SICE Journal of Control, Measurement, and System Integration, Vol. 6, No. 2, pp. 147–156, March 2013

Relations between Partial Diversity and Organizational Performance in an Organization

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Abstract: This paper presents an agent-based simulation model to analyze performance of organization with heterogeneous members. A hierarchical landscapes model with organizational and personal landscapes is proposed and it puts difference of skills and values into difference of personal landscapes. The use of this model shows that an organization needs to have a certain amount of diverse members to improve the whole organizational utility under the changing environment. This is because while the uniform members stay at a state with higher individual utility even if there are diverse members in the organization, the diverse members discover a new state with higher organizational utility and then take others to that state.

Key Words: agent-based model of organization, NK model, diversity, learning.

1. Introduction

For the last decades, employees with various backgrounds, experience, and concept of values have been working together because of the increase in international workers, women, and job changes. Likewise, more and more companies actively recruit various people because such individuals are expected to help enhance the organizational ability to adapt to changing environments.

Several earlier case studies have reported that these diversities make problem-solving abilities higher in organizations, but, at the same time, let their decision-making be slower (e.g. [1]). In addition, researchers are trying to find out why such organizations with slow decision-making can adjust to changing external environments. Yet, although such case studies have clarified the effects of diversities and systems in organizations on their performance, they have not investigated the processes themselves, how the members do or do not change their minds, or to what extent an organization needs to have such diverse members. This is because the number of case studies is relatively small and it is difficult to observe the processes of behaviors in organizations (e.g. [2]–[5]).

On the other hand, there have been attempts to use computational approach, agent-based simulation (ABS), to study activities of organizations (e.g. [6]–[10]. Chang and Harrington give a comprehensive survey [11].). Among these, Hong and Page have built a simulation model about the search ability of agents in problem spaces and compared uniform organizations with diverse ones [12],[13]. Kollman et al. have constructed a model by considering various skills of members, organizational structure, abilities in discovering solutions for problems, and productivity, and examining an optimal structure for their external environment [14]. However, these computational studies seem to focus their attentions on the search abilities of various individuals only, not how many diverse members an organization requires to save and improve its productivity by helping its uniform members.

Takahashi et al. have constructed an agent-based computational model and pursued simulations to analyze performance of organization with heterogeneous members [15]. They use hierarchical landscapes model, organizational and personal landscapes, and put difference of skills and values into difference of personal landscapes. Their main finding is that an organization with fully diverse members is able to find proper problem-solving states when it faces an external shock but that with completely uniform members fails to do so. Instead, what they have done in that study is that the environmental change the organizations face was only once and that the comparison was just between a completely uniform one and a fully diverse one, not a partial one. For this reason, when one considers the fact that such an environmental change always occurs, (s)he also needs to know whether an organization with or without diversity is still able to adapt to it. Or, it is not practical to replace most of the members when the organization switch its characteristics from a uniform one to a diverse one, meaning that a realizable solution is a uniform organization partially incorporates members with various backgrounds and sense of values. To this end, this study needs to examine whether it is effective to reform the organization in such a way to adjust to changing environments.

Therefore, the aim of this study is to clarify how diversities in an organization may improve its productivity. For this purpose, the authors implement a simulation model [15] by changing the external environment periodically in a fully unified, partially diverse, or completely diverse organization, and analyz-

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(Received August 22, 2012)
(Revised October 3, 2012)

ing changes in personal and organizational utilities.

The rest of this paper is organized as follows: Section 2 explains the simulation model. Section 3 presents the computational experiments and results. Finally, Section 4 gives concluding remarks.

2. The Model

In this section, an ABS model is proposed which represents the influences of members with various problem solving abilities and different satisfactions to the organizational performance, based on the factors of the previous studies.

2.1 Assumption

When building a model, the authors employ the following six findings from earlier case studies [2],[3]:

Incentive aims at making members arduously contribute to their affiliation. The way to give preferential treatment to minority members to raise their incentives is an example.

Performance evaluation involves how to evaluate members' decision-making and how to distribute reward to raise the organization income. In other words, relationship between pitch of reward distribution and members' loyalty to organization is the related study.

External environment studies what kind of organizations immediately adapts for dynamic environment and then increases its productivity. Denison has analyzed the relations between the robustness of organizational culture and accounting result for 34 companies in United States. As a result, he has found that high consistency of organization is associated with high current performance and short-term performance, but is associated with low long-term performance [16].

Experience and concept of values is how the differences of experience and concept of values between members influence the whole problem-solving skills. For example, Hambrick has revealed that team of diversified members has better solving skills than team of uniform members [1]. On the other hand, decision making speed of diversified members is slower than that of uniformed members due to different opinions.

Social network means how the shape of a social network influences the decision making of members in it. Nathaniel et al. have studied the relationships between network centrality and the performance of recruiters by analyzing the E-mail log of executive recruiters in a company [17].

Decision-making process deals with how each member does their decision making. Members with different types of experiences and concept of values have different limitations of information and prediction, *i.e.*, bounded rationality, which yields various decision making.

2.2 Outline

In the proposed simulation model, agents search a solution in the hierarchical landscapes with limited information and predictive ability (Fig. 1).

An organization and its members are in this model. The members are connected to some of others, which builds an official network called organizational structure. Therefore, the official network stands for the link between a boss and his/her subordinates in an organization and is fixed by the organization. Member agents do their decision-makings to acquire higher personal and organizational utilities when given a task by the organization. The organization then collects the organizational utilities and distributes them to the members according to a reward distribution system. Finally, the member agents calculate the degree of satisfaction from their personal utilities and a given reward, and update their strategies to have higher utilities and rewards.

