A MULTI-AGENT MODEL APPROACH TO INTERNATIONAL CLIMATE CHANGE POLITICS

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ABSTRACT

The essence of the global climate change politics is the public goods provision problem. In the present paper, we discuss what kind of process is necessary to form an effective international regime for the global climate change problem, by utilizing multi-agent simulation model. We formulated a multi-agent model for the climate change politics in which the actors (agents) are governments, NGOs and the industries. The simulation results indicate that the NGO's roll of propagating the international norm to governments and the adequate relationship between governments and industries are substantial to form an effective international climate change regime.

1. INTRODUCTION

There is a range of options for advancing the international climate effort. What kind of process is needed to form an effective international regime for the global climate change problems? We try to answer the question by utilizing agent-based simulation model. The climate change problem involves a various actors (agents) such as sates, NGOs, and industries. Moreover, their decision making process is affected by each other. Therefore, multi-agent model that simulate the interactions among a variety of actors is suitable to discuss advancing climate change effort. We used a multi-agent model to simulate the international politics for the climate change problems.

2. INTERNATIONAL POLITICS ON CLIMATE CHANGE PROBLEM: "KYOTO" AND "US-CENTERED" REGIMES

In 2006, the Twelfth Session of the Conference of the Parties to the UN Framework Convention on Climate Change (COP12) and the Second Meeting of the Parties to the Kyoto Protocol (COP/MOP2) were held in Nairobi, Kenya. Although COP12 and COP/MOP2 made little progress, there was a growing consensus about the urgency to address the challenge of global climate change. The UN Framework Convention on Climate Change (UNFCC) and the Kyoto Protocol can appreciate to mark a significant step toward international climate change effort. Meanwhile, the U.S. withdrawal from the Protocol, no participation from the main developing countries such as China, India, Indonesia, Brazil, and the difficulty to meet the commitment to Protocol made by Annex I parties raise a debate over the alternative initiative to meet the challenge of climate change.

There is a range of options for advancing the international climate effort. According to Bodansky, Chou, and Jorge-Tresolini (2004), there are approximately 40

approaches to the international climate efforts beyond 2012. Some of them are built on the basic architecture of Kyoto Protocol, and others are far different from Kyoto Protocol. The latter prefers different type of commitment (technology oriented policy cooperation) and forum (a smaller group/ public-private partnership) to Kyoto Protocol that has quantitative emission target and negotiates through a global process. We call this type of options "U.S.-centered regime". In the international arena surrounding climate change, the perception is that the two bipolar big coalitions will continue for the time being - the EU centered "Kyoto Protocol regime" block, and the "US centered regime" block which created its own initiative. The important point, however, is that both parties are not exclusive of each other.

In this case, however, what is important when dealing with climate issues is the existence of the Convention and the Protocol. The international regime like Kyoto Protocol is suitable to advance the climate change effort by the following reasons.

- International regime can give guidance and set a norm to address climate change.
- It is only states that are responsible for consensus building and implementation of agreements in current international relations.

From the perspective of systems, history and incentives, it is important to maintain momentum towards continuing beyond the first commitment period of the Protocol as part of the next step towards future actions to climate change.

3. MULTI-AGENT MODELING

Multi-Agent Model

Multi-agent model is a framework in which many agents are set on computer and their decision rules are defined as micro level rules, and the macro level phenomena that is resulted from the micro-level rules is observed.

The climate change problem involves a various agents such as sates, NGOs, and industries. Moreover, their decision making process is affected by each other. Therefore, multi-agent model that simulate the interactions among a variety of actors is suitable to discuss advancing climate change effort. We used a multi-agent model to simulate the international politics for the climate change problems.

Definition of Actors and the Interdependence among the Actors

We focused on three types of actors in the climate change politics, which are governments, NGOs and industries. In the international climate change politics, governments decide which regime they support. As we reviewed above, in the real world, some governments support Kyoto regime, some others support U.S.-centered regime, and others might prefer to other regimes. Governments' decisions are influenced by the other governments' decisions as well as by their domestic NGOs' and industries' preferences. The NGOs and industries also have their preferences. Some prefer to Kyoto regime and others prefer to U.S. centered regime. Their attitudes influence the governments' decisions. Their preferences are also affected by the governments' decisions in international society as well as their own governments' decision. Figure 1 outlines the interdependence among the actors in climate change politics.

