A Study on the Problem of Poverty and Inequality using the Artificial Society Model : Multi Agent Based Simulation

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In this study we explored the effect of public assistance on society as a whole, using a multi agent based simulation model. We used the KK-MAS, which is developed by KOZO KEIKAKU ENGINEERING Inc., as a tool of analysis, and extended the simulation program developed by Yamamoto [12]. We show that our result becomes contrary to Yamamoto's result in regard to the Gini coefficient if public assistance is given.

1. Introduction

In this paper, we examine the effect of public assistance on society as a whole, using a multi agent based simulation model. There is no objective mean to analyze the effect of public assistance on society as a whole. There are two reasons for it. Firstly, there is no data on any strata of society but the poor, who have received public assistance. Secondly, there is no data that distinguishes the poor and the non-poor by any criteria other than income. Therefore, we used a multi agent based simulation model to analyze the problem of poverty and inequality. In this study, we used the KK-MAS, which is developed by KOZOKEIKAKU ENGINEERING Inc., as a tool of analysis.

The second chapter describes the complex system that was used as the foundation of analysis in the multi agent based simulation model. The third chapter describes the limitations of the current poverty statistics and describes the artificial society model, which is one of the agent based simulation models. The fourth chapter describes several studies that have been

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conducted on the problem of poverty and inequality, using the agent based simulation model. In addition to this, we describe the fundamental characteristics of the model adopted in this study. The fifth chapter describes the modifications made to the model, and presents the results of the analysis. Finally, in the last chapter, we will consider the results of the analysis.

2. Multi Agent System and Complex System

From the second half of the 1980s, both natural and social scientists have paid considerable attention to what is known as the "complex system". Although there is no exact definition of this system, according to Ohuchi, Yamamoto & Kawamura, "it is the complicated and unexpected systems that arise from the interaction of elements". In other words, a complex system is not one that deals with complicated interactions separately, but one that deals with them as they are. Interest in the multi agent system has, therefore, been growing over the last several years (see, Ohuchi, Yamamoto & Kawamura [8]: p.3).

The multi agent system is one in which two or more autonomous agents come together and are mutually dependant. Moreover, agent based simulation is a method that analyzes the behavior of the entire system using agents as the composition elements of the system and describing the interaction between them.

So far, we have dealt with the problem of assessing poverty statistically. However, very little is known about the effects of changes in the definition of poverty and in policies for low-income groups, on the entire society. In Japan, it is probable that no study has ever tried to analyze these effects.

For the reasons mentioned above, in this paper, we would like to explore the effects of changes in the definition of poverty and policies for low-income groups, on society as a whole. We will realize it by using the artificial society model, which is one of the agent based simulation models.

3. The Artificial Society Model, Poverty, and Inequality

3.1. Economic Conditions in Japan and Statistics of Poverty and Low-Income Groups

The 20th century witnessed a great improvement in the overall well-

being of society. However, as pointed out in reports by various international organizations such as the World Bank, poverty remains all over the world as the global problem, even at the start of a new century. In recent years, the increasing inequality between developed and developing countries and within developed countries has become serious problem (as for this point, see for example, World Bank [13]).

On the other hand, it has also been recognized that poverty and inequality cannot be analyzed on the basis of level of income alone. Various factors are involved in and responsible for the problem of poverty and inequality (as for this point, see for example, Esho & Yamazaki [3]).

Although issues for poverty and inequality have been developed in Japan after the collapse of the "bubble" economy, there are no accurate statistics on the poor in Japan. The only statistics available in Japan are related to the poor who were eligible for public assistance. Needless to say, there are no statistics, which distinguish between the poor and the non-poor on any basis other than income. Therefore, it follows that there are no objective mean to verify the effect of policies on the poor of society, which is not taken into account in statistical analyses.

3.2. The Artificial Society Model

We now take up the sugar model in order to explain the artificial society model. The sugar model, developed by Epstein, J. M. and Axtell, R. [2], consists of ants and two hills of sugar (sugarscape). In the sugar model, two or more ants (agents), according to a fixed state and action rules, move around in a two-dimensional area, where food resources (sugar) are produced as the occasion demands. Ants accumulate and consume resources, and if the resources that an ant has accumulated are exhausted, it dies. Inequality of resources is resulted by this simulation.