2.3 Member Agents

2.3.1 Objects

A member agent A_i ($i = 1, \cdots, n$) has four objects to do her decision-making and learn: behavior X_i^k, personal utility function $Uind_i(\cdot)$, organizational function $Uorg(\cdot)$, and satisfaction function $S(Uind_i(\cdot), Re_i)$ where k is the learning step and Re_i stands for her reward given by the organization.

Behavior object X_i^k represents how she will deal with a problem given by her organization. Here this object is expressed as an array whose length is N [18]. Each element takes a nonnegative integer up to M and is a nominal measure. In addition, L is defined as Manhattan distance which measures the ratio of different elements between two behaviors.

To represent personal experience and concept of values, business models in organizations, and complexity in economic situations, Kauffman's NK model for utility functions is used [19]. This model is an evaluation function for string of integers whose length is N. NK model consists of dependence relationship table and fitness table, and thereby gives each integer an evaluation value. The evaluated value depends not only on the integer itself but also on the other K integers. Thus, an integer is valuated as string of integers whose length is $K+1$ by fitness table. The dependence relationship table determines dependence relationship of integers. The evaluated value of the string is the average of the evaluated values of all integers. The fitness function is made up of the uniform random numbers between 0 and 1. The following points are represented: (1) The difference between the landscapes as the difference of the fitness function and the neighborhood relation, (2) The time change of the organizational utility function by changing the elements of fitness function randomly, and (3) The differences between concepts of value of individuals as those of the elements of fitness function in personal utility function.

Personal utility function $Uind_i(\cdot)$ represents the personal experience and concept of values. Member agent A_i calculates the extent to what her behavior X_i^k is desirable in the light of her experience and concept of values using $Uind_i(X_i^k)$. The use of this function represents heterogeneity in an organization, namely the dependencies and the evaluation values are assigned arbitrary.

In addition, x is defined as the level of diversity of organization. In the organization whose diversity level is x, x of all agents have different personal utility function each other, and $1 - x$ of all agents have the same personal utility function. Hence, if $x = 0$, the all agents have the same elements of fitness in personal utility function. On the other hand, if $x = 1$, then all

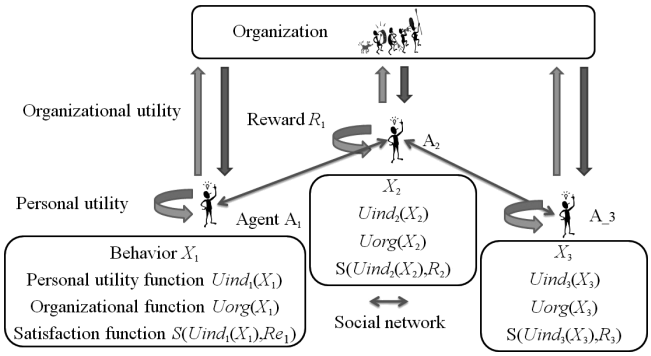


Fig. 1 Simulation model.

agents have different personal utility function each other.

Organizational utility function $Uorg(\cdot)$ stands for the organizational problem or business model. Changes in dependence relationship table and fitness table of organization utility function mean that there is an environmental change or variation of tasks of the members due to a change of organizational policy. For simplicity, this study assumes that this function is common to all member agents.

Satisfaction function $S(Uind_i(\cdot),\ Re_i)$ calculates the degree of satisfaction from their personal utilities and a given reward. Here the following function form is used (equation (1)):

$$S(Uind_i(X_i^k),\ Re_i) = Uind_i(X_i^k) + Re_i. \tag{1}$$

2.3.2 Learning

Member agents usually update their behaviors to improve their satisfaction. This study considers two kinds of learning procedure, individual learning and social learning [20]. Individual learning, on the one hand, is that an agent learns from her own past experience. Since she knows how change in her behavior will affect the performance of her organization a certain extent, she updates her behavior little by little. Social learning, on the other hand, is that a member may imitate behaviors of others who worked well so that she will be able to earn more rewards. But, if the imitated behavior does not fit well, she will give up employing this.

The information a member agent uses is the evaluation values of personal and organizational utility functions, and the behavior and reward of her neighborhood when she learns. Among these, she cannot predict reward she may receive because this is determined by her affiliation.

When learning, a member agent will determine individual or social learning. First, she selects one agent among her neighbor agents and herself based on $P_{i,j}$ (eq. (2)). The learning is individual if she chooses herself, whereas it is social otherwise.

$$P_{i,j} = \frac{Re_j \times (1 - L_{i,j})}{\sum_{k \in N_{f_i}} Re_k \times (1 - L_{i,k})}, \tag{2}$$

where N_{f_i} is a set of neighbor members for a member i.

- Individual learning

  A member agent tries to enhance her expected satisfaction $PS_i(\cdot)$ given by equation (3) instead of her actual satisfaction. Therefore, $PS_i(\cdot)$ is such that one of the two inputs Re_i in $S(Uind_i(\cdot), Re_i)$ is replaced to $Uorg(\cdot)$. Although S depends on the reward from the organization, the member agents cannot know this until they receive because the reward is determined by the organization. That is why a member agent needs to predict the reward and the degree of satisfaction and updates her behavior based on the organizational utility not the reward. In this study, only one element in organizational utility function is changed to a new integer such that the improved $PS_i(\cdot)$ becomes the highest. This procedure is considered as a kind of hill climbing algorithm.

$$PS_i(X_i^k) = Uind_i(X_i^k) + Uorg(X_i^k). \tag{3}$$

- Social learning

  In social learning, whether a member agent will imitate the behavior of a selected neighbor is dependent on the imitation probability P_{IX} which is assigned to each integer. Besides, if the imitated behavior is found to be unsatisfactory, then she employs the former behavior again.