A multi-agent model approach to international climate change politics
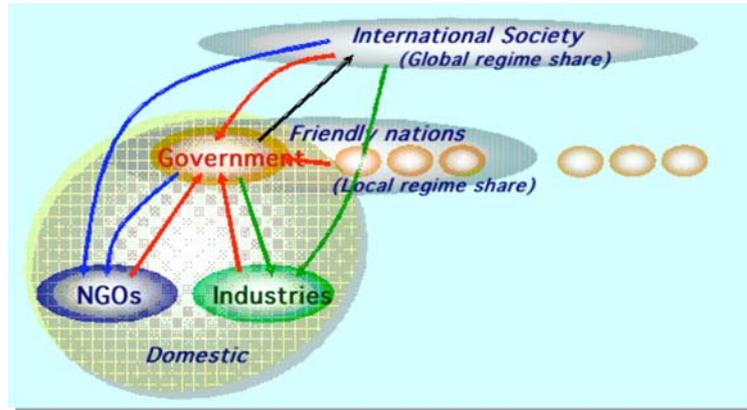
Figure 1. Interdependence among agents in the climate change politics

In order to model formally, we formalized interdependence among the actors as follows.

Governments decide the regime they support. The governments' decisions are affected by following five factors.

1. Independent preferences: Government actors have their own preferences for regimes. (We name this preference an "independent preference" to distinguish from their total preference to a regime.)
2. Global regime share: When a regime is supported by more governments (nations) than other regimes, the majority one is more likely to be preferred by the governments. The tendency is related to norm proliferation.
3. Regime share among friendly nations (local regime share): Besides the global share, governments are influenced by regime share among their friend governments.
4. Domestic NGOs: Governments are influenced by the preferences of NGOs in their countries.
5. Domestic industries: Governments are influenced by the preferences of industries in their countries.

NGOs also decide the regime they support. Their decisions are affected by following three factors.

1. Independent preferences: NGO actors have their own preferences for regimes.
2. Global regime share: NGOs are also affected by the global regime share of governments.
3. Their governments: NGOs are influenced by the preferences of their own governments.

Interdependence of the industries is similar to those of NGOs, although the degrees of the influences might differ.

1. Independent preferences: Industry actors have their own preferences for regimes.
2. Global regime share: Industries are affected by the global regime share of governments.
3. Their governments: Industries are influenced by the preferences of their own governments.

Based on these formalizations, we formulated a multi-agent simulation model.

Formulation of Multi-Agent Simulation Model

We set hypothetical 400 nations in model. They are placed at a 20x20 plane. Each nation has three actors --- a government, an NGO and an industry. In total, there are 1,200 agents.

We set 5 regimes. They are distinguished by color --- green, blue, yellow, red and black.

A simulation proceeds from term 0 until some term. Each agent decides regime (color) at each term. We define actors' decision rules below. In making decisions, agents refer to other agents' decisions at previous term. We observe the trends of actors' decisions.

