybacks. Although our model has realistic balances between the effects of education investments, children's competitiveness, the learning ability of different genders, the huge utility differences cause a 1.06 SRB bias eventually. When the init_utility=1, representing there was no gender income gap between male and female. Based on the model description statement, girls outperform boys in standardized exam scores under the same educational investment. Hence, girls' utility would be generally higher than boys and more likely to become family's better choices, resulting SRB a little bit smaller than 1. Then, in the scenes of init_utility=1.5, where females' payment is 50 percent higher than males. This setting doesn't quite match the reality, but adding it gives us more sight in how this system works. In addition to the given high female utility, women's natural advantage in study also contributes to this SRB=0.95 deviation. On the whole, our experiment revealed that a larger gender income gap, decided by initial_utility, would lead to an imbalance in SRB. Creating more jobs for women, and thus higher average earnings for female would reduce the gender gap problem in society.

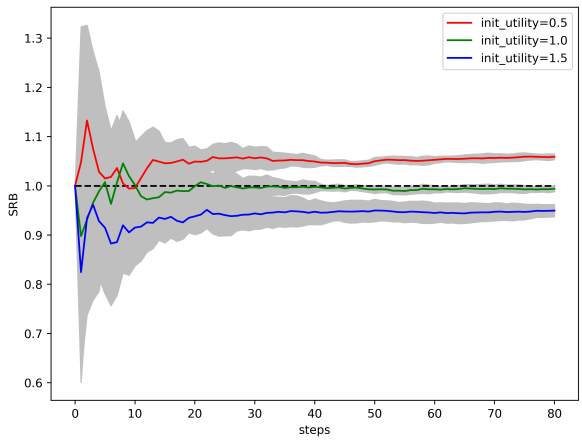


Fig. 9: SRB with different initial_utility with replicates=10, max_steps=80, planning=3, min_distance=0.7, vision=1.1, sex_ratio=1.

5. Conclusion

In this project, we developed an agent-based model to investigate the effect of the gender income gap on Sex Ratio at Birth(SRB). A connection between the micro agent and macro population was built through the dynamic that an individual's marriage and decision on reproducing plan contribute to the society SRB. We created heterogeneous agents with complex interactions with their neighbors, including marriage and reproduction, the core mechanism in our model. To assess the uncertainty and detect influential parameters, we implemented OFAT and Sobol sensitivity analysis to see each parameter's single and interaction influence. As shown in sensitivity analysis, the initial population sex ratio was the most critical parameter influencing sex ratio at birth. However, The interaction effect of other parameters was also quite influential. The inner mechanism in our model caused this complex relationship. Finally, based on experiment results, we can conclude that biased gender income could lead to an imbalance in SRB. When male income exceeds female income, the SRB would be greater than 1. On the contrary, if female income exceeds male income, more newborn girls will be more than boys. While there was no gender income gap, the SRB would stay in a neutral position. Hence, one way to solve the increasingly serious problem of society gender differentiation is increasing women's average earnings.

6. Future work

In the future, we still have several tasks to investigate further. Firstly, we noticed that the simulation error of utility =1.5 was larger than the other situations and we would operate more experiments on this to find the reason. Then, we would conduct more experiments to predict SRB evolution in adapting to real-world countries. Finally, more parameters' influences like society type and national development level could be integrated in the model.

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