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Working Paper No.14

Simulating the Classical International System: A Model of Tribute System Built on the Agent Based Simulator (ABS)

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"Project for New-Type Simulators" is developing a multi-agent based simulator and a simulator of iterated cognitive games, among others, for scientific and/or educational purposes. This working paper series aims at disseminating interim but interesting outcomes of this on-going project. Back numbers of this series are available in the PDF format through the web site shown below.

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Introduction

Agent based model (ABM) is a term to describe a simulation model in which autonomous units (agents) interact with one another under simple rules. A simple example of this can be seen in Thomas Schelling's *Micromotives and Macrobehavior* [1978: chap.4]. 22 pennies and 23 dimes are randomly located in 64 cells (8×8 grid). 19 cells remain vacant. Every turn, each coin (agent) looks around and if it cannot find certain number of the same kind of coin in the neighborhood, it moves to a vacant place where it can be satisfied. Following this simple rule, Schelling shows that segregation occurs even when each agent wants only three out of 8 adjoining agents to be like itself.

Schelling's model can be said to be "agent-based", because each coin operates by its own rules and independent "decision". One of the important points in his study is that a social phenomenon emerged out of these decisions of independent agents who do not know nor even want the aggregated result. As this example indicates, ABMs can have considerable validity in simulating how simple sets of rules constitute social phenomena[1].

This method opens another way to consider the validity of hypotheses that are difficult to verify by conventional induction or deduction. For instance, it is hard to confirm a hypothesis that says "social phenomena A is due to property B of its members", when empirical data are scarce, too many potential variables exist, the process of interaction is too complex, or the experiment is not feasible. That is often the case with International Relations. By conducting agent based computer simulations, it is possible to estimate at least the logical validity of such hypotheses.

Robert Axelrod makes one such attempt [1997: chap.6]. He created an ABM, "tribute model", to show that a combination of simple dynamics of "pay or else" and changing commitments between agents makes up a social situation in which aggregations of agents act like independent political states[2]. Although there remain some questions about the appropriateness of his set of rules as a model of "Tribute System"[3], the model deserves attention because it suggests a new way to simulate the creation of alliances, larger political units, and resulting world system.

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[1] As for Schelling's Model and its revisions, see WP No. 2, 5, 7 (in Japanese) of this WP series.

[2] Axelrod refers to the units as "actors". Although there is not much difference in meaning, we use the term "agent" because this kind of model is usually called an agent-based model.

[3] For example, it is possible that important characteristics ordinal states in tribute system are missing in the model. This is one of the reasons why further investigation

One of the serious difficulties of multi-agent computer simulation used to be the absence of a user-friendly simulator. The Agent Based Simulator (ABS) is a software specially designed for agent-based simulation. For the purpose of further research, we have translated Axelrod's model into a setting file of ABS[4]. (The original source code is written in Pascal). This paper is aimed at presentation and demonstration of the tribute model that we have translated.

The first section describes the basic structure of our model. As there exists no "perfect" translation, the model presented here also includes some modification largely for technical reasons. However, basic features of the model are kept same as Axelrod's. The second section demonstrates how the ABS version of tribute model works.

Basic Features of the Model

What does what?

The original model proposed by Axelrod has 10 agents, but our model consists of 7 agents for technical reasons[5]. The 7 agents stand for nations or states, which are put in a row. (see Figure 1) However, as both ends of the row are linked, it would be better for us to imagine a situation where 7agents make up a circle, or a Ring-world, so to speak.

Each of these agents has its own wealth. The initial level of wealth is given randomly, which is between 30 and 50, while in Axelrod's model the initial wealth is between 300 and 500. The wealth of an agent is, in a sense, the power of the nation. When nations interact, the wealth matters.

The basic cycle is called a *year*. Each year, an agent is randomly selected to be active, and demand tribute of another agent. The targeted agent has to make a choice between paying and fighting. If it chooses to pay, it loses its own wealth and the demander receives it. The amount of tribute is 25, or what the victim has in the case the victim's wealth is less than 25, while in the original model, this value is 250.