2.4 Organization

An organization tries to control behavior and learning of member agents indirectly and make them produce organizational utilities as many as possible. For these purposes, it has two systems, reward system and organizational structure.

- Reward system

  This system is how to distribute the reward to its members. The organization provides the members with incentive to increase organizational utility by distributing more rewards to the member agents who produce more organization utility.

  This study uses a cumulative reward distribution presented in equations (4) and (5) to deal with proportional distribution:

$$IR_e = IP^D, \tag{4}$$

$$Re_i^k = D(\frac{n - Ra_i^k + 1}{n})^{D-1} \frac{\sum_{i=1}^{n} Uorg(X_i^k)}{n}, \tag{5}$$

  where IR_e is the ratio of cumulative rewards, IP is the ratio of cumulative population, D is the reward distribution degree, Ra_i is the ranking of produced organizational utility for member i.

- Organizational structure

  This means official network in which a member agent is linked to others. Since her learning is strongly affected by

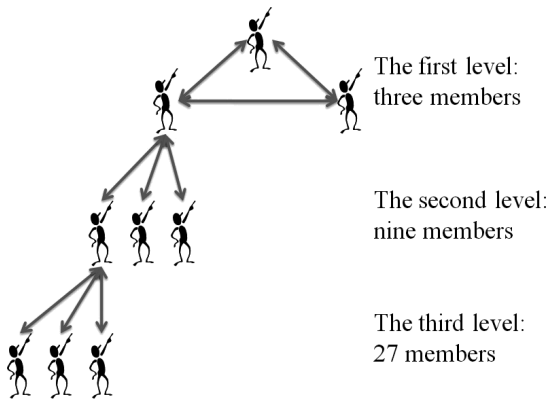


Fig. 2 Social network in this model.

the behavior of others, this system helps control behavior and learning of members indirectly.

This study uses a hierarchical network structure shown in Fig. 2. This network consists of three levels: the first level has three members, the second level has nine, and the bottom level does 27 members, *i.e.*, there are totally 39 members there. As in Fig. 2, a member at a upper level has three members at lower one, but the three members at the top level are connected to each other.

2.5 Flow of the Model

First, all the members process stages 1 and 2. Then stage 3 is processed. These stages constitute one step:

Stage 1 Judgment of imitation

Members who selected social learning at the previous step compare the degree of current satisfaction to that of previous one. If the current one is worse off, she employs the former behavior X_i^{k-1}.

Stage 2 Learning

Members choose one learning method and learn.

Stage 3 Reward distribution

The organization distributes rewards to its members according to the organizational utilities the members produce and the reward system.

3. Computational Experiments

This section presents computational results of whether heterogeneous members in an organization improve the organizational productivity when the members face changing environments using the proposed model. For this purpose, the organizational utility is changed periodically to see both individual and organizational utilities of members. In other words, what this experiment investigates is to what extent an organization requires diversity to have both decrease in average individual utilities and increase in average organizational utilities.

3.1 Setup

Table 1 is the parameter set used in this study: The number of agents and their network structure are explained in Sect. 2.4. Each simulation run has 20,000 steps, iterated 1,000 times. The organizational utility is partially changed, 1 evaluation value, at every 1,000 steps after 1,000 steps in each run. Finally, reward distribution degree D and imitation probability P_{IX} are determined so that they satisfy the following conditions clarified in the earlier case studies:

Table 1 Parameter set.

Parameter	Value
The number of agents n	39 (See Fig. 2)
N (NK model)	5
K (NK model)	2
Array values in NK model	0, 1, $\cdots$, 4
Step at which environmental change occurs	every 1,000 steps after 1,000
The number of evaluation values to be changed	1
Degree of diversity x	0, 0.126, 0.25, 0.5, 0.75, or 1
Reward distribution degree D	1.2
Imitation probability P_{IX}	0.5
The number of steps	20,000
Duration	10,000

Dependencies in NK model are set to random.

1. Slowing of organizational decision making

   It takes the members lots of steps to raise their average organizational utility.

2. Deterioration of satisfactory degree

   The degree of satisfaction of members $S(Uind_i(\cdot), Re_i)$ is low on average.

3. Deterioration of group cohesiveness

   Their behaviors are diverse, *i.e.*, L increases.

4. Upskilling of searching solution

   They have experienced to search X with higher organizational utility.

5. Decreasing of communication

   Social learning happens not so often.

3.2 Results

3.2.1 Relations between diversity and organizational utilities

Figure 3 illustrates the time series plot of average organizational utilities for each setup[1]. What this figure tells is that an organization with high diversity could recover the average organizational utilities and eventually acquires larger ones but that with low diversity failed to do so. That indicates that an organization needs members with a different sense of values to adapt the changing environments.

There are two possible reasons why a diverse organization can deal with the environmental change:

Hypothesis 1 The heterogeneous members save the uniform ones from getting together at a behavioral state.

Hypothesis 2 They accelerate the increase in average organizational utilities after the change.

3.2.2 Characteristics of the effects of partial diverse members

Now this part of the section discusses how an organization with a certain degree of diversity may improve the organizational productivity when the members face changing environments.

[1] Some of the figures including this hereafter are divided into several panels to clearly display each result.

