Study on Agent-Based Modeling to Simulate the Causes of Declining Marriage Rate in Japan

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Abstract: The field of Agent-Based Modeling (ABM) focuses on simulating social issue to shed some significant light on one specific problem. The model has been built on the assumption that low marriage rate is a shadow behind the falling number of children. In this model, KEKKON (marriage) model, ABM is used to simulate the way how Japanese people get married via bottom-up approach. By changing policies, the flow of population can be observed.

Keywords: Agent-Based Modeling, bottom-up approach, marriage rate

1. Introduction

Declining number of child born has been an issue in Japan since the end of World War II [1]. Study by Ryuichi et al. postulated a decrease in population, based on medium-variant projection, to be about 115.22 million in 2030, with tendency to fall below 100 million in 2046 and drop to 89.93 million by 2055 [2].

The National Institute of Population and Social Security Research (IPSS) is a national research institute of Japan. Every five years since 1952, IPSS has been conducting National Fertility Survey (*Shussho doko kihon chosa*) to understand the process of marriage and fertility of married couple and, since 1982, expanded the survey to include unmarried persons [3, 4]. "Completed fertility rate" data showed that, on average, 2.2 children are born to a couple [5].

Various measures have been taken to help support married couple like, increasing allowances for childbirth and child care, improving child-care center, amongst others. However, such measures do not help promote fertility rate which has been shown to decrease over the period (1970s to 2002). The reason that bringing up a child is too expensive attributes to the main causes of the falling number of children, and hence occurs before marriage, not after it [5].

Agent-Based Modeling (ABM) is a new analytical method for social scientist and has become a popular approach as it enables one to build models where individual entities and their interactions are directly represented [6]. It is used as a representative of real world system to understand and help make decisions [7]. Implementing various factors into ABM to simulate the desired outcome might help develop strategies and/or policies to improve marriage rate.

2. From Social Concern to the Simulation: ABM

ABM can be used as a tool to simulate social structure (environment) and study the behavior (interaction) of people (agents) [8]. Many scientists conduct research on social concern using ABM as a main simulation approach. Following are some selected studies that are specifically in concern with marriage process which are also related to this paper.

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2.1 Individual Mate-Search Heuristics [9]

Sociological and demographic researches have gathered and analyzed data on population-level (top-down) patterns such as age at marriage which is typically void of choice made by individuals. On the contrary, psychologist and economist model of individual-level (bottom-up) process omits the pattern emerging in a group of deciding individuals. ABM is used as an attempt to foster communication between top-down and bottom-up approach. Set of simulated individuals trying to get married was created and their success (or lack of) of marrying over period of time was monitored. With this, the age of individuals getting first marriage and overall number of individual ever getting married was recorded.

Although the initial models allowed expansion of the range of explanation to consider for demographic data, these simple mechanism of individual search was, in various ways, unrealistic. One of the assumptions made in the model was that the decision of getting married is made instantaneously. Another was the strict cutoff level set up in the model where individual above certain quality level were accepted and others were rejected. The simple model set up was although unrealistic, showed room for improvement which can be exploited for further refinement of the model to meet the realistic data.

2.2 The "Wedding-Ring" [10]

Social interaction is one of the factors influencing marriage. Here, ABM was developed based on the concept of social interaction and the impact or influence it has on agents in getting married. Population of interacting agents whose willingness to marry depends on the availability of partners and share of relevant others who are married in the social network was studied.

The hypothesis is that, for an individual agent, there are sets of "relevant others" who are close to him/her and fall within their "social network". The model assumes that if the share of "relevant other" getting married increases, the social pressure to get married on unmarried agents will also increase. The aim is to let macro-level shape of age-at-marriage pattern emerge from the bottom-up micro-level.

Although the model used was able to recapitulate the hazard of marriage observed in macro-level (population level) from the micro-level (individual social interaction), it fails to account for important factors like divorce or negative social pressure.

3. KEKKON model: Methodology

Using NetLogo, the model has been built on the assumption that low marriage rate is a shadow behind the falling number of children. It is constructed on the basis of structure of Japanese marriage process (university → work → marriage). The purpose of this work is to understand why there is an increase trend of marrying late or not marrying in Japan.

3.1 Variables of agent

In the establishment of the model, it is necessary to indicate how values of each variables of an agent are set. Table1 below shows all the important variables and its values.