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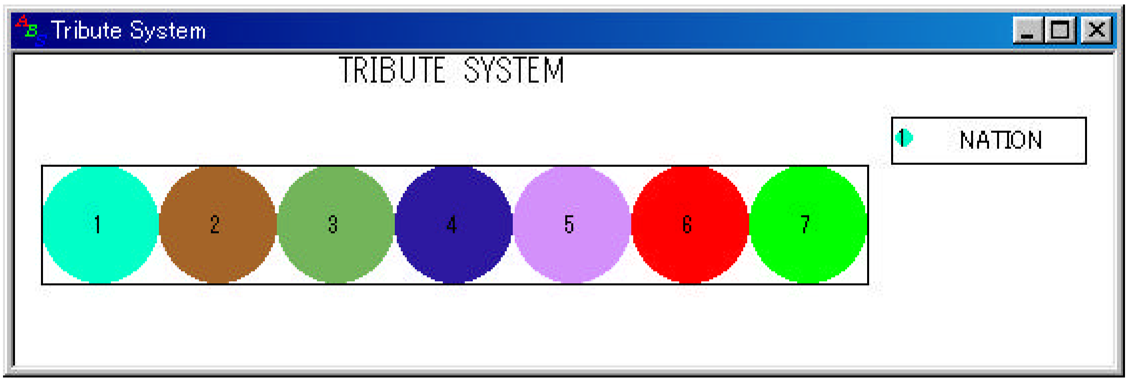
is needed.

4 This simulator is developed by Kozo Keikaku Engineering Inc. (http://www2.kke.co.jp/). One of its advantages is that it has GUI and is easy to use even for a beginner.

5 Current version of ABS has a limit in the numbers of data that can be output. Although it is possible to set 10 or more agents in the row, or even to put them in a two-dimensional space, we set the number of agent to 7 and put them in a row, in order

Figure 1 MAP OF TRIBUTE SYSTEM



If the target prefers fighting, on the other hand, the offender as well as the defender have the other side lose 25% of its own wealth (i.e. power). These losses represent the damages caused by the war.

When a demand is made, the victim first calculates the costs of fighting and paying the offender off, and then compares them. Only when the cost of war is less than the anticipated amount of tribute, does it choose to fight.

The rule by which the activated agent selects among potential victim is a bit more complicated. This rule includes two criteria. First, the victim must be weak enough so as not to choose fighting, and not to cause severe damage to the offender in case it does decide to fight. At the same time, the wealthier the victim is, the more favorable to extract from it. This is because the anticipated amount of tribute depends on the wealth of the victim, except the case where all potential targets have more than 25.

To take these two elements into consideration, we use the same rule that Axelrod uses. That is, an activated agent issues a demand to another agent that has the largest value in the product of the target's vulnerability multiplied by anticipated amount of tribute. A target's vulnerability is expressed as $(W_A - W_T) / W_A$, where W_A is the wealth of activated agent and W_T, target's.

Figure 2 shows the overall process. A yearly cycle starts with the nomination of active agent (phase 1), fallowed by an issue of demand by this activated agent (phase 2). Then the targeted agent decides whether to fight or to pay and react accordingly