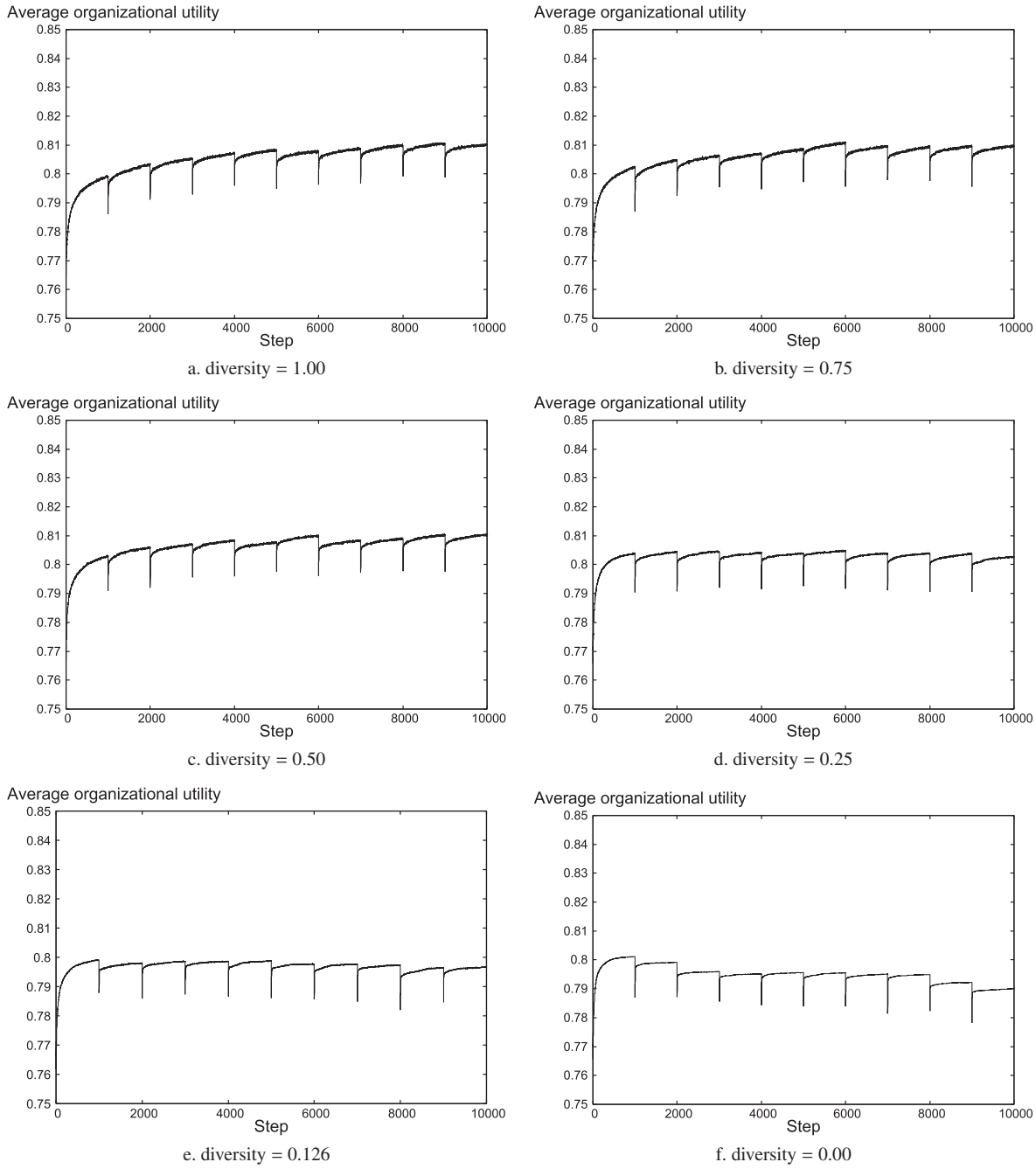


Fig. 3 Average organizational utility for each diversity in case that environmental change occurs every 1,000 steps.

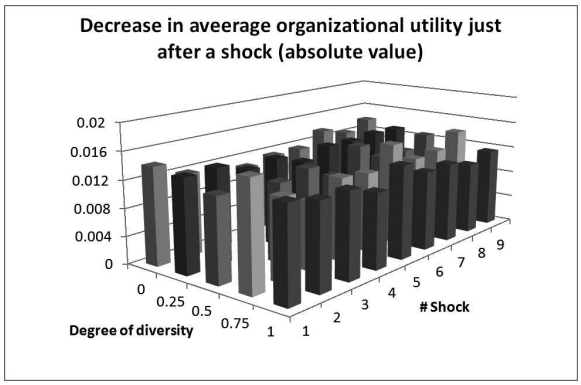
Figure 4 a plots the absolute changes in average organizational utilities for each diversity and shock. As in this figure, there seems no difference between the parameters with respect to the amount of decrease (panel a) because all changes take a value between −0.016 and −0.010 On the other hand, panel b of this figure which displays the average recovery of the utilities shows that the value for each degree of diversity tends to be similar and that at earlier stages the values take larger [2]. Finally, the absolute decrease of average organizational utility and its recovery afterward for the first five changes are compared (Fig. 4 c). According to this panel, while there is a weak relation between the decrease and the degree of diversity (correlation: 0.314), a strong positive relation is observed in terms of the recovery (correlation: 0.903), namely an organization with more diversity is able to retrieve their productivity more.

To this end, incorporating partial diversities into an organization helps increment the recovery of the organizational utility after environmental changes. In addition, the more diverse members an organization has, the more the recovery increases.