VARIABLE	VALUE
sex	M, F
age	0 – 40
financial	0.00 – 9.99
intelligence	0.00 – 9.99
status	0 – 3
U-type	0 – 4
SN-university	Agent list
work-type	0 – 10
SN-work	Agent list
salary	0, 180 – 530
partner	Agent list
w1, w2	Sum = 1.0
kekkon?	Boolean (T, F)
w3, w4	Sum = 1.0
alive?	Boolean (T, F)

Table 1: *Agent's variables*

Each agent has equal probability (50%) of being male (M) or female (F). Age is randomly assigned to each agent. Financial is a value that reflects economic status of agent's parent generated by combination of Roulette Wheel algorithm and random-normal (μ = 4.5, σ = 1.5) techniques. Intelligence is set using random-normal (μ = 6, σ = 1.8) technique. Status represents student status (at university level) of agent with different meaning for each value as follow: 0 = age under concern (18), 1 = cannot go to university, 2 = currently studying and 3 = graduated. U-type is used for representing the type of universities an agent belongs to which are; public (national), public (local), private (normal), or private (top). SN-university and SN-work are the list of other agents that an agent knows during study and work (social network), respectively. Work-type is the value assigned to classify type of work for each agent consists of three different types; high-work-type, medium-work -type and low-work-type. Partner is a list of agents that are treated as their partner. W1 and W2 are weights applied to evaluate finding of acceptable partners. Weights W3 and W4 are applied to evaluate partner for marriage. Kekkon? and alive? are the Boolean values with value of either true or false. If kekkon? = false, it means that an agent is still unmarried and is otherwise considered as married. Agents are considered as dead when alive? = false (age = 40) and alive when contrary.

3.2 Model detail: bottom-up approach

The flow chart (figure 1) is an overview of the model used in this study. It is a flow of agent with series of events along the way up until marriage, a concept of bottom-up approach.

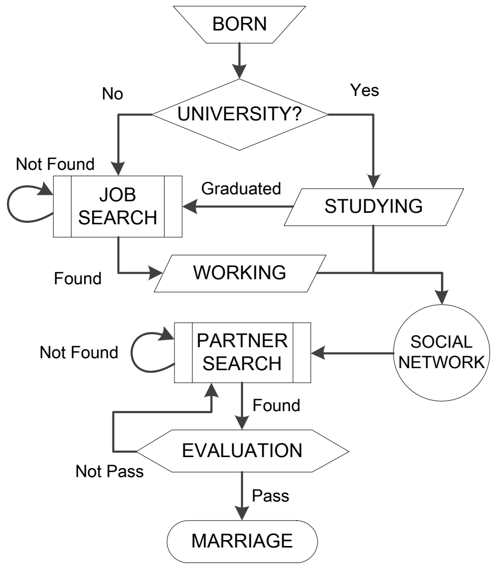

Figure 1: *Flow Chart*

Each phase evaluated in the flow chart is described below:

3.2.1 University-phase

Start from Born (age = 0) up until age become 18, agents are evaluated using function: *(β * financial) + (α * intelligence) > γ* to classify the type of university for them. Table 2 shows different standards (β, α, and γ) of each university type.

TYPE	β	α	γ
Public (National)	0.1	0.9	8.3
Public (Local)	0.1	0.9	6.8
Private (Top)	0.4	0.6	6.0
Private (Normal)	0.6	0.4	4.6

Table 2: *Standard of U-type*

If agent passes one of the universities, they will go to study for random (4 - 6) years. In the case that an agent cannot pass any type of university, they will be treated as uneducated (in university level) agent.

3.2.2 Job-search-phase

Agents graduated from university or those who could not attend university will search for a job. The factors used for assigning work to them are U-type (where U_N= Public National University, U_L= Public Local university and U_{Pri}= Private (Top and normal) University) and intelligence with the probability of being hired (pH) as follows:

- **High-work-type:** pH=80% for U_N in first chance, pH=50% for remaining U_N (20%) and intelligence is > 7.0, pH=40% for U_L when intelligence is >7.5 and pH=50% for U_{Pri} when intelligence is > 7.0

- **Medium-work-type:** pH=50% for remaining U_N (20%), pH=50% for remaining U_L (60%) and pH=50% for remaining U_{Pri} (50%), with regardless of their intelligence
- **Low-work-type:** pH=50% for remaining U_L (60%) regardless of intelligence

Those who did not attend university will go to low-work-type with 90% probability, but if the intelligence is > 5.0, they have a chance (probability of 10 %) to get to medium-work-type.