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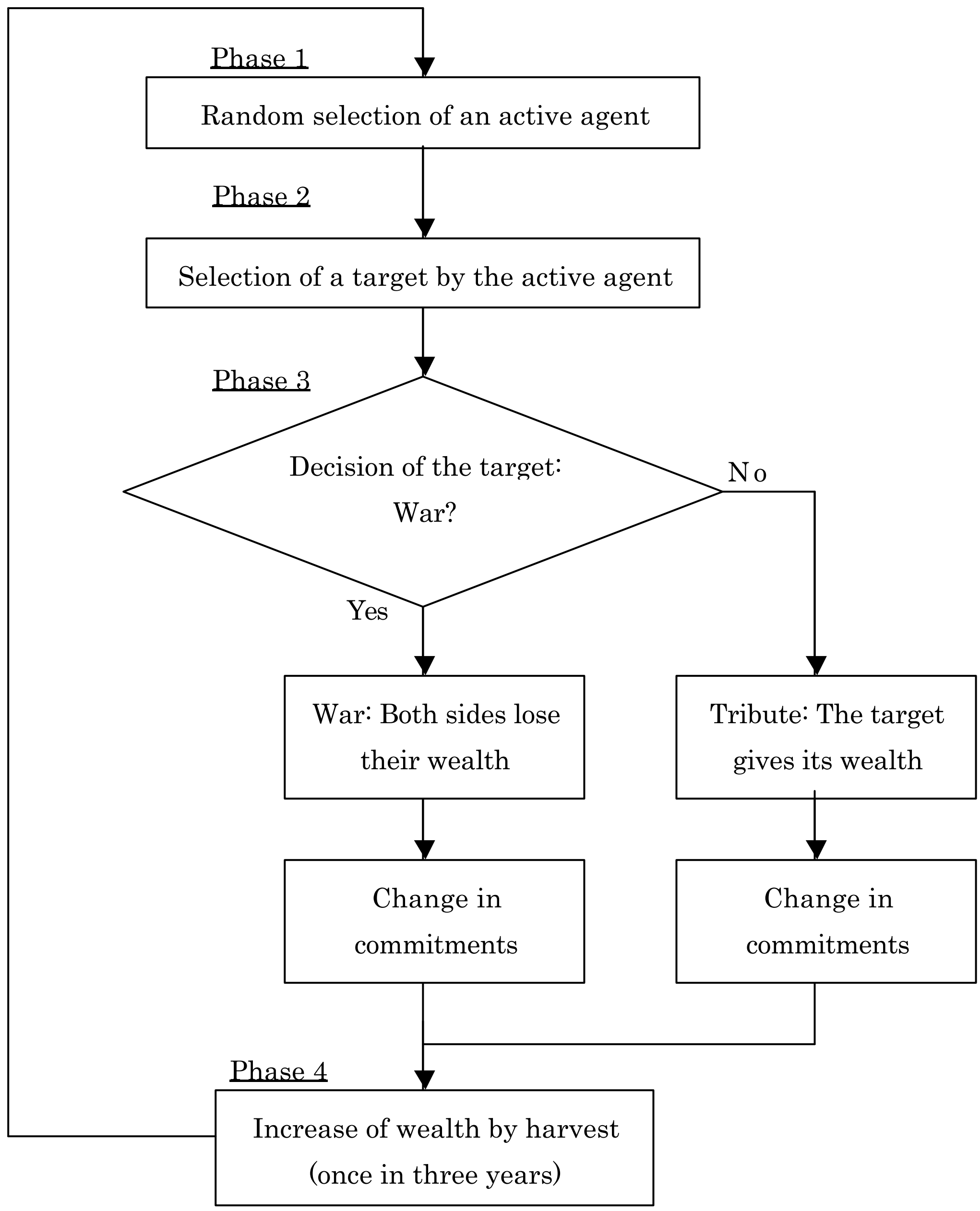
to keep the model simple and gather minute data set.

(phase 3). Finally, this cycle ends with a "harvest phase" when the wealth of each nation grows by 2 points (phase 4). To keep the incidence of harvest same as Axelrod's original model, in which there are three activations in a year, the harvest in our model comes once in every three years. Thus, three years in our model correspond to one year in the original model.

Figure 2 A yearly cycle



Alliance and war

With this basic structure in mind, we will now take a look at the more complicated settings, namely, rules of alliances and war between them.

Alliances are formed as a result of commitments. Individual agents develop commitments to each other. When two or more agents (1) fight in the same side, (2) pay/receive tribute, each agent's commitment to another increases by 10%. On the contrary, if two agents fight each other, the commitment between these nations decreases by 10%. Note that under these rules, agent A's commitment to agent B is always the same as agent B's commitment to A.

This commitment matters when the activated agent issues a demand. Each time a target nation is nominated, the adjoining agents determine whether to support the target or to join the demander, depending on the commitment they have.

If the adjacent agent is more committed to the target than to the demanding nation, it supports the target by sending a part of its wealth (i.e., power) to the targeted nation. The level of commitment determines the degree of the contribution. If an agent's commitment is 30%, it will contribute 30% of its wealth to the target. If it is more committed, on the contrary, to the demander nation, it will join the demander side to the degree it is committed to the demander. A neighboring agent remains neutral when it has equal commitment to the demander and target nation. Thus, the level of commitment represents cohesiveness of alliance.

Another important feature has to do with eligibility of target. That is, agents cannot attack an agent if the target nation is separated by other nations that do not support the attackers. If Agent 4 is activated and Agent 3 and 5 remains neutral, 4 cannot issue a demand to 1, 2, 6, or 7. If, on the other hand, only Agent 3 stays neutral and the other agents (5, 6, 7, 1) are for Agent 4, it can attack Agent 2 taking a round trip and thus it can credibly make a demand.