Based on this model, Epstein and Axtell reproduced many interesting phenomena such as seeking feed, having feed, reproduction, genetic inheritance, evolution, propagation of disease, spread of culture, warfare, and so on.

If we regard food resources as property (income and assets), a sugar model could be similar to actual society expressed in a simple form. As in the model, in society too, people compete or cooperate with each other, and also accumulate and consume property independently. It has been pointed out that property distribution becomes infinitely unequal when

agents begin to follow the simple action rule described above.

A complicated phenomenon arises from the interaction of agents which have relatively simple action rule. This phenomenon is called "emergence." Moreover, the structure formed by emergence is called "emergent structure." Infinitely unequal property, as mentioned above, is interpreted as emergent structure.

However, various statistics make it clear that actual society is more equitable compared with the artificial society mentioned above. Moreover, in actual society, people do not consume all their accumulated property and die. There, the government collects appropriate portion of the property that people have accumulated, such as a premium and tax. And the government redistributes such a collected property among the aged as well as people who own property below a fixed level. Although the sugar model indicates some significant results of simulation, a more detail conditions are needed to analyze the problem of poverty and inequality in actual society.

4. Artificial Society Model Dealing with the Problem of Poverty and Inequality

4.1. Some Studies of the Problem of Poverty and Inequality using the Artificial Society Model

Only a few studies, e.g., Yamamoto [12], Tsuya & Iba [11], and Arai [1], have approached the problem of poverty and inequality using the artificial society model.

Our model retains the basic features of the model considered by Yamamoto. Hence, we will take up Yamamoto's model in the next chapter. However, we would first like to examine the arguments presented by Tsuya & Iba [11] and Arai [1].

According to Tsuya & Iba [11], if the concepts of "entitlement" and "capability," as developed by Sen, A. K. [10], can be introduced to the agents and into the environment of the artificial society model, there is a possibility of being able to analyze the problem of poverty from various view points. "Entitlement" can be defined as "a series of alternative goods that an individual can control" and "capability" can be defined as "a series of alternative functions that a certain individual can attain under certain economic, social, and individual conditions." The former concept refers to

a society to which an individual primarily belongs, and the latter refers to the individual himself. Since both concepts are closely associated with each other, it is necessary to deal with them without separating them and their complex interaction. However, when we analyze them in such a way, the list of the alternative goods and functions contains a huge variety of elements. For example, in case of a statistical investigation, it is necessary to design a questionnaire that includes all alternative goods or functions. Actually, this may be rather difficult. Regarding this point, Tsuya and Iba pointed out that it is possible for the artificial society model to measure many of the choices or analyze the possibility of the selection of goods or functions that are valuable to people (see, Tsuya & Iba [11]).