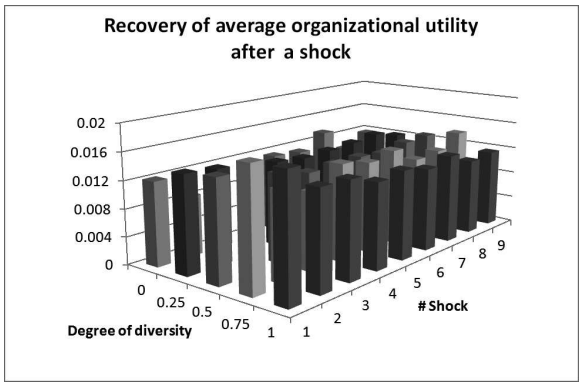
3.2.3 Differences between effects and non-effects of diverse members

Next, why and how the diverse members can or cannot provide their organization with adaptability for changing environments is discussed. For this purpose, two comparative results will be presented, namely the organization with diversity being

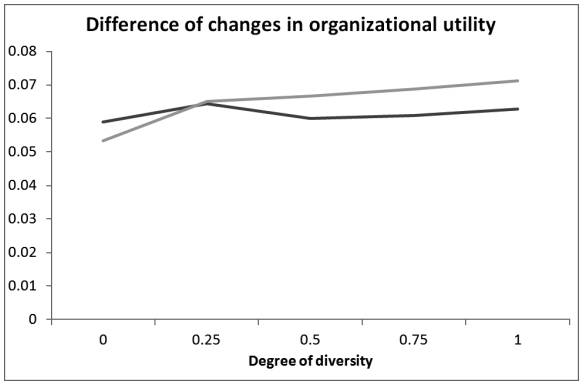
[2] According to the results of two-way analysis of variance, the p-values in panel a are 0.0326 (no. changes) and 0.390 (degree of diversity), and those in panel b 0.008 (no. changes) and 0.003 (degree of diversity), which suggests that every organization may become less sensitive to external shocks.



a. Decrease in average organizational utilities just after a shock (absolute value)



b. Recovery of average organizational utilities



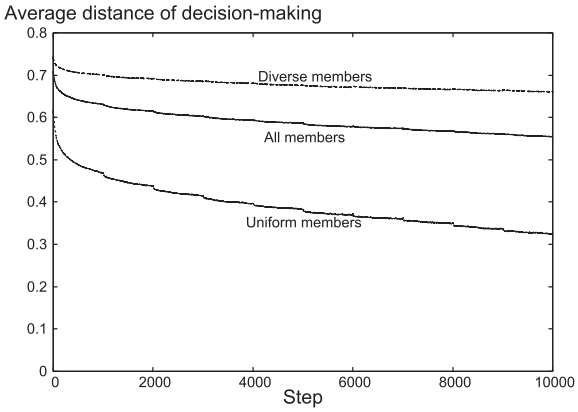
c. Differences of changes in average organizational utilities (thick line: decrease in average organizational utility, light line: increase in average organizational utility)

Fig. 4 Decrease and increase in average organizational utilities for each shock and degree of diversity.

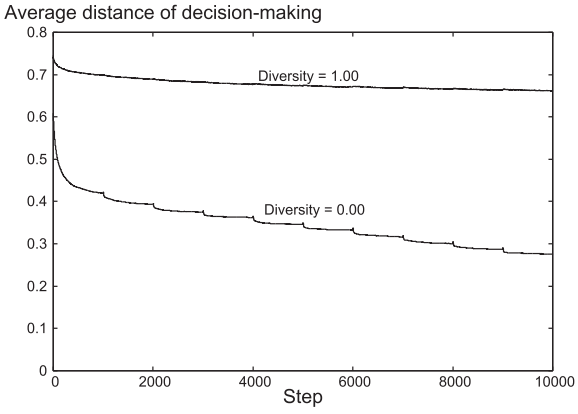
0.5 or larger (success) and 0.25 or smaller (failure).

- Case of success

  Figure 5 illustrates the time series plot of average distance of individual decision-making with respect to whole organization, uniform members, and diverse members for diversity being 0.5. This figure also has the plots in the organizations with diversity being 0 and 1 for comparison. The distance is becoming smaller as the step goes by as a whole (all: 0.711 → 0.555, uniform: 0.612 → 0.325, diverse: 0.745 → 0.661 in panel a). Among these, the average distance of diverse members there is almost the same as that in a fully diverse one (0.745 → 0.661 in panel b). On the other hand, the average distance of uniform members in such an organization sharply declines and takes



a. diversity = 0.50
(Solid line: All members, Dashed line: Diverse members, Dotted line: Uniform members)



b. diversity = 0.00 and 1.00 (for comparison)

Fig. 5 Average distance of behavioral states in the organization.

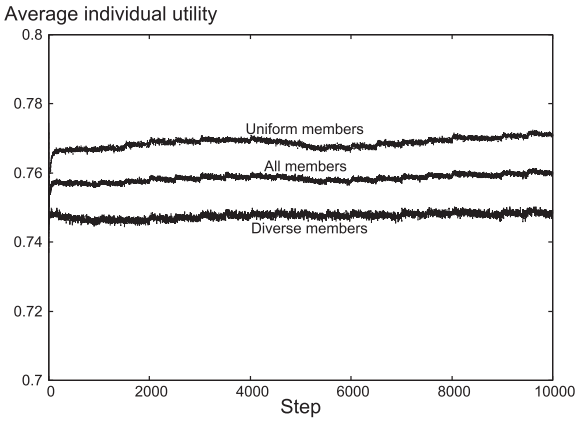
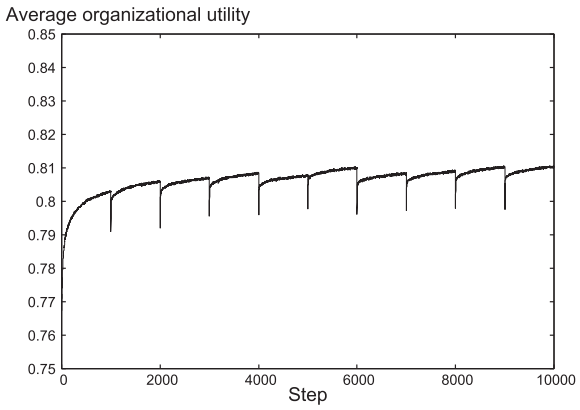


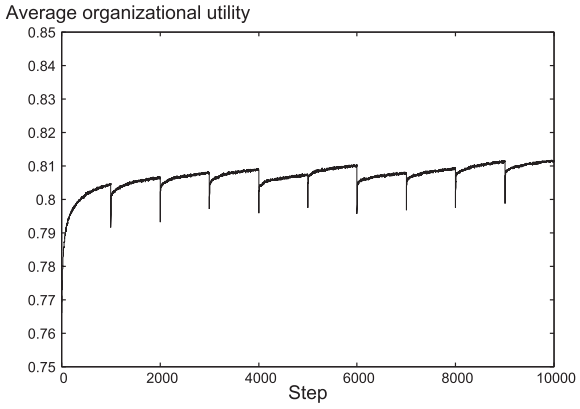
Fig. 6 Average individual utility in the organization with degree of diversity being 0.5 (Solid line: All members, Dashed line: Diverse members, Dotted line: Uniform members).

similar values to that in completely uniform organization (0.609 → 0.276 in panel b). Instead, the average individual utilities do not fluctuate all time so much though they become a bit larger (all: 0.756 → 0.760, uniform: 0.767 → 0.771, diverse: 0.746 → 0.749 in Fig. 6).

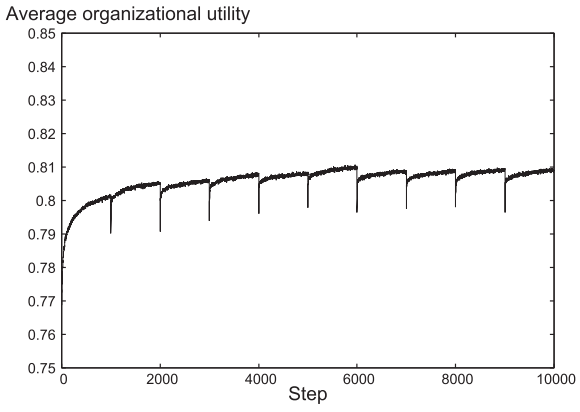
Next, Figs. 7 and 8 present the average organizational utilities and the changes in average individual utilities respectively. The average organizational utility for 1,000 steps after a shock is not so different between the uniform members and the diverse members (all: 0.803 at 1,000 → 0.810 at 10,000, uniform: 0.804 → 0.812, diverse: 0.801 →



a. All members



b. Uniform members



c. Diverse members

Fig. 7 Average organizational utility in the organization with degree of diversity being 0.5.

0.809 in Fig. 7). And, while the changes in average individual utility of diverse members fluctuate around zero, it takes the uniform members about 1,000 steps to recover their average individual utility due to rapid increase just after a shock (Fig. 8).

What these results imply is "the diverse members take the uniform ones from a state of behavior to another with higher organizational utility" (Hypothesis 2), not "the diverse members keep the uniform ones from gathering around a state of behavior" (Hypothesis 1). That means, the uniform members perhaps try to increase their organizational utility and decrease their individual utility by imitating the behavior of diverse members.

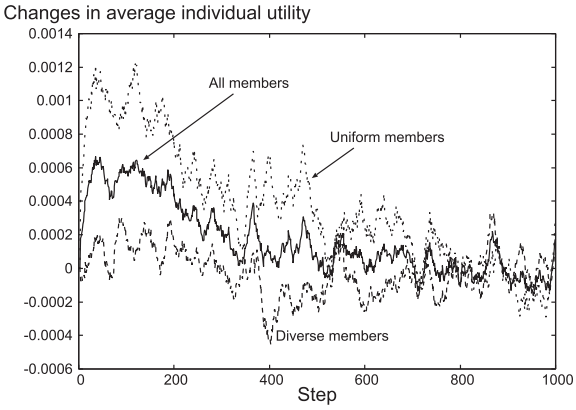


Fig. 8 Changes in average individual utility just after the shock in the organization with degree of diversity being 0.5 (Solid line: All members, Dashed line: Diverse members, Dotted line: Uniform members).

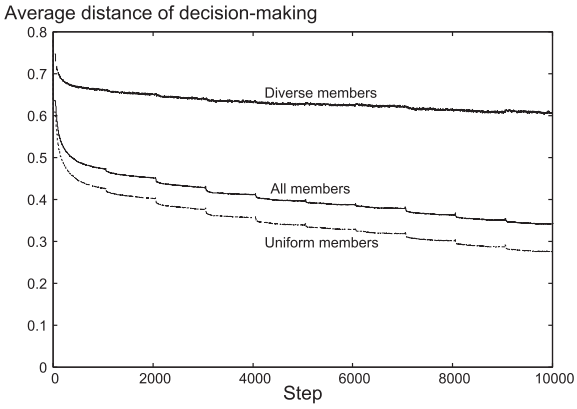


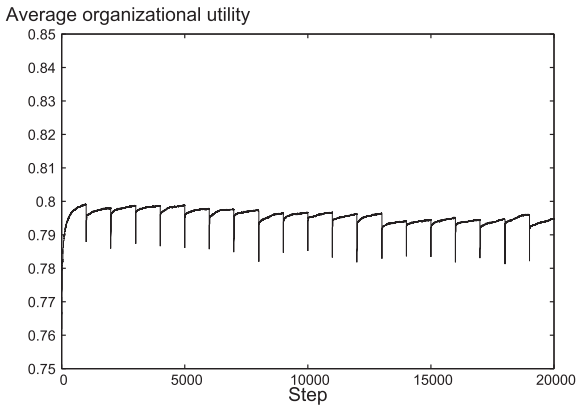
Fig. 9 Average distance of behavioral states in the organization with degree of diversity being 0.126 (Solid line: All members, Dashed line: Diverse members, Dotted line: Uniform members).

- Case of failure

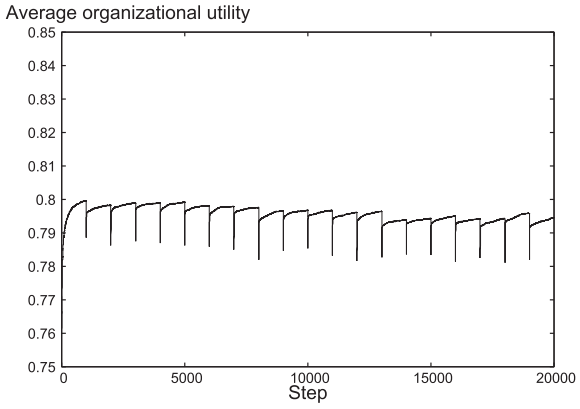
  Figures 9, 10, and 11 give a time series plot of average distance of behavioral state, average organizational and individual utility respectively, and Fig. 12 provides the changes in average individual utility after a shock. Note that the results in these figures are from the organization with degree of diversity being 0.126.

  With respect to the average distance of behavioral state (Fig. 9), that for the diverse members becomes much smaller compared to the preceding result (0.790 → 0.609). Likewise, the average distance of uniform members there sharply declines and takes nearly the same value as that in completely uniform organization (0.780 → 0.276). Next, while the average organizational utility of uniform members becomes relatively smaller (0.800 at 1,000 → 0.794 at 10,000), that of diverse members does a bit larger (0.793 → 0.796) (Fig. 10). Thirdly, the average individual utility for the uniform members gradually increases (0.783 → 0.787) while that for the diverse ones does not so much (0.746 → 0.745) (Fig. 11). This is also confirmed from the fact that the values for the uniform members are positive all time (Fig. 12).

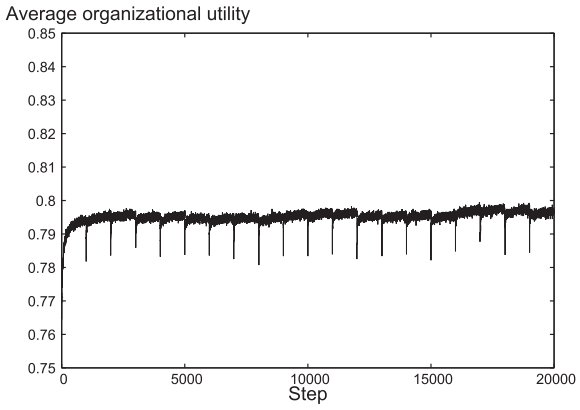
  To summarize, although the diverse members managed to recover the organizational utility by sacrificing themselves, the fact that they were minority there made it al-



a. All members

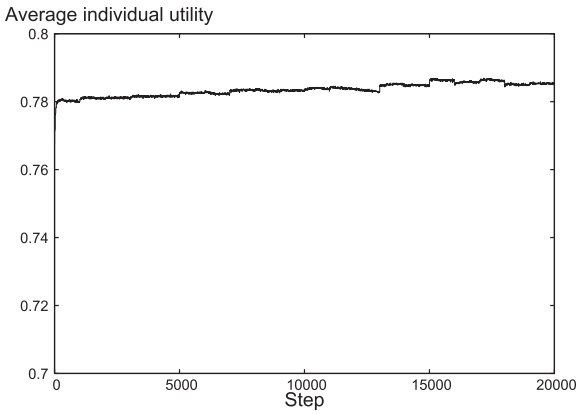


b. Uniform members

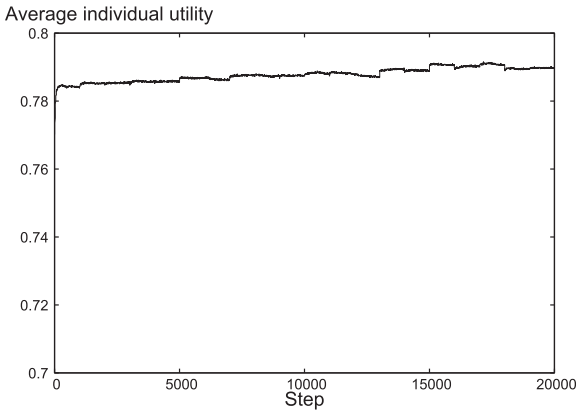


c. Diverse members

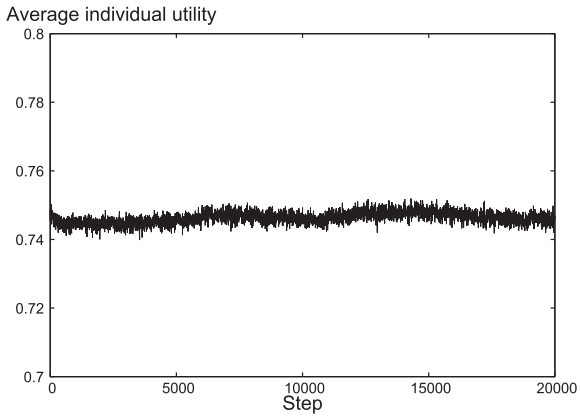
Fig. 10 Average organizational utility in the organization with degree of diversity being 0.126.



a. All members



b. Uniform members



c. Diverse members

Fig. 11 Average individual utility in the organization with degree of diversity being 0.126.

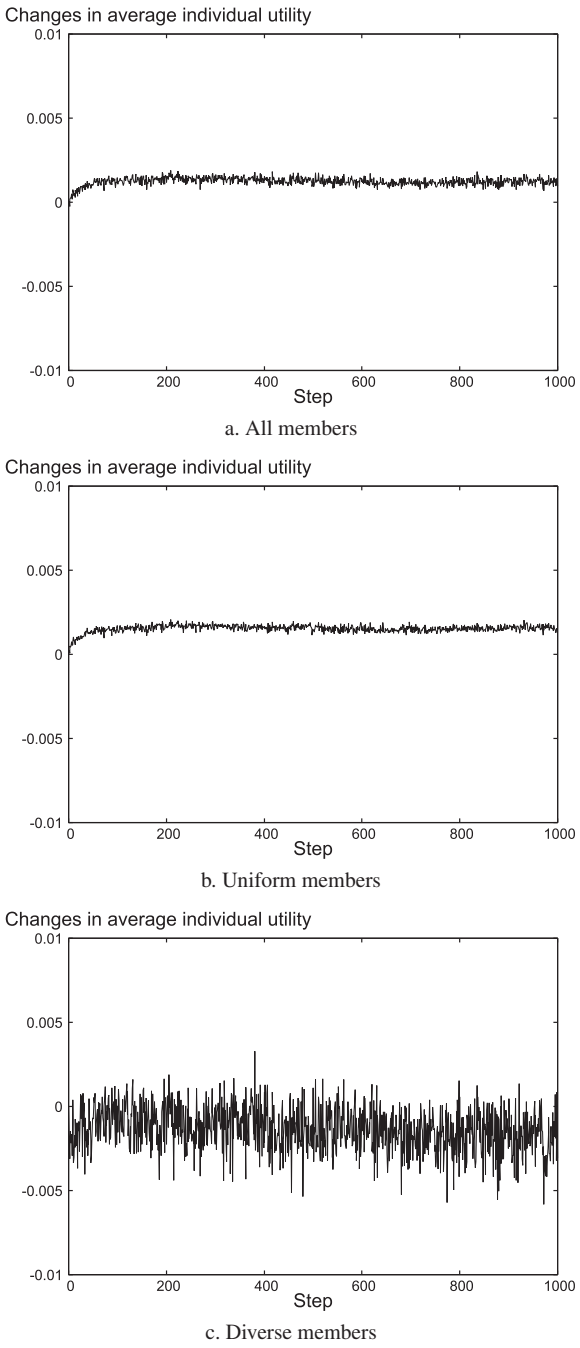
most impossible to take the uniform members to such a state. On the contrary, the uniform members did not take care of the decrease in the organizational utility because they became to earn more individual utilities whenever their organization had an environmental change. That is why an organization with less diversity failed to recover its organizational utility under changing environments.

3.3 Discussion

This part discusses in what respect the proposed simulation model corresponds organizational equilibrium theory and what kind of meanings the computational results have for the theory. Then, possible subsequent outcomes in such a diverse organization will be addressed.

First, the behavior of members to contribute to their organization in organizational equilibrium theory is consistent with that by increasing organizational utility and by decreasing personal one. Likewise, the incentive with which an organization provides its members is equivalent to the reward in the proposed simulation model (Sect. 2.4).

Based on this correspondence, a possible interpretation of this computationally observed phenomenon, *incorporating diverse members into an organization prevents its uniform members from getting away to a state with higher individual utility in case of environmental change*, is that *ways except for the one in which an organization increments the incentives given to its members help prevent the uniform members from decreasing in their contributions when an environmental change outside loses the incentives*. In other words, the proposed model and the con-



a. All members

b. Uniform members

c. Diverse members

Fig. 12 Changes in average individual utility just after the shock in the organization with degree of diversity being 0.126.

sequent results offer a new interpretation for the core idea in organizational equilibrium theory, the ordinal incentive is more than the contribution made by its members.

On the other hand, there are two possible scenarios such that a partially diverse organization cannot adapt to changing environments: (1) The fact that the average distance of behavioral states rapidly becomes smaller (Fig. 9) means that if one of the uniform members happens to find a state with quite a high individual utility then they will keep staying there which prevents them from adapting to the changes. (2) If the diverse members reach a state with higher individual utilities, not organizational ones, during their recovery process, they may lose their motivation to adapt to the changes. These scenarios suggest that every organization, even if it has sufficient diversity, has a possibility to fail to properly react to external changes. Those issues will be deeply examined in the near future.

4. Concluding Remarks

This study compares the organizational utility between uniform organization and diverse one by feeding a periodical environmental change in an agent-based model of organization. The main findings are as follows: Firstly, the partial diversities push up the rise of average organization utilities after an exogenous change occurs. The more the rise amount increase, the more diversity level becomes high. Secondly, the diverse members discover a new state with higher organizational utility and then take others to that state. Finally, to make this effect meaningful, an organization needs to have a certain amount of diverse members. These results give a new explanation for the relations between contributions of members and incentives in organizational equilibrium theory.

Acknowledgments

The authors thank the editors and two anonymous referees for helpful comments and suggestions.

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