Figure 2 presents flow of the simulation.
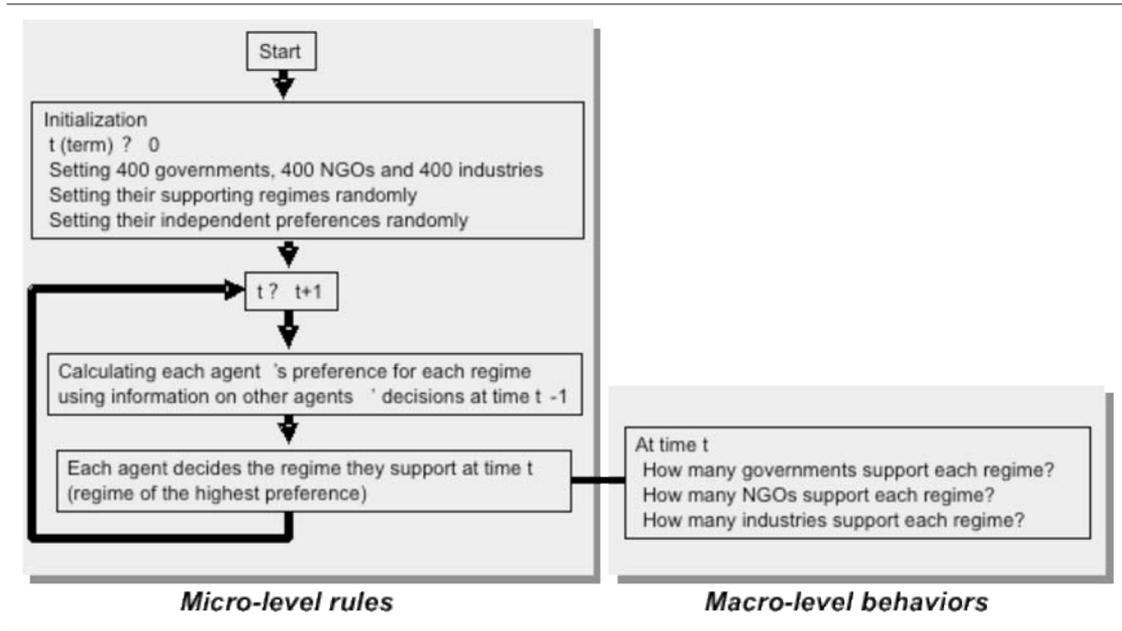
Figure 2. Simulation flow

Decision Rule of Agents

Based on the definition of interdependence among actors, we formulated the agents' preferences to regimes.

We defined the government actor i's ($i \in \{1,2,\cdots,400\}$) preference to a regime j ($j \in \{1,2,3,4,5\}$) at time t as follows. The five terms correspond to the five interdependence factors we formalized above.

$$gpref_{i,j,t} = w_1 \cdot gidprf_{i,j} + w_2 \cdot gshare_{j,t-1} + w_3 \cdot lshare_{i,j,t-1}$$
$$+ w_4 \cdot \delta ngo_{i,j,t-1} + w_5 \cdot \delta ind_{i,j,t-1} \qquad (1)$$

where w_k is the weight of preference factor k on total preference, and $gidprf_{i,j}$ is agent i 's independent preference to regime j.

$gshare_{j,t-1}$ is regime j's share among 400 government agents at time $t-1$. $gshare_{j,t-1} \in \{0, 1/400, 2/400, \cdots, 399/400, 1\}$. And $\sum_j gshare_{j,t-1} = 1$

In our model, we defined that the neighborhood agents of a government agent are familiar governments for the government. $lshare_{i,j,t-1}$ is regime j's share among 8 neighborhood agents at time t-1. So, $lshare_{i,j,t-1}$ is the share of regime j among i's familiar government $\sum_j lshare_{j,t-1} = 1$ $lshare_{j,t-1} \in \{0, 1/8, 2/8, \cdots, 7/8, 1\}$. And

$\delta ngo_{i,j,t-1}$ is either 1 or 0. If the NGO actor i supports regime j at time t-1, it is 1. And if it supports other regime at t-1, it is 0.

$\delta ind_{i,j,t-1}$ is either 1 or 0. If the industry actor i supports regime j at time t-1, it is 1. And if it supports other regime at time t-1, it is 0.

We defined NGO actor i's preference to a regime j at time t.

$$npref_{i,j,t} = w_6 \cdot nidprf_{i,j,t} + w_7 \cdot gshare_{j,t-1} + w_8 \cdot \delta gov_{i,j,t-1} \qquad (2)$$

where $nidprf_{i,j,t}$ is agent i's independent preference to regime j at time t, and $gshare_{j,t-1}$ is regime j's share among government agents at time t-1 (same as above). $\delta gov_{i,j,t-1}$ is either 1 or 0. If the government agent i supports regime j at time t-1, it is 1. And if it supports other regime at t-1, it is 0.