Using the artificial society model, Arai [1] verified the hypothesis that was raised in educational sociology. She pointed out that there is hierarchic difference for academic performance and higher education will among social classes, and that this educational inequality has widened due to the reformation of Japan's educational system in recent years. In her model, according to economical and cultural factors, agents (students), who receive education, are divided into three classes i.e., a high-ranking group, an intermediate group, and a low-ranking group. Moreover, she simulate how the academic ability and motivation for study of agents belonging to each class change by the educational policy of "relaxed education".
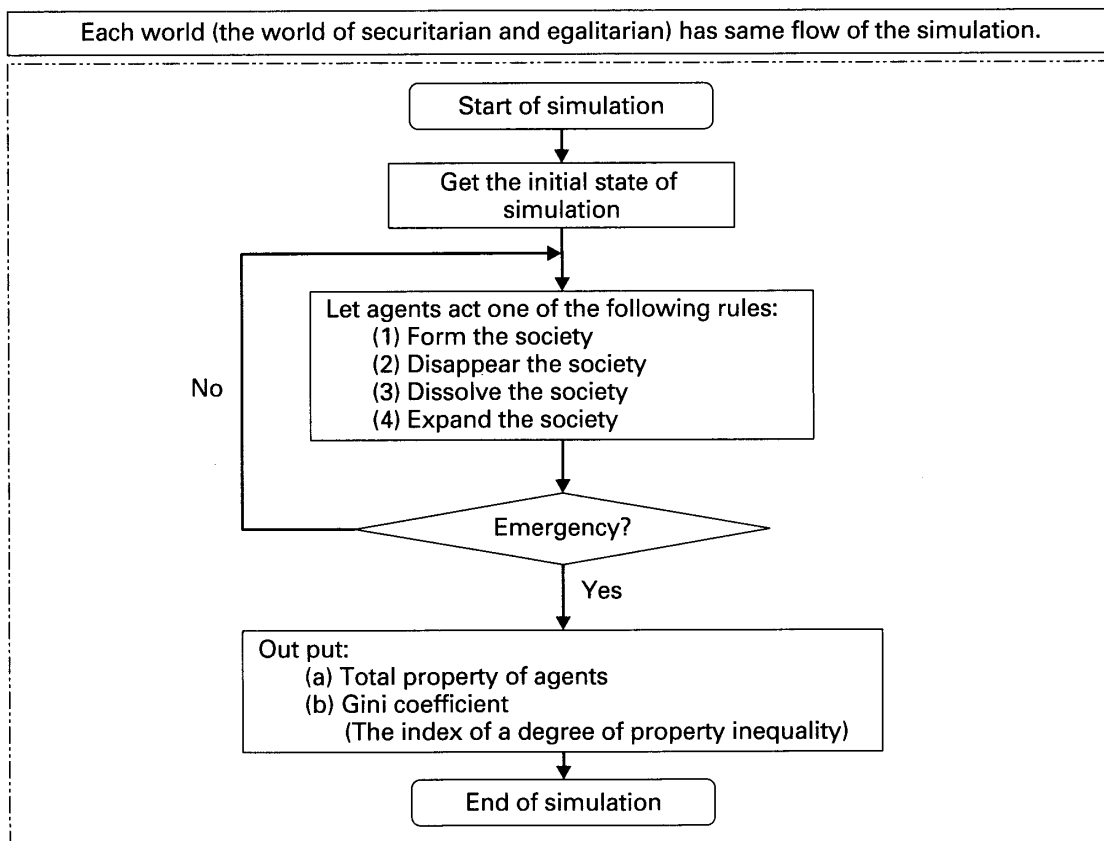
Although agents play by a common action rule (e.g., taking an examination etc.), their property, such as their natural academic ability, their parents' property, and the encouragement the parents give, varies in every class. Based on the above assumption, Arai verified how the gap in the academic ability and study motivation between various classes change in the case that the external factors such as the educational policy change. The results clearly indicated that academic ability and study motivation declined, and the academic gap between classes widened due to the policy of "relaxed education" (see, Arai [1]).

Judging from this, one can conclude that only a few studies have dealt with the problem of poverty and inequality using the artificial society model.