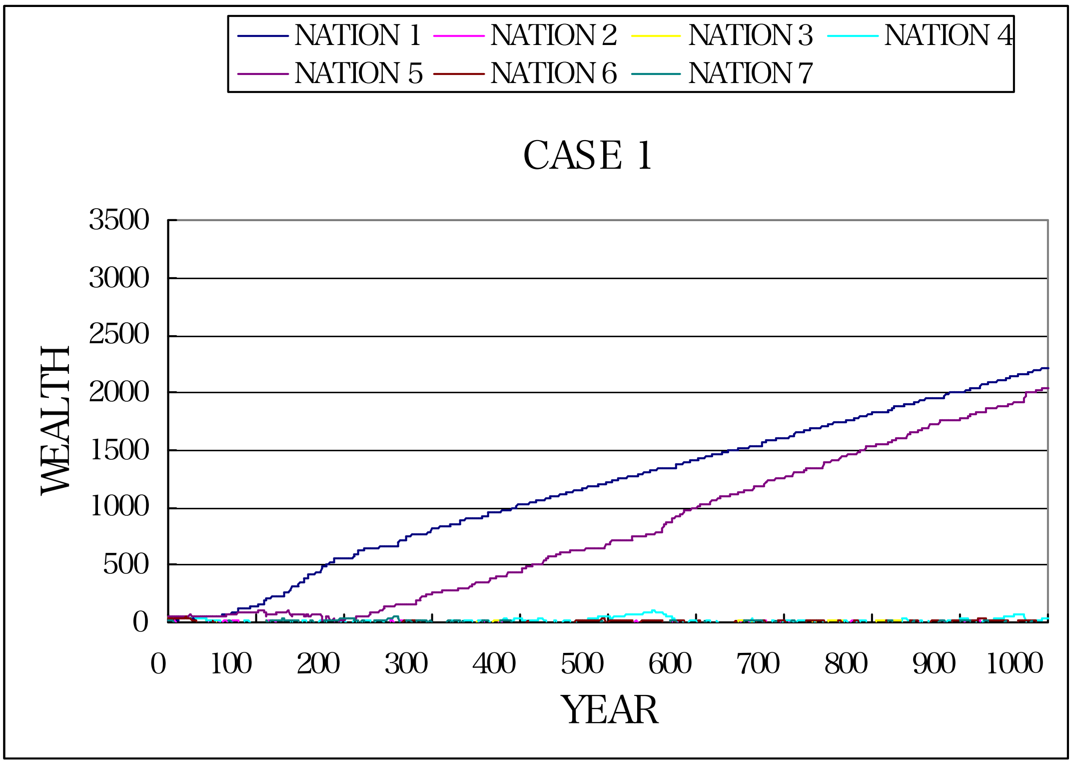
The Simulation in ABS

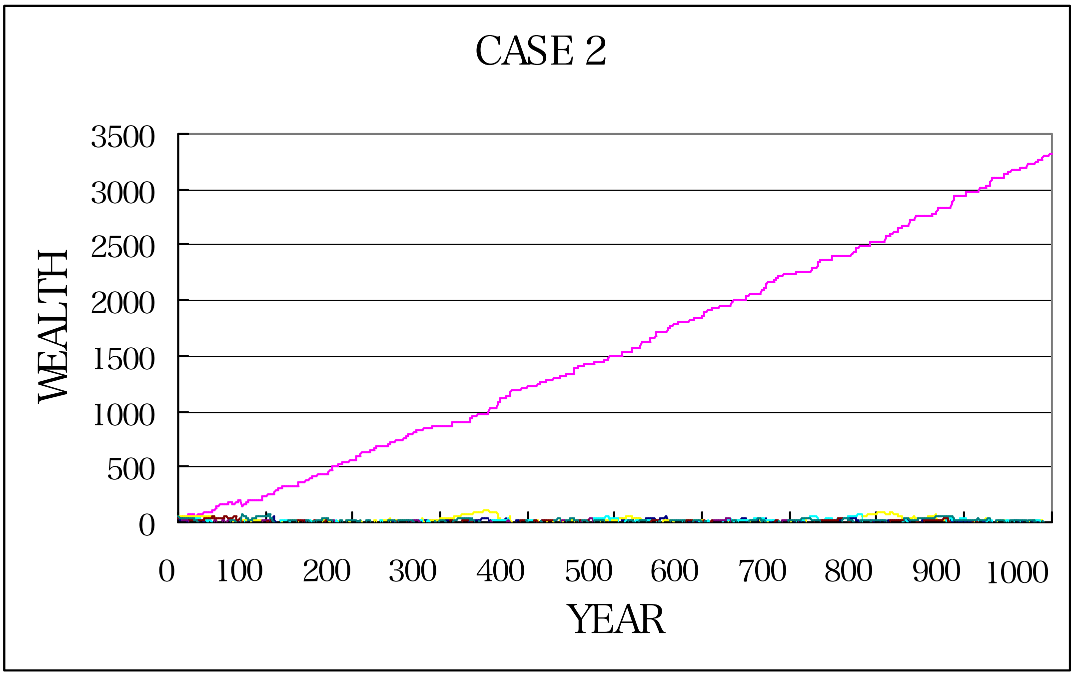
This section shows how the tribute model runs. Axelrod runs the program for "1,000 years" each time, which include 3,000 activations and 1,000 harvests. This corresponds to our 3,000 years. For the purpose of demonstration, however, a shorter run is better because it is easy to have a closer look at how the agents are working. Therefore, we will use data up to 1,000 years (which is 333 years in Axelrod's model) in following part.