We defined industry actors' preferences as follows.

$$ipref_{i,j,t} = w_9 \cdot iidprf_{i,j,t} + w_{10} \cdot gshare_{j,t-1} + w_{11} \cdot \delta gov_{i,j,t-1} \qquad (3)$$

where $iidprf_{i,j,t}$ is agent i's independent preference to regime j at time t, and $gshare_{j,t-1}$ and $\delta gov_{i,j,t-1}$ are same as above.

Simulation Tool

In the model, we formulated that the weight coefficients (w_1, w_2, ..., w_{11}) are identical to all the agents. In the formulation, exogenous variables are w_k and 3 variables --- $gidprf_{i,j}$, $nidprf_{i,j,t}$ and $iidprf_{i,j,t}$. Other variables such as $gshare_{j,t-1}$, $lshare_{i,j,t-1}$ and so on, are indigenous ones except for them for t=1. The indigenous variables are calculated in simulation processes. We set the value for $gidprf_{i,j}$, $nidprf_{i,j,t}$ and $iidprf_{i,j,t}$ with random numbers. In precise, for $gidprf_{i,j}$, we set one of the five $gidprf_{i,j}$ (j={1,2,3,4,5}) with values between 0 and 1 by uniform probability. We set other four $gidprf_{i,j}$ be 0. We set $nidprf_{i,j,t}$ and $iidprf_{i,j,t}$ with values between 0 and 1 by uniform probability. We set the agents' supporting regimes at term 0 with uniform probabilities.

Besides the definitions, we need to define w_k.

We made a simulation tool. We developed the tool using Visual Basic 6.0.

Using the tool, we can simulate the actors' regime selections and see the transitions visually. Users can set and change the values for w_k and observe the effect of the changes. Figure 3 presents the simulation tool window. The left side of the window displays the agents' decisions at a term t. As term proceeds, the pictures change like an animation. In the right side, users set the values of w_k (k={1,2,...,11}).
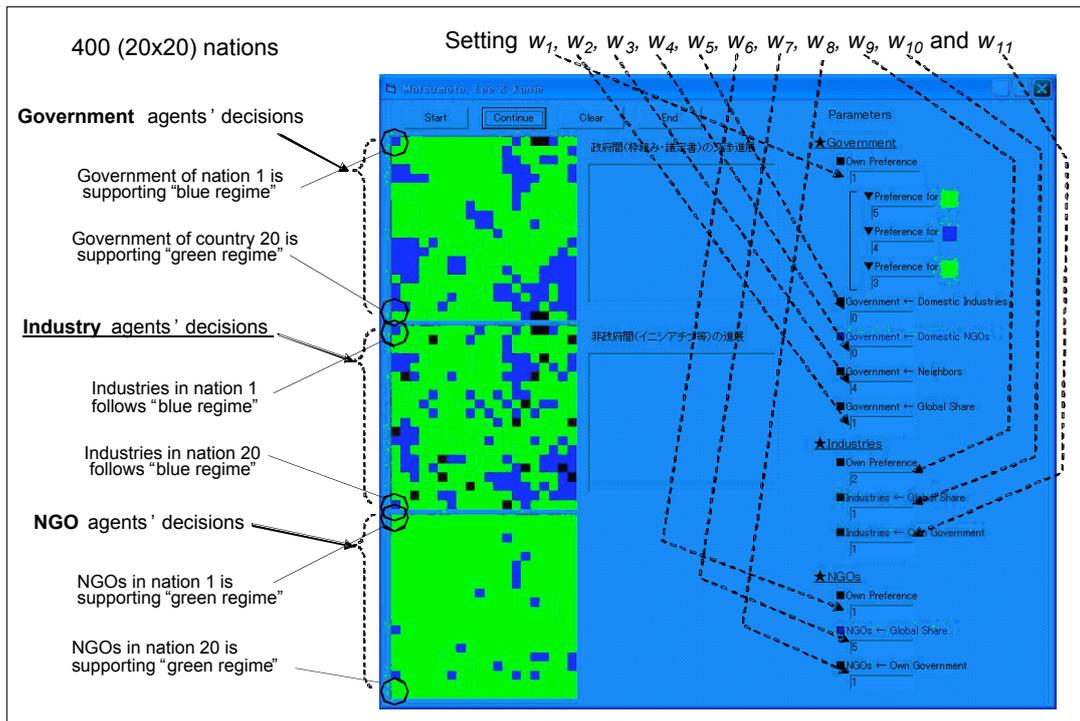
Figure 3. Simulation tool (The tool window with explanatory notes)