4.2. Problem of Poverty and Inequality and Yamamoto's Model

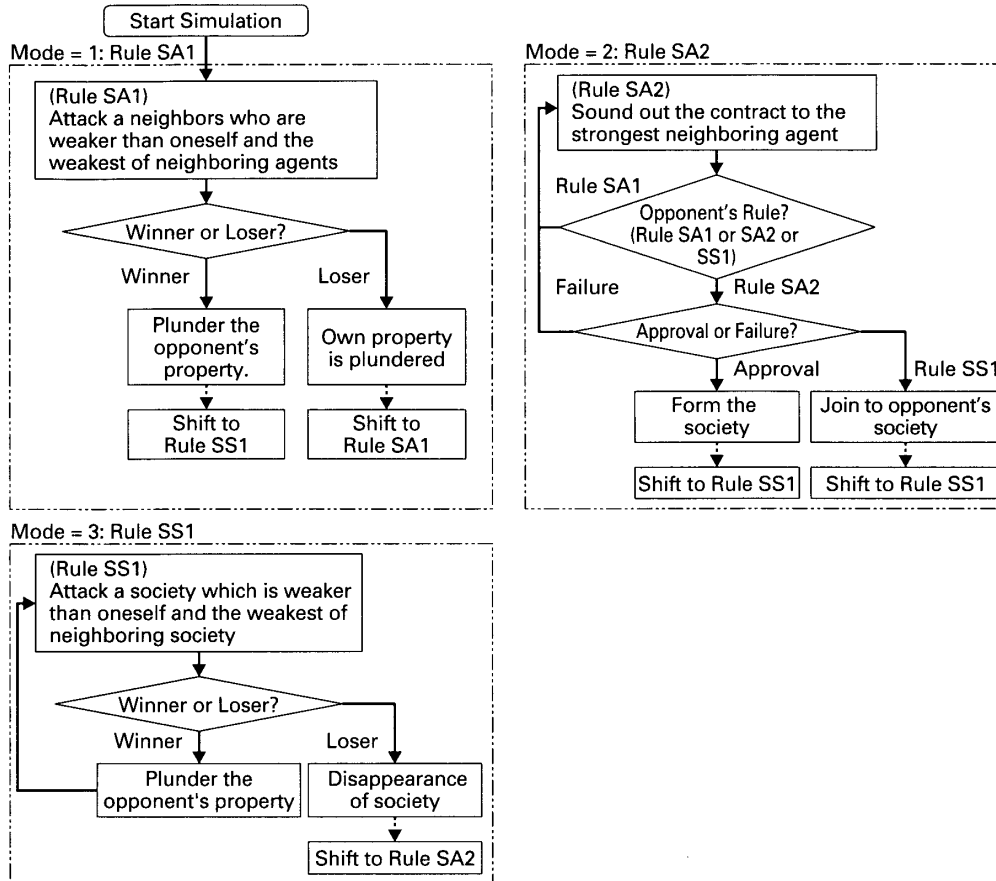We describe Yamamoto's model whose basic features our model retains here.

Yamamoto developed his model of the social formation process, based on the social contract theories of Rousseau [9]. With respect to this, he described, "We modeled the process by which people, who are in an initial state and have specific characteristics, try to form a society based on a specific reason, and analyzed whether the society thus formed is as the people originally intended it to be." He constructed a model of "two kinds of worlds." One is the world where "human beings bear malice toward others and form a society in order of maintenance of their life." Another is a world where "human beings have feeling of goodwill each other and form a society for the purpose of creating an equitable world." Finally, he analyzed these two kinds of worlds, with respect to the size of the society and the inequality of the society (see, Yamamoto [12]: pp.140-141).

Each world (the world of securitarian and egalitarian) has same flow of the simulation.

Start of simulation

Get the initial state of simulation

Let agents act one of the following rules:
(1) Form the society
(2) Disappear the society
(3) Dissolve the society
(4) Expand the society

No

Emergency?

Yes

Out put:
(a) Total property of agents
(b) Gini coefficient
(The index of a degree of property inequality)

End of simulation

Figure 1. The Flow of the Simulation of Yamamoto's model

Source: Yamamoto [12], p.142.

Securitarian (Characteristic: malice, Purpose: self-preservation)

Start Simulation

Mode = 1: Rule SA1

(Rule SA1)
Attack a neighbors who are weaker than oneself and the weakest of neighboring agents

Winner or Loser?

Winner

Loser

Plunder the opponent's property.

Own property is plundered

Shift to Rule SS1

Shift to Rule SA1

Mode = 2: Rule SA2

(Rule SA2)
Sound out the contract to the strongest neighboring agent

Rule SA1

Opponent's Rule? (Rule SA1 or SA2 or SS1)

Failure

Rule SA2

Approval or Failure?

Approval

Rule SS1

Form the society

Join to opponent's society

Shift to Rule SS1

Shift to Rule SS1

Mode = 3: Rule SS1

(Rule SS1)
Attack a society which is weaker than oneself and the weakest of neighboring society

Winner or Loser?

Winner

Loser

Plunder the opponent's property

Disappearance of society

Shift to Rule SA2

Egalitarian (Characteristic: cooperation, Purpose: equality)

Start Simulation

Mode = 4: Rule EA1

(Rule EA1)
Sounds out the contract to neighboring agent which has the smallest gap with regard to property

Failure

Approval or Failure?

Approval

The opponent has Rule EA1 or Rule ES1?