3.2.3 Working-phase

When an agent gets a job, their salaries are set up depending on their work-type. Every two years, after first year of work, their salary will increase according to their work-type and age. The amount used for increase is obtained from Ministry of Health, Labour and Welfare research with adjustments before implementing into the model.

3.2.4 Social-network-phase

In this model, agents live on patches with y-coordinate equal to their age and x-coordinate equal to their intelligence.

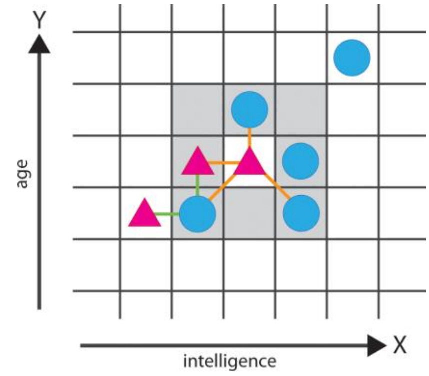

Figure 2: *An agent and its social network.*

In order for agents to know other agents, they will first search for within their 8 surrounding patches (neighbors) [11], which is the acceptable range [10]. If an agent is still a student (status = 2), their social network (SN-university) will include other agent from the same U-type, assuming that student spend more time with agent of the same U-type. On the other hand, if agents are workers, their social network (SN-work) will count for other working agents and is irrelevant of work place and type.

Assume that triangles are female and circles are male (figure 2). Female at the center of figure has five agents in the acceptable range (highlight patches) consisting of four males and one female. If she is a student, an orange-link is created with other agents belonging to the same U-type, otherwise not. Hence, the orange-link is her social network.

3.2.5 Partner-search-phase

To search for partner, agent (female student mentioned above) will look for other agents within her social network and check for mutual interest between them. By algorithms, she will consider only other agents of opposite sex who are not married, i.e., three circles that do not have red-line link (figure 3).

The agent then judges these male agents (who simultaneously judges female agents) by using the function: *(w1 * financial) + (w2 * intelligence)* >= λ If the value of λ equal 4 for both agents, they become partner and change orange-line to green-line link.

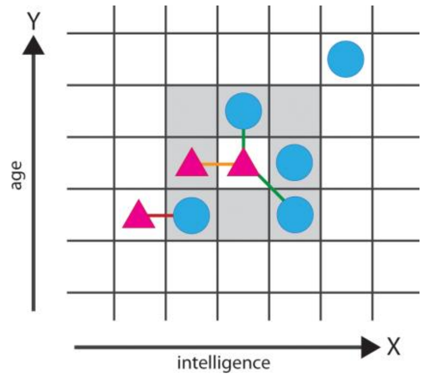

Figure 3: *An agent and its partners.*

3.2.6 Evaluation-phase

When an agent has at least one partner, they will evaluate their partner whether to marry or not. The factors used for evaluating marriage are age and salary.

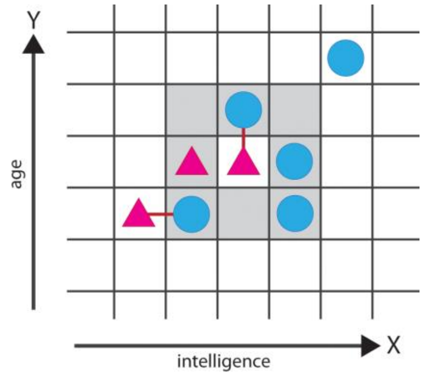

Figure 4: *An agent and its spouse.*

By using operation (a), male will decide whether to propose one of his partners or not. If he decides to propose her (evaluation score >= 0.6), she then starts to evaluate this male agent using the same operation and decide whether to accept (evaluation score >= 0.6) or reject his proposal.