4. SIMULATION AND RESULTS

General Patterns

We simulated actors' decisions on which regime they support as term proceeds. At initial term ($t=0$), their decisions are defined randomly. As term t proceeds, their decisions are mutually influenced and macro-level patterns appear. In simulations, some patterns in macro-level behaviors are observed.

In the government agent arena, characteristically 3 patterns are observed.
1. Single color (regime) dominates: As term proceeds, all government agents come to support a same regime.
2. Blocks of colors (regimes) appear: As term proceeds, agent-groups that support same regime appear. It is analogous to the two block situation --- Kyoto block and U.S. block. In Figure 3, there are green, blue and yellow blocks.
3. Random: Like the initial states, there appears no block.

The NGO arena and industry arena have characteristically 2 patterns, respectively.
1. Single color (regime) dominates: As term proceeds, all NGO (industry) agents come to support a same regime.
2. Random: Like initial states, uneven decisions are made.

In the government agent arena,
・ The first pattern occurs when the global regime share influences the government agents' preferences strongly. It is the case when the value of w_2 is relatively large.
・ The second pattern occurs when the local regime share influences the government

agents strongly. It is the case when the value of $\underline{w_3 \text{ is large}}$.
- The third pattern occurs when the independent preference influences the government agents strongly. It is the case when the value of $\underline{w_1 \text{ is relatively large}}$.
- When the influence from domestic NGOs or industries is strong, that is when $\underline{w_5}$ $\underline{\text{or } w_4 \text{ is large}}$, the macro-level pattern depend on the pattern in NGO arena or industry arena.

In the mixture cases, the mixtures of the patterns appear. For example, when both w_1 and w_2 are relatively large, mixture of the first and the third pattern appears.

In the NGO agent arena,
- The first pattern occurs when the global regime share influences the NGO agents' preferences strongly. It is the case when the value of $\underline{w_7 \text{ is relatively large}}$.
- The second pattern occurs when the independent preference influences the NGO agents strongly. It is the case when the value of $\underline{w_6 \text{ is relatively large}}$.
- When the influence from their government is strong, that is when $\underline{w_8 \text{ is large}}$, the macro-level pattern depend on the pattern in government arena.

As in the government agent arena, in mixture cases, the mixture patterns appear. The industry agent arena is similar to the NGO agent arena.

An Example Simulation

We carried out a series of simulation to evaluate the rolls of government agents, NGO agents and industry agents in climate change international politics. In the simulation, firstly we set the variables as follows.

$$w_1=3, w_2=1, w_3=4, w_4=0, w_5=0 \; ; \; w_6=1, w_7=0, w_8=0 \; ; \; w_9=2, w_{10}=0 \text{ and } w_{11}=0$$
(4)

In the case, w_3 is relatively large. Interdependence between governments and NGOs, governments and industries are not set so far. The result is presented as (B) in Figure 4. (A) in the figure is the status at term 0. In (B), in government agent arena, green, blue and yellow blocks appeared.

From this situation, we changed the values of the variables as follows.

$$w_1=3, w_2=1, w_3=4, w_4=0, w_5=0 \; ; \; w_6=1, w_7=0, w_8=0 \; ; \; w_9=2, \underline{w_{10}=5} \text{ and } \underline{w_{11}=1}$$
(5)

In the case, NGO agents are influenced by their governments and the global regime share. As the global regime share influences NGO agents' preferences, NGOs' preferences for green regime increase. As the result, NGO agents which support green regime increase ((C) in Figure 4).