Rule EA1

Rule ES1

Form a new society with agreement

Join to opponent's society

Shift to Rule ES1

Shift to Rule ES1

Mode = 5: Rule ES1

(Rule ES1)
Select a society which has the smallest degree with regard to inequality of property

Join to the selected society (Disappearance of former society)
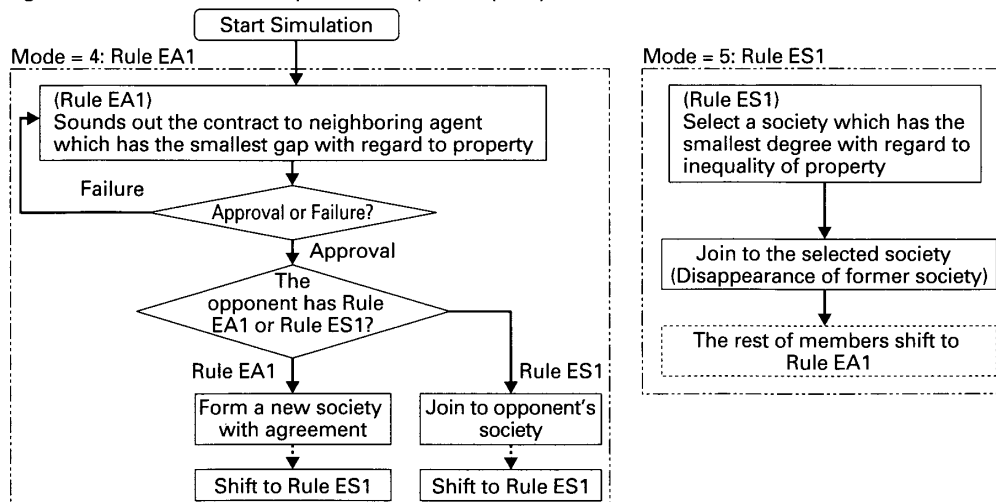
The rest of members shift to Rule EA1

Figure 2. The Action Rule of Each Agent in Yamamoto's model

Source: Yamamoto [12], p.149.

Figure 1 denotes the flow of the simulation of Yamamoto's model. The terms "securitarian" and "egalitarian" are used to express the characteristics of human beings who are in an initial state as described by Hobbes [5] and Rousseau [9], respectively. "Securitarian" can be defined as a person who bears malice toward others and forms a society for the purpose of self-preservation. On the other hand, "Egalitarian" can be defined as a person who believes in equality and has feeling of goodwill toward others and forms a society based on equality. Thus, the world is divided on the basis of differences in the characteristics of human beings, such as self-preservation or cooperation and malice or goodwill. The action rules shown in Figure 2 are applicable to each agent.

In Figure 2, the term "property" is used in a broad sense. It is assumed that the property in the initial state has the normal distribution with mean (500), and variance (75). The agents to whom the property was distributed act under the action rule as explained in Figure 2, and they try to form a society that they aim to create. If the property of an agent becomes below one, the agent will perish. Figure 2 shows that the action taken by an agent depends on the amount of the property and adjacent agents and society.

As mentioned earlier, we extended Yamamoto's model to match to the actual society as we know today.

5. The Structure of Model and the Simulation

5.1. The Structure of Our Model

In this section, we describe the structure of our model.

The mean of agent's property (μ) was set at 540, according to the mean of income of worker's household reported in the *Annual Report on the Family Income and Expenditure Survey 2002*. The variance in property distribution (σ^2) was set at 330, to be settled an initial Gini coefficient of approximately 0.4.

Our model is different from Yamamoto's model in that our model grants property to every agent who owns property less than 200. As explained earlier, this modification was made because in our actual society, people do not consume all their accumulated property and die. That is, we provide aid to agents, such as the poor or members of the low-income group. We will now explain the criterion for receiving this aid of our model.

In Yamamoto's model, the agent's property decreases by a certain

amount as the agent acts. Since this decrease can be assumed to be consumption, we set to grant 70% of the reduction in property as aid to every agent who has property less than 200. That is, we assume that the criterion for aid is 70% of the general consumption. This is because the criterion of public assistance in Japan is settled at about 70% of general consumption. (As for this point, see, for example, Ministry of Health, Labour and Welfare [7])

The aid criterion mentioned in our model is for "charitable aid," because the model cannot be one in which the government collects a certain amount of every agent's property, in advance, as a source of revenue, and then redistributes it.