$$evaluation\ score = \sum_{i=0}^{n} w_i e_i \qquad (a)$$

In operation (a), *w* is the value of weight of an agent who is going to evaluate other agents and *e* is the values of factors of agent being evaluated, calculated using the following function:

$$f(x) = \ln(x - 0.23) + 2e^{-0.6x^3}; x = \frac{age\ of\ male}{max\ age} \qquad (b)$$

$$f(x) = \ln(x - 0.2) + 2e^{-0.57x^3}; x = \frac{age\ of\ female}{max\ age} \qquad (c)$$

$$f(x) = 1 - e^{-3x^3}; x = \frac{salary\ of\ male}{max\ salary} \qquad (d)$$

$$f(x) = e^{-2x}; x = \frac{salary\ of\ female}{max\ salary} \qquad (e)$$

Functions (b) and (d) are used for evaluating age and salary of male, respectively and (c) and (e) are to evaluate age and salary of female, respectively.

If both agents decide to marry each other, they will remove all the links to other agents from themselves and create a red-line link with their spouse to represent a married couple (figure 4). Hence the aim to have people marrying is accomplished.

4. Model Validation

To be able to validate the process of simulation, it is necessary to make the model as stable as possible. Initial model showed decrease in number of population over a period of time. By setting number of new born to be 25 in each year, the model can run without limitation. The total number of population is equal to 1000 (initial population). Simulation is set to run for 140 years and the data is obtained from within year 50 to 89 (a total of 40 years). The average value of couples married first time in each age group, i.e., (20 – 24), (25 – 29), (30 – 34), (35 – 39), was similar to that reported in Population Statistics of Japan 2012 by IPSS. Average marriage rate from simulation is equal to 5.56 while 5.3 was the value reported by Statistics Bureau in 2012.

Number of agents who attended either type of university was similar to statistic data obtain from Ministry of Education, Culture, Sports, Science, and Technology (MEXT). For validation of this process, age of all agents was set to 17 and the model was run for 1 year. At the age of 18, around 61.8% will go to university, distributed to National (5.2%), Local (6.2%), Top Private (24.4) and Normal Private (26%).

In the context of partnership, survey done by IPSS reported that number of singles who are not in a relationship with the opposite sex increased to 60% for man and 50% of female. In this model, agents with total number of partner equal to 0 are approximately 60% without gender consideration. Even though it yields similar result as reported by survey, the number of average marriage rate is shown to decrease to about 3, differing from actual statistic data. By adjusting the value of λ, from the function used in partner-search-phase, the number of agents who have no partner will decrease to around 40%. With this adjustment, the number of average marriage rate is closer to realistic data.

5. Simulation Results and Analysis

Results obtain from simulation showed the distributed of age-at-marriage by age groups as follow: 17% (20 - 24), 39.5% (25 - 29), 36% (30 - 34) and 7.5% (35 - 39).

In age group of 20 – 24, a lot of agents are still studying which contributes to reason for not getting married. Approximately 50% of those married are agents who do not have work and could be people who are pregnant before marriage [4].

The highest first marriage age group is 25 - 29. This could because several events have taken place such as graduation and getting job (start to have salary). In unmarried agents, on average the U-type of female is slightly higher than male. This because female with high education tend to work, obtain salary and with function (e) shows that the more salary they have, the less intention to get married.

As for age group 30 - 34, married male are those with high salary and education than female (corresponds to [5]). By function (d), male will increase intention corresponds with increased salary [3]. Unmarried agents in this group are often female with average salary higher than that of male.

In the married age group 35 - 39, the average age of female (34) is lower than that of male (36). Female apply more weight on appropriate age to get married [3], increasing their intention proportional to age (function (c)).

6. Conclusion and Discussion

As shown from the validation process, the ideal number of new born should be 25 agents every year. Assuming that each married couple will have an average number of 2 children during their life time (until age 40), then there must be 12.5 married couples every year (which means that more than double of unmarried agents should get married every year).

By applying a policy to allow more of uneducated agents (30%) to go to university, slightly increase (from 5.56 to 6.07) on average marriage rate can be seen (with assuming that agents can increase their intelligence during study). Another method that showed higher increase (from 5.56 to 8) is to let agents have more chance to know other agents from different society (random meet), for example, a policy to reduce working hours so that they can spend more time with other society and hence, expand their social network.

However, study shows that two most important factors leading to low marriage rate in Japan are: 1) high standards set in mate search and 2) the less interaction (social network) between opposite sex (partner formation).

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