Next, we changed the values of the variables as follows.

$$w_1=3, w_2=1, w_3=4, \underline{w_4=1}, w_5=0 \; ; \; w_6=1, w_7=0, w_8=0 \; ; \; w_9=2, w_{10}=5 \text{ and } w_{11}=1$$
(6)

In the case, government agents are influenced by their domestic NGO agents. As most NGOs support green regime, many government agents' preferences for green regime increase. As the result, government agents which support green regime increase ((D) in Figure 5).

Finally, we changed the values of the variable as follows.

$$w_1=3, w_2=1, w_3=4, w_4=1, w_5=0 \; ; \; w_6=1, \underline{w_7=1}, \underline{w_8=1} \; ; \; w_9=2, w_{10}=5 \text{ and } w_{11}=1$$
(7)

In the case, the industry agents are influenced by their government and the global regime share. As most of government agents support green regime, industry agents come to support green regime ((E) in Figure 5).

We interpreted the simulation result in Figure 4 as follows.

1. *The blocks of governments are formed (the Kyoto regime block and the US-centered regime block) and the situation fell into a deadlock.*

In the parameter set (4), interaction among governments within groups (local interaction) is strong. As Figure 4 (B) presents, the blocks appear in the government arena. We regard that the green block is "Kyoto regime" block and the blue regime is "US-centered regime" block. From (B), the situation does not change anymore. It is a "deadlock". The situation is analogous to the current status of the international climate change politics where the blocks are formed and the situation fell into a deadlock.
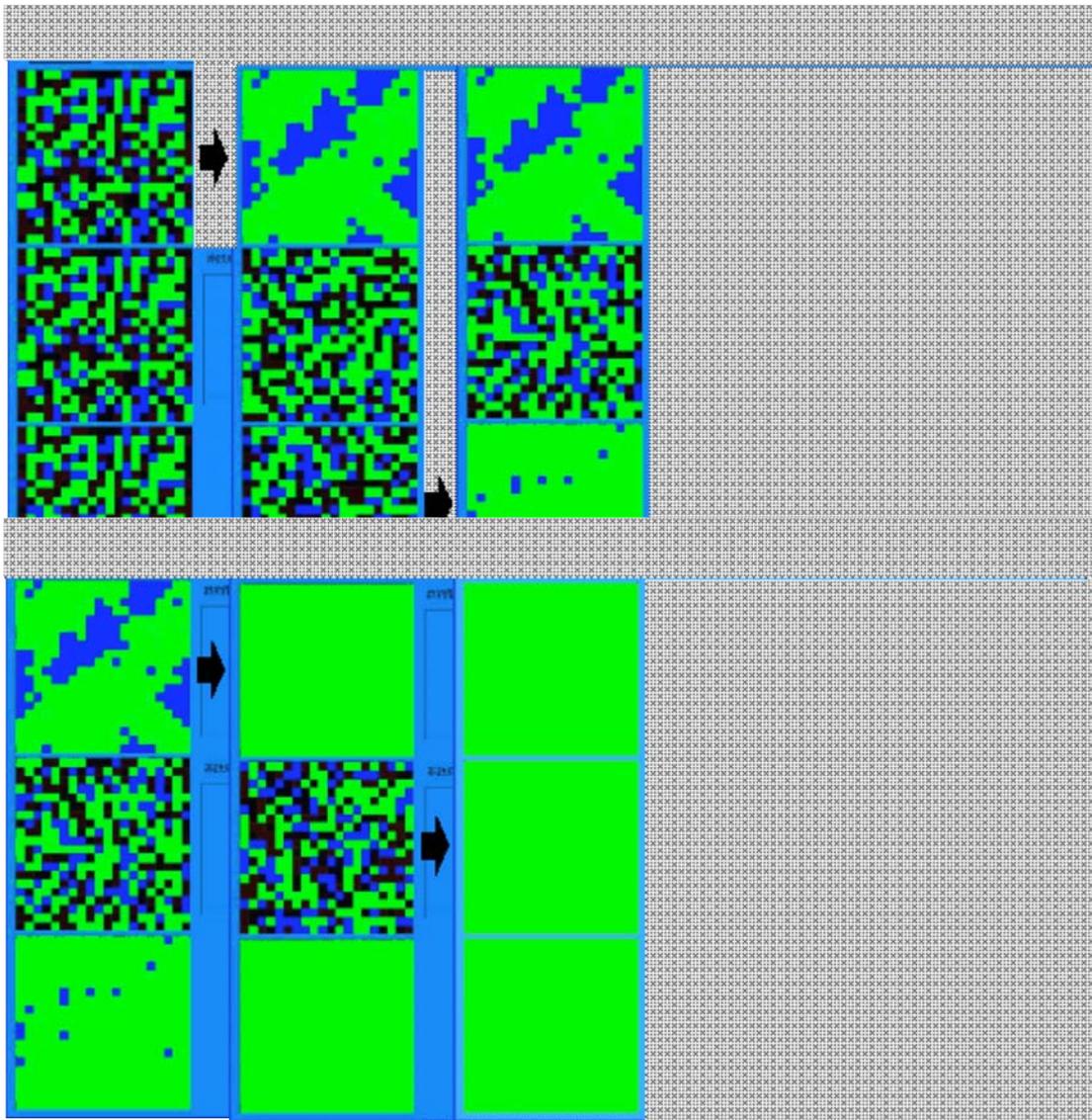
Figure 5. A simulation result series: (C), (D) and (E)

2. *NGOs are affected by international norm (the most popular regime among governments) and propagate the influence to their governments. As the results, the deadlock becomes solved and the governments come to support an identical regime. A unified international regime appears.*

The parameter set (5) changed the situation from (B) to (C) in Figure 4. In (C), the NGOs are influenced by the government arena --- the international "Kyoto regime" norm, and most of them come to support the Kyoto regime. The parameter set (6) changed the situation from (C) to (D). In (D), the governments are affected

by their domestic NGOs and come to support the Kyoto regime. As more governments come to support the Kyoto regime, NGOs' preference to the Kyoto regime increase and more NGOs come to support the Kyoto regime. It further increases the governments which support the Kyoto regime.

3. *The industries are affected by international norm (the most popular regime among governments) and are controlled by their governments. As the industries comply with the international regime, the climate change measures come to be effective.*

The parameter set (7) changed the situation from (D) to (E). In (E), the industry agents are affected by the most popular regime in the government agent arena and are controlled by their government agents. They come to comply with the Kyoto regime.

4. CONCLUSIONS

The simulation result indicated that, in the situation where the government blocks are formed and fell into a deadlock, two factors could dissolve the deadlock.

The first factor is NGOs' roll in propagating the international norm to their governments. As Princen and Finger (1994) pointed out, the most significant activities of NGOs are aiming at shaping international laws and institutions. In the era of networked distributive governance, transparent and accountable diplomacy will be a key factor. In an era where information holds value in governance issues, the factor of rapid information flow is the foundation for effectiveness of diplomacy that could create comparative advantage in negotiation settings.

The second factor for the effective international regime is the capabilities of governments in controlling industries. Industries play a key roll in mitigating climate change. Without governments' control over the industries, effective measures for climate change are difficult. New technology also plays a major role in efforts to mitigate climate change, and most innovations in technological development come from private firms. In that sense, public-private partnership can be a complement to Cap-and-Trade regimes, because government policy, which is affected by Cap-and-Trade regime, will encourage and accelerate private firms to develop new technology to mitigate climate change.

The both factors are necessary to realize an effective international climate change regime. In current situation, the Kyoto Protocol is an energetic driving force for promoting international norm for climate change problem, and the US centered regime is effective in enforcing the relationship between industries and governments and the relationship between industries and the international regime. The both parties (Kyoto regime block and the US centered regime block) are not exclusive of each other. When solving complex issues such as climate change, a co-existing framework of conventions, protocols and other initiatives may stimulate structural innovation (or synergy effects) based on the reinforced characteristics of the latter system (other initiatives) which are constituted by "partnerships". From the perspective that the climate change issue is long term in nature, it is recommended to establish a security system by creating a mechanism for an autonomous dispersive cooperation which permeates into various sectors.

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