5.2. Results of Simulation

We now compare the results of Yamamoto's model with those of ours. These results are shown in Table 1.

As shown in Table 1, Yamamoto indicated that the total amount of property is less in a society in which people work toward creating an equal society, as compared with one in which the only aim is self-preservation. In addition, the inequality in property in an equality-oriented society is greater than that in a self-preservation-oriented society. In fact, the total amount of property in a society in which people aim at self-preservation is 67 times as large as the total amount of property in a society in which people aim at equality. Moreover, the Gini coefficient for an equality-oriented society is larger than that for a self-preservation-oriented society. Furthermore, from the point of view of speed of formation, a self-preservation-oriented society is formed much faster than an equality-oriented society.

Table 1. Comparison of the Results

|	Number of steps (average)	Gini coefficient (average, initial)	Gini coefficient (average, final)	total property (final)
Self-preservation-oriented society (with aid)	37.7	0.368	0.252	9655.758
Equality-oriented society (with aid)	5299	0.328	0.009	4785.044
Self-preservation-oriented society (without aid)	—	—	0.227	9020.013
Equality-oriented society (without aid)	—	—	0.41	134.93

Note: Results without aid, Yamamoto [12], p.150, Table 9-2.

However, as a result of our modifications to the model, our result is different from that of Yamamoto's, especially with regard to equality-oriented societies.

Although with regard to the speed with which a society is formed, our result does not differ from that of Yamamoto's model, the Gini coefficient for an equality-oriented society becomes smaller than that for a self-preservation-oriented society. Moreover, in our model, the total amount of property in an equality-oriented society is 35 times as large as that in Yamamoto's model. It follows from what has been said thus far that a security of life and property result in an increase of social property and a diminution of inequality.

With these results in mind, we will now consider the property per agent and its transition till the end of the simulation. The results are shown in Figure 3.

As line graphs indicate, there is no change in the rate of decrease of an agent's property in a self-preservation-oriented society, regardless of the aid. However, we cannot completely analyze the effects of the aid, since a self-preservation-oriented society is formed before the aid is implemented. Although it is necessary to investigate this from the other point of view as well, it has not been done.
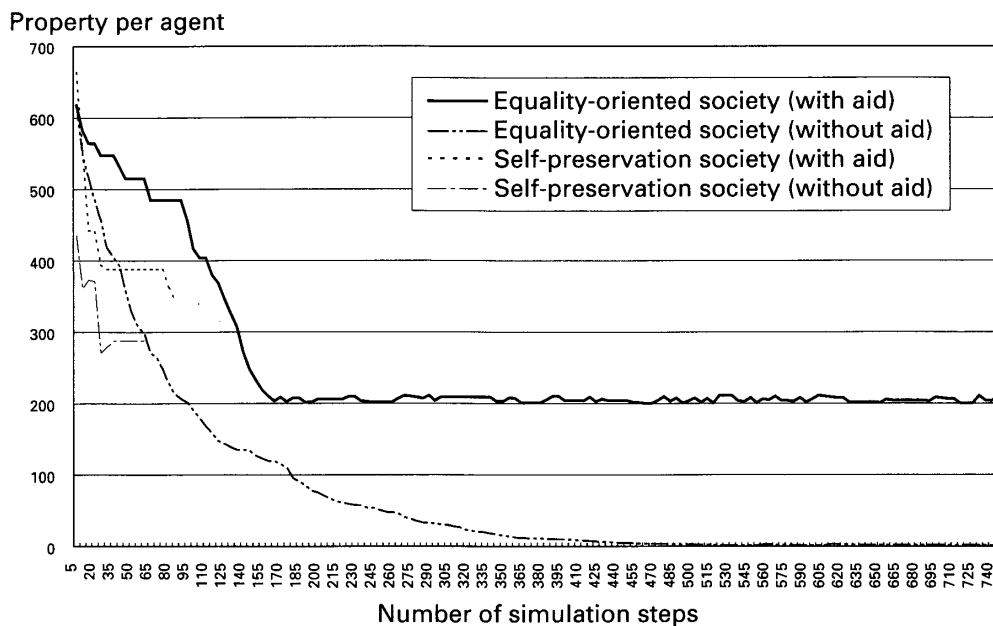
Figure 3. The Comparison of Property per Agent according to the Model