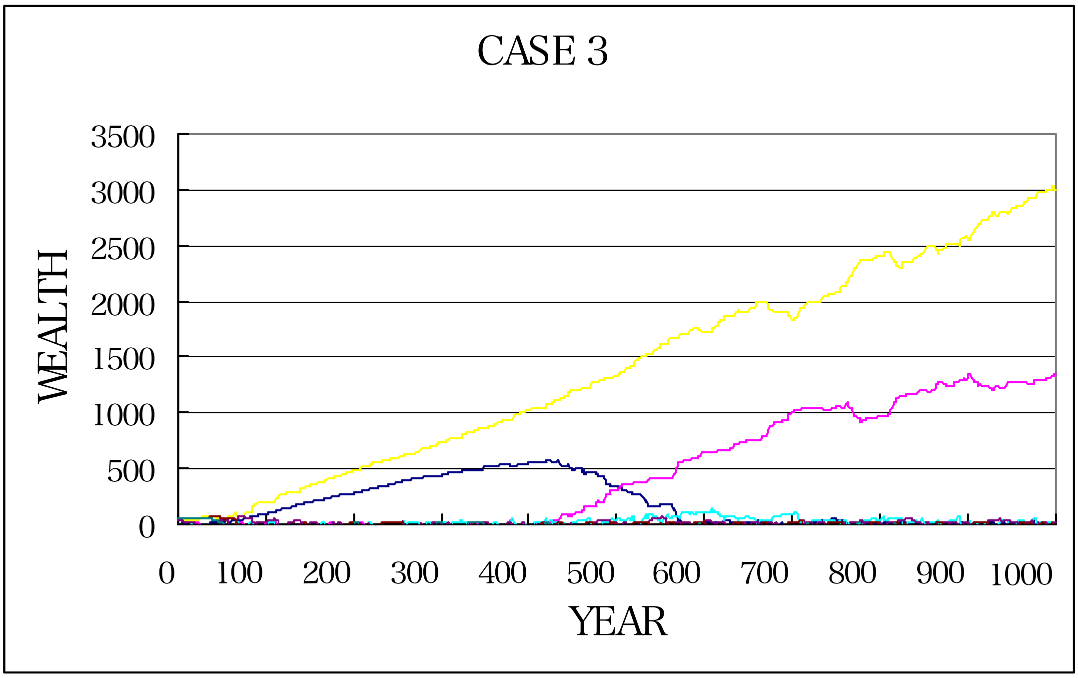
Some illustrations

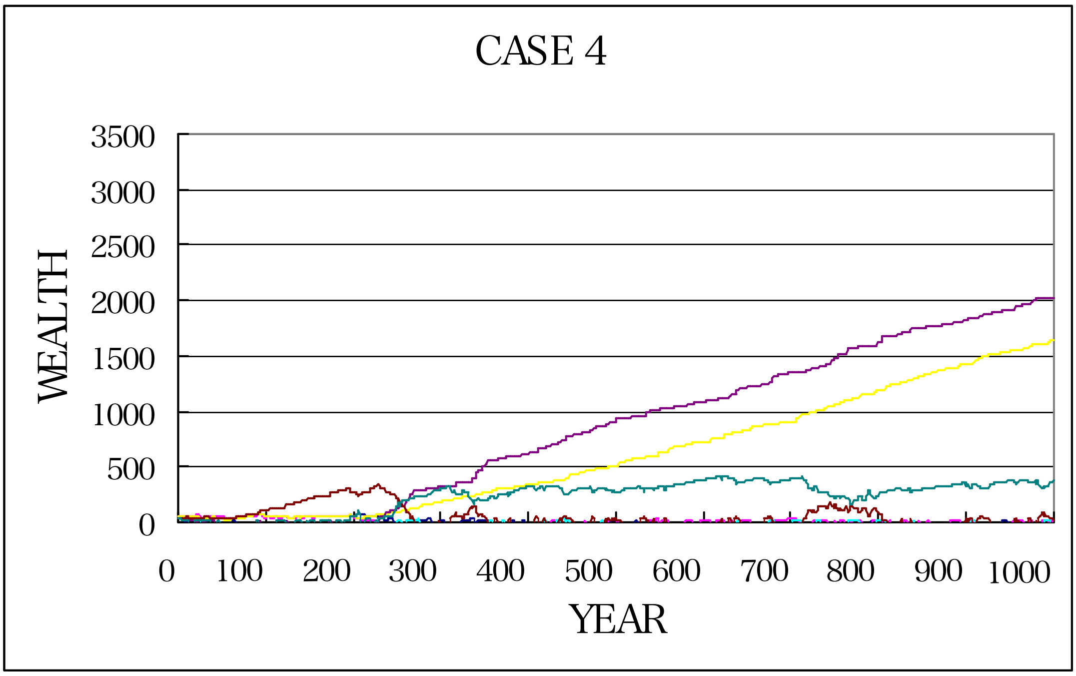
Figure 3 shows the levels of wealth of 7 nations in 4 successive runs of the tribute model. We see from these examples that the result can be considerably different, in spite of the fact that the only difference in these cases is minute variety in the level the initial wealth. Furthermore, Case 3 and 4 indicate that there is a good chance of catching up even for a poorest agent.

Figure 3 Change in wealth of agents in 4 typical runs




CASE 2
WEALTH
3500
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
500
600
700
800
900
1000
YEAR


CASE 3
WEALTH
3500
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
500
600
700
800
900
1000
YEAR



A detailed examination

Let us take Case 3 to see what is happening more closely, because this one has simple and clear change in the positions of agent 1 and 2. When a demand is issued, the targeted agent in this model has a choice between fighting and paying tribute. Therefore, to see which of these two options is preferred, we have to look at the incidence of war and conditions of commitments.

The incidence of war in Case 3 appears in Figure 4. We find high frequency of war in the beginning of the simulation but no war is observed after 500th year, although there is a considerable change in the wealth of nation 2 and nation 1 in this period. This suggests that the decline of nation 1's power is not a result of war, but a result of tribute.

Figure 4 Incidence of war in Case 3

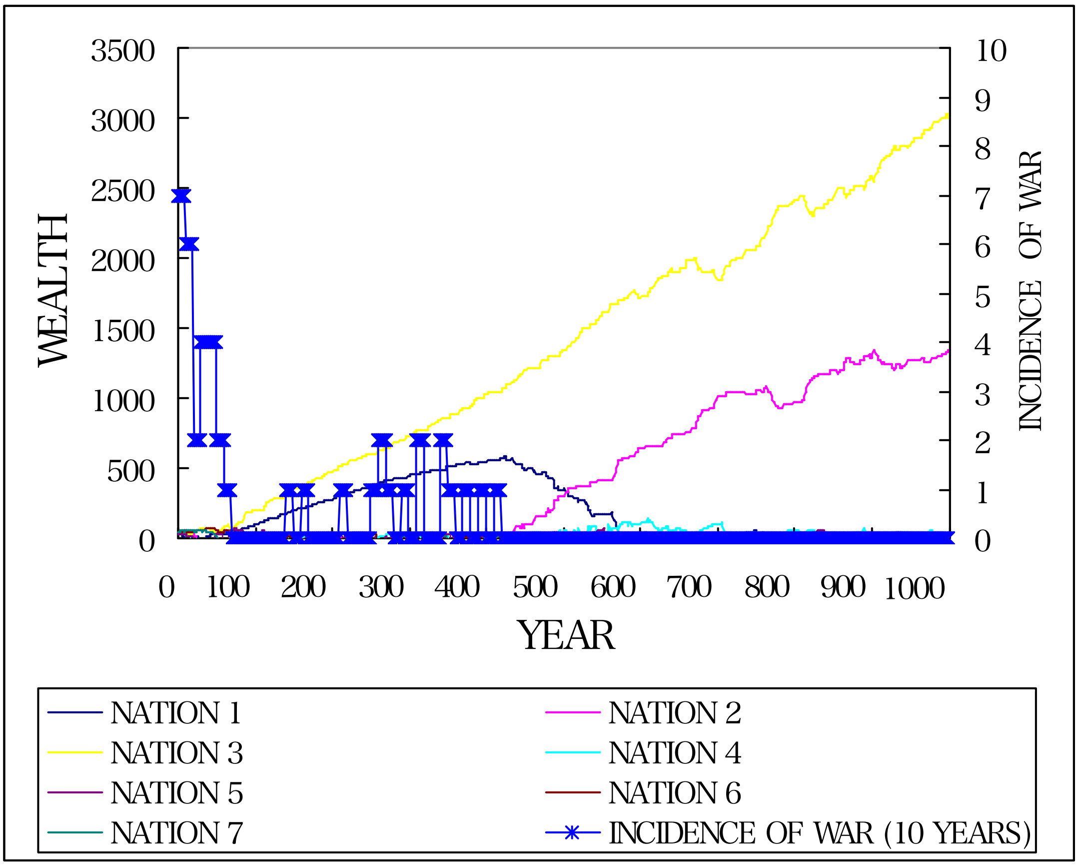


Table 1 seems to support this view. The commitment between nation 1 and 3 (0.5) is higher than that of nation 2 and 3 (0.4) in 300th year, while nation 1 and 2 are fully committed to each other. In this situation, nation 2 has disadvantage because if 1 makes demand of 2, nation 3 (the most powerful) supports that attack. By contrast, nation 1 has clear advantage. It is difficult for the most powerful 3 to demand tribute of 1, because 2 is always against 3's attacking 1, and therefore 3 have to go the other way around (that is, 3→4→5→6→7→1). This isolation explains the relatively high level of wealth of nation 1 in the beginning of the run.

This situation changes as the time goes by. In 400th year, 3 has become more attached to nation 2 rather than to nation 1. This means that if nation 2 demands tribute of 1, nation 3 will now support nation 2. As the commitment of nation 2 to 1 is still higher than that of 2 to 3, however, it continues to be difficult for nation 3 to extract directly from nation 1. As a consequence, nation 2 begins to extract from 1 and finally successes to trade places.

Table 1 Commitments between nations (300^{th} to 600^{th} year)

300^{th} year	NATION 1	NATION 2	NATION 3	NATION 4	NATION 5	NATION 6	NATION 7
NATION 1		1	0.5	0	0	0	0.2
NATION 2			0.4	1	0	0	0.3
NATION 3				1	1	0.4	0
NATION 4					0.7	0.1	0
NATION 5						1	0.3
NATION 6							1

400^{th} year	NATION 1	NATION 2	NATION 3	NATION 4	NATION 5	NATION 6	NATION 7
NATION 1		1	0.5	0	0	0	1
NATION 2			0.6	1	0	0	0
NATION 3				1	1	0.4	0
NATION 4					0.7	0	0
NATION 5						1	0.3
NATION 6							1

500^{th} year	NATION 1	NATION 2	NATION 3	NATION 4	NATION 5	NATION 6	NATION 7
NATION 1		1	0.5	0	0	0	0.2
NATION 2			0.9	1	0	0	0
NATION 3				1	1	0.4	0
NATION 4					1	0	0
NATION 5						1	0.3
NATION 6							1

600^{th} year	NATION 1	NATION 2	NATION 3	NATION 4	NATION 5	NATION 6	NATION 7
NATION 1		1	0.5	0.9	0	0	1
NATION 2			1	1	0	0	0
NATION 3				1	1	0.4	0
NATION 4					1	0	0
NATION 5						1	0.3
NATION 6							1

Concluding Remark

This article has presented Axelrod's "tribute model" translated in ABS, and demonstrated how it works. Although what we have shown is just a part of what the model can do, modifications will further amplify the possibility of this model as a tool to investigate social phenomena.

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