On the other hand, it is clear that the equality-oriented society in Yamamoto's model is a society in which the property per agent is close to zero. Since, in our model, we have not replaced the assumptions regarding the characteristics of agents outlined in Yamamoto's model, the property per agent fluctuates around level of the aid criterion. In an equality-oriented society, even if an agent who has property below a fixed level receives aid, he does not compete but corporate with other agent. As a result, in equality-oriented societies, the agents, who consume all the property granted to them and receive aid, once again, come to have great majority. These results are shown above.

It is clear that, in order to make this model more realistic, it would be necessary to combine the characteristics assumed in Yamamoto's model with other characteristics. In addition to this, it will also be necessary to make the model more realistic in terms of the quality and quantity of aid systems.

6. Conclusion

In this paper, we analyzed the effect of aid on society as a whole, using an artificial society model. In conclusion, we would like to make the following points.

We found that if aid is included in the artificial society model, the result is opposite to that of Yamamoto's model, and that inequality of society is greater in an equality-oriented society than in a self-preservation-oriented society. However, as stated in advance, in order to arrive at a realistic analysis, it is necessary to construct a model without merely retaining the characteristics of the society.

It is believed that the kinds of society people aim at, depend on the state of society, economy, policy, or educational policy. In this sense, it is necessary to not only conduct one's analysis without merely retaining the characteristics of societies, but to also add other characteristics to it.

For the purpose of this paper, it is not necessary to discuss which model of society is more desirable – a self-preservation-oriented or an equality-oriented society. This is because this paper does not express our judgment and because further modifications to our model are needed. These considerations should be dealt with in future studies.

Acknowledgement

References

[1] Arai, A. (2003) "The Educational Inequality between The Social Classes", The Third KK-MAS Competition, KOZO KEIKAKU ENGINEERING Inc. (in Japanese)

[2] Epstein, J. M. and Axtell, R. (1996) *Growing Artificial Societies – Social Sciences from the Bottom Up*, MIT Press, Cambridge, MA.

[3] Esho, H. & Yamazaki, K. ed. (1998) *Development and Poverty In Search for Economic Analysis of Poverty*, The Institute of Developing Economies. (in Japanese)

[4] Gilbert, N. & Troitzsch, K. G. (1999) *Simulation for the Social Scientist*, Open University Press.

[5] Hobbes, T. (1946) *Leviathan, or The matter, forme and power of a commonwealth, ecclesiastical and civil*, Blackwell. (edited with an introduction by Oakeshott, M.)

[6] Iba, T. & Fukuhara, Y. (1998) *An Adventure to The Frontier of Knowledge*, NTT Publishing Co. Ltd. (in Japanese)

[7] Ministry of Health, Labour and Welfare, Website, http://www.mhlw.go.jp (As of 26/Feb./2004)

[8] Ohuchi, A., Yamamoto, M. & Kawamura, H. (2002) *Theory and Application of Multi agent Systems – Computing Paradigm from Complex Systems Engineering –*, Corona Publishing Co. Ltd. (in Japanese)

[9] Rousseau, J. J.: translated by Cole, G. D. H. (1913) *The Social Contract, and, Discourses*, Dent, London.

[10] Sen, A. K. (1999) *Development as Freedom*, Alfred A, Knopf, New York.

[11] Tsuya, R. & Iba, R. (2001) "The possibility of analyzing the problem of poverty by the agent base economic model", 2001 JAFEE Annual Meeting, discussion paper. (in Japanese)

[12] Yamamoto, K. (2002) "The Logic and the Conclusion of a Social Contract – Securitarian's and Egalitarian's World –", Yamakage, S. & Hattori, S. ed. (2002) *Artificial Society in Computer – Multi agent Simulation Model and Complex System –*, KYORITSU SHUPPAN CO., LTD. Chapter 9, pp.140-157. (in Japanese)

[13] World Bank (2000) *World Development Report 2000/2001: Attacking Poverty*, Oxford